Lessons and Implications for REDD+
Implementation Experiences from Tanzania

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The 5 year CCIAM programme which ended in December 2015, focused on promoting natural forest conservation, afforestation, reforestation and better agricultural practices for improved livelihoods related to the “Reduced Emissions from Deforestation and Forest Degradation (REDD)” initiative.
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Acronyms

AGB  Above-Ground Biomass.
AGC  Above Ground Carbon.
AIC  Akaike Information Criterion
ANOVA  Analysis of Variance.
ARU  Ardihi University
AWF  African Wildlife Foundation.
AWF  African Wildlife Fund.
BD  Basal Diameter.
BGB  Below Ground Biomass
CA  Conservation Agriculture.
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<tr>
<td>CBFM</td>
<td>Community-Based Forest Management.</td>
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<td>CBOs</td>
<td>Community-Based Organisations.</td>
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<tr>
<td>CCIAM</td>
<td>Climate Change Impacts, Adaptation and Mitigation.</td>
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<td>CGE</td>
<td>Computable General Equilibrium.</td>
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<td>CGFR</td>
<td>Central Government Forest Reserve.</td>
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<tr>
<td>CIFOR</td>
<td>Centre for International Forest Research</td>
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<tr>
<td>CO₂</td>
<td>Carbon Dioxide.</td>
</tr>
<tr>
<td>CSOs</td>
<td>Civil Society Organisations.</td>
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<tr>
<td>DBH</td>
<td>Diameter at Breast Height.</td>
</tr>
<tr>
<td>DEMO</td>
<td>District Environmental Management Officer.</td>
</tr>
<tr>
<td>DFM</td>
<td>District Forest Manager.</td>
</tr>
<tr>
<td>DFO</td>
<td>District Forest Officer.</td>
</tr>
<tr>
<td>DRRI</td>
<td>Dakawa Rice Research Institute.</td>
</tr>
<tr>
<td>DT</td>
<td>District Treasurer.</td>
</tr>
<tr>
<td>EAM</td>
<td>Eastern Arc Mountains.</td>
</tr>
<tr>
<td>ECCAg</td>
<td>Environmental and Climate Compatible Agriculture Project</td>
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<td>FAO</td>
<td>Food and Agricultural Organization</td>
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<td>FGD</td>
<td>Focus Group Discussion</td>
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<td>FMRs</td>
<td>Forest Management Regimes.</td>
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<tr>
<td>FP</td>
<td>Farmers’ Practice.</td>
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<td>FREL</td>
<td>Forest Reference Emission Level.</td>
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<td>FSC</td>
<td>Forest Stewardship Council.</td>
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<td>Abbreviation</td>
<td>Name</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product.</td>
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<td>GHG</td>
<td>Green House Gas.</td>
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<td>GLM</td>
<td>General Linear Model</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System.</td>
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<tr>
<td>HADO</td>
<td>Hifadhi Ardhi Dodoma.</td>
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<tr>
<td>HPN</td>
<td>Home Pasture Nursery.</td>
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<tr>
<td>HT</td>
<td>Total Height.</td>
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<td>IFR</td>
<td>Iyondo Forest Reserve.</td>
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<td>IIED</td>
<td>International Institute for Environment and Development.</td>
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<tr>
<td>INCUSEINOFERT</td>
<td>Increased Adoption of the use of Inorganic Fertilisers.</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change.</td>
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<td>IRA</td>
<td>Institute of Resource Assessment.</td>
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<td>JFM</td>
<td>Joint Forest Management.</td>
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<td>JUHIBEKO</td>
<td>Jumuiya ya Hifadhi Bereko na Kolo</td>
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<td>JUWAMA</td>
<td>Jumuiya ya Watunzaji wa Msitu wa Masuto-Ugalla.</td>
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<td>KFO</td>
<td>Kilwa District Forest Office.</td>
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<td>KIIs</td>
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<td>LAAC</td>
<td>Local Authority Accounts Committees</td>
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<td>LAFR:</td>
<td>Local Authority Forest Reserve.</td>
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<td>LGAs</td>
<td>Local Government Authorities.</td>
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<td>LSD</td>
<td>Least Significance Difference.</td>
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<td>Acronym</td>
<td>Description</td>
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<tr>
<td>LUC</td>
<td>Land Use Change.</td>
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<td>LUPs</td>
<td>Land Use Plans.</td>
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<tr>
<td>MAI</td>
<td>Mean Annual Increment</td>
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<tr>
<td>MCDI</td>
<td>Mpingo Conservation and Development Initiative.</td>
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<tr>
<td>MJUMITA</td>
<td>Mtandao wa Jamii wa Usimamizi wa Misitu Tanzania.</td>
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<tr>
<td>MNL</td>
<td>The Multinomial Logit.</td>
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<td>MNRT</td>
<td>Ministry of Natural Resources and Tourism.</td>
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<tr>
<td>MODIS</td>
<td>Moderate Resolution Imaging Spectroradiometer</td>
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<td>MPE</td>
<td>Mean Prediction Error.</td>
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<td>MRV</td>
<td>Measurement, Reporting and Verification.</td>
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<td>NAFORMA</td>
<td>National Forest Resources Monitoring and Assessment.</td>
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<td>NCAS</td>
<td>National Carbon Accounting System.</td>
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<td>NDCs</td>
<td>Nationally Determined Contributions.</td>
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<td>NDUFR</td>
<td>New Dabaga Ulongambi Forest Reserve.</td>
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<td>NGOS</td>
<td>Non-Governmental Organizations.</td>
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<td>NMDS</td>
<td>Non-Linear Multidimensional Scaling.</td>
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<td>NORAD</td>
<td>Norwegian Agency of Development Cooperation.</td>
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<td>NR</td>
<td>Nature Reserve.</td>
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<td>NSCA</td>
<td>National Sample Census of Agriculture.</td>
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<td>Non-Timber Forest Products.</td>
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<td>Description</td>
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<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development.</td>
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<td>PAC</td>
<td>Project Advisory Committee.</td>
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<td>PCQM</td>
<td>Point Centred Quarter Method</td>
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<td>PEEM</td>
<td>Public Environmental Expenditure Management</td>
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<td>PES</td>
<td>Payment for Environmental Services</td>
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<td>PFM</td>
<td>Participatory Forest Management.</td>
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<td>PLUM</td>
<td>Participatory Land Use Management.</td>
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<td>PPP</td>
<td>Public Private Partnership.</td>
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<td>Participatory Rural Appraisal.</td>
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<td>Participatory Village Land Use Planning.</td>
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<td>RCC</td>
<td>Regional Consultative Committee</td>
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<tr>
<td>RCPs</td>
<td>Representative Concentration Pathways.</td>
</tr>
<tr>
<td>REDD+</td>
<td>Reducing Emissions from Deforestation and Forest Degradation.</td>
</tr>
<tr>
<td>REL</td>
<td>Reference Emission Levels</td>
</tr>
<tr>
<td>RMSE</td>
<td>Relative Root Mean Square Error.</td>
</tr>
<tr>
<td>ROW</td>
<td>Rest of the World.</td>
</tr>
<tr>
<td>SAS</td>
<td>Statistical Analysis System.</td>
</tr>
<tr>
<td>SFM</td>
<td>Sustainable Forest Management.</td>
</tr>
<tr>
<td>SIDA</td>
<td>Swedish International Development Co-operation Agency.</td>
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<tr>
<td>SOC</td>
<td>Soil Organic Carbon.</td>
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<tr>
<td>SPSS</td>
<td>Statistical Package for Social Sciences</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<td>-----------</td>
<td>-----------------------------------------------</td>
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<tr>
<td>SSPs</td>
<td>Shared Socioeconomic Pathways.</td>
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<tr>
<td>SUA</td>
<td>Sokoine University of Agriculture.</td>
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<td>Tanzania Forestry Research Institute</td>
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<td>TaTEDO,</td>
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<td></td>
<td>Organization.</td>
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<td>UDSM</td>
<td>University of Dar es Salaam.</td>
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<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change.</td>
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<tr>
<td>USNR</td>
<td>Uluguru South Nature Reserve.</td>
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<tr>
<td>VC</td>
<td>Village Council.</td>
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<tr>
<td>VEC</td>
<td>Village Environmental Committee.</td>
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<td>VG</td>
<td>Village Government.</td>
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<td>Village land use Planning Committee.</td>
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<td>VNRC</td>
<td>Village Natural Resource Committee.</td>
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<tr>
<td>WCS</td>
<td>Wildlife Conservation Society.</td>
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<tr>
<td>WDC</td>
<td>Ward Development Committee.</td>
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WMA  Wildlife Management Area.
WSSD  World Summit for Sustainable Development.
WWF  World Wildlife Fund.
Foreword

This book on, ‘Lesson and Implications of REDD+ implantation: Experiences from Tanzania’ from the Climate Change Impact Adaptation and Mitigation (CCIAM) project, is released at the time when Climate change has received much attention and REDD+ in particular has been given recognition during the Paris COP 21 Climate Accord in Article 5 para 2 which heralds in a new era of REDD+ implementation by committed parties to adapt to and/or mitigate climate change impact in their countries. It is a welcome addition to many other books on the subject which national and local policy makers, development agencies forest institutions and organization will find interesting, relevant and useful. It provides excellent empirical information and analysis pertinent to issues of sustainable forest conservation and livelihoods.

This book is a result of research projects conducted on 8 pilot projects implemented by local NGOs on various themes. As the Chairperson of the National REDD+ Task Force in Tanzania, I followed closely the implementation of these projects and I am elated to see some of the lessons we can learn from the pilot being documented to benefit. As it is now widely understood, REDD is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-
carbon paths to sustainable development. REDD was subsequently developed into REDD+, which goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. The publishing of the lessons emerging from the research builds on globally accepted aspects of REDD+ readiness to provide relevant inputs to the global discourse with measures to ensure that findings and outcomes feed into global discussions at international meetings on REDD+.

The 15 research chapters touch on important and relevant themes for REDD+ implementation in terms of output or result based initiatives in relation to MRV and REDD+ financing mechanism in Tanzania implemented according to UNFCCC decision 4/CP.15 which requires countries to develop national forest reference emission level (REL) and/or forest reference level (RL) for REDD+. Once a global agreement on REDD+ is reached, we expect to have a mechanism for accessing international financing and disbursing REDD+ funds to actors within Tanzania. Supporting REDD+ policy processes was relevant and much needed in order to make Tanzania REDD+ ready so as to feed into the international REDD+ agreement and architecture. These chapters include articles which focus on climate change mitigation and adaptation strategies, forest carbon assessment strategies, community climate change adaptation and livelihoods strategies under REDD+ initiative, REDD+ Governance Processes in Tanzania and Economics of REDD+ implementation. These are consistent with the Climate Change and REDD+ Strategies and it is consistent with selected aspects of sustainable natural resource, agriculture and energy strategies in the country. The Tanzanian Government is committed to the process of getting ready for implementation of REDD+ so as to benefit from possible global funding opportunities. However, the ability of REDD+ process to promote broader goals of sustainable development and address multiple drivers of deforestation need to be strengthened. The book provides lesson from the REDD+ pilot implementation which may facilitate mainstreaming of REDD+ efforts crucial for ensuring a clear focus on supporting sustainable forest management especially participatory forest management. Other important aspects include inputs to strategic sector policy development. Delivery of these results depends on anticipated longer and more complex government reforms and decision-making.

We have noted that REDD initiatives implemented across the country have improved the quality and ownership of forests and environmental conservation. The strategies mentioned above including social and environmental safeguards, represent important milestones in the readiness process to deliver elements of REDD+ readiness and the needed long term sustainability as per Annex 1 of the Cancun agreement (UNFCCC decision 1/CP.16 appendix 1) and as agreed in Durban (UNFCCC decision 2/CP.17). Description of decision-making, roles
and responsibilities of partners need to be sufficiently are crucial for timely and smooth implementation of the initiative.

We know that the intention of REDD+ readiness initiative is to respond to the need for integrating environmental concerns into rural development, poverty reduction and addresses drivers of deforestation. This is where the sections on REDD+ Governance Processes in Tanzania and Economics of REDD+ implementation, provide valuable empirical insights as to how this can be achieved while taking into consideration the obtaining local conditions. It needs to have a clear focus on the key agenda of sustainable forestry management within the forestry sector and recognise the role of participatory forest management as a prioritised investment in addressing sustainable natural resource management. The ability of REDD+ to influence a broad and complex development agenda in several sectors need to be an inclusive process so as to secure an international REDD+ readiness for the process to be sufficiently internalised. Therefore empirical analyses and evidence such as those contained in this book are essential for us to learn from, and improve upon, for a successful implementation of REDD+.

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Acknowledgements

The process of producing this book has taken about six months from the time of calling for articles for inclusion in the book to the time of completion of printing the book. This has been quite an involving undertaking requiring the dedication of a number of committed individuals including authors, reviewers, the book project committee members, the CCIAM programme secretariat at SUA, the CCIAM programme institutional focal point at the University of Dar es Salaam and the book project coordinator and chief editor. As editors, it has been an experience to work with all those involved. The process started with 30 manuscripts but ended with only 15 articles which could be included in the book. The core of the books is 15 chapters contained in 5 sections covering issues pertaining to Climate change mitigation and adaptation strategies, Forest Carbon Assessment Strategies, Community Climate Change Adaptation and Livelihoods strategies under REDD+ initiative, REDD+ Governance Processes in Tanzania, and Economics of REDD+ implementation.

At the CCIAM programme secretariat at SUA a number of individuals contributed to the facilitation of the whole process. These include Prof Salim Maliondo who was the CCIAM programme coordinator, Prof. Z.K. Mvena, Dr.Tryphone George, Prof. Jumanne Abdalla, Prof. E.K. Batamuzi, Mr. David Mapugilo
(Accountant), Mr. Nathan Mwendamseke (Admin Assistant). The Director of Research and his accountant Mr Kasanyi. The Dar es Salaam University Directorate of Research (as the institutional focal point for the CCIAM project). The coordinator and chief editor of the book was central for the administering and coordination of the whole process from the initial workshop where prospective authors of book chapters presented their papers, to the last point when publishing processes were finalized. Without his dedicated and efficient efforts the book would not have met such a tight deadline.

The production of the book, including very thorough language editing, graphic design and typesetting, has been done by E&D Publishers. We are grateful for the professionalism and flexibility provided by the Executive Director Ms. Elieshi Lema and her team at E&D Vision publishers. The chapters have been double blind internally reviewed by the reviewers including by the book project committee members and others from The Sokoine University of Agriculture (SUA) and the University of Dar es Salaam (UDSM) faculty members from relevant departments, as well as by 22 other external reviewers.

We therefore thank and highly appreciate the contribution of the following people for their valuable suggestions and critiques which went a long way to improve the articles included in this book. Prof. Larwanou Mahamane, Prof Rogers Malimbwi, Dr. Lawrence Mbwambo, Dr. Mwita Mangora, Prof. Shaaban Chamshama, Prof Claude Mung’ong’o, Prof. Razack Lokina, Prof. Wisdom Akpulu, Prof. Jafari Kidegesho, Prof. Pål Olav Velded, Dr. Babatunde Abidoye, Prof. Salome Misana, Prof. Arild Vatn, Prof. Adolfo Mascarenhas, Prof Arild Angelsen, Prof. Yonika Ngaga, Prof. Aida Isinika.

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All of the chapters in this book are based on the research projects undertaken through the CCIAM programme which was implemented between 2009 and 2015. Whereas many individuals and government and non-government institutions, were involved in making the research projects successful, it is however difficult to mention each and every one of them individually by name. Suffice to recognize the many government offices and officers at the regional,
district and village levels where the field studies were conducted, without leaving out research assistants, data encoders, field research supervisors, respondents, key informants among others. We wish to thank them all on behalf of all the researchers involved, for their assistance and making the research projects successful.

Dar es Salaam and Morogoro, Tanzania
31 July 2016

*Kassim Kulindwa, Dos Santos Silayo, Eliakim Zahabu, Razack Lokina, Joseph Hella, Aloyce Hepelwa, Deo Shirima, Samora Macrice and Severin Kalonga.*
Introduction

Kassim Kulindwa, Dos Santos Silayo,

Forests play a dual role in climate change. Forests can be a source of greenhouse gases, emitting carbon dioxide to the atmosphere when they are burned or destroyed, and forests can also act as a “sink,” removing carbon dioxide from the atmosphere and storing it as carbon in their biomass as they grow. In fact, the terrestrial carbon sink, which includes soils, trees and other vegetation, soaks up as much as half of all GHG emissions from fossil fuels each year, significantly slowing the buildup of climate-warming gases in our atmosphere. Since the thirteenth UNFCCC Conference of Parties (COP 13) and the third Meeting of the Parties to the Kyoto Protocol of the UNFCCC in Bali in 2007, REDD+, in all its facets, has been embraced with flavour rarely witnessed in environmental circles. Currently, there appears to be a consensus that the issue of deforestation and forest degradation must be addressed as a low cost option to reduce greenhouse gas emissions and avoid an increase in temperature beyond acceptable levels. This book comes out at the time when Climate change has received much attention and REDD+ in particular has been given recognition at the Paris COP 21, 2015 Climate Accord in Article 5 para 2 which states;
“Parties are encouraged to take action to implement and support, including through results-based payments, the existing framework as set out in related guidance and decisions already agreed under the Convention for: policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries; and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests, while reaffirming the importance of incentivizing, as appropriate, non-carbon benefits associated with such approaches.” As one of the countries with a higher rate of deforestation and forest degradation, Tanzania also contributes high CO2 emissions per annum through deforestation estimated to be in the order of 78 million tons and forest degradation of about 48 million tons amounting to a total of 126 million tons CO2 emissions per year (Zahabu, 2008). The country has therefore decided to embark upon a national REDD+ program to manage its forests sustainably while responding to poverty reduction and sustainable development needs. Similarly, REDD+ issues are being mainstreamed into national development planning through the National REDD+ strategy.

Tanzania was privileged to be among the countries earmarked for piloting REDD+ activities in order to inform the UNFCCC global process on designing and implementing REDD+. Therefore, between April 2009 and December 2015, the country has been engaged in piloting REDD+ after signing a Letter of Intent with the Government of Norway on a Climate Change Partnership with a focus on reduced emission from deforestation and forest degradation. The commitment was to support the National REDD+ Strategy development; REDD+ Piloting; Research and Capacity Building (including the Program on Climate Change Impacts, Adaptation and Mitigation (CCIAM); Investments in National Forest Monitoring and Assessment (NAFORMA); Empowering Communities through Training on Participatory Forest Management, REDD+ and Climate Change Initiatives (ECOPRC); Private Sector Engagement; and Establishment of a National REDD+ Trust Fund and Carbon Monitoring Centre.

With support from the various stakeholders, nine REDD+ pilot projects were implemented in Tanzania by the government in collaboration with national and international NGOs. The REDD+ as part of REDD+ piloting a capacity building and research programme named ‘Climate Change Impacts, Adaptation and Mitigation (CCIAM)’ was designed to increase capacity through training and research where by 21 research project were implemented in different places of the country. These projects were designed to draw lessons from the piloting process that would help to shape future REDD+ in Tanzania. This book therefore, documents some of the key lessons addressed in five sections with 15 chapters. These sections include; Climate change mitigation and adaptation strategies; Forest Carbon Assessment Strategies; Community Climate Change
Adaptation and Livelihoods strategies under REDD+ initiative; REDD+ Governance Processes in Tanzania; and Economics of REDD+ implementation. The following is a brief summary of the discussions contained within the various chapters in each section.

Section 1: Climate change mitigation and adaptation strategies

Climate Change mitigation is defined as “An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases” while Adaptation refers to “the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences”. Therefore these two are important terms that are fundamental in the climate change debate. With this understanding several projects were designed to assess and develop strategies that can help the ecosystems and communities adapt to the changing climate. This section presents strategies for sustaining carbon storage in forest ecosystems such as Miombo woodlands, rangelands as well as community adaptive capacities at local level. The strategies for sustaining carbon storage especially in the miombo ecosystems have been developed to include wildfire management. Wildfires are world-wide problems and uncontrolled or misused fire inflicts disaster on society and the environment. In Tanzania fire occurs in most parts of the Miombo woodlands, and some of them cause significant ecological and socio-economic impacts. Several efforts have been done in Tanzania to reduce the occurrence of fire in Miombo but their success has been constrained with underfunding and/or lack of proper strategies. Therefore fire management strategy for the Miombo woodland has been developed as a tool for climate change mitigation while indicating a number of activities to be implemented and responsible actors.

On the other hand strategies have been addressed in the two main sectors of Agriculture and livestock keeping. Experience have shown that despite the number of coping strategies employed by agro-pastoralists in the study areas, the climate variability and change has evidenced to have serious impact on rangeland condition and livestock performance. The section also explores how information provided by different research perspectives about impacts and adaptation to climate change matter to recommendations for adaptation strategies in the agricultural sector in Tanzania. This has been done by comparing conclusions from a macroeconomic model, a microeconomic sector model, and a field study of a local community.

Section 2: Forest Carbon Assessment Strategies

There is growing concern about the consequences of biodiversity loss for ecosystem functioning, including the ability of ecosystems to fix and store carbon. Natural forest and woodlands have complex structures in flora and fauna which if well understood and properly managed will provide long-term
ecosystem goods and services to local livelihoods. This requires stand-based assessments of structural components such as carbon stocks, plant species diversity and composition as well as their links to ecosystem processes and functions. Moreover, additional conservation benefits for biodiversity in REDD+ require developing explicit “biodiversity-friendly” strategic methods, which spatially target interventions and finances focused on biodiversity delivery.

Therefore this section presents models that can be used to assess biomass and volume for different vegetation in Tanzania. This is on the understanding that the choice of a system to adopt relies heavily on the accuracy of the method for quantifying biomass and volume as important primary variables for computing C stock and changes over time.

Section 3: Community Climate Change Adaptation and Livelihoods strategies under REDD+ initiative

In Africa including Tanzania, more than 70% of the population earns their living from agriculture, and a majority of the remaining population depends on exploitation of other natural resources through hunting, fishing and use of forest products. Therefore, Climate change threatens the livelihood security of millions of rural Tanzanian households who rely on natural resources and rain-fed subsistence farming especially women; because their livelihoods are vulnerable to climate hazards that are expected to become more frequent as climate change accelerates. Experience have shown that Forest dependent communities in Tanzania are particularly sensitive to changes affecting forest resources because the changes may cause resource degradation and in turn contribute to increased vulnerability and reduced capacity to adapt to climate change. This section therefore, presents some lessons on how communities adapt to the changing climate with the use of non-timber forest products.

Similarly it looks into the existing balance between intensification and environmental sustainability under smallholder maize and rice cropping systems in Tanzania. This is due to the fact that maize and rice constitute 50% dietary energy of Tanzanian. Smallholder farmers produce 90% of these crops. Productivity is low due to low soil fertility, low use of agricultural inputs due to lack of capital, knowledge and extension services. Access to land is another area that has been looked into by assessing the implications of potential REDD+ Initiatives on Smallholders’ Livelihoods through Access to Land in Singida and Manyara Regions. Pressure on land in Tanzania is increasing through population growth and expansion of protection areas raise a number of challenges in land uses including conflicts and over utilization of resources. On the other hand, more than 40 % of the land area in Tanzania is under some form of conservation regime. Environmental protection intervention through expansion of conservation areas such as wildlife conservation, strategies to implement agricultural corridors to mention a few have been reported to accelerate land
use conflicts in the country. As REDD+ is being introduced in Tanzania, there is need to think on how this can be done to have a balance between mitigation and other land use need communities.

**Section 4: REDD+ Governance Processes in Tanzania**

Establishing REDD+ demands creation of new governance structures – i.e., institutions and actors to manage forest resources. When the international engagement for REDD+ ‘took off’ at the UNFCCC COP at Bali in 2007, it was believed to be a cheap mitigation strategy and fairly simple to introduce. But experiences regarding establishing REDD+ governance structures in various countries have shown that it is demanding. This section presents some experiences from local level on the implementation of REDD+ in several areas of Tanzania.

Experience has shown that REDD+ has a potential to contribute to reducing poverty, combating global warming, and conserving biodiversity. Amongst its challenges is the issue of governance. The issue of governance arises from the fact that one of the crucial actors in REDD+ implementation is local government authorities (LGAs). The LGAs are crucial for not only ensuring regulations are followed, but also in ensuring that REDD+ finances (money) are used to improve welfare of the adjacent communities and conserve forests.

While, it is well recognized that Forest Stewardship Council (FSC) forest management certification standards can maintain and support the enhancement of forest ecosystem integrity, including forest structure and biodiversity conservation little has been done to evaluate its influence on community forest management. There is a section that presents evidence, from the assessment on the performance of a set of FSC-certified forests in REDD+ pilot project under village management through socio-ecological system conceptual framework.

**Section 5: Economics of REDD+ implementation**

This section presents some lessons on REDD+ implementation from the economics point of view. The analysis has been done on the opportunity cost of reducing deforestation, transaction costs and incentives for managing REDD+ initiatives. Opportunity costs refer to the net benefits forgone because of not deforesting (preventing conversion of forestland to other land-uses, particularly to agriculture) or degrading forests (preventing non-sustainable wood harvest). Such costs may be calculated for individual landowners/users, for districts or nations. Opportunity costs can therefore be seen as payments required for compensating individuals for their forgone benefits. In this section a chapter is designed to discuss costs and benefits of deforestation from the point of view of farming families in Morogoro region/province.

On the other hand the emerging governance structures have been examined, associated transaction costs and incentive schemes in the implementation of REDD+ piloting in the context of Participatory Forest Management (PFM) have also been assessed.
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Part 1

Climate change mitigation and adaptation strategies
Developing Fire Reduction Strategy for Miombo Woodlands as a Potential tool for Carbon Storage and Sequestration

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Abstract

World-wide, wildfires cause problems and when uncontrolled or misused they wreak havoc on society and the environment. In Tanzania, fire occurs in most parts of the Miombo woodlands, and some of them cause significant ecological and socio-economic impacts. Several efforts have been made in Tanzania to reduce the occurrence of fire in Miombo but their success has been constrained by underfunding and/or lack of proper strategies. Moreover, in many districts of Tanzania there are no apparent solutions to the fire problem, despite years of regulation and attempts to control fire, and in many places fire incidences are actually increasing. Therefore, this study intended to develop a fire management strategy for the Miombo woodland as a tool for climate change mitigation. This study also strived to identify causes, effects and factors contributing to fire prevalence. Spatial and temporal distribution of fires and burnt extents of wooded areas were determined from the Moderate Resolution Imaging Spectroradiometer (MODIS) active fires product and Landsat satellite images for the past 40 years (1972–2012). Vegetation and household surveys were used to capture empirical data on carbon stock and how different burning regimes and forest management scenarios influence carbon sequestration potentials.

Furthermore, the role of formal and informal framework for the prevention, control and management of wild fires in the Miombo was determined. The main output of this study is a proposed fire reduction strategy in Miombo. The study findings show that, to a wider extent, 1.8 and 2.9 years mean fire return interval persist in western and eastern dry Miombo areas, respectively, burning up to 50.6% of the woodland. These wildfires were largely human-driven and commonly occur in all the villages surveyed whereas the existing local governance structures and institutions suffered from poor coordination, severe underfunding and poor support from the villagers. Torching of forests was largely perpetuated by weak enforcement of laws and regulations, poverty and existing local beliefs. On average, there is an indication that the central government forests have higher stock of carbon than the local government forests and village government forest reserves. However, there was no significant difference in carbon stock between forests experiencing no burning, early burning and late burning. The proposed fire management strategy for Miombo woodlands focused on the promotion of sustainable alternative land preparation methods, improved household income sources and awareness, sustainable land use management and promotion of sustainable charcoal production. The strategy indicates a number of activities to be implemented and actors responsible for each activity.
1.0 Introduction

1.1 Background information

The global greenhouse effect caused by the rising levels of atmospheric CO$_2$ and the disturbance of the ozone layer as a result of burning fossil fuels and forest destruction is regarded a major threat to life (Sarre and Goldammer, 1996, Danthu et al., 2003). The Inter-governmental Panel on Climate Change (IPCC) estimates that 20-25% of the current annual carbon emissions result from the loss of tropical forests (IPCC, 2007). Forests that store 20-100 times more carbon per unit area than cropland play a critical role in the terrestrial carbon cycle. One major way of mitigating carbon emission is emission avoidance or conserving the existing carbon pools on land by slowing down deforestation or by adopting improved forest harvesting practices. In fact, tropical forests have a greatest potential for mitigating atmospheric CO$_2$ emissions through conservation and management and their biomass and carbon content are high, thus influencing their role in the global carbon cycle (Munishi et al., 2000).

Wildfires constitute a worldwide problem with uncontrolled or careless fire wreaking havoc on society and the environment, destroying property and natural capital, including killing people (Sarre and Goldammer, 1996). The main effects of fires on forests are losses in stocks of biomass, change in the hydrological cycle and nutrients (Salati and Vosep, 1984) and impoverishment of native plants and animal communities, which may be followed by biological invasions (Mueller-Dombois, 2001). Moreover, wildfire contributes to the changing the landscape structure and species composition in addition to altering site quality by influencing the vegetation, soil property and processes of grasslands, savannahs, closed forests and woodlands (Christensen, 1985; Goldammer, 1990; Tyler, 1995).

Globally more than 350 million ha of forest were burned in 2000 of which 95% were caused by human activities (FAO, 2003). Global records show that about 3.9 Gt of carbon (Gt C) are released annually into the atmosphere through biomass burning (Andreae, 1991). This amounts to more than 70% of the annual anthropogenic fossil fuel emissions. With its inherent sensitivity to climatic conditions, and with the prospect of rapid future climate change, wildfire has been a focus of intensive investigation in recent years (Hesseln, 2001). The World Summit for Sustainable Development (WSSD) in Johannesburg, South Africa, 2002, provided groundwork for an action programme to reduce the negative effects of wild land fire on the environment and humanity. The follow-up International Wild land Fire summit held in Sydney, Australia in October 2003 was geared towards developing synergistic solutions to strengthen international cooperation in order to reduce the negative impacts of forest fires on humanity and the global environment.
Africa leads the world in the number of wildfires and area burned almost every year in total or by areas (FAO, 2003). For example, in 2000 an estimated 175 million hectares of forest, savannah woodlands and grasslands were burned south of the equator in Africa. Many of these wildfires were intentionally set to clear land for agriculture, and many others spiralled out of control to burn much larger areas than those originally intended. It is not possible to state conclusively that there is a long-term upward trend of wildfires at the global level, since historical data are available for only a small number of countries. However, the problems experienced by individual countries and regions are such that an increasing number of national and local governments are placing wildfire as a priority issue requiring increased policy attention and increased allocation of resources (FAO, 2005). In Tanzania, between 2000 and 2009, forest fires affected about 65,000 ha of forests and woodlands annually of which more than 75% occurred in Miombo woodlands (FAO, 2011; Kideghesho et al., 2013). On the average, 11 million ha burn annually (ranging between 8.5 and 12.9 million ha) in Tanzania and this corresponds to between nine and 14% of Tanzania’s land area (Rücker and Tiemann, 2012). This widespread burning has alarmed the Tanzania government, forest managers, researchers and communities. In response, different efforts have been made to address the challenge. These efforts include the Community Based Fire Management Plan (CBFMP) and bye-laws in Bukombe district and East Usambara (Nssoko 2002, WWF 2006). Despite several efforts having been made in Tanzania to reduce fire outbreaks in Miombo woodlands, the success has been constrained due to lack of appropriate strategies.

1.2 Rationale for the study

Fire occurs in many parts of the Miombo woodlands. In fact, local farmers adjacent to the forests practice subsistence traditional farming and use fire as a management tool. Moreover, fire is used for hunting, taboo reinforcement, encouraging growth of grasses on grazing land by pastoralists, and pyromaniacs. Sometimes such fires are started out of recklessness or arson motives. Some of these fires cause significant ecological and socio-economic impacts. The negative environmental consequences of the loss of the Miombo woodland through fire include the reduction in water supply and biodiversity, pollution of water sources, carbon sequestration and reduction in agriculture production.

Human agents can promote carbon sequestration in woodlands by increasing the fire return interval and/or by decreasing the pressure of grazing animals exert on the grass layer. In addition to this management driven carbon sequestration, potential elevated atmospheric CO₂ is expected to favour carbon sequestration in woodlands and facilitate tree growth. Although savannas and woodlands have the potential of flipping between carbon-poor and carbon-rich states, the current and future carbon storage potential of the African savannah woodland has hitherto not been well articulated or quantified. In fact, there have been very
little or no concerted efforts made to bring about on-the-ground interventions in relation to fire management in the area. Remote sensing followed by ground truth could be a compromise in determining burnt areas and estimate the amount of carbon pumped into the atmosphere through fire and/or sequestration.

In many districts of Tanzania, there are no apparent solutions to the fire problem, despite years of regulation and attempts to control, and in many areas, fire incidence is actually increasing. National forest laws preventing fires also exist, but they tend to be ignored in the rural areas where local bye-laws are more important. In fact, there are some areas where fire incidences are rare and these local successes in fire control can be scaled up to address the fire problems in the Miombo. In the Miombo woodland, the major handicap to forest fire management is lack of forest fire records, which should highlight the location of the incident, time and day of occurrence, causes of the fire, and financial losses incurred. There is also lack of detailed local fire knowledge and practices. These data would provide a foundation for the design and prioritisation of future wildfire management activities in the country. Several efforts have been made in Tanzania to reduce fire frequency in Miombo woodlands but the success has been constrained by underfunding and/or lack of proper strategies. In recent years, fire has compromised efforts towards forest sustainability and biodiversity conservation, raising great concerns among government authorities and local and international researchers and conservation agents.

The institution of policies and establishment of procedures for fire occurrence documentation at village, ward and district, regional and national levels can help villagers in the planning process, as well as in sourcing funding, infrastructure and training human resources capable of contributing to combating fire. Moreover, little is known on the place of fire in the society in terms of what triggers the fire and whether there are traditional institutions governing the use of fire. Also, what do villagers know about the impact of fire on the environment in terms of water supply, species diversity of flora and fauna? What are the best mechanisms of fire control from their point of view? Therefore, the understanding of the fire regimes and the effects on the vegetation under different management scenarios as well as the overall socio-economic situations can help to develop fire management strategies that can serve as a tool for carbon storage and sequestration in the Miombo ecosystem. On the whole, the fire management strategy is critical for local, national and global interests.

The envisaged strategy can enhance the establishment of an effective and functional National Forest Policy in Tanzania. For smooth running of the project, local communities and forest practitioners were involved during project design and implementation stages.
1.3 Objectives of the study
The main objective of this study was to address climate change mitigation and adaptation strategies through the development of a fire management strategy for the Miombo woodlands as a potential tool for carbon storage and sequestration. Specifically the project focused on the following objectives:

1. To determine the intensity and impact of fire on forest degradation in the entire Miombo ecosystem
2. To determine carbon stocks in woodlands under different burning regimes scenarios
3. To identify causes, impacts and factors contributing to fire prevalence
4. To determine the role of formal and informal governance structures for the prevention, control and management of wild fires in the Miombo woodlands

2.0 Methodology

2.1 Location
The study was conducted in three districts, namely Handeni, Kilosa and Kilwa (Figure 1.1:). However, for the determination of the intensity and impact of fire on forest degradation data were collected from the entire Miombo ecosystem in Tanzania. These districts were chosen based on the availability of Miombo, annual fire incidences and different forest management regimes therein. In these districts, some Non-governmental organisations (NGOs) are also involved in forest conservation. Three forests one each either under Central government management (CGFR), Local government (LAFR) and Village Forest (VLFR) was selected. The chosen forests were Handeni: Kiva hill (LAFR), Handeni Hill (CGFR) and Gumba (VLFR); Kilosa: Palaulanga (CGFR) Magubike South (LAFR) and Ihombwe (VLFR); and Kilwa: Mitalule (CGFR), Kiwawa (LAFR) and Kikole (VLFR). In each forest, three blocks of three plots each were established. Within each block, the plots are as follows: main plots (28x28 m); sub-plots plots (7x7 m); sub-sub plots (3.5x3.5 m). A 30m strip was marked to separate the main plots and fire breaks of 4 m width surrounded each main plot. Three treatments were considered for this study; no burning, early burning and late burning. Experimental early burning was conducted in July and late burning in September for all the sites for three consecutive years from 2011 to 2013.
2.2 Approaches to data collection and analysis

Different methods were used to capture empirical data in this study. Spatial and temporal distribution of fires and burned wooded savannah areas in Tanzania were determined from the MODIS active fires product and Landsat satellite images for the past 40 years (1972 – 2012). The images were analysed following standard procedures in GRASS GIS V.7 and ArcGIS 10.0. Data on carbon stock was collected in December of the current year after short rains. Data were collected for three consecutive years; 2011, 2012 and 2013. In each site and each main plot (28 x 28 m) all the trees with dbh >10 cm were identified and measured for diameter at 1.3 cm and height. To determine forest biomass, we used the allometric equation developed by Chamshama et al. (2004). This equation includes trees from 1 cm diameter at breast height (dbh) and it has the advantage of requiring only dbh as a variable. It also had $R^2$ of 97%, hence making it reliable for the estimation of biomass. The equation is:

$$\text{Biomass} = 0.0625D^{2.553}$$

Where: \( \text{Biomass} \) = total tree biomass (kg/ha) and \( D \) = tree dbh (cm) \( (R^2 = 0.97) \)

The biomass was then converted into carbon using a biomass-carbon ratio of 0.49 (49 (MacDicken, 1997; Brown, 1997; Brown, 2003)).
The analysis of Variance (ANOVA) was performed to compare the study variable between different management regime and burning regimes. Significant differences in carbon stock in trees were tested using Tukey’s Test in SAS-JMP software.

The availability and contribution of formal and informal governance structures in fire prevention, control and management was captured through Participatory Rural Appraisal (PRA) and Structured Interviews. Similarly, the causes, impacts and factors contributing to fire prevalence were captured using the same methods. PRA methods include Participatory Resource mapping, Transect Walks and Matrix Scoring. Ten village participants from different backgrounds were used for the PRA exercise and nine PRA meetings were conducted during data collection. Direct observations helped the researchers to cross check the validity of the information obtained using other methods and to gain more understanding of the real situation on socio-economic activities, fire incidences, forest conditions, and understanding the organisation of existing governance structures on how they played their roles. A total of 270 structured questionnaires were administered with the heads of randomly selected households from one village adjacent to the study forests (30 households in each village). Also, semi-structured interviews were conducted with key informants such as village leaders, traditional leaders and heads of NGOs and district natural resources officers including District Forest Officers to capture issues related to wildfires. Content analysis was used for the qualitative data collected through PRA, direct observation and key informant interviews. This method involved breaking down the components of recorded discussion with the respondents into smallest meaningful units of information or themes. The quantitative data from structured questionnaires were coded and entered into the Statistical Product and Service Solutions (SPSS) version 22 for analysis. Descriptive statistical analysis was used in exploring the data for distribution of responses. The Chi square ($\chi^2$) tests at 99% ($\alpha = 0.01$) and 95% ($\alpha = 0.05$) Confidence Intervals (CI) were used to test the hypotheses ($H_0$: The causes of wildfires do not differ across the different management regimes; $H_1$: The causes of wildfires differ based on differences in forest management regimes). Furthermore, Analysis of Variance (ANOVA) was used on responses across management regimes based on the matrix scores developed during PRA exercises.

### 3.0 Results and key lessons from the study

#### 3.1 Fire intensity and impact on forest degradation

##### 3.1.1 Fire return interval

The mean fire return interval for an area of ~314ha was 2.7 years (range: 1 - 13 years) based on MODIS detected fires between 2001 and 2013. When
the analysis was performed for every 2500ha during 1972 – 2011 based on burned areas detected from Landsat images, the interval was shortened to 2.1 years (Tarimo et al., 2015). Moreover, 74% of the woodland area had a return interval of <2 years for every 2500ha between 1972 and 2011. Field observations in a dry Miombo site have shown a mean fire return interval of 1.6 years in Zambia (Chidumayo, 1997), whereas a return interval of 3 years on a regional scale was observed based on satellite data (Frost, 1996). The fire return interval and burning seasonality have selective effects on different components of the woodland, as they influence the intensity of fires and extent of the burning. Results from a study that combined field observations and modelling from Miombo sites in Zimbabwe and Mozambique show that, at least two years are required between successive low intensity burns to allow for tree establishment and development (Ryan et al., 2011).

The mean fire return interval was 2.5 years and 3.8 years for western and eastern dry Miombo, respectively, for the period 2001 – 2013. On a wider scale, 1.8 and 2.9 years mean return intervals were observed in western and eastern dry Miombo areas respectively for the period 1972 – 2011 (Tarimo et al., 2015). Similar findings were established in southern African savannas where return intervals were shorter in higher rainfall areas than in low rainfall areas (Van Wilgen et al., 2000). Management strategies can, therefore, benefit from this information on recurrence and seasonality of fires, which when combined with stand level ecological characteristics may highlight spatially specific management needs of wet and dry Miombo.

3.1.2 Impacts of burning

Analysis of Landsat satellite images revealed that annually, up to 12.6% and 13.7% of the total area with available imagery was detected as burned in dry and wet Miombo, respectively (Tarimo et al., 2015). Between nine and 14% of Tanzania’s area was detected as burned on an annual basis between 2000 and 2011 from a lower (500 m) resolution burned area product (FAO, 2013). Much of the burned areas in the country are evidently not detected at this resolution. Lower detection rate is possibly higher in the mixed burned-unburned patches. However, rigorous validation was not performed for partially burned areas. They provide crucial information for understanding vegetation dynamics, which require seasonality and severity of fires at specific areas but may be less useful in emission estimates which require accurate sizes of areas burned. For the later extensive validation of partially burned areas may be required.

3.2 Impacts of burning and management regimes on carbon stock

Both burning regimes and management scenarios did not show any significant impacts on above ground carbon stock (Table 1.1). However, there was a
noticeable lower carbon stock in late burning than in other burning regimes. Similarly, there was lower carbon stock in forests under village management than other management regimes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Carbon stock for trees dbh&gt;10 cm (t/ha)</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burning regime</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No burning</td>
<td></td>
<td>26.07 (4.6)a</td>
<td>28.84(4.4) a</td>
<td>26.12(4.9) a</td>
</tr>
<tr>
<td>Early burning</td>
<td></td>
<td>28.32 (4.6)a</td>
<td>28.94(4.4) a</td>
<td>28.24(4.9) a</td>
</tr>
<tr>
<td>Late burning</td>
<td></td>
<td>23.12 (4.6)a</td>
<td>23.22(4.4) a</td>
<td>19.81(4.9) a</td>
</tr>
<tr>
<td><strong>Management regime</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Village Forest Reserve</td>
<td>21.74 (4.4) a</td>
<td>23.84(4.4) a</td>
<td>22.22(4.9) a</td>
<td></td>
</tr>
<tr>
<td>Local Authority Forest Res</td>
<td>25.22 (4.4) a</td>
<td>27.23(4.4) a</td>
<td>23.52(4.9) a</td>
<td></td>
</tr>
<tr>
<td>Central Government Forest</td>
<td>30.55(4.4) a</td>
<td>29.92(4.4) a</td>
<td>28.43(4.9) a</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Above ground Carbon stock for trees dbh>10cm across different burning regimes and management scenarios.

The number in parenthesis is Standards Error and the numbers in columns with similar letter are not significantly different (p>0.5).

The range of carbon stored in trees (21.74 – 30.55t/ha) in the study forest reserves is slightly higher than the one reported for Miombo woodlands in the southern highland Miombo forests (17.9 – 20.4 t/ha) (Munishi et al., 2010). These differences could be attributed to the fact that the present study included only reserved forests, which are a bit protected from illegal extractions, hence limiting human activities. Another study by Munishi et al. (2010) included trees outside forest reserves.

3.3 Causes, effects, factors contributing to fire prevalence and potential strategies to reduce wildfire incidences

3.3.1 The proximate causes of wildfires

Five proximate causes of wildfires were identified by local communities in the study villages in order of prevalence in terms of farm preparation, hunters, arsonists, livestock keepers and charcoal makers. The study hypothesised that causes of wildfires depended on differences in forest management regimes. Farm
preparation was identified as the most significant causes in CGFR as compared to the VLFR and the LAFR. The practice was most (94.4%) common in Kilwa district followed by Kilosa (45.6%) and least practiced in Handeni district (34.4%). Kilwa leads in such practice due to the abundance of unreserved land and low population density estimated to be 13 people/km² compared to 31 and 77 people/km² for Kilosa and Handeni, respectively (URT, 2013). Wildfires caused by livestock keepers were mostly (15.6%) reported in LAFR compared to VLFR (67%) and CGFR (4.6%). It was further established that illegal hunting was mostly reported in CGFR whereas arson was mostly reported in LAFR. Charcoal-burning is a potential cause of forest fire in CGFRs and LAFRs. This could be attributable to factors such as weakness in law enforcement, increasing demand for charcoal in big cities, and construction of tarmac roads connecting these districts to charcoal markets. Forest clearing and charcoal-burning have been responsible for the rapid loss of forest cover and the deterioration of local biodiversity along Tanzania’s main roads (Ahrends et al., 2010; Kideghesho et al., 2013). Chi-square test revealed no significant difference ($\chi^2 = 16.391$ and $p = 0.089$) on the most important cause of forest fire across forest management regimes, implying that there are similarities when it comes to the causes of wildfires.

Wildfires were either deliberate (arson) or accidental in occurrence. The former was a result of fire due to anthropogenic activities such as taboos (measuring life-span e.g., in Tanzania some ethnic groups believe that if one starts a fire and it lasts longer and spreads to a large extent such a person is considered to live a long life); clearing up of landscapes to allow safe and free movement in the forest during hunting or collection of forest products, forage production, controlling parasites such as ticks and tsetse flies and vermin and eliminating cover to discourage dangerous animals. The use of fire during hunting of small mammals such as Giant rats (Ndezi) was practiced in all the forests under study. Such traditional hunting involves burning of bush on one side and waiting for escaping animals on the opposite side of the bush. The causes of wildfires in this study have also been acknowledged in other studies, with farm preparation being the main cause (Fitzgerald, 1971; URT, 1998; FAO, 2007; FAO, 2011).

The months of June, July, August, September, October, November and December were reported by 5.6%, 17.3%, 51%, 63.5%, 66.3%, 33.3% and 12.4% of respondents respectively as a season of wildfires. The months of August, September and October were reported by 20.5%, 25.5% and 26.6%, respectively, as the peak fire season. Similar peak fire season was reported in Masito Ugalla Ecosystem (Kashula and Gobbo, 2011). The months of June, July, November and December had low wildfire incidences as reported by 2.3%, 6.9%, 13.5% and 5% of respondents, respectively. It was observed that June and July were onset months of the dry season with little fuel load and fresh grasses. November and December had low fire incidences because of the short rains that minimise
combustibility of fuel biomass. In addition, during that period, most of the villagers are usually engaged in farm activities with little engagement in risky activities such as illegal hunting and honey collection that could cause fire eruption.

Further analysis shows that the peak fire season is not determined by forest management regimes but rather by geographical locations of research sites. Minor variations were observed among the sites. For instance, Handeni hill CGFR and Kiva hill LAFR (in Handeni District) experienced peak fire season in September and October whereas Bumba proposed VLFR (in Handeni District) experienced it in September. Variation in peak fire season was also found in Kilosa District where Mbilili VLFR experienced a peak fire season in August whereas Palaulanga CGFR and Magubike South LAFR experienced fire season in October. In Kilwa, Kikole VLFR and Mitalule CGFR experienced the peak fire season in September and October whereas in Kiwawa LAFR the fire season peaked in October. Across all the forests very few fire incidences were reported before and after the peak fire season. Such findings suggest that any campaign attempting to reduce forest fires incidences should start at the end of the rainy season mainly in May and June. Frost (1996) and Kall (2006) argue that fire burning in the early dry season (May-June), when the ground layer is still moist tends to be very low in intensity and limited in extent and, hence, affects grasses and mammals negatively whereas woody plants are less affected.

1.1.2 Point of ignition of forest fires
The point of wildfires in the forests under review was identified to be around residential areas, inside the forest reserve and around farms. The chi-square test indicated a significant difference in origin of forest fires across forest management regimes ($\chi^2 = 13.341$ and $p = 0.031$). About 59%, 46% and 69% of respondents adjacent to VLFRs, CGFRs and LAFRs respectively revealed that most of the forest fires start from inside the forest. The high proportion of wildfires starting from inside the forest suggests the existence of illegal anthropogenic activities. Such illegal activities include hunting, honey harvesting, livestock keeping, charcoal-burning and lumbering, which usually happen inside the forest. About 16%, 28% and 16% of respondents adjacent to VLFRs, CGFRs and LAFRs respectively reported that wildfires start from around residential areas. Wildfires that start around farms were common in VLFR as reported by 10% compared to NFR and LAFR reported by 7.8% of the respondents.

3.3.3 Effects of forest fires in the study villages and forests
Discussion with people living in villages adjacent to the forests covered by this study revealed both positive and negative effects of forest fires. Positive effects of forest fires as perceived by local communities in order of importance include simplifying farm preparation, chasing away pests/parasites, stimulating growth of
grass for fodder, a tool during illegal hunting, improving soil fertility especially in millet fields, and as a tool for clearing routes during the harvesting of forest products such as timber. The F test indicated that there was no significant difference on the positive effect of forest fires across forest management regimes (F=0.111, p=0.895). Nevertheless, the results suggest existence of social ties between forest fires and the daily life of local communities. Economically, forest fire was perceived to increase household income when it was used to stimulate growth of fodder, hunting, collection of forest products, and killing of pests/parasites, which could transmit disease to livestock. Culturally, forest fire is used as a yardstick of the lifespan of individuals involved in torching forests.

Negative effects of forest fires in order of severity include loss of biodiversity, causing climate change, loss of the property, causing soil erosion, drying of water sources and loss of soil fertility. Comparing people’s perception on negative effects of forest fires across forest management regime using F test indicated no significant difference (F = 0.852 and p = 0.446). Citing an example of the negative effect of forest fire on biodiversity, elders in Kwedibangala Village, in Handeni District, reported that the forest fire of 1977 led to the disappearance of Mnwahungo forest. In such incidence, animals and birds that escaped were also affected by changes in their habitat. Moreover, a loss of soil fertility in burnt areas negatively affects crop production, especially paddy. Similarly, Zolho (2005) reported that in the long-term frequent fires may result into changes in productivity and population structure of the plant and animal species due to reduced plant biomass and litter, thereby altering the energy, nutrient and water fluxes between the soil, plants and atmosphere.

3.3.4 Factors underlying forest fire incidences

Factors underlying forest fire incidences include poverty, weak law enforcement, climate and ignorance of the local people (Figure 1.2). Of the four factors, poverty was reported by 34% of the respondents living adjacent to LAFR as compared to 22% in VLFR and 28% in CGFR. Poor economic situations were reported to drive local communities to engage in unsustainable and often destructive means of accruing income or food from the forests such as illegal hunting, honey collection, extraction of forest products and shifting cultivation.
Ignorance on negative effects of forest fires was more evident among local communities adjacent to CGFR (43%) as contributing to fire incidences as compared to VLFR and LAFR. Ignorance could be partly explained by the majority of forest adjacent communities failing to link biotic and abiotic components of the environment. Therefore, it was not surprisingly for someone to start a forest fire when hunting small mammals to earn cash income. Moreover, weak enforcement of the existing laws and bye-laws was acknowledged by most in VLFR (34%) and in LAFR (33%) as an underlying factor behind forest fires as compared to CGFR. Lack of funds, vehicles and staff to patrol forest were singled out as overriding factors hindering law enforcement. Climatic factor mainly drought and wind were also reported by local communities adjacent to VLFRs and LAFRs as underlying factor of forest fires.

### 3.3.5 Potential focus areas to reduce forest fire incidences in the study area

Figure 1.3 presents five (5) potential focus areas to reduce forest fire as identified by communities living adjacent to forest reserves. These include awareness creation, formulation and enforcement of bye-laws, making firebreaks, provision of alternative income generating activities (IGAs) and improving agriculture...
through the provision of subsidies. Awareness creation, which was the most prioritised by communities adjacent to VLFRs and CGFRs entail the provision of conservation education. This probably due to limited extension and publicity services provided in villages adjacent to the study forests. For instance, only 38.9%, 37.8%, 36.3% and 32.2% of the respondents living adjacent to LAFR, VLFR and CGFR, respectively, acknowledged having seen forest fire campaigns being conducted in their respective villages. Kashula and Gobbo (2011) reports that awareness creation for forest adjacent communities is important in minimising forest fires in the area as it has been confirmed to work efficiently in the conservation of forests in Western Tanzania, where forest fire incidences have been reduced by 80%.

![Figure 1.3: Focus areas to reduce fire incidences identified by local people during household survey](image)

Enacting and enforcing existing laws and bye-laws as a focus area of reducing forest fires ranked first in CGFR and second in VLFR and LAFR. Both laws and bye-laws have provisions on restricting burning of vegetation. For instance, the Forest Act no. 14 of 2002, sections 70–76, restrict burning of vegetation (URT, 2002). With regard to bye-laws, they vary across villages. Of the nine (9) villages surveyed, only Kikole and Ihombwe had approved forest bye-laws. On the other hand, making firebreaks was identified and prioritised by communities living adjacent to the forest reserves. Firebreaks help to protect forest reserve from forest fires started outside the reserve. Essentially, out of the nine forests surveyed, only Kikole VLFR had firebreaks. Nevertheless, neither CGFRs nor LAFRs had firebreaks. With regard to IGAs, local communities identified fish farming, beekeeping and commercial tree-planting that could increase income of the rural poor, hence reduce pressure on the forest reserves. In addition, the adoption of such environmental-friendly activities could instil a sense of ownership in the forest resources, and potentially ultimately protect the forests and biodiversity (Songorwa, 1999). Furthermore, increasing agricultural
production through the provision of subsidies on agricultural inputs could relieve
of forests of some of the human pressure, therefore, reducing the eruption of
forest fires. Such intervention could reduce dependency on forest resources.

3.3.6 Role of formal and informal governance structures for
the prevention, control and management of wild fires
in the Miombo woodlands

In this study, 57.8%, 64.4% and 50% of the respondents sampled in villages
adjacent to VLFR, CGFR and LAFR, respectively, acknowledged the presence
of informal and formal governance structures which deal with environmental
issues including the management of wildfires. Nonetheless, the chi-square test
indicated that the difference in responses of villagers regarding the presence of
governance structures was not statistically significant ($\chi^2 = 3.847$, $p = 0.146$)
between forest management regimes. This suggests that there is no variation across
forest management regimes, possibly because the structures are formed based
on the provision of the law. Informal governance structures identified include
elders, traditional/clan leaders and herbalists. Their role include 1) disseminating
information to youngsters on the importance of not starting wildfires in
sacred forests/plants or mountain; 2) transferring knowledge to youngsters on
traditional rituals, norms, taboos and initiations; and 3) punishing any person
found guilty of starting fires in the restricted area by using customary rules. It
was also revealed that these informal governance structures had been proven
to be powerful in the past contrary to the current situation, presumably due to
changing attitudes and beliefs among many youths. Similarly, increased ethnic
intermarriages, in-migration, modernisation and technological intervention are
threatening and transforming or eroding the cultural rules, beliefs and taboos
governing the management of forests (Katani, 2010).

Furthermore, the formal governance structures identified in the villages include
Village Government (VG), Village Council (VC), Village Natural Resource
Committee (VNRC) or Village Environmental Committee (VEC), Ward
Development Committee (WDC) and the Primary court. These structures have
been established in accordance with formal laws such as the Local Government
Act No. 20 of 2004. Matrix ranking based on activity of the structure on
forest protection including the prevention, control and management of wildfires
revealed that VEC/VNRC was leading followed by VC whereas WDC ranked
third and the Primary Court was the least effective. Table 1.2: presents the
roles of these formal governance structures. The roles of VG/VC and VEC/
VNRC originated from forest management plans, PFM guidelines and bye-
laws, Forest Act No. 4 of 2002, Local Government Act No. 167 of 1982 and
Environmental Management Act of 2004. The roles of WDC with regard to
forest protection have been extracted from section 32 of the Local Government
Governance structure | Roles
--- | ---
Village government (village assembly) | - Discuss and approve draft of management plan and by-laws including those prohibit wildfires; and 
- Participate in forest management activities including making fire breaks.

Village council | - Discuss and provide suggestions of forest management by-laws; 
- Dislodge VEC/VNRC if proved failure in performing its duties including failure to reduce incidences of wildfires; 
- Awareness creation on forest protection including matters related to wildfires; and 
- Enforce bye-laws.

VEC/VNRC | - Plan and supervise everyday forest activities including doing forest patrols; 
- Propose draft of by-laws that govern management of the forest reserve; and 
- Enforce bye-laws including fining any person caught committing illegal activities and take criminals to the court including those caught starting wildfires.

WDC | - Formulation, and submission to the village councils or to the district council proposals for formulating bye-laws in relation to the affairs of the ward.

Table 1.2: Roles of existing formal governance structures in the surveyed villages

3.3.7 Performance of governance structures in the management of wildfires

Governance indicators including accountability, transparency equity, rule of law, responsiveness, participation and effectiveness were used to measure the performance of different governance structures at the village level based on 5-points scale (very good = 5, good = 4, satisfactory = 3, poor = 2 and very poor = 1). Overall, the performance of governance structures in forest protection against wildfires was rated as poor in all the villages under review. This finding suggests that local structures have not been adhering to the principles of good governance. The reported increasing wildfire incidences testify to the weakness of the existing local governance structures. For instance, VC and VEC/VNRC were rated as poor and as satisfactory, respectively, upon looking at the issue of accountability. This performance was, perhaps, due to limited village assemblies convened to discuss forest related issues. And even in such assemblies, the agenda of forest protection against wildfire never feature in the discussions. Such a situation denies the villagers of their right to access information regarding
forest protection, and potentially increases conservation threats to the forest. Similarly, very few forest patrols were made and lawbreakers were not punished accordingly. Our results also show that 68.7% of the respondents claimed not to participate in forest protection owing to their discontent over how the existing governance structures handled forest management activities.

Furthermore, interviewees in villages adjacent to the forests under review reported a low level of transparency amongst members of VC and VEC/VNRC. Members of the respective structures withheld information on income and expenditure and often took no action against offenders reported to them by villagers. Similar scenarios were reported by Rafael and Swai (2009) and Nuru et al. (2009), which found poor transparency in the handling of forest destructive actions. There are several reasons contributing to poor performance of the local governance structures. These include poor co-ordination among structures at the village level, severe underfunding and poor support from the villagers. For instance, VEC/VNRC were frequently found to be engaged in a tussle with the VC on who is responsible for collecting and managing forest revenue. With regard to funding, the only source was fines from arrests of people implicated in illegal activities within the forests, an unreliable source of funding that cannot be integrated in the forest protection plans. On the other hand, funds generated by the village government from other sources such crop levies were not allocated to forest protection. As a result, members of the VEC/VNRC lacked incentives and protection gears to execute forest protection duties such as forest patrols.

4.0 Implications of the lessons learnt relevant to the REDD+ process and climate change mitigation and adaptation in general

i) Socio-economic welfare: Reduced fire incidences and frequencies will improve or increase ecosystem services and goods in the areas consequently the livelihood of the people

ii) Environment aspects: Fire is usually an environmental nuisance and, therefore, its reduction could lead to an improved environment for both humans and other living organisms

iii) Policy reforms: Fire problems are not well-articulated in our natural resources (forestry, wildlife, land, agriculture and beekeeping) based policies and laws despite the fire being caused by different activities related to different sectors. Findings from this study could be used to review and improve these policies and laws

iv) Capacity building: During the project development and implementation, villagers through VEC, District officers, NGOs and Project researchers have increased their understanding on forest fires and REDD initiatives at large.

v) Cross-cutting issues i.e. Collaboration, gender and HIV/AIDS: Through
this project participating researchers have increased their scientific/social network at village, district, Institutional, national and International level. Similarly, constraints hindering the smooth implementation of the project such as lack of or limited women’s empowerment and participation, diseases, education and poverty were discussed.

5.0 **Recommendations:**

Results from this study lead to the proposed fire management strategy in Miombo woodlands of Tanzania (Table 1.3):

<table>
<thead>
<tr>
<th>Main causes of Fire</th>
<th>Focus area</th>
<th>Activities</th>
<th>Actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm preparation</td>
<td>Promote sustainable alternative land preparation methods</td>
<td>Provision of agricultural extension services</td>
<td>Community members, Village Council, District Council, NGOs, Forest owners and farmers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Construction of fire break between farms and the forests</td>
<td></td>
</tr>
<tr>
<td>Hunting</td>
<td>Improvement of household income</td>
<td>Promote alternative livelihood strategies</td>
<td>Community members, Village Council, District Council, NGOs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Awareness creation through meetings, seminars, posters, leaflets</td>
<td></td>
</tr>
<tr>
<td>Arsonism</td>
<td>To reduce ignorance among local communities related to fire and environment</td>
<td>Awareness creation through meetings, seminars, posters, leaflets, Law enforcement</td>
<td>Community members, Village Council, District Council, Central government, NGOs</td>
</tr>
<tr>
<td>Livestock keepers</td>
<td>Sustainable land use management</td>
<td>Land use planning</td>
<td>Community members, Village Land Use Planning Committee (VLUPC), Village Council, District Council, Central government, NGOs, Judiciary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Law enforcement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Awareness creation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provision of livestock extension services</td>
<td></td>
</tr>
<tr>
<td>Charcoal makers</td>
<td>Promote sustainable charcoal production</td>
<td>Use of alternative and sustainable source of energy</td>
<td>Village Land Use Planning Committee (VLUPC) Village Council, District Council, Central government, NGOs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Law enforcement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Awareness creation</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1.3: Fire reduction strategy in Miombo woodlands of Tanzania*
References:


Tyler, C.M. 1995. Factors contributing to post-fire seedling establishment in chaparral; direct and indirect effects of fire. Jr. of Ecology 83:1009-1020


Adoption of rangeland management strategies for mitigating climate change in agro-pastoral communities in Gairo District, Tanzania

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Abstract

Climate variability and change coupled with increased number of livestock in Gairo District have resulted into land use conflicts and encroachment on village forest reserves. Rangeland management strategies for reducing the vulnerability of agro-pastoral communities to climate change and reducing pressure on forest resources is, therefore, imperative. In this regard, the current rangeland management practices of three selected villages in Gairo District were assessed in response to the prevailing climate change and variability. Vegetation condition and soil properties in relation to land use practices were also assessed.

Various pasture establishment technologies using different agronomic practices were tested. The number of coping strategies employed by agro-pastoralists in
the study areas notwithstanding, the climate variability and change have had a devastating impact on rangeland condition and livestock performance. Indeed, there has been an increase in animal deaths and human conflicts due to inadequate pasture resources. The decline in herbaceous vegetation cover, tree density and above-ground biomass were attributed to the effect of climate change and poor land use practices. The higher values of bulk density in the cultivated land and grazing land coupled with low value of total porosity were associated with increased soil compaction due to grazing and continuous cultivation.

Higher organic carbon in forest reserves and old farms was most likely due to adequate organic matter decomposition. The adoption of pasture nursery using sunken bed techniques by most of the agro-pastoralists was probably because of their good capacity of moisture storage. Key lessons drawn from the current studies affirm that, climate change has had adverse effects on human and livestock performance and inappropriate land use practices increased pressure on grazing land and forest reserves. Since improved rangeland cover through pasture establishment has a potential for Carbon sequestration, we recommend up-scaling and out-scaling the home garden pasture model in wider areas of semi-arid grazing lands in the country.

1.0 Introduction
The negative effects of climate change on pastoral and agro-pastoral communities are becoming rather intolerable in arid and semi-arid rangelands of Tanzania (Paavola, 2008). Erratic rainfall, prolonged and frequent droughts, severe floods and frequent crop failures are among the precarious effects of climate change. According to Mary and Majule (2009), the rainfall pattern in most semi-arid areas of Tanzania has been decreasing with time whereas both the minimum and maximum temperatures have been increasing by 1.9 and 0.2°C, respectively. Some climate projection models suggest an increase of global average surface temperature of between 1.8 and 4.0°C by 2100 (Jones and Thornton, 2008). These changes have serious impact on livestock production systems (Thornton et al. 2009) particularly in arid and semi-arid regions. Jones and Thornton (2008) predicted that, the continuous increases in frequencies of heat stress, drought and flooding would result into further deleterious effects on crop and livestock productivity in Africa. Agro-pastoralists and smallholder farmers, particularly in developing countries, are more vulnerable to the effects of climate change because their socio-economic status, demographic trends and inappropriate policies limit their capacity to adapt these changes (Morton, 2007).

In addition, the increasing human population is exerting more pressure on rangelands through agricultural expansion and overgrazing. According to Jones and Thornton (2008), the human population in Africa is expected to increase by 1 billion in 2050. Haines et al. (2006) pointed out that, increased
human population and changes in land use practices are among major factors exacerbating the effects of climate changes. In consequence, many traditional adaptive knowledge and livelihood strategies practiced by pastoral and agro-pastoral communities for centuries are no longer efficient in coping with the negative effects of climate change and rangeland use pressure. Furthermore, pastoral and agro-pastoral communities have increased encroachments on adjacent forest reserves especially during the dry season in search of water and pasture. Inevitably, the degradation of rangelands and catchment forests has led to reduced water flow of the major river ecosystems.

On the other hand, the well managed rangelands provide important benefits such as increased water infiltration, retention and improved nutrient cycling, associated with organic matter accumulation in the soil as well as increased plant growth, biomass and diversity of species. Appropriate rangeland management practices are, therefore, good mitigation measures to climate change as they reduce the risks associated with prolonged drought periods and unreliable rainfall.

1.1 Rationale and objective of the study
An adverse environmental degradation has been witnessed in the western semi-arid rangeland of Gairo District. Rangeland deterioration in these regions is evident in soil erosion, unavailability of water, decreasing vegetation cover, changes in plant species composition, declining forage yields and reduced livestock performance including death (Sangeda et al., 2013). This trend has lowered human and livestock carrying capacity of these semi-arid regions and has increased the encroachments on the forest reserves and water catchments. These regions will continue to deteriorate due to increased pressure from agro-pastoral activities occasioned by an increase in livestock population and immigrants from other areas. Indeed, very little is known about sustainable rangeland use practices and innovative strategies to overcome the problem in the area and the country in general. In addition, improved rangelands have high potential of reducing atmospheric greenhouse gas emissions and enhancing carbon stock and sequestration. Against this backdrop, our research focused on investigating different rangeland improvement strategies to reduce the vulnerability of agro-pastoral communities to climate change.

3.0 Methodology

3.1 Study area
This study was carried out in three agro-pastoral villages of Gairo District, namely, Kinyolisi, Leshata and Mkalam (see Fig.2.1). Gairo is one of the
seven districts of Morogoro region in the country. It is located in the northwest corner of Morogoro between 36° 45’ E and 6° 30’ S with an altitude of about 1,000m above sea level. Gairo receives rainfall of between 400 mm and 500 mm per year. The rain is unimodal and falls between December and April with the dry season falling between May and November. Rainfall is normally erratic and in storms it results into high runoff and intensive soil erosion, especially in cultivated and overgrazed areas. The study villages were originally inhabited by the Kaguru, Nguu and Kamba ethnic groups. Now the Maasai and Nyaturu are emerging groups in the area. The major economic activities are subsistence crop farming and livestock keeping of indigenous cattle, goats and sheep. The vegetation type in the study area is wooded grassland and Miombo woodlands.

3.2 Study design and sampling procedures
For socio-economic variables, both quantitative and qualitative data were collected through a combination of methods including interview with household heads, focus group discussion (FGD) with selected agro-pastoralists, leaders and elders using a checklist, and personal observation method. A total of 64 heads of households were interviewed in the three villages of Kinyolisi (n =21), Mkalam (n=21) and Leshata (n=22). The sample size was based on 5% of the total number of households in the three villages. Information collected included the respondents’ perceptions of climate variability and change, farming practices,
forest and water resources management, range management practices, gender roles, resource access, ownership and decision making, adaptation, opportunities and barriers towards climate change.

For range inventory data, survey was conducted in the three selected villages towards the end of wet season to evaluate the available range of resources, which are useful in the development of appropriate rangeland improvement strategies. Vegetation attributes were measured in terms of herbaceous vegetation cover, above-ground biomass, tree densities and crown cover. A 50m tape measure was used as basic sampling unit to estimate the basal cover along the established transect lines. The distance along the tape measure, intercepted by grasses, litter, forbs and shrubs were recorded and finally the bare ground was calculated. For the herbaceous above-ground biomass, destructive method was used whereby fresh samples of vegetation were harvested within 0.25m² and oven dried for computation of dry matter. For tree density and canopy cover the Point Centred Quarter Method (PCQM) was used as described by Cottam and Curtis (1956).

In addition, soil physical and chemical characteristics were assessed to inform the development of improvement strategies and the adoption of appropriate land use type. The Leshata village was selected for assessment of land use practices in relation to soil physical and chemical properties. The selection of Leshata was based on the existence of all four land use types—grazing land, forest land, old farmland and new farmland. The old farmlands in this context are lands which have been used for crop cultivation for over 15 years whereas new farmlands are lands which have been under crop cultivation within the past three years. From each land use type, three sites (of 4,900 m²) were selected randomly for soil sampling. A total of 60 soil samples were collected and taken to the soil laboratory at the Sokoine University of Agriculture (SUA) for the determination of bulk density, particle density, total porosity, particle size distribution (soil texture), and soil pH, total Nitrogen, extractable Phosphorus, and exchangeable bases.

For the determination of soil physical and chemical properties, soil sampling was done in two selected villages, namely Leshata and Mkalama. Leshata was selected to represent high density vegetation cover whereas Mkalama represents low density vegetation cover (see Fig. 2.2). Soil samples were collected from two different depths of (0-15) cm and (15-30) cm. Each village was composed of two transects and each transect had eight sampling points. A total of 64 soil samples were collected and taken to SUA for chemical analysis.
For the determination of bulk density in each land use type, three identical cores were hammered into the soil and the soil cores were excavated gently (see Fig. 2.3). The soil samples within the core were carefully put into the plastic bag and taken to the laboratory for the analysis.

### 3.3 Data analysis

Socio-economic data were analysed using the Microsoft Excel spreadsheet. Soil physical and chemical properties and vegetation attributes were subjected to
analysis of variance (ANOVA) using general linear model (GLM) procedure of the statistical analysis system (SAS institute, 2003). A least significance difference (LSD) test was used to separate significantly differing treatments means after main effects were found to be significant at \( p \leq 0.05 \).

4.0 Results and key lessons from the study

4.1 Effects of climate change on rangeland healthy and livestock performance

Climate variability and change was found to have adverse effects on the rangeland condition in Gairo District. Prolonged drought was found to lower the quantity and quality of forage in the three selected villages of the district. During interviews with agro-pastoral communities, over 50% of the respondents reported that the length of hot days had significantly increased and subsequently affected forage production. In addition, about 52% of the respondents claimed that, the rainfall pattern and distribution in the study area was unpredictable. Prolonged drought in the study area resulted into poor livestock productivity. This poor livestock performance has been attributed to the decline in the quality and quantity of forage, especially during the dry season. Sangeda et al. (2013) associated the livestock mortality and increase in human conflicts with scarcity of feed and grazing land due to multiple land uses in the Gairo villages.

The effect of climate variability and change coupled with the declining of grazing land due to multiple land uses has adverse effects not only on livestock productivity but also on increased human conflicts in Gairo district. A decrease in grazing lands and declining quality and availability of forage lowered the grazing capacity of remaining grazing lands and, thus, forced livestock keepers to encroach upon conservation areas. It has been noted that villagers from the villages under review tend to encroach upon forest reserves for grazing purposes. Belsky and Blumenthal (1997) reported that, livestock induce deforestation of forestlands. From the focus group discussions with district officials, it emerged that the degradation of forest resources was also associated with encroachment by villagers mainly for firewood and grazing. Firewood collection and charcoal-burning are lucrative businesses that attract villagers as alternative income generation activities. Abdallah and Monela (2007) reported that more than 90% of wood production in Tanzania is consumed as wood-fuel which mainly comes from reserved forests.

4.2 Range condition in the three selected villages of Gairo District

Changes in vegetation cover can be used to monitor the rangeland condition and process of land degradation. Despite relatively lower number of livestock
(Sangeda et al., 2013) in Mkalamo village (1,800 cattle, 500 goats and 5 sheep) compared to Leshata village (12,114 cattle, 5,724 goats and 2800 sheep), the land in Mkalamo village was highly degraded as manifested by a high percentage of bare ground (see Table 2.1). Poor land use practices are most likely to be the main cause of severe land degradation in Mkalamo village. The village is very close to the Dar es Salaam - Mwanza highway, which makes the area vulnerable to encroachment for farming and charcoal-burning by immigrants, who take advantage of easy accessibility for transportation of produce to the market. Increased runoff and inadequate moisture content in soil are major consequences associated with low vegetation cover and land degradation as a result of poor land use practices. Increase in invasive plant species called Ipomea kituensis locally known as “Mahata” was an indicator of land degradation in Mkalamo village.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kinyolisi</th>
<th>Leshata</th>
<th>Mkalamo</th>
<th>Mean</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass cover (%)</td>
<td>10.69</td>
<td>12.16</td>
<td>6.5</td>
<td>9.78</td>
<td>1.42</td>
</tr>
<tr>
<td>Litter cover (%)</td>
<td>59.54</td>
<td>59.94</td>
<td>17.15</td>
<td>45.54</td>
<td>4.7</td>
</tr>
<tr>
<td>Forb cover (%)</td>
<td>4.29</td>
<td>5.42</td>
<td>4.32</td>
<td>4.68</td>
<td>0.59</td>
</tr>
<tr>
<td>Shrub cover (%)</td>
<td>9.85</td>
<td>10.04</td>
<td>5.1</td>
<td>8.33</td>
<td>1.15</td>
</tr>
<tr>
<td>Bare ground (%)</td>
<td>15.63</td>
<td>12.44</td>
<td>66.93</td>
<td>31.67</td>
<td>5.76</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1: Vegetation covers in three selected villages

In addition to poor vegetation cover in Mkalamo village, it was also observed that the average forage yield per hectare (ha) in 2012 was almost zero percent (see Table 2.2). Nevertheless, the average absolute density of tree per ha in the same year was zero. This implies that, the areas under review were highly degraded beyond normal restoration measures and, thus, required special rehabilitation measures. Hume and Barker (1991) recommended reseeding as a best option for severely degraded rangeland.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kinyolisi</th>
<th>Leshata</th>
<th>Mkalamo</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage yield (kg DM /ha)</td>
<td>270</td>
<td>188.33</td>
<td>0</td>
<td>152.78</td>
</tr>
<tr>
<td>Tree density (N/ha)</td>
<td>884.19</td>
<td>546.41</td>
<td>0</td>
<td>476.87</td>
</tr>
<tr>
<td>Tree canopy cover (%)</td>
<td>59.27</td>
<td>65.77</td>
<td>2.25</td>
<td>42.43</td>
</tr>
</tbody>
</table>

Table 2.2: Forage yield and absolute density of trees in three selected villages
4.3 Effects of land use types on soil characteristics

Land use types were found to have a significant bearing on soil physical properties as evidenced by the relatively higher mean values for bulk density observed in both the old and new farmlands (see Table 2.3). The higher values of bulk density in cultivated land than in forest reserves were also reported by Celik (2005). Higher values of bulky density in the cultivated lands might be associated with soil compaction due to grazing over the crop residues after harvest that left the crop land bare throughout the dry season and, thus, vulnerable to wind and rain water erosion. However, this argument is contrary to Abdel-Magid et al. (1987) who reported that bulk density was neither affected by the grazing system nor by stocking rate. An alternative explanation for higher values of bulky density in the cultivated lands could be soil compaction as a result of use of heavy equipment during the tillage process. During field survey, many of the farmers in this area were found to use tractors for tillage which most likely caused soil compaction. According to Hamza and Anderson (2004), inappropriate farming practices leads to soil compaction. In this case, the percentage of total porosity was significantly higher in the forest reserve than in other land use types (see Table 2.3) due to low soil disturbances as most reserved forests are highly protected from human activities.

<table>
<thead>
<tr>
<th>Land use types</th>
<th>Bulk density (g/cm³)</th>
<th>Total porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing land</td>
<td>1.50 ± 0.06&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>40.69 ± 2.26&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Forest reserve</td>
<td>1.40 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.50 ± 2.26&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Old farm land</td>
<td>1.64 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>37.24 ± 2.26&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>New farm land</td>
<td>1.63 ± 0.06&lt;sup&gt;c&lt;/sup&gt;</td>
<td>36.66 ± 2.26&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 2.3: Influence of land use types on bulk density and total porosity

The mean values with different superscript differ significantly at $p \leq 0.05$

Soil organic carbon (SOC) is a key attribute of soil quality that impacts on soil aggregation and water infiltration. The amount of SOC depends on soil texture, climate, vegetation, historical and current land use or management practices (Jobbágy and Jackson 2000). Climate affects SOC amount as it is a major determinant of the rate of decomposition and, therefore, the turnover time of C in soils. Since all study sites were under similar climatic conditions, the variation in SOC was probably influenced by different land use types. The high value of SOC in the forest reserves compared to new farmland and grazing
land (see Table 2.4) is in agreement with Milne (2009) who reported that, soils under natural forests tend to have higher SOC content than soils under cropland (Milne, 2009). However, the non-significant difference in SOC between forest land and old farm is debatable. The amount of organic C in the soil is normally affected by plant production (Jobbágy and Jackson 2000).

<table>
<thead>
<tr>
<th>Land use types</th>
<th>Soil Ph</th>
<th>Total N (%)</th>
<th>Organic Carbon (%)</th>
<th>Organic Matter (%)</th>
<th>Available Phosphorus (mg/kg)</th>
<th>Exchangeable bases K (Cmol kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing land</td>
<td>6.03 ± 0.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.077 ±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.37 ±0.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.71±0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.40±1.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.69±0.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Forest reserve</td>
<td>6.32 ± 0.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.083 ±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.52 ±0.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.13±0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.86±1.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.760.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Old farm land</td>
<td>6.20 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.090 ±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.64 ±0.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.45±0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.99±1.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.820.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>New farm land</td>
<td>5.79 ± 0.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.057 ±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.39 ±0.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.76±0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.94±1.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.700.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 2.4: Effects of land use on soil chemical composition in Gairo District

The mean values with different superscript differ significantly at \( p \leq 0.05 \)

### 4.4 Rangeland improvement strategies

#### 4.4.1 Pitting technique

The results from the field survey and range inventory from three selected villages were discussed at a feedback meeting of all stakeholders. The poor range condition observed in Mkalama village prompted the carrying out of range improvement interventions in that village. These interventions included pitting on bare grazing field (see Fig. 2.4). This technique has helped to reduce run-off and thus improved moisture availability and consequently fostered vegetation growth and cover in these dry land soils within three years. Figure 2.4 shows the effects of pitting in Mkalama village, with the same interventions also being implemented in Leshata and Kinyorisi villages:
After three years of intervention, pasture production was found to have increased from 0 kg/ha in 2012 to more than 1,000 kg/ha in 2014 (see Fig. 2.5). This technique was easily adopted by many agro-pastoralists not only at Mkalam village but also by other nearby villagers. The adoption of this technique by most of the agro-pastoralists was probably because of the better yield registered within short time. In addition, this technique was useful in soil conservation because of its capacity of moisture conservation. Mupagawa et al. (2006) reported that plant grown using-pitting technique have significant yield because of less moisture stress than those grown on non-pitted areas.

**4.4.2 The Home Pasture Nursery (HPN)**

Home pasture nursery (HPN) was another technique that was used in the study area to improve the range condition. This technique was adopted following the failure of demonstration sites (farmer field school) to bring about desired change of imparting on rangeland rehabilitation knowledge and skills to the agro-pastoral communities in Kinyolisi and Leshata villages. The HPN was innovated for multiplication of pasture planting materials among agro-
pastoralists as an alternative to the field demonstration site. The new approach used sunken seedbed that was prepared like a contour furrow of around 50cm deep. In the semi-arid rangelands with unreliable and highly variable rainfall of below 500 mm annually, a sunken seedbed improves moisture availability to planted pasture. Dry farmyard manure was added to the furrow up to around 10 cm and then the topsoil was returned. Manure improved rain water holding capacity in these dry land soils. Manure and top soil were thoroughly mixed followed by planting the grass tillers and biomass production was high as figures 2.6 and 2.7 illustrate:

![Figure 2.6 (i): Preparation of home pasture nursery by sunken seedbed technique at Mkalama village, Gairo District](image)

![Figure 2.6 (ii): Planted tillers of Cenchrus ciliaris in Sunken seedbed at Leshata village, Gairo District](image)

![Figure 2.7 (i): Home pasture nursery with fully grown C. ciliaris at Mkalama village, Gairo District](image)

![Figure 2.7 (ii): Training of agro pastoralists in a farm after upscaling the home pasture nursery technology in Gairo District](image)

On the basis of the findings and subsequent discussion, the following key lessons can be summarised from the study:

i. Climate change has adverse effects on human and livestock performance. This was apparent from the responses of most the respondents who frequently cited poor animal condition and human conflicts as consequences of climate stress. Also, inappropriate land use practices increase pressure on grazing land and forest reserves as agro-pastoral communities are forced to encroach the village forest reserves and important catchment areas.
ii. Improved rangeland management practices have a potential for carbon sequestration. Improved pasture in communal grazing lands and home pasture nurseries through appropriate agronomic techniques in selected villages in Gairo increase the potential for carbon storage and sink.

iii. Although pasture establishment is a new innovation for most of the pastoral and agro-pastoral communities, pitting and sunken seedbed techniques were easily adopted because of better yield in terms of forage biomass.

iv. Improved forage resources through the establishment of pasture plots have a positive implication for REDD+ initiatives. Also, improved pasture resources is a potential sink for greenhouse gases particularly carbon-dioxide. Furthermore, improved livestock diet through high quality pasture significantly reduces methane emission from livestock.

5.0 Implications of the lessons learnt for REDD+ process and climate change mitigation and adaptation

A successful REDD+ initiative towards climate change adaptation and mitigation requires a better understanding of impacts of climate change and variability by the community. About 98% of agro-pastoral households in Gairo were found to have knowledge on the precarious effects of climate change and were willing to adopt various innovations for reducing these effects. In fact, many of the agro-pastoralists had engaged in various coping strategies to mitigate the negative effects of climate change and variability. These strategies include shifting cultivation, vegetable gardens, pastoral mobility, digging boreholes in sand rivers and mixed crop cultivation.

On the other hand, inappropriate land use practices may have negative implications for REDD+ initiatives as they increase pressure on grazing land and forest reserves. The agro-pastoralists cope with scarcity of grazing land by encroaching upon village forest reserves in their search for forage availability and water resources. Various project interventions in the study villages created awareness among agro-pastoralists on the importance of forest conservation and vital catchment areas. Following this awareness creation, different bye-laws have subsequently been enacted and enforced in the study villages.

Improved forage resources through the establishment of pasture plots have a positive implication for REDD+ initiatives. Moreover, improved pasture has potential for carbon sequestration. In this regard, literature shows that well-managed grasslands have capacity of carbon sequestration that reaches on average $5 \pm 30$ g C/m$^2$ per year (Soussana et al., 2010). In addition, one of the most promising approaches to improving livestock production and subsequently
reducing greenhouse gas emission is through better nutrition (Steinfeld et al., 2006). Therefore, improved pasture will not only enhance carbon sequestration but also reduce other greenhouse gas emissions particularly methane.

**Conclusion**
The precarious effects of climate change and variability in the Gairo district have been manifested by soil erosion, unavailability of water, decreasing vegetation cover, declining forage yields and reduced livestock performance including mortality. Some direct effects of climate variability and change in Gairo were associated with an increase in the length of hot days and unpredictable rainfall pattern. On the other hand, inappropriate land use practices have accelerated the effect of climate change by reducing vegetation cover, above-ground biomass yield and density of trees per ha. Nevertheless, land use types were found to have significant effects on soil physical and chemical characteristics. Grazing activities and feeding on crop residues in situ after harvest in crop fields have been associated with increased soil compaction and reduced water infiltration. However, the most important finding is an increase in forage yield and potential for carbon sequestration following the establishment of improved pasture plots in both communal grazing land and home garden nurseries. Therefore, there is a need to upscale and out-scale pasture establishment and moisture conservation technologies to a wide range of other semi-arid areas in the country with similar ecological zones. The adoption of these range management practices can help reduce the effects of climate variability and change in semi-arid areas that are the most vulnerable to climate stress.

**Acknowledgement**
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**References**


National and local perspectives on adaptation strategies

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Abstract

This paper explores how information provided by different research perspectives about climate change impacts and adaptation matter to recommendations for adaptation strategies in Tanzania’s agricultural sector. We compare conclusions from a macroeconomic model, a microeconomic sector model, and mixed methods research in a village in Morogoro Region. The macroeconomic perspective enables policy-makers to evaluate climate impacts on national development pathways. However, a perspective based on aggregated information may underestimate the challenges to adaptation that poor farmers face if the impacts of climate change on household food security are not considered. In fact, the resulting welfare losses are hidden behind the macroeconomic aggregates. A sector perspective suggests that poor people need access to stable off-farm sources of income to limit the effects of climate change on rural food security and livelihoods. However, the local case study shows that poorer households
cultivating less land tend to engage in less reliable and less remunerative seasonal work, potentially making poor farmers even more vulnerable to the impacts of climate change than indicated by the models. Consequently, poverty is not only a barrier to climate adaptation, climate change is a barrier to mitigation of poverty.

1.0 Introduction

Many smallholders in Tanzania rely on agriculture as well as utilising forest services to meet their daily needs. REDD+ projects will affect their livelihoods, but it is difficult to tell whether it represents a notable change to them or to the communities in which they live, and whether the perceived consequences suggest a general change in the evaluation of REDD+ initiatives in Tanzania. In undertaking this evaluation, national authorities will have to consider many factors on a rather general basis. When considering REDD+, it is vital to know how it may affect the adaptive capacity of smallholders, who also need to relate to climatic changes in the context of wider livelihood priorities and constraints. The perspectives of smallholders and communities need to be adequately represented and combined with the national perspectives in a transparent and consistent manner in order to do so. This is one reason why macroeconomic models are used for planning purposes. The models project national economic indicators derived from statistical information with reference to a theory of economic behaviour of individuals. Such models thereby support national authorities in developing strategies to the benefit of individuals. However, the models assume that everybody is fully integrated in markets, that they all have equal opportunities to take part, and that they are compensated by a monetary income for all the work that they do. This applies to most developed economies, but is far from reality in developing economies, such as Tanzania. Here, a share of the production on farms, where more than 80 percent of the population lives, is consumed by the household on the farm, and not sold. In addition, studies show that markets are the main source of food for the urban population and 60 percent of rural households (KI, 2011). Smallholder food security therefore depends on having access to agricultural land as well as income, which may include income from forest products and services. This implies that it matters for both poverty reduction and climate adaptation strategies where smallholders work, and what kind of work they undertake.

This paper explores caveats in using a traditional macroeconomic model to assess the impacts of climate change on the Tanzanian economy, and to evaluate the vulnerability of the agricultural sector in order to develop adaptation strategies. We compare three approaches to addressing impacts and evaluate adaptation options. First, we use a macroeconomic computable general equilibrium (CGE) model for Tanzania to analyse the impacts on the national economy under a standardised scenario for global development and climate change, and discuss
possible adaptation strategies on this macro level. Second, we use a sector model for Tanzanian smallholders, based on statistical data for Tanzania. We then explore the challenges that agricultural households face, given the changes described by the macro model. In the third approach, we compare the conclusions from the sector model to findings from a survey of 50 households in a village in Morogoro region, and ask what is lacking from the statistical information that makes a difference to adaptation strategies among smallholders.

2.0 Global development, climate change and consequences for Tanzania

Climate change, its impacts and the adaptive capacities of people in Tanzania depend heavily on future global development trajectories. This study employs the shared socioeconomic pathways (SSPs) and the representative concentration pathways (RCPs), which are recommended by the Intergovernmental Panel on Climate Change (IPCC) for projections of climate and related studies of climate impacts, mitigation and adaptation. The SSPs provide assumptions about social and economic drivers of development, whereas the RCPs provide assumptions about emissions and resulting concentrations and radiative forcing. Here, we combine SSP5 (O’Neill et al., 2014) and RCP8.5 (Riahi et al. 2011).

SSP5 describes an optimistic future with high economic growth, particularly in developing countries, and a moderate population growth. Global population increases to nearly 8.6 billion in 2055, but decreases thereafter to 7.4 billion in 2100. The population in Tanzania increases from the present 50 million to 90 million in 2080, and decreases slowly to 87 million in 2100. The global gross product doubles nearly four times from now to 2100. The global gross product doubles nearly four times from now to 2100. Economic growth is particularly high in developing countries, including Tanzania, where the Gross Domestic Product (GDP) doubles seven times from now to 2100. This is partly due to the higher population growth in Tanzania, but also GDP per capita grows much faster here than in the rest of the world (ROW). Income per capita is only 18 percent lower than the world average in 2100, compared to the 87 percent lower income per capita today.

The pathway thereby describes a future with success in making Tanzania transform from a developing country to a semi-developed country. This may imply that poverty is more or less eradicated in the course of this century, but this depends also on how the income is distributed in 2100. The economic growth implies tremendous structural changes, including in agriculture, and it will take time before everybody can enjoy it. The main economic growth takes place before 2050, when the income per capita is still much lower in Tanzania than in ROW. Income per capita is approaching the world average when economic growth rates in Tanzania and in ROW is 1/3 of the growth rates in the first half of this century.
Figure 3.1: Changes in mean temperature and annual precipitation under RCP8.5 over crop land in Tanzania and in the rest of the world derived from global projections 2005 – 2100.

The transformation assumed here is far from a transformation to a low-carbon world. Instead, the high economic growth requires a major increase in energy use worldwide, which is based primarily on fossil fuels. Thus, global emissions grow steadily throughout the century, although at a steadily declining rate in the second half. In 2100, global CO$_2$-emissions are 2.5 times the present emissions. Figure 3.1 shows the resulting changes in mean temperature and annual precipitation for Sub-Saharan Africa and ROW. The indicators were derived from projections by the MPI-ESM model (Giogietta et al., 2013). Note that further downscaling of these projections was not available, and the projections for Sub-Saharan Africa are, therefore, used as a reference to illustrate climatic changes in relation to the Tanzanian economy in this paper. Temperatures then increase steadily by 5.4 °C in this century, which is more than 6 °C from preindustrial times. Precipitation increases both in Tanzania and in ROW, with an upward jump in Tanzania after 2080, amounting to 69 mm/year over the century. Variability will also have to be considered when addressing impacts on communities, and we will return to this below.

3.0 The national perspective: macroeconomic impacts and adaptation strategies

The national accounts are a system of social and economic statistics aimed at supporting national governments in monitoring structural changes and economic development. Data from national accounts can be used in macroeconomic models to assess the economic consequences of policy choices, and to project
economic indicators with reference to assumptions about the development of
the main socioeconomic drivers of economic growth. This is helpful to policy-
makers in interpreting results, and facilitates a transparent communication of
policy choices and their consequences.

We use a computable general equilibrium model, GRACE (Aaheim and Rive,
2005) to derive the economic consequences of the projections presented in the
previous section. Computable general equilibrium models are rather extensive
models of national accounts data, which aim to derive impacts on a broad range
of economic indicators of changes in major drivers of economic development.
Figure 3.2 shows a schematic overview of the GRACE model:

![Diagram](image)

*Figure 3.2: A schematic overview of sectors and climate impacts in the GRACE model*

The version of the model used here has 7 economic sectors listed in the first
column. The same sectors are listed in the heading and data from national
accounts are filled in each cell with the values (price x quantities) of deliveries
from each sector (column) to all other sectors (row) in a base year. The last
two columns give deliveries from each sector to end use, consumption and
investments. Thus, the sum over rows gives the value of total production or the
supply of goods and services from each sector. The columns show the value of
input factors used in each sector, and the composite of goods to consumption
and investments. The three last rows provide the input of the primary factors
of production, labour, capital and natural resources. Columns thereby show
the demand for various goods and services from each sector and for end use.
Emissions are derived from the production and use of specific goods and services,
for example, energy.

Remunerations to labour, capital and natural resources are income generated
by work and ownership, and can be spent on consumption and investments.
In the model, it is assumed that total income equals total expenditures every year. The model used here has two regions, Tanzania and ROW. The trade between Tanzania and ROW is determined by modelling of import shares of each demanded good and service. Foreign investments take place depending on differences in the remuneration to capital. Labour supply is based directly on the projections of population, and the supply of natural resources is estimated for each sector, based on the availability in the base year. A change in these drivers or in policy, for example, through an increase in taxes, spurs a shift in supply or demand in the affected sectors, and propagates to other sectors by the resulting change in the demand for input. The model then generates a new set of prices to restore equilibrium.

Items that may be affected by climate change are shown by the dark red rectangles in Figure 3.2. Agriculture, forestry, fisheries and the electricity sector are impacted by sector specific impacts on their use of natural resources. Extreme events and sea-level rise affect the availability of capital, and health effects change the supply of labour to all sectors. Climate change also affects the demand for tourism with direct impacts on the service sector, and energy demand is sensitive to temperature in both energy sectors and households. The impacts affect supply and demand in the same way as changes in other drivers and policies and propagate to other sectors with resulting price effects. In fact, the responses among economic agents can be associated with autonomous adaptation.

The impacts of climate change are represented by specific relationships between the value in each item and chosen climate indicators. It is important to note that this is highly uncertain information, however. The functional forms are based on surveys mainly from Europe (Aaheim et al., 2012), and the parameterisations are based on relatively few available studies on the global impacts of climate change on national economic aggregates, and discussed in Aaheim et al. (2015). The results illustrate how climate change may impact specific sectors of the Tanzanian economy when the interactions with all other sectors are taken into account. The resulting information is relevant for building adaptation strategies at the national level with an eye on economic development.

Figure 3.3 shows the assumptions that are applied here on the percentage direct effect of climate change on each of the items in Figure 3.2 at +1.5 °C, +3.0 °C, and +4.5 °C in Tanzania. The effects become increasingly negative as the temperature increases, with agriculture and electricity supply being the most adversely affected. Tourism is assumed to be strongly affected, but the effect does not increase much as temperature increases. The effect on forests is slightly positive at +1.5 °C, but becomes negative at +3.0 °C and +4.5 °C. Health effects
and extreme events increase significantly with increasing temperatures.

Note that the immediate costs of these effects on the Tanzanian economy depend on the relative economic influence of each item. The effects on agriculture and health give the strongest direct effect on GDP. Although losses from agriculture constitute steadily about 40 percent of total losses at increasing temperatures, contributions from losses due to health effects increase from 25 percent at 1.5 °C to 42 percent at 4.5 °C. Losses from extreme events increase from 6 percent of GDP at 1.5 °C to 10 percent at 4.5 °C. In total, losses constitute 3.3 percent of GDP at +1.5 °C, 9.3 percent at +3.0 °C, and 19.7 percent at +4.5 °C.

These losses can be interpreted as the direct economic impact of climate change. However, the change in climate will also induce adaptation, leading to market responses. Moreover, climate change affects also other countries, with trade effects on Tanzania. Using the projections of economic and population growth presented in Section 2 in combination with the impacts shown in Figure 3.2 in the GRACE model, we find that the GDP losses in Tanzania increase exponentially over the century, and amount to 1.8 percent in 2050, 4.9 percent in 2075 and 9.7 percent in 2100. This is nearly twice as strong as the total impacts in ROW. This can be explained partly by a more rapid economic growth in Tanzania, and partly by a strongly affected agricultural sector, which is assumed to continue to be an important sector throughout the century.
Figure 3.4 shows how the value added by sector is affected over this century. The sum of value added across all sectors equals GDP. The impacts on four of the sectors follow more or less the impacts on GDP, whereas electricity, energy and to some extent agriculture deviate. The energy sectors in the model comprise fossil fuels and hydro power, although biomass is the most important energy source in Tanzania. The fossil fuel sector is only slightly affected directly by climate change, and value added is reduced by only three percent in 2100. The reduction in electricity use is nearly 18 percent. This difference is due mainly to higher prices. Impacts of climate change worldwide reduce the demand for fossil energy without impacting supply. World-market prices, therefore, decrease. However, renewable energy in the electricity system is negatively affected by climate change. This dominates the price effect of fossil fuels, meaning that the price of electricity increases. As a result, there is a notable substitution from electricity to fossil fuels.

The message from these calculations is that climate change will have substantial impacts on the Tanzanian economy, and more so than in most other countries of the world, although it is likely that other Sub-Saharan African countries will be similarly affected as. One reason is the high projected economic growth in Tanzania under SSP5. The scenario assumes that the economy will go through a substantial restructuring, which increases the vulnerability of the economy to climate change. The increasing limits to adaptation are illustrated by differences between the direct effects shown in Figure 3.3 and the impacts presented in Figure 4. In 2050, when the increase in temperature is slightly above +2 °C, autonomous adaptation contributes to a 67 percent reduction of the direct effects of climate change. In 2100, when temperature increase is above +5 °C, adaptation reduces the direct effect by 57 percent.

From a national policy perspective, projections such as these can be used to appraise policy strategies for economic development. Climate change will have
major impacts on the economy in Tanzania if efforts to curb global emissions of greenhouse gases fail. On the other hand, the costs of a transformation to low-carbon economies worldwide may also be large, and exceed the negative impacts of climate change. The economic development in these projections may turn out to be more attractive, after all, than a low-carbon alternative. In that case, the projections suggest prioritising a strategy for adaptation within the agricultural sector. This sector contributes to 40 percent of the GDP throughout the century and suffers the largest losses from climate change, also in relative terms. The loss in productivity is compensated only by slightly higher prices (+2 percent in 2100). From a governmental perspective, an adaptation strategy should include the implementation of measures to motivate planned adaptation. This can be done by facilitating flexibility and resilience in farmers’ choices of crops and livestock production technologies to enable them to take advantage of changing climatic and marketing conditions in the future. Measures may include providing farmers with enhanced agricultural extension information connected to climate information and services, improving access to climate smart production technologies and inputs, supporting diversified production systems, encouraging precautionary investments, and developing road, telecommunications and marketing infrastructure to reduce transaction costs.

4.0 The sector perspective: Impacts and adaptation among smallholders

The macroeconomic model focuses entirely on economic transactions. It assumes that producers of goods and services achieve their goals only by considering the available technologies and market prices, although the choice of consumption goods and services depends on the same prices adjusted for taxes, and constrained only by monetary income. It does not matter if this income is earned by paid work or by selling products or services.

Most smallholder Tanzanian farmers are in a different situation. A varying portion of labour provided on smallholder farms is unpaid labour that is undertaken by family members, and food is produced for own consumption, for sale, as well as for meeting social obligations. The share of food produced for own consumption depends, among other factors, on smallholders’ access to land. Only a portion of smallholders’ production is sold to generate income, and this portion varies over time according to the socioeconomic position and needs of the household, and climatic and other conditions affecting farmers’ yields. On the other hand, income can be earned from activities performed outside of the farm. This income is spent on food and other goods and services, which include consumption, re-investment in farming, and investments in improving the education and health of the household. Choices between production, income, investments and consumption are integrated, negotiated, appraised and
undertaken in the context of wider livelihood strategies, and depend on access to land and other income opportunities, in addition to prices and transaction costs, and a range of social factors. Below, we ask how the evaluations in the previous section are affected if these factors are taken into account.

Figure 3.5 shows composites of income, production and consumption in the agricultural sector, when based on a combination of National Accounts data and the National Sample Census of Agriculture 2007/2008 (NSCA). Subsistence farming is estimated from a survey-based study by Ellis (2007). The left bar shows the contributions from the use of labour and from the availability of land to total agricultural output. The numbers indicate that more than half of the production is generated by land. Note, however, that this includes contributions from other non-human input factors, such as machinery. This contribution is substantial on large farms, but probably less important on small farms, which will be the focus here. The second bar shows how consumption is divided into food from farm, food bought in markets and other consumer goods. Food from own farm contributes to 60 percent of total consumption, and a little more than 10 percent of the food is bought from markets. Consumption of other goods and services constitutes nearly 30 percent. The third bar shows that 80 percent of monetary earnings is generated from sales of agricultural produce, whereas 20 percent comes from activities outside the farm.

Macroeconomic models describe the economic behaviour of individuals whose choices correspond exactly to the aggregated data, so-called representative agents. We do the same here, meaning that the numbers in Figure 3.5 are
interpreted as the composites of production, consumption and income in an average, or representative, Tanzanian farming household. What differs is the scale, which is adjusted by dividing these numbers by the 5.8 million Tanzanian farming households that existed in 2007/08, according to the NSCA. Further adjustments are made to estimate the labour force available in each household, using information on age distribution and corresponding activities from NSCA. Adjustment of the consumption in each household are made with reference to assumed relative consumption levels in different age groups, as compared to "full consumption" for adults aged between 15 and 64 years. Then, the average of 5.3 persons per household corresponds to 4.2 "adult consumer equivalents". The micro model is similar to that in Aaheim and Garcia (2014), and presented in the appendix. Here, we confine ourselves to a verbal discussion on how the aforementioned characteristics are taken into account, in comparison to the modelling of farming in the macroeconomic model, with attention being paid to how consumption and income patterns change with access to land on single farms, which we refer to as "size of the farm". The numbers in Figure 3.5 were used to calibrate the micro model for a typical farm of average size in Tanzania, which is approximately 2 ha.

In contrast to the macroeconomic model, a change of farm size may change the composite of consumption and the division of work in the micro model due to constraints that smallholders face, but which the macroeconomic model ignores. First, the budget constraint is confined to spending monetary income on food and other goods that are bought in markets. The consumption of food produced on the farm is constrained by the output. Finally, there is a lower limit to the consumption of food in a household, which can be associated with a nutrition constraint.

To examine the consequences of these constraints for the allocation of working time and consumption, the micro model was run for farms of different size. In correspondence with the three constraints, the farms are then divided into three groups: farms subject only to the budget constraint, farms subject to the budget constraint and the output constraint and farms subject to the budget, output and nutrition constraint. The latter group are left with few choices, however: They personally consume everything they produce on the farm. If they earn money from other work, they first have to buy food. If there is money left over, everything will be spent on other goods. This is called a "corner solution". In analysing the impacts of climate change or policies, the question is how many farmers belong to this group.
Figure 3.6: Percentage allocation of income sources and consumer goods by farm size. Hectares.

Figure 3.6 shows the allocation of income and consumption for households with access to different farm sizes. Households on farms of less than 0.55 ha are subject to the nutrition constraint. The output constraint appears where the curves in the figure break at a farm size of 1.1 ha. For smaller farms, the assumption in the macroeconomic model on independency of scale is violated both for the sources of income and for the consumption pattern. The consumption pattern on large farms is unaffected by the farm size as the macroeconomic model assumes, whereas the income from the farm as a share of total income increases slightly with size also on larger farms.

The break of lines shows where the output constraint is encountered. The constraint imposes an implicit cost, or shadow price, of consuming food from own farm. This shadow price increases from 0 to 150 percent times the market price of food as farm sizes are reduced from 1.1 ha to 0.55 ha. This is a result of lack of income needed to buy the food that the household would have consumed had they had a sufficiently large farm, and can be interpreted as a loss of welfare measured in food prices. The model assumes that these farmers manage to earn some income outside the farm, and the figure shows that the household's dependency on these sources increases as the farm size decreases. The contributions from the production on own farm to the consumption of food declines with declining farm size for households subject to the output constraint. Hence a slightly larger share comes from food bought from markets. The high shadow price of food implies that smaller farmers also substitute between consumption of food and other goods.
Consequences on a macro scale can be derived by using the size distribution of farms. The present distribution is shown in Figure 3.7, according to NSCA. An estimate of 850 000 farms are less than 0.55 ha, where the nutrition constraint set in these calculations are binding. About 1.1 million farms are less than 1.1 ha, and subject to the output constraint. There are more than 5 persons per household on average, meaning that the macroeconomic indicators fail to address climate impacts on livelihoods for 10 million people in farming households today. Note, however, that the nutrition constraint is set more or less arbitrarily in these calculations. We also assume that the size of a farm corresponds to the productivity of the land, which is clearly problematic (Chand et al., 2011). These figures do not account for intensification of labour or other production factors that may increase yields on smaller farms. Our point here is to show how and why the impacts on smallholders differ from the impacts on large-scale farmers, which the macro model addresses.

Reduction in the productivity of land caused by climate change was estimated at 22 percent. We examine the impacts on the different farm sizes in three steps. First, we calculate the impacts on the productivity of land in isolation. Then, we add the corresponding impacts on prices from the macroeconomic projections, where food prices increase by two percent, prices of other goods by one percent, and wages are reduced by 3.6 percent. Finally, we consider consequences of a possible policy response, namely to reduce the difference between selling price and buyer price of food (transaction costs) by 20 percent.

Lower productivity of land increases the number of farms that encounter the nutrition constraint. With the present distribution of farms, this happens with households on between 270 and 300 thousand farms, but this number depends fully on how the income distribution develops over this century. Increasing
prices and lower transaction costs have an insignificant impact on the number of farms subject to the nutrition constraint. There is also a significant increase in the number of farms that encounter the output constraint, but the combination of impacts matters to them. Households on nearly 400 thousand more farms become subject to the output constraint if only the productivity of land changes. This is reduced to 250 thousand if impacts on prices are included, and reduced further to 30 thousand if there is success in reducing transaction costs. Figure 3.8 displays the estimated impacts of the three different runs on the composite of consumption and work in a household with a 0.7 ha farm. A household of this size is subject to the output constraint in all alternatives but avoids the nutrition constraint in all of them. All numbers are converted to 1,000 US$.

The main consequences stem from the impacts on the productivity of land. The impacts on prices have moderate consequences, partly because these impacts are relatively small in climate projections. The policy alternative of reducing transaction costs has a negligible consequence for this household. Recall, however, that this policy matters a lot to the number of farmers that avoid the output constraint. The main impact of higher market prices and lower wages is a shift from work outside the farm to work on the farm. The consumption of food from own farm thereby increases, and the consumption of market goods changes from an increase under constant prices to a decrease. Possible positive impacts of higher prices for agricultural products are neutralised partly by lower wages and partly by a higher dependency on subsistence.

The micro model adds vital information about the impacts of climate change on smallholders, when compared with the interpretation from the macroeconomic indicators. It reveals the necessity of distinguishing between the impacts of climate change on traditional economic indicators such as production, income and consumption, and the impacts on constraints that rural households live and farm under. These include a nutrition constraint and a constraint to the ability to supply agricultural products to the market and thereby enjoy the flexibility
that monetary income provides. Moreover, the climate impacts on traditional economic indicators differ between households, depending on whether these constraints are binding or not. Households subject to an output constraint become increasingly dependent on income from sources outside the farm as the productivity of the land decreases. To account for the possibility that there is correspondence between human and natural resources, we have assumed that the maximum time a household can spend on work outside the farm decreases slightly as the farms become smaller. However, we have found no support for a numerical assessment of this sensitivity. Uncertainty related to the possibility of earning income from activities outside the farm may, therefore, further increase the vulnerability of poor households, and put people in households subject to the nutrition constraint in an even more difficult situation.

5.0 The local perspective: A village study from Morogoro Region

The analyses in the two previous sections are based on statistical information from Tanzania, and are confined to aggregated information. As with the interpretation of the results from the macroeconomic model, the micro model also addresses “representative agents”, but highlights logical consequences of the fact that people have access to farms of different sizes. This is to avoid inconsistent interpretations of how changes in macroeconomic indicators and general policies affect the population. The aggregated point of departure implies, however, that we cannot claim insight into how farmers with access to a certain area of land will be affected, because the variability in conditions that households must relate to in their daily life goes far beyond their access to land. Moreover, the micro model is based on approximations and assumptions that we have limited or no statistical information about. To better understand how macroeconomic drivers and national policy strategies may affect the livelihoods of smallholders, we need to examine the micro level more closely.

The assumptions underlying the micro model and the derived composites of consumption, production and work are, therefore, checked against information from a case study of Lungo village in Mvomero District, Morogoro Region. The village is located adjacent to Mtibwa Sugar Estates in a flat area of approximately 350m above sea level, and has a population of about 1,000 people. It has a relatively high agricultural potential, with annual precipitation of between 850 and 1750 mm/year. This is close to the 1200 mm/year average for Tanzania, although precipitation patterns here, as elsewhere in Tanzania, differ considerably within and between years. Infrastructure is moderately developed, with travel time to the Morogoro-Dodoma tarmac highway of 1.5 – 3 hours, with longest time in the rainy season.
The study is based on semi-structured interviews conducted with 50 households. Knowledgeable local people helped to divide the 184 households in the village into wealthy, average and poor households, based on an evaluation the households’ ownership of land and livestock, access to off-farm sources of income, ability to produce enough food for the household, crops grown, education and quality of home. Nineteen poor, 24 average and seven wealthy households were then selected, who reflect the distribution of farming profiles, wealth, ethnicity and share of women-headed households in the community. Most of the families owned their own land, but some, most of them poor ones, borrowed or rented land. A typical poor family cultivated 1.17 ha, an average family cultivated 3.36 ha and a wealthy one cultivated 5.02 ha. This corresponds reasonably well with the distribution of farm plots in Tanzania.

The main crops cultivated are maize, rice and sugarcane. Other crops include sunflower, cowpeas, soya and irrigated vegetables, the latter grown mainly by average and wealthy households. Maize and legumes are often intercropped. Most of the maize is consumed by the households as a food crop. Rice is a food crop too, but also a key cash crop. On the other hand, all sugarcane is sold to the nearby Mtibwa Sugar Estates. The usage of areas for cultivation of maize, rice and sugarcane among the different categories of households is as illustrated in Figure 3.9. Maize covers more than 50 percent of the cultivated area in poor farms, but less so in larger farms. Rice covers increasing areas as farms become larger, and provides increasing opportunities to earn an income. Sugarcane covers only six percent of the cultivated area on the farms of poor households and between 25 and 30 percent on other farms.

Most of the households keep livestock. Whether they keep livestock or not seems to be rather independent of farm size, but the size matters to the kind and number of livestock that they keep. Stall-fed dairy production is prevalent only among average and wealthy households. Ownership of traditional cattle spans the range from poor to wealthy households, with wealthier households owning larger numbers of cattle compared to poor households. Poor households
typically keep smaller livestock such as sheep, goats and chicken. The village study shows an increasing share of cash crops being cultivated by households of increasing wealth, which conforms to the result in the micro model that the degree of subsistence decreases with increasing farm size. Although the model simplifies the output to one product, the correspondence between subsistence and production for the market can be read from the composite of crops in the study. This illustrates an aspect of adaptation implicit in economic models, where agents change behaviour along with changes in input factors. In this case, composites of crops and livestock differ depending on the farm size, which is consistent with the assumption that farmers maximise utility. However, the model ends up with extreme solutions, such as producing only for own consumption as soon as the output constraint is binding. In reality, seasonal variations and individual variability in needs and farming conditions across households make these shifts less rigorous.

![Figure 3.10: Allocation of working days on farm by crop. Days per hectare per season.](image)

The working time spent on the farm depends on the crops cultivated, as shown in Figure 3.10, where the number of days spent per season per hectare is divided into different activities. Sugarcane is the least labour intensive crop, according to these figures. Most of the work undertaken by farmers for sugarcane relates to land preparation, weeding and field clearing, as the crop is perennial, and harvesting is mechanised and organised by the outgrower associations to which all cane farmers belong. Maize is more labour intensive than sugarcane, and also involves more activities. Rice is clearly the most labour intensive, primarily because of the need for weeding, and time-consuming harvesting and bird scaring activities. One explanation for the differences is that sugarcane production is a more mechanised process than the production of maize and rice.

In some cases, the use of labour is hired from outside the farm, at varying costs, depending on the activity and season. For example, the estimated cost of weeding land planted to maize is between 45 and 55 thousand TSH/ha (2012 prices), and the crop normally requires two weedings per season. Hiring labour to weed a rice field costs between 125 and 370 thousand TSH/ha, and hiring
labour for bird-scaring ranges from 50 to 125 thousand TSH/ha. No time is spent on marketing sugarcane directly, as Mtibwa Sugar Estates is the only buyer and a fixed price is negotiated with the two out-grower associations that serve smallholder cane growers in surrounding communities ahead of the harvesting. However, there are supervision costs involved in preparing and guarding cane that has been harvested for transport, and overseeing the cane loading process. The time available to farming households to earn an income from off-farm sources depends, therefore, on the crops cultivated on the farm, which is closely related to the farm size, as well as to the availability of labour, and to the season in which crops are cultivated.

The pattern is that farmers on the smallest farms concentrate on cultivating food crops for their own consumption, mainly during the long rains (MAM) season. As farms become larger, more emphasis can be placed on producing cash crops, including sugarcane and irrigated vegetables, which are produced/harvested in the short rains season and after the main and rice crops have been harvested, respectively. In addition, rice provides a nice flexibility in being both a food and a cash crop (West, 2015). Variations in time needed to produce what is possible means that households with small farms have, in general, more time available to earn an income by activities outside the farm, although this depends also on many other factors. The findings from the village study that households who are more oriented towards cash income also have larger farms implies that the farming activities of wealthier households correlate better with the activities within the agricultural sector presumed in the macroeconomic model. The micro model projects that more time to do other things implies that the income from activities outside the farm increases, but the model does not consider variations in income opportunities.

The village study reveals a broad range of alternative income opportunities, which vary considerably regarding both permanency and remuneration. In general, the most predictable income is earned by having a permanent source of off-farm income, such as working as a teacher, as a permanent employee at Mtibwa Sugar Estates, or engaging in a trade. Sale of products from the farm or from forest-related activities, such as production of charcoal and honey, offer seasonal sources of income, as do wages from casual work on other people's farm or on the Mtibwa Sugar Estates. The most uncertain income is derived from petty trading, where the daily income in most cases varies more than the average income. The income opportunities utilised by the people in the village are in most cases reached within a distance of 20km, meaning that people access local markets in most cases, but with moderate transaction costs.

Against this background, the reality of the underlying assumption about income earned from activities outside the farm in the micro model can be checked against information from the findings related to households’ engagement in permanent employment outside the farm. The data show that 57 percent of
wealthy households are engaged in this kind of employment, whereas only eight percent of the average households and none of the poor households are. In fact, households on smaller farms depend—to a larger extent—on variable income from selling farm produce or variable or even highly uncertain income from activities outside the farm, meaning that earnings from one day spent on activities outside the farm most likely decrease notably with farm size.

On the other hand, the village study does not provide sufficient details for assessing a relationship between monetary income opportunities and farm size that can be implemented in the micro model. And yet, it more than suggests that the micro model is too optimistic about households’ sensitivities to variations in the productivity of land. For example, poor farmers are not that flexible when it comes to substitution between consumption of food from own farm and food from markets if the productivity of their land changes. Consequently, households that encounter the nutrition constraint and the output constraint at a change in productivity under climate change are likely to be more sensitive to changes in the productivity of land than the modelling indicates.

The increased dependency on increasingly uncertain off-farm sources of income enhances smallholder’s vulnerability to changes in the productivity of land, when compared with the interpretation of models based on statistical information at the national level. This applies, in particular, to interpretations of the macroeconomic model. But also the micro model fails to address this challenge, as it assumes that those who are subject to the output constraint can easily earn an income outside the farm and buy food instead. This seems to be far from reality in practice, meaning that consumption is more sensitive to the farm size and to changes in the productivity of land than the models indicate. Indeed, it is more difficult to tell how this uncertainty affects responses to changes in wage and price levels, and how this uncertainty may affect smallholder’s vulnerability to climate change impacts.

6.0 Conclusions
The potential benefits of REDD+, which are related to preserving bio-diversity and mitigating climate change, may impose losses on the local users of the forests, who depend on both agriculture and forest products to meet their income and other needs. The foregone benefits are difficult to measure, however there is increasing recognition of the need to take a landscape approach and to incorporate wider livelihood concerns and non-economic values associated with forest use, when assessing potential benefits and losses of REDD+. This paper discusses smallholder vulnerability to climate change in Tanzania, with attention being paid to the role of both access to land and off-farm sources of income, including utilisation of forests, in securing their food and other consumption needs. We compare assessments based on three different perspectives. First, we take a general national economic perspective using a macroeconomic model.
Second, we pay attention to smallholders by means of a sector model. Third, we compare conclusions from the models with conclusions derived from field research in Morogoro Region.

The macroeconomic projections assume high economic growth under a temperature increase of more than 5 °C throughout this century. The economic impacts are large, and particularly large in the agricultural sector. Agriculture will nevertheless continue to dominate economic activity, and contributes steadily more than 40 percent of the GDP. The productivity is affected considerably by climate change, but with moderate impacts on prices. There is a huge uncertainty about predictions of both climate impacts and societal development trajectories, however, and climatic variabilities and differences in underlying socio-economic conditions imply that certain regions and sectors will become more vulnerable than others. This is highlighted by the finding that moderations of impacts due to autonomous adaptation declines as the climatic changes become larger. Proactive adaptation strategies are, therefore, needed. From a macroeconomic perspective, attention should be paid to enhancing the resilience of crop, livestock and farming systems stimulating flexible production systems and technologies, and making precautionary investments that reduce transaction costs.

The macroeconomic model ignores vital adaptation constraints that smallholders face. With structural transformation of the Tanzanian economy, the number of smallholders will most certainly decrease, but the model gives no indications of the magnitude. Approximately 10 million Tanzanians live on small farms, on which they rely for their food security. In addition, many rural households rely on purchasing food in the market to supplement production on their own farms. This number will probably remain significant for a long time, and climate variability implies that the climatic changes projected in 2100 will affect many smallholders long before that. The micro model indicates that, if the climatic changes in 2100 occurred today, the impacts on agricultural productivity would result in food consumption of nearly 1.5 million more people falling below the minimum supply of food, and more than two million additional people would depend entirely on the food that they can produce themselves. Price effects in the wake of climate change may reduce this number to 1.2 million and further to 150 thousand if policies succeed in encouraging adaptation and reducing transaction costs. Households that manage to stay above the nutrition constraint before and after the projected climatic changes will have to reduce their food consumption, and the price effects worsen their situation slightly, whereas lower transaction costs have no impact. The analysis of smallholders thereby suggests that although the estimates of autonomous adaptation derived from the macroeconomic model are useful, they may be of limited relevance to smallholders. Their challenges in adapting to climate change are related both to the worsened conditions for farming and to an increasing need to gain income from off-farm activities. Major investments to generate
jobs that provide alternative and complementary sources of income for rural households are therefore needed.

The village study from Morogoro Region confirms the production and consumption patterns described by the micro model. Poorer farmers, who cultivate smaller farms, plant a larger share of their land to maize, which is the staple food crop. Rice, which can be used both as food and cash crop, is comprised of a greater share of cultivated acreage among households of average and above-average wealth, whereas sugarcane, which is exclusively a cash crop, is generally cultivated by average and wealthy farmers, who also have more land at their disposal. It is, therefore, likely that a greater share of poorer households’ agricultural production goes to meeting their food needs, compared to wealthier households, whose farms are larger than those of poor households. In the micro model, lower productivity of land due to climate changes encourages work outside the farm, meaning that the dependency on income from other sources increases among poorer households who have smaller farms. In the village case presented in this paper, this represents a serious constraint to the livelihoods of poor smallholders, because only a small proportion of smallholders are engaged in reliable and remunerative employment, and these tend to be wealthier households, with larger farms and more education. Poorer households cultivating smaller farms have to rely on unpredictable income from casual work and petty trading. Removal of sources of off-farm income, including from forest products such as charcoal, in the case of a REDD+ project, will further increase dependency on farm products, making poorer smallholders more vulnerable to the impacts of climate change than what is estimated by the micro model. Climate change thereby represents a barrier to mitigation of poverty, which is more challenging than indicated by analyses of the statistical data.
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Appendix

A micro model for smallholder farming

The micro model addresses consequences of constraints that smallholders have to relate to, which do not apply to the farmers described by the macroeconomic model. One is a nutrition constraint, meaning that there is lower limit to the food consumption, \( \bar{x} \). There is also an output constraint, meaning that smallholders cannot consume more food from own farm than the size of their farm allows them to produce. The limited farm size also limits the time they can spend on farming in a useful way. Additional time may be spent to earn an income from other activities.

The aggregated output from the agricultural sector in the macroeconomic model, \( Y \), is replaced with a sum of farm-specific output \( y_i \), \( i = 1, \ldots, N \) from \( N \) farms. Output is a function of time spent to work on the farm, \( n_i^f \), and the size of the farm \( r_i \):

\[
Y = \sum_{i=1}^{N} y_i = \sum_{i=1}^{N} f(n_i^f, r_i)
\]

As in the macroeconomic model, the output at a given combination of input is independent on scale.

Consumption is divided into three categories. Food is split into consumption from own farm, \( x_i^f \), and consumption bought in the market, \( x_i^m \) at price \( p \), while all other consumption is grouped into one aggregate, \( z \) at price \( q \). If sold, the price they get for the output is \( (p - t) \), where \( t \) is the transaction cost. If the total time they have available for work, \( \bar{n} \), exceeds the time on farm, they can work elsewhere with expected payment \( w \) per unit of work. Then, the monetary budget constraint to a single household is:

\[
(p - t)(f(n_i^f, r_i) - x_i^f) + w(\bar{n} - n_i^f) = px_i^m + qz_i
\]

The nutrition constraint requires that

\[
\bar{x} \leq x_i^f + x_i^m
\]

As in the macroeconomic model, the households maximises utility, \( V = V(x_i^f, x_i^m, z) \). However, the allocation of working time cannot be taken independently of the consumption composite, as

\[
y_i \geq x_i^f
\]
Welfare maximisation under the constraints (2) – (4) gives the following first-order conditions for the consumption composite:

\[
\frac{V'_{xf} - \lambda^N - \lambda^O}{p_x - t_x} = \frac{V'_{xm} - \lambda^O}{p_x} = \frac{V'_q}{q}
\]  

(5)

\(\lambda^N\) and \(\lambda^O\) are the shadow prices imposed by the nutrition constraint (3) and the output constraint (4), respectively. If both \(\lambda^N\) and \(\lambda^O\) apply, we have a corner solution: Time is spent on the farm to produce as much as possible for own consumption. Extra consumption of food needed to meet (3) has to be bought in the market. This creates a relative shortage of other goods, which the remaining income, if any, is spent on. For the division of work, the first order condition is

\[
(\lambda^B (p_x - t_x) - \lambda^O) f'_n = w
\]  

(6)

Here, \(\lambda^B\) is the shadow price of the budget constraint, or marginal utility of money. Equation (5) gives rise to ordinary demand functions for consumption goods and corresponds to the demand functions in the macroeconomic model. We assume constant elasticity of substitution (CES), where endogenous shadow prices of the constraints are included; (6) is parallel to the demand function for labour by sector in the macroeconomic model, but applies here to the time spent on the farm and the time spent on paid activities outside the farm. These are also based on CES functions.

The model combines a physical measure for consumption of food, \(x^f\), and a value of food consumption, \(p_x \cdot m\). When all goods are measured in monetary terms, we have the marginal utility of money, \(\lambda^f = 1\). To keep \(\lambda^f = 1\) valid, we consider a separable welfare function which is optimized in two stages. First, the composite of \(x_f^f\) and \(x^m\) is determined by maximization of the utility of a given consumption of food \(x^f_i = x^f_i + x^m_i\). In the second step, market consumption is optimized given the disposable amount of money. The welfare function can then be written as

\[
V(x^f_i, x^m_i, z_i) = u(x^f_i | z_i) + u(x^m_i, z_i)
\]  

(7)
Climate Change, Smallholders farmers’ Adaptation in Pangani Basin and Pemba
Implications for REDD+ initiatives

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Abstract

This chapter is based on a study conducted in Pangani river basin and on Pemba Island in Tanzania. The main objective of the study was to assess evidence of the climate, small farmers’ adaptive strategies and associated implications for REDD+ initiatives in the country. Historical climate data over more than 30 years were collected from nine stations in Pangani river basin and on Pemba. Qualitative and quantitative data were collected from 11 villages purposively selected based on the location (upper and lower basin and altitude). A questionnaire survey and Focus Group discussions were used to collect data from 387 respondents and 40 key informants, respectively. The respondents for the survey were randomly selected from 11 study villages. The results show evidence of rising temperatures, changing rainfall patterns, an increase in extreme weather conditions such as droughts, floods and hurricanes and the shifting distribution of pests and

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diseases. Expert opinions also confirmed major changes in climate parameters in recent years. About 89 percent and 95 percent of small-scale farmers perceive that there is a change in temperature and rainfall, respectively, and linked the changes to crop types, cropping patterns, and outbreak of human, animal and crop diseases in their respective areas. Results from Multinomial Logit Model indicate that farmers’ choices of climate change coping strategy depend on their access to extension services and credit, their education level, location as well as experience. Adaptive strategies range from change of crop types, farmers and livestock keepers moving to new areas near water sources and forests and increased farm activities. Unfortunately most of the smallholders’ adaptive strategies are compromising REDD+ initiatives. The study concludes that successful REDD+ initiatives within the framework of smallholders adaptive strategies to impacts of the climate changes requires externally sourced support for sustainable adaptation to climate changes.

1.0 Introduction
Climate change is a global problem; however, the associated impacts and vulnerability vary across the countries, regions, districts and individuals. Studies indicate that Africa is one of the continents that have severely been affected by climate change. Over the past few decades the continent has experienced a decreasing number of extremely cold days coupled with an increasing numbers of warm days (New et al., 2006). Spatial and temporal variability of precipitation, more intense and widespread of droughts and aggravated floods have been common during this period (Deressa, 2010). Climate change impact on natural and human systems alters the productivity, diversity and functions of many ecosystems and livelihoods around the world. The African continent is more vulnerable to climate change impacts because the majority of the population on the continent primarily depends on rain-fed agriculture (IPCC, 2007; Boko et al., 2007). For poor people natural resource-dependent communities, climate change compounds the existing vulnerabilities. Heavy dependence on ecosystem services places their welfare at the mercy of environmental conditions. As the availability and quality of natural resources decline, so does the security of their livelihoods.

In Tanzania, temperature has generally increased and precipitation decreased in many areas of the country. The average annual temperature is projected to increase by 2.2°C and precipitation to decreased by 100mm by 2100 (Agrawal et al., 2003). As a result, many of the country’s nine river basins (Pangani, Wami and Ruvu, Rufiji, Ruvuma and the Southern Coast, Lake Nyasa, Lake Tanganyika and the Lake Victoria and internal drainage such as Lake Rukwa Basin) are drying out at an alarming rate. This is evidenced by reduced water flow from these basins (Kulindwa, 2005).
In developing countries such as Tanzania, water basins play a pivotal role in the livelihoods of poor communities. Their ability to supply water throughout the year provides poor communities with opportunities to grow crops and keep livestock throughout the year. However, in recent years communities in these areas have experienced a serious decline in the availability and quality of natural resources *in situ* water (MEA, 2005). As a result, agriculture, which is dominated by small-scale farmers in these areas, has been seriously affected (Sanga et al., 2013). In fact, many farmers have failed to recover from climate change effects (Sanga *et al*., 2014).

The current literature proposes a number of mitigation measures designed to reduce GHG such as carbon in the atmosphere in a bid to reverse this worrisome trend (Gibbs *et al*., 2007). Approaches such as REDD+, which emphasise on planting trees for carbon sink, are underscored and promoted in developing countries where land scarcity is not a problem. This approach is favoured because it has multiple advantages. To begin with, it allows for the absorption of carbon from the atmosphere, improves water retention capacity and reduces runoff hence curbing soil erosion. Although such mitigations are useful in reducing and reversing the impact of climate change and offering long-term solutions, they need to involve the entire world and take several decades. Therefore, short-term actions to cope with climate change effects are deemed necessary considering the current climate change effects. Conversely, projects that promote resilient crop species, diversified livelihood activities, and risk-reduction activities (such as seed banks, storage facilities, early warning systems) increase local adaptive capacity. Without having a clear understanding of the right intervention, at the right time and the right segment of the population (including men, women and indigenous people), all efforts aimed at introducing long-term mitigation measures such as REDD are less likely to succeed.

Nevertheless, in developing countries such as Tanzania agriculture is dominated by small-scale farmers who also have to contend with poverty and food insecurity. Thus, in these countries the farmers’ primary objectives focuses on meeting basic food needs for their families and pay less attention to climate change adaptation and associated consequences (World Bank, 2006). This presents an important limitation to efforts on the ground to introduce long-term mitigations such as REDD. Apparently, long-term mitigation planners on the ground have insufficient understanding of the impacts of climate change, the vulnerability levels and small-scale farmers’ adaptation choices (Hassan and Nemachena, 2008; Kurukulasuriya and Mendelsohn, 2006). Proposing that farmers should invest in long-term climate change mitigation measures in Pangani basin is one issue and understanding the impacts of climate change, especially the segment of the population who are vulnerable and how they respond to these impacts, is another entirely different issue. In fact, the latter issue if much more fundamental in the view of this paper as the former long-term mitigation
measures depends on the success of the latter. In principle, it involves clarifying questions such as: What are impacts of climate change on Pangani basin? Which segment of the population of small-scale farmers who are vulnerable to climate change in the basin? What determines small-scale farmers' adaptation choices? Are the designed mitigation measures in line with the small-scale farmers’ adaptation choices? This research was designed to provide a better understanding of these issues for the purpose of deepening our understanding before embarking on long-term mitigation measures related to REDD+ in Tanzania.

2.0 Study Justification and Objectives

Essentially, agriculture is not just a victim of climate change; it is also a significant cause. It is directly responsible for 10–12 percent of human generated greenhouse gas emissions, and much more if the forest clearance to make way for crops and livestock is included. Enteric fermentation in livestock accounts for around a third of all the nitrogen oxide emissions produced by agriculture, and overgrazing by livestock leads to significant greenhouse gas emissions. This study was conducted in Pangani Basin and on Pemba Island with a view to drawing a deeper understanding of the impacts of climate change, the level of vulnerability across different segments of ecosystem users and its implication for the implementation REDD+ initiatives in Tanzania.

As already noted, water basins play a vital role in providing, supporting, regulating, and learning (cultural) aspects. However, many of the water basins in Africa have been affected by climate change extremes and variability, and this has affected a significant portion of the farming population in these areas (IUCN, 2009). In Pangani basin and on Pemba Island, climate change extremes have increased the number of largely subsistence farmers who are vulnerable. This has reduced their capacity to invest in the long-term mitigation measures such as REDD. Generally, efforts to reverse the situation which are suggested by the current literature are for the long-run. For example, Bolin et al.’s (2012) study “Can REDD+ reconciles local priorities and needs with global mitigation benefits? Lessons from Angai Forest, Tanzania” provides similar thoughts for research in Pangani river basin and Pemba. Thus, understanding the impacts of climate change prevailing in the basin, the level of vulnerability, farmers’ respond to climate change and mitigation measures is necessary for designing appropriate policy measures aimed at enhancing adaptation capacities of vulnerable farming populations of the basin and Pemba within the REDD+ initiative framework. Nevertheless, the outcome of the study can guide us to make evidence-based decision recommendation to policy-makers and other practitioners on the best approach to intervening for sustainable REDD+ implementation.
Objectives
Specifically the study sought to:

i. Establish and characterise climate change scenarios in Pangani basin.
ii. Identify and assess the vulnerability of small-scale farmers to climate change impacts in the established scenarios.
iii. Investigate determinants of farmers’ choice of climate change adaptation measures in the established scenarios.
iv. Assess the economic and environmental compatibility of farmers’ adaptation measures in the established scenarios.
v. Establish smallholders’ adaptive strategies and implication for REDD+ initiatives measures.

3.0 Methodology

3.1. Location of the Study
The study was conducted in Pangani river basin on Tanzania mainland and on Pemba Island in the Zanzibar archipelago. Pangani River basin is shared by Tanzania and Kenya extending as it does from northern highlands comprising Mount Meru, Kilimanjaro and Taita Hill to the north-eastern coast of the Indian Ocean. The basin lies between latitude 03° 05’ 00 and 06° 05’ 00 south and longitude 30° 45’ 00 and 39° 00 east. The basin covers an area of 56,300 km² out of which five percent lies in Taita-Taveta district of Kenya (Figure 4.1). In Tanzania the basin is distributed among the Kilimanjaro, Manyara, Arusha and Tanga administrative regions. To improve our findings, Pemba Island has been included in the study.

Figure 4.1: Location of the study (Pangani river basin and Pemba)
Topographically, the basin is not uniform. Its altitude ranges from 700-5825m above sea level; the ice cap of Mount Kilimanjaro forms the highest point not only of the basin but also of Africa. This altitude has a significant influence on the basin climatic conditions. The temperature ranges between 14°C and 25°C in Kilimanjaro and 17 and 29°C in south-eastern part of the basin and Pemba Island. On the other hand, precipitation varies considerably. The basin is divided into three rainfall zone: the high rainfall zone which receives rains between 1200 and 2000mm per year. The high rainfall zone is distributed on the slopes of Mount Kilimanjaro, Meru, Pare and Usambara mountain ranges. Other zones have medium to low rainfall. In Pemba, two locations were chosen, low rainfall Micheweni and relatively high rainfall Makangale Shehias

The basin is characterised by bimodal rainfall pattern with two distinct rainy seasons: long rains from March to June and short rains from November to December. The highest rainfall is 1000-2000mm per annum and occurs in the south-eastern slopes of Kilimanjaro and Meru mountains (IUCN, 2003). The moderate rainfall zone, which receives rains of between 800 and 1200mm per year, is distributed on some parts of Babati and Simanjiro districts. Lastly is the low rainfall zone which receives rainfall ranging from 500-800 mm per year (Makurira et al., 2007). The zone covers the low lands of the basin in all districts of Meru, Simanjiro, Same, Mwanga, Korogwe, Handeni, Muheza and Pangani. In this report, Pemba Island is also included in this zone. Also the basin is characterised by minimal seasonal variation of temperature (Senkondo et al., 2004).

On the other end of the spectrum, Pemba Island is located a few nautical miles east of the point where Pangani River enters the Indian Ocean. The Island has a total of 984 square kilometres and is characterised by two major climatic conditions which also demarcates the Island into two sides: the wet and dry side. Similarly, the area is characterised by migration of people from the dry to the wet side, hence creating conflicts over land and other resources. Nevertheless, the Island faces an increasing salt water intrusion on farm land, making it unsuitable for crop production, an effect which is an indicator of rising seas levels which is eating away the Island gradually.
3.2. Justification for choosing Pangani Basin and Pemba Island

Pangani basin has been chosen because of its unique topography and ecology. The basin begins from the highest to the lowest point of Africa (the Kilimanjaro Mountain and Indian Ocean respectively). The basin is one of Tanzania’s nine drainage basins. It plays three major roles of providing for, supporting, and regulating the communities within and downstream. Water in this basin is of great economic importance as it is used for irrigation to a large number of people living in the low lands of the basin. Water supports nearly 310 sq km of irrigated farmland owned by both small and large-scale farmers growing a variety of crops such as coffee, paddy, flowers and vegetables (Kulindwa, 2005; Mbonile, 2005). The basin also supports water demand for domestic and industrial use in the three major urban centres of Arusha, Moshi and Tanga and several small towns within the basin (Meena and Raphael, 2008). Furthermore, the basin is also used to generate hydropower (Nyumba ya Mungu and Hale). On the other hand, the basin provides habitat to a unique biodiversity and water to wild animals found in Kilimanjaro, Mkomazi, Arusha and Manyara national parks (URT, 1995).

However, in the last two decades years the basin has been unable to provide adequate ecosystem services to the communities in upper and downstream areas (Komakech et al., 2004). Many of them have lost their economic power or have become more vulnerable to climate change. Almost similar situations have been reported on Pemba Island where various impacts of climate-related changes are critically changing the whole farming systems and livelihoods of the people to varying degrees. For example, women as the main household livelihood providers and water users for domestic purposes have been adversely affected (Mtabazi et al., 2005). These reasons justified the choice of this basin as a study area.
Pemba Island was also chosen because of the challenges climate change poses to the area. As already noted, movement of people from the dry side to the wet side of the island foments conflict over limited resources available on the wet side. Moreover, the increasing encroachment of salt water on farm land increases challenges to the Island which are already overstretched by presence of drought on one side (Watkiss et al., 2012). Equally important, the Island’s population is growing and so is the need for arable land for food production to meet the need for food that is growing in the Island (URT, 2012). It was, therefore, considered important to find a better way to mitigate climate change impact in response to the migration and conflict over the little finite resources existing on the Island.

The sites were also selected to test another approach to the study of climate change. Most of the studies on climate change view the problem holistically without taking into account the most likely climate differences (scenarios) within the area which dictate the level of impact, vulnerability and adaptation choices in a given area (see, for example, Kurukulasuriya and Mendelsohn, 2006; Seo and Mendelsohn, 2006; Mano and Nhemachena, 2006). This study divides the Pangani basin into three area of the high rainfall low temperature, medium rainfall medium temperature and low rainfall high temperature and Pemba into two areas of the wet and dry scenarios. Each of these scenarios has unique characteristics in terms of land use, cropping patterns, livestock keeping methods and hence impact, vulnerability and adaptation. Categorising the areas under consideration into scenarios determines the likely effect of change of one scenario on another under the changing climatic conditions. Therefore, 10 districts in Pangani river basin and on Pemba were chosen for the study on which this chapter is based.

3.3. Type of data and collection

The study employed both secondary and primary data. Primary data used in this study were collected from eleven (11) villages found in 10 districts of Pangani river basin and Pemba Island using a cross-sectional survey of small-scale farmers. The villages were purposively selected to include different climatic variations in the Pangani river basin and Pemba Island. Initially, the basin was categorised into three scenarios: (i) upper, (ii) middle, and (iii) lower. On the other hand, Pemba Island into two scenarios: (i) wet and (ii) dry (see Table 4.1). These categories were established based on the assumption that the areas have different rainfall and temperature, hence offer different farmers’ perception and adaptation strategies. From each of the eleven villages an average of 35 farmers was randomly selected based on the assumption that they all practice agriculture (including livestock keeping) and, therefore, are affected by climate change. To obtain data related to rainfall, temperature, change in crop/livestock types and cropping/grazing patterns, outbreak of both plant and animal diseases, the
study also collected data from key informants aged between 40 years and above through focus group discussion.

<table>
<thead>
<tr>
<th>High rainfall &amp; low temperature (I)</th>
<th>Climate scenarios (I, II, III) &amp; study locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin position (L1, L2, &amp; L3) &amp; study locations</td>
<td>Medium rainfall &amp; medium temperature (II)</td>
</tr>
<tr>
<td>L₁ (Upper basin)</td>
<td>Hai 🟢 Lyamungo Kilanya</td>
</tr>
<tr>
<td>L₂ (Mid basin)</td>
<td>Lushoto 🟢 Baga</td>
</tr>
<tr>
<td>L₃ (Lower basin)</td>
<td>Korogwe 🟢 Bungu</td>
</tr>
<tr>
<td>Pangani 🟢 Kigurusimba</td>
<td>Pangani 🟢 Micheweni</td>
</tr>
<tr>
<td>Pemba 🟢 Makangale</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1: Locations for defining climatic scenarios in studying climate change in Pangani basin

NOTE: For Pemba scenarios are based on rainfall pattern instead of elevation as in PRB

In addition to the scenarios highlighted in Table 4.1, the study chose the location which is comprises eight main ethnic groups (the Meru, Maasai, Chaga, Pare, Sambaa, Bondei, Digo and Pemba) with differing socio-cultural practices, hence potentially with different outlook in understanding and adapting to different climate scenarios. These differences were deemed crucial in deepening our understandings of the dynamics necessary in achieving long-term climate change mitigation measures and establishing the implications for the REDD+ initiatives.

The secondary data on trends of rainfall and temperature were collected from the Tanzania Metrological Agency (TMA) for a span of 51 and 37 years. The period is long enough for detection of change and determining trend and correlation analysis. The monthly rainfall and temperature data from 16 rainfall stations and six synoptic stations, respectively, were collected, covering high to lower altitudes of Pangani river basin and wet and dry areas of Pemba Island (See Figure 4.3). Initially, there were 31 rainfall stations; others were rejected due to insufficient data. All the stations with missing monthly data equivalent to five or more years (that is around 15% of the data) were rejected (PWBO/IUCN, 2008). Pangani basin and Pemba areas are characterised by bimodal rainfall patterns as two rainy seasons exist.
<table>
<thead>
<tr>
<th>Location</th>
<th>Station’s name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meru</td>
<td>Arusha – Airport</td>
</tr>
<tr>
<td>Hai</td>
<td>Maua seminary</td>
</tr>
<tr>
<td>Moshi Rural</td>
<td>TPC Langasani</td>
</tr>
<tr>
<td>Mwanga</td>
<td>Mwanga agric.</td>
</tr>
<tr>
<td>Same</td>
<td>Same met. station</td>
</tr>
<tr>
<td>Lushoto</td>
<td>Lushoto agric. station</td>
</tr>
<tr>
<td>Korogwe</td>
<td>Korogwe agric. station</td>
</tr>
<tr>
<td>Pangani</td>
<td>Pangani agric station</td>
</tr>
<tr>
<td>Pemba</td>
<td>Karume - airport</td>
</tr>
</tbody>
</table>

Figure 4.3: Reference weather station used in the study and location in Tanzania (source TMA)

3.4 Data analysis

3.4.1 Smallholder farmers’ awareness and perception of climate change effects
To collect requisite data, we employed both the descriptive and empirical analytical framework. Descriptive analysis was used to establish the farmers’ awareness of climate change and its impacts; their ability to associate climate change with change in crop types, cropping pattern, livestock grazing, outbreak of human, animal and crop diseases in their respective areas; links with natural resources utilisation their efforts to cope with climate change; and what they perceive as the limitations to their efforts.

3.4.2 Trends of climatic parameters and correlation with climate change
Data on trends of rainfall and temperature were analysed using INSTAT statistical computer package (Kihupi et al., 2007). Missing data were replaced by long-term mean values. Total annual rainfall, highest maximum temperature and lowest minimum temperatures were computed and linear trend analysis was carried out for each parameter. Results of computations were cross checked physically by viewing the raw data in spreadsheet format before making necessary adjustments.
3.4.3 Smallholder farmers’ choices of adaptation strategies

Empirical framework was used to assess the factors influencing farmers’ choices of adaptation measures. The framework was selected based on the assumption that adaptation measures help farmers guard against crop failure due to increasing temperatures and decreasing rainfall, but the choices differ across them. In Pangani basin and Pemba smallholder farmers have several adoption options such as migrating to water-rich areas such as river valleys and wetlands; increasing the application of fertilisers; planting drought-resistant crops; irrigating farm lots; early planting; using manure; growing fast-maturing crops; planting timber trees in their farm lots instead of crops; focusing on non-farming activities; and practicing mixed cropping. The Multinomial Logit (MNL) model was chosen as a farmer can adopt any or two to three of these options and our intension was designed to establish what conditions their choices against the base choice which in this case is migration to water-rich areas. The approach is appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies (Green, 2000; Wu and Babcock, 1998; Long, 1997). In this study, we used Multinomial Logit (MNL) Model to analyse the determinants of farmers’ decisions because it is widely used in adoption decision studies involving multiple choices and is easier to compute than its alternative multinomial Probit model.

Let $A_i$ be a random variable representing the adaptation measure chosen by any farming household. We assume that each farmer faces a set of discrete, mutually exclusive choices of adaptation measures. These measures are assumed to depend on a number of climate attributes, socioeconomic characteristics and other factors $X$. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option $A_i$ and the set of explanatory variables $X$ as:

$$\text{Prob}(A_i = j) = \frac{e^{\beta_i x_i}}{\sum_{k=0}^{J} e^{\beta_k x_i}}, \ j = 0, 1, \ldots, J$$

(1)

Where $\beta_j$ is a vector of coefficients on each of the independent variables $X$. Equation (1) can be normalized to remove indeterminacy in the model by assuming that $\hat{a}_0 = 0$ and the probabilities can be estimated as:

$$\text{Prob}(A_i = J|x_i) = \frac{e^{\beta_i x_i}}{1 + \sum_{k=1}^{J} e^{\beta_k x_i}}, \ j = 0, 2, \ldots, J, \beta_0 = 0$$

(2)
Estimating equation (2) yields the $J$ log-odds ratios
\[
\ln \frac{P_{ij}}{P_{ik}} = x_i' \left( \beta_j - \beta_k \right) = x_i' \beta_j, \text{ if } k = 0
\]
(3)

The dependent variable is, therefore, the log one alternative relative to the base alternative. The MNL coefficients are difficult to interpret, and associating the $b_j$ with the $j$th outcome is tempting and misleading as it simply show the effect of a change in $x$ on $y$ as if the $y$ is continuous variable while is categorical. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as:
\[
\delta_j = \frac{P_j}{x_i} = P_j \beta_j \prod_{k=0}^j P_k \beta_k = P_j \beta_j \overline{\beta}
\]
(4)

Therefore, the full model is specified as follows:
\[
y = i_x + i
\]
(5)

Where: $b_{ij}$ are parameters to be estimated; $y_i$ are adaptation options (or alternatives); $x_i$ is a set of independent variables; and $\epsilon_i$ are the error terms.

### 4.0 Results and key lessons from the study

#### 4.1 Farmers awareness and perception of climate change

Results from a comprehensive household survey conducted in 11 villages of Pangani river basin and Pemba Island indicate that farmers perceive changes in the temperature and rainfall trends in their respective areas. Results in Table 4.2 indicate that 88.8 percent and 94.9 percent perceive that there have been significant changes on temperature and rainfall in their respective areas over the past 30 years. They testified that these changes have been characterised by change in the start and end of rainfall, its amount, intensity and frequency during the rainy season; 30.9 percent admitted that there have been erratic rain in their areas, 62.8 percent pointed out that there has been small amounts of rainfall which falls for a very short period.
Table 4.2: Farmers’ perceptions of long-term change in climatic variables (temperature and rainfall)

Farmers were also asked to report on the changes they had witnessed in their respective areas and what they thought could be the reason behind such changes. Results in Table 4.3 show that 87.5 percent reported that they experienced crop failure due to drought in their areas, 63.7 percent experienced change in cropping pattern, 66.9 percent experienced disappearance of crops that used to be produced in their areas, 33.9 and 45.6 percent noted outbreak of crop diseases and human diseases such as malaria, respectively. Crops such as coffee and banana, which used to dominate mid and lower attitudes of the slopes of Mount Kilimanjaro, were being replaced with pasture vegetables. These farmers associated these problems with climate change. According to them the increase in temperature and reduced rainfall has favoured growth of some crop diseases such as head and fruit rots and pests such as aphids in plant and tick borne diseases in livestock. Most of these ailments were associated with changing trends of temperature, droughts and other attendant factors.

Table 4.3: Farmers linking of the climate change to the change experienced in agriculture cycle and health in their respective areas
4.2 Small farmers’ climate risk perception and decisions

Information gathered from farmers through focus group discussions revealed that Pangani river basin and Pemba Island are increasingly experiencing droughts, with marked changes in the rain days and intensity (Table 4.4). In total, 90.7 percent of the respondents perceived that there had been significant changes in rainfall patterns in their respective areas over the past 15-30 years. About 30.5 percent of the farmers interviewed perceived long-term changes in temperature.

<table>
<thead>
<tr>
<th>Perception</th>
<th>Heavy rainfall (N=105)</th>
<th>Moderate rainfall (N=175)</th>
<th>Low rainfall (N=140)</th>
<th>Total (N=420)</th>
<th>Sig diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall Decrease</td>
<td>89.4</td>
<td>90.9</td>
<td>91.9</td>
<td>90.7</td>
<td>0.47</td>
</tr>
<tr>
<td>Increased in frequency of droughts and floods</td>
<td>34.1</td>
<td>25.6</td>
<td>26.6</td>
<td>28.6</td>
<td>2.91</td>
</tr>
<tr>
<td>Temperature Increased</td>
<td>18.2</td>
<td>31.1</td>
<td>42.7</td>
<td>30.5</td>
<td>18.25***</td>
</tr>
</tbody>
</table>

Table 4.4: Perceptions of rainfall trend

Furthermore, the results shows that, the subjective rainfall satisfaction index obtained from asking farmers a series of questions related to rainfall adequacy in the previous growing season, of 0.22 was obtained, which indicates that during the growing season of February to July the rainfall situation was undesirable (Table 4.5). Farmers’ generally reported late onset of rain, poor distribution within the season, and sometimes early cessation. Also farmers highlighted specific problems of variability in the duration, timing and intensity of the rains, including winds and heavy rains at the start of the seasons. In the moderate and lower rainfall areas of the basin respondents highlighted drought as an increasing problem, and more frequent flash floods as a result of increased rainfall intensity. In the highland areas, increased rainfall intensity leading to increased runoff was reported.
<table>
<thead>
<tr>
<th>Variables</th>
<th>Heavy rainfall (N=105)</th>
<th>Moderate rainfall (N=175)</th>
<th>Low rainfall (N=140)</th>
<th>Overall (N=420)</th>
<th>sig diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>St.d</td>
<td>Mean</td>
<td>St.d</td>
<td>Mean</td>
</tr>
<tr>
<td>Annual Rainfall trend Decreasing</td>
<td>0.11</td>
<td>0.31</td>
<td>0.09</td>
<td>0.29</td>
<td>0.08</td>
</tr>
<tr>
<td>During growing season Rainfall come on time</td>
<td>0.21</td>
<td>0.41</td>
<td>0.27</td>
<td>0.44</td>
<td>0.36</td>
</tr>
<tr>
<td>During growing season Rainfall stopped on time</td>
<td>0.3</td>
<td>-0.46</td>
<td>0.26</td>
<td>0.44</td>
<td>0.3</td>
</tr>
<tr>
<td>Enough rain at the beginning of the growing season</td>
<td>0.18</td>
<td>0.38</td>
<td>0.18</td>
<td>0.39</td>
<td>0.16</td>
</tr>
<tr>
<td>Enough rain during the growing season</td>
<td>0.26</td>
<td>0.44</td>
<td>0.23</td>
<td>0.42</td>
<td>0.25</td>
</tr>
<tr>
<td>Frequency of heavy rainfall increase</td>
<td>0.24</td>
<td>0.43</td>
<td>0.2</td>
<td>0.4</td>
<td>0.25</td>
</tr>
<tr>
<td>Number of Rainfall days decrease</td>
<td>0.14</td>
<td>0.35</td>
<td>0.14</td>
<td>0.35</td>
<td>0.16</td>
</tr>
<tr>
<td>Frequency of dry spells/ droughts increased</td>
<td>0.18</td>
<td>0.38</td>
<td>0.32</td>
<td>0.46</td>
<td>0.43</td>
</tr>
<tr>
<td>Average rainfall satisfaction index</td>
<td>0.20</td>
<td>0.28</td>
<td>0.21</td>
<td>0.40</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 4.5: Farmers’ rainfall satisfaction index
4.2.1. Meteorological results on climate change (rainfall and temperature)

The results in Figures 4.4a and 4.4b show that there is a general decrease of rainfall in the area over the period under review (i.e. more than 30 years). Moreover, there is a high variation of rainfall in the area, with five stations registering a significant decrease of rainfall. Higher rainfall decreases are evident in Maua seminary and Kilema Chini (Lower) in Moshi rural which are found in the upper altitude of the basin. The trend also evident on Pemba Island, in Pangani and Korogwe districts, which are found in the lower altitudes of the basin. A slight decreasing trend in rainfall is observable in Arusha, Lyamungo, Moshi and Same. These factual data confirm the perception of the farmers (see Table 4.4)

![Figures 4.4: Rainfall trends at (a) Maua seminary station (upper altitude) and (b) Pangani district station (lower altitude of Pangani Basin)](image)

On the other hand, a slight increase in rainfall (see Figure 4.5a) is observable in Lushoto, Shingatini (Mwanga) and Kibong’oto (Hai), which are found in high altitudes of the basins. The highest value recorded during the period is 4551mm at Maua Seminary and lowest value is 265mm over Same, which are higher and lower altitude areas, respectively, implying that the higher the altitudes the more the rainfall. Constant rainfall trend is observed in Mazinde, Figure 4.5b, which is found in highest altitude of the basin.

![Figures 4.5: Rainfall trend (a) increasing at Shigatini station and (b) remaining constant at Mazinde station (both in middle altitude of Pangani basin)](image)

The results on temperature trends indicate that the annual highest maximum and lowest minimum temperature has been increasing over the 30-year period in the entire area of the basin and Pemba Island. A slight increase of maximum
temperature has been observed Kilimanjaro airport, Moshi and Tanga, and Pemba, which shows the highest increasing trend (Figure 4.6a). On the other hand, decreasing trends of maximum temperature has been observed in some areas of Arusha and Same (Figure 4.4b). The highest maximum value of temperature recorded during the period is 35.9°C at Kilimanjaro airport and the lowest maximum value is 28.2°C recorded over Arusha. Similarly, the results indicate that the lowest minimum temperature has been increasing at a higher rate over 30 years in the basin and on Pemba Island. The highest minimum value of temperature recorded during the period is 23.2°C at Pemba (Figure 4.7a) and lowest minimum value is 11.4°C in Arusha (Figure 4.7b).

The variation in rainfall and temperature observed indicate that climate is changing over time and by so doing it influences the type of crops, cropping patterns and crop diseases. It also influences adaptive strategies with the likely implication for the REDD+ initiatives. This is confirmed by data gathered from small-scale farmers, elders, opinion leaders, and local government leaders from high altitudes of the basin who admitted that over the period there had been a change in type of crops produced in the area: for example, 30 years ago in the high altitudes of Kilimanjaro, particularly Moshi rural (Mahoma and
Kilanya villages), yams, sweet potatoes, mangoes, avocados, and maize were being produced, but these crops have since disappeared. Now farmers in this area depend on banana, coffee, and beans for food and cash. Witnesses also attest to the fact that, although banana is currently the main source of food and income in the area, the crop is highly affected by diseases, which many of these plants’ stems rotting before they withered and died.

A similar observation is shared by smallholder farmers in the other upper altitudes (Lekitatu) of the basin which are dominated by irrigation agricultural practices. The witnesses in these areas admit that 30 years ago they were producing a number of crops (i.e. maize, coffee, banana, beans, finger millet, sweet potatoes, paddy, sugar cane, Irish potatoes, yams and tree fruits such as oranges, avocado, and pawpaw), but very few of these still exist and even then marked by low productivity due to unfavourable climate. One of the witnesses pointed out that to-date you hardly find orange and lemon fruit trees, yams, banana, Irish potatoes, and coffee in their area. He further mentioned that even the remaining crops were severely attacked by diseases, hence leading to higher production costs than was the case 30 years ago. The witnesses also admitted that, water was aplenty 30 years back and the area was mainly rain-fed agriculture, with very few irrigating their fields. This was attributed to the fact that rain was enough to ensure good harvests.

On the other hand, witnesses from the middle altitude (Mgwashi, Mabilioni and Baga villages) also admit to experiencing changes in climatic parameters, which have induced shifting in economic activities in the area over the past 30 years. Crops such as banana, yams, beans and coffee have disappeared from the area over this period. Persistent drought and the emergence of diseases were reported as the main cause of the disappearance of these crops from this area. Changes in climatic parameters have also induced changes in cropping pattern, with the witnesses admitting that 30 years ago they were tilling small pieces of land, but now they were cultivating large pieces of land and diversifying crops for the purpose of spreading out the risks of crop failure due to drought and diseases.

Finally, witnesses from lower altitude of the basin (Bungu, Mafuleta, Kigurusimba and Pemba – Makangale and Micheweni) also admitted experiencing changes in climatic parameters. This has induced a shift from rain-fed agriculture to irrigation, which has resulted into conflict due to water shortage. Demand for water has increased abruptly as more and more small-scale farmers shift to irrigation to cope with climate change effects. Similarly, these areas have experienced a disappearance of many crops that used to be grown 30 years ago; crops such as maize, beans, and coffee are slowly replaced by new crops like paddy and vegetable. Paddy and vegetable are mainly grown in irrigated areas. In some areas, farmers have turned to livestock keeping that allow for mobility when drought sets in.
4.3 Small farmers’ adaptive strategies

To cope with the climate change effect at least in a short-term some farmers in the area reported that they have increased the use of inorganic fertilisers (see Table 4.6). Farmers living in areas where water is relatively available pointed out that they use irrigation to cope with climate change stresses (35.7%) (see Table 4.6). A significant proportion of the farmers in the area admitted to resorting to soil and water conservation mechanisms (10.7%), change crop from perennial to annual which matures faster (14.3%).

<table>
<thead>
<tr>
<th>Copping strategy</th>
<th>% respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigating farm plots</td>
<td>35.7</td>
</tr>
<tr>
<td>Grow crops that mature faster</td>
<td>14.3</td>
</tr>
<tr>
<td>Practice intercropping</td>
<td>16.8</td>
</tr>
<tr>
<td>Planting trees around the farm plots for shading and wind break</td>
<td>13.3</td>
</tr>
<tr>
<td>Applying soil and water conservation mechanisms</td>
<td>10.7</td>
</tr>
<tr>
<td>Planting drought resistant crops</td>
<td>8.4</td>
</tr>
<tr>
<td>Involved non-farm activities such as charcoal business</td>
<td>6.9</td>
</tr>
<tr>
<td>Change planting dates (i.e. planting at first rain)</td>
<td>6.5</td>
</tr>
<tr>
<td>Increase use of inorganic fertilizers</td>
<td>0.01</td>
</tr>
<tr>
<td>Migrating from dry to wet, river banks, wetlands and deforestation</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

*Table 4.6: Adaptation strategies farmers employ*

Other farmers, especially those found dry areas in Pangani river basin and Pemba indicated that they plant at the onset of first rains, plant fast-maturing crops, plant drought-resistant crops and mix crops on the same plot to accommodate climatic changes. About 8.3, 18.1, 10.1, and 16.8 percent admitted to employing these mechanisms, respectively. Some farmers mentioned that they have abandoned agriculture and embraced non-farming activities. About 8.8 percent of the farmers pointed out that they have turned to non-farm activities due to increased risk of crop failure and disease in their areas (see Table 4.6).

On the other hand, a significant proportion of the farmers believe that the long-term solution to climate change challenges is increasing efforts to plant trees, which will help in absorbing greenhouse gases that are major causes of climate change. They also admitted that planting trees improved shading, shelter and produced foliage which is important for mulching and making farmyard manure. Survey results presented in Table 4.6 show that 13.3 percent of farmers plant trees in and around their farm plots and river banks for the aforementioned purposes.
The study also asked farmers’ about barriers to using various farm level climate change adaptation strategies presented in Table 6. Results in Table 4.7 show that, 9.6 percent pointed out that the shortage of farm land is the main barrier to adopting coping mechanisms. Others pointed out that the shortage of water for irrigation limits adaptation to climate change in the area. About 47.7 percent cited this as a climate change adaptation barrier. In a situation where rainfall reliability is low, the use of irrigation remains the most sustainable means for assured crop and livestock production. Also, lack knowledge or information about proper adaptation mechanisms was pointed out as the one of the limiting factors in the area; about 14.7 percent mentioned it as the main limiting factor. Lack of timely weather forecast information on the expected climate change (variability) was pointed out as one of the limiting factor; about 8.8 percent declared that this is one of the main limiting factors.

<table>
<thead>
<tr>
<th>Constraints</th>
<th>% of respondents (n=375)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortage of water for irrigation</td>
<td>47.7</td>
</tr>
<tr>
<td>Lack of necessary farm inputs</td>
<td>20.0</td>
</tr>
<tr>
<td>Lack of information about proper adaptation mechanisms</td>
<td>14.7</td>
</tr>
<tr>
<td>Shortage of farm land</td>
<td>9.6</td>
</tr>
<tr>
<td>Lack of timely climate forecasting information on the expected climate changes</td>
<td>8.8</td>
</tr>
<tr>
<td>Lack of capital</td>
<td>8.0</td>
</tr>
<tr>
<td>Shortage of labour force to implement some of the coping strategies</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Table 4.7: Farmers’ constraints to adaptation methods

Other factors pointed out by the farmers include lack of necessary farm inputs such crop varieties tailor made for coping with extreme climatic conditions as the main constraint to applying the mechanism. About 20 percent pointed out this as the limiting factor. Finally, lack of capital to invest in adaptation mechanisms such as irrigation, rain water harvesting and soil water conserving mechanisms were cited as major limiting factors according to eight percent of the respondents.

4.4. Factors conditioning farmers’ choice of adaptive strategy

To adapt to climate change effects, farmers employ strategies analysed here in combination with other strategies. The various combinations of measures and practices may be grouped into the following categories: Increase in the use of inorganic fertilisers (INCUSEINOFERT); Planting drought resistant crops (DROURESCROPS); Irrigating farm lots (IRRIGATEFARMPlOTS); Early
planting (EARLYPLANTING); Use of mulching (USEMA); Grow crops that mature faster (GROWCROPMATFAST); Plant trees (PLANTTREES); focus more on or turn to non-farming activities (FOCUSNONFARMACT); and Practice mixed cropping (MIXEDCROPPING).

To capture the effect of various factors on the probability of adopting various climate change adaptation alternatives at the farmers’ disposal, we used migration to river banks, wet or wetlands that are available in the basin and Pemba Island as the base category for no adaptation and evaluate other choices as alternatives to this option. The first column of Table 4.9 compares the probability of increased adoption of the use of inorganic fertilisers (INCUSEINOFERT) as opposed to no adaptation. The marginal effects and their signs reflect the expected change in probability of preferring to increase the use of inorganic fertilisers to migrating to river banks or wetlands available in the basin and Pemba Island (the base) per unit change in an explanatory variable. The same applies to the remaining alternatives in the table.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH head age</td>
<td>46.97</td>
<td>25</td>
<td>85</td>
<td>13.92</td>
</tr>
<tr>
<td>HH head education level (measured as number of years in schooling)</td>
<td>7.01</td>
<td>0</td>
<td>20</td>
<td>2.69</td>
</tr>
<tr>
<td>Upper</td>
<td>989.65</td>
<td>787.98</td>
<td>1356.42</td>
<td>178.97</td>
</tr>
<tr>
<td>Middle</td>
<td>756.54</td>
<td>698.76</td>
<td>936.46</td>
<td>169.33</td>
</tr>
<tr>
<td>Lower</td>
<td>213.43</td>
<td>0</td>
<td>456</td>
<td>166.78</td>
</tr>
<tr>
<td>Dry</td>
<td>156.34</td>
<td>0</td>
<td>346</td>
<td>102.36</td>
</tr>
<tr>
<td>Wet</td>
<td>167.25</td>
<td>10</td>
<td>536</td>
<td>116.32</td>
</tr>
<tr>
<td>HH size</td>
<td>5.29</td>
<td>1</td>
<td>13</td>
<td>2.12</td>
</tr>
<tr>
<td>Primary occupation</td>
<td>2.43</td>
<td>0</td>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>Number of years lived in the area</td>
<td>4.87</td>
<td>1</td>
<td>6</td>
<td>1.18</td>
</tr>
<tr>
<td>Access to extension services</td>
<td>0.73</td>
<td>0</td>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>Farm size</td>
<td>3.04</td>
<td>0.5</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Access to crop failure subsidies</td>
<td>0.73</td>
<td>0</td>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>Access to credit</td>
<td>0.73</td>
<td>0</td>
<td>1</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 4.8: Descriptive statistics: Variable for the regression model

The estimated marginal effects and P-levels from the Multinomial Logit Model and the estimated coefficients are presented in Table 4.9. The results show that most of the explanatory variables are statistically significant at 10 percent or lower which are described and discussed below. The chi-square results show that likelihood ratio statistics are highly significant (P<0.00001), suggesting that the model has a strong explanatory power. Specifically, the results in Table 4.5 show
that the age of the head of household positively influences the probability of adopting all the alternatives, and also significantly influences the probability of adopting soil conservation mechanisms and adopting mixed cropping adaptation alternatives as opposed to the base alternative. The results also indicate that the education level of the household head positively influences the probability of adopting all climate change adaptation alternatives and significantly influences the probability of adopting early planting, applying soil water conservation mechanisms, growing crops that take a short period to mature (mature faster), turning to non-farming activities and practicing mixed cropping adaptation alternatives as opposed to the base alternative.

Furthermore, results in Table 4.9 indicate that the location of a farmer in the basin and the Island i.e. upper, middle, lower, wet or dry influence farmers’ probability of adopting adaptation alternative as opposed to the base alternative differently. The upper locations of the basin, for example, appears to influence negatively the probability of increasingly adopting use of inorganic fertilisers, irrigation of farm plots, applying soil and water conservation mechanisms, turning to non-farming activities, and practicing mixed cropping adaptation alternatives as opposed to the base alternative. On the contrary, the middle parts of the basin appear to influence positively the probability of increased adoption of the use of inorganic fertilisers, planting of drought-resistant crops, planting trees, turning to non-farming activities and practicing mixed cropping adaptation alternatives as opposed to the base alternative. The locations also appear to influence positively the probability of adopting irrigating farm plots, early planting and applying soil and water conservation adaptation alternatives as opposed to the base alternative. The lower locations of the basin appear to have a negative influence on the probability of increased adoption of the use of inorganic fertiliser adaptation alternatives as opposed to the base alternative. On the other hand, these locations appear to have a positive influence on the probability of adopting planting of drought-resistant crops, irrigation of farm plots, early planting, use of mulching as soil and water conservation mechanisms, turning to non-farming activities and practicing mixed cropping adaptation alternatives as opposed to the base alternative. Other factors determining the type of adaptive strategy include ownership of livestock, permanency nature of crops grown and genders. It is more likely that farmers owning large number livestock will migrate to other areas. Similarly, out-migration is common to farmers who cultivate annual crops and men.

The wet areas appear to have negative influence on adaptive strategies and, conversely, dry areas appear to have positive effect. In fact, farmers living in areas with relatively lower climatic stress are reluctant to adapt to climate change than those in areas with more stress.
<table>
<thead>
<tr>
<th>Variable</th>
<th>INCFERT USE</th>
<th>DROURES CROPS</th>
<th>IRRIGATE FARM PLOTS</th>
<th>EARLY PLANTING</th>
<th>USEMA</th>
<th>GROW CROP MAT FAST</th>
<th>PLANT TREES</th>
<th>FOCUS NON FARM ACT</th>
<th>MIXED CROPPING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household head age (years)</td>
<td>0.0315</td>
<td>0.0015</td>
<td>0.0044</td>
<td>0.0025</td>
<td>0.0036</td>
<td>0.0026</td>
<td>0.0004</td>
<td>0.0044</td>
<td>0.0044</td>
</tr>
<tr>
<td></td>
<td>(0.53)</td>
<td>(0.63)</td>
<td>(1.46)</td>
<td>(1.16)</td>
<td>(1.57)</td>
<td>(1.17)</td>
<td>(0.29)</td>
<td>(0.38)</td>
<td>(1.69)</td>
</tr>
<tr>
<td>Household level of education (years)</td>
<td>0.0331</td>
<td>0.0007</td>
<td>0.0179</td>
<td>0.0276</td>
<td>0.0146</td>
<td>0.0166</td>
<td>0.0019</td>
<td>0.0389</td>
<td>0.0026</td>
</tr>
<tr>
<td></td>
<td>(0.97)</td>
<td>(0.07)</td>
<td>(1.24)</td>
<td>(1.67)</td>
<td>(1.78)</td>
<td>(1.57)</td>
<td>(0.32)</td>
<td>(1.63)</td>
<td>(2.32)</td>
</tr>
<tr>
<td>Upper</td>
<td>-0.0389*</td>
<td>-0.0489</td>
<td>-0.0920</td>
<td>-0.0672</td>
<td>-0.0156</td>
<td>-0.0582</td>
<td>0.0151</td>
<td>-0.0223</td>
<td>-0.0154</td>
</tr>
<tr>
<td></td>
<td>(-1.54)</td>
<td>(-1.04)</td>
<td>(-1.56)</td>
<td>(-1.10)</td>
<td>(-1.63)</td>
<td>(-1.20)</td>
<td>(0.62)</td>
<td>(-2.20)</td>
<td>(-1.62)</td>
</tr>
<tr>
<td>Middle</td>
<td>-0.0426**</td>
<td>-0.0327*</td>
<td>0.0597***</td>
<td>0.0026</td>
<td>0.0318</td>
<td>-0.0217</td>
<td>-0.0054</td>
<td>-0.0453</td>
<td>-0.0355***</td>
</tr>
<tr>
<td></td>
<td>(-1.85)</td>
<td>(-1.65)</td>
<td>(2.34)</td>
<td>(3.44)</td>
<td>(1.54)</td>
<td>(-1.14)</td>
<td>(-0.48)</td>
<td>(-1.88)</td>
<td>(-2.48)</td>
</tr>
<tr>
<td>Lower</td>
<td>-0.0327*</td>
<td>0.0126*</td>
<td>0.0422***</td>
<td>0.0087***</td>
<td>0.1468***</td>
<td>0.0067</td>
<td>-0.0364***</td>
<td>0.0342**</td>
<td>0.0253***</td>
</tr>
<tr>
<td></td>
<td>(-1.51)</td>
<td>(1.01)</td>
<td>(2.53)</td>
<td>(2.60)</td>
<td>(2.60)</td>
<td>(0.60)</td>
<td>(-3.11)</td>
<td>(1.95)</td>
<td>(3.21)</td>
</tr>
<tr>
<td>Dry</td>
<td>-0.0254</td>
<td>0.0253*</td>
<td>-0.0476*</td>
<td>0.0025*</td>
<td>0.0324</td>
<td>0.0224</td>
<td>-0.0045</td>
<td>0.0525***</td>
<td>0.0433**</td>
</tr>
<tr>
<td></td>
<td>(-1.27)</td>
<td>(1.46)</td>
<td>(-1.54)</td>
<td>(1.95)</td>
<td>(1.55)</td>
<td>(1.25)</td>
<td>(-0.05)</td>
<td>(2.82)</td>
<td>(2.10)</td>
</tr>
<tr>
<td>Wet</td>
<td>0.0263</td>
<td>-0.0057</td>
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<td>-0.0013</td>
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<td>-0.0065</td>
<td>-0.0415**</td>
<td>-0.0526</td>
</tr>
<tr>
<td></td>
<td>(1.18)</td>
<td>(-0.42)</td>
<td>(-0.33)</td>
<td>(-0.23)</td>
<td>(-2.06)</td>
<td>(0.10)</td>
<td>(-0.06)</td>
<td>(-1.66)</td>
<td>(-1.66)</td>
</tr>
<tr>
<td>Household size</td>
<td>-0.1682***</td>
<td>0.0091</td>
<td>0.0108</td>
<td>0.0351***</td>
<td>0.0733</td>
<td>0.0241***</td>
<td>0.0042</td>
<td>0.0232***</td>
<td>0.0343**</td>
</tr>
<tr>
<td></td>
<td>(-2.42)</td>
<td>(0.72)</td>
<td>(0.64)</td>
<td>(1.83)</td>
<td>(1.53)</td>
<td>(1.93)</td>
<td>(0.53)</td>
<td>(2.53)</td>
<td>(1.53)</td>
</tr>
<tr>
<td>Primary Occupation (1/0)</td>
<td>0.0324</td>
<td>0.0222</td>
<td>0.0012</td>
<td>0.0332***</td>
<td>0.0622</td>
<td>0.0232</td>
<td>-0.0022</td>
<td>-0.0325</td>
<td>0.0232**</td>
</tr>
<tr>
<td></td>
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<td>(1.15)</td>
<td>(0.05)</td>
<td>(1.56)</td>
<td>(1.70)</td>
<td>(1.30)</td>
<td>(-0.17)</td>
<td>(-0.16)</td>
<td>(2.17)</td>
</tr>
<tr>
<td>Number years lived in the area</td>
<td>-0.0513**</td>
<td>-0.0402*</td>
<td>0.0263</td>
<td>0.0380*</td>
<td>0.0432*</td>
<td>0.0270</td>
<td>-0.0131</td>
<td>0.0242***</td>
<td>0.0432**</td>
</tr>
<tr>
<td></td>
<td>(-1.88)</td>
<td>(-1.71)</td>
<td>(0.83)</td>
<td>(1.64)</td>
<td>(1.93)</td>
<td>(1.14)</td>
<td>(-0.93)</td>
<td>(1.93)</td>
<td>(2.43)</td>
</tr>
<tr>
<td>Access to extension services (1/0)</td>
<td>0.0853</td>
<td>0.0752</td>
<td>0.1129*</td>
<td>0.1533***</td>
<td>0.0356*</td>
<td>0.1634***</td>
<td>0.0246</td>
<td>-0.0436*</td>
<td>0.0257*</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
<td>-----------</td>
<td>---------</td>
<td>-----------</td>
<td>--------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>(1.32)</td>
<td>(1.23)</td>
<td>(1.51)</td>
<td>(3.68)</td>
<td>(1.74)</td>
<td>(3.27)</td>
<td>(0.74)</td>
<td>(-1.74)</td>
<td>(1.74)</td>
</tr>
<tr>
<td>Farm size (ha)</td>
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<td>0.0214*</td>
<td>-0.0349*</td>
<td>0.0048*</td>
<td>0.0253*</td>
<td>0.0018</td>
<td>0.0152*</td>
<td>-0.0163*</td>
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<tr>
<td></td>
<td>(1.87)</td>
<td>(1.77)</td>
<td>(-1.85)</td>
<td>(1.64)</td>
<td>(1.68)</td>
<td>(0.14)</td>
<td>(1.78)</td>
<td>(-1.68)</td>
<td>(1.78)</td>
</tr>
<tr>
<td>Access to crop failure subsidies</td>
<td>-0.0325***</td>
<td>-0.0317</td>
<td>-0.1863*</td>
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Table 4.9: Marginal effects of explanatory variables from multinomial Logit climate change adaptation model

Note: Values in brackets are z-values.
5.0 Implications of the lessons learnt for REDD+ process and climate change mitigation and adaptation in general

The United Nations Framework Convention on Climate Change (UNFCCC) conference agreed in Bali in 2007 that a comprehensive approach to climate change mitigation should include the reduction of emissions from deforestation and forest degradation (REDD) in developing countries (UNFCCC, 2007). REDD+ is a financial mechanism compensating countries for the prevention of deforestation and forest degradation that could otherwise occur. The 2009 Copenhagen Accord of the UNFCCC recognised REDD+ as a valid mitigation strategy and has increased interest in and funding of it. An international accord on REDD+ emphasises alongside effective greenhouse gas mitigation its environmental co-benefits such as biodiversity protection, sustainable forest management, provision and quality of soil and water, as well as socioeconomic co-benefits, pro-poor development, protection of human rights, and improved forest governance (UNFCCC, 2007).

Many agricultural and forestry practices emit GHGs into the atmosphere. According to Seeberg-Elverfeldt (2010), using fertilisers release N₂O from the soil and burning agricultural residues gives rise to CO₂ levels. Also, CH₄ is set free in the digestion process of livestock, as well as when rice is grown in flooded conditions. When land is converted to cropland and trees are felled, CO₂ emissions result. Based on the study findings in Pangani river basin and Pemba, small farmers’ adaptive strategies and mitigation against climate change have both positive and negative implications for GHG formation and thus somehow in conflict with REDD+ initiatives in Tanzania. The implications summarised in six points below are also mentioned in the National Climate change adaptive strategies (see URT, 2007):

a) Evidence of change in type crops cultivated from permanent tree crops such as coffee, tea and banana to short maturing annual crops contradict REDD+ initiatives which is against the reduction of emission and deforestation.

b) Evidence of increased non-farm activities such as charcoal-burning and cutting down of mangrove forest as an adaptive strategy against declining income from crops due to climate change exerts pressure on forest reserves, hence further contradicting the spirit of REDDS initiatives.

c) Evidence of increased use of inorganic fertiliser and farm yard manure in response to declining land productivity due to, among other things, climate change-related factors increases the GHG emission thus in contradiction with REDD+ initiatives.

d) Increased evidence of farmers and livestock outmigration in search of pastures in marginal and forested areas, thus destroying highly needed carbon sink as addressed by REDD+ initiatives.
e) Evidence of declining yield climate related challenges in the context of population growth makes smallholder farmers expand production to marginal and forest reserves and they practice shifting cultivation. These measures have high a impact on REDD+ initiatives.

f) Isolated evidence of tree planting as adaptive strategies for mitigating the impact of climate change has been reported. This initiative increases carbon since within the REDD+ initiatives.

The empirical results from the study which are the basis of this chapter posit that smallholder farmer’ activities, their adaptive strategies climate change in Pangani basin and Pemba compromise in many ways the REDD+ initiatives. Whereas REDD+ initiatives are long-term, the adaptive strategies for mitigation resource-poor farmers employ against the impact of climate are short-term strategies. This observation implies that efforts for sustaining REDD+ initiatives must go hand in hand with assisting farmers to meet short-run basic needs such as food in addition to the provision of services which can stop them from turning to natural resources (carbon sink). This approach can facilitate their meeting of their immediate survival needs and co-opt them into the long-term REDD+ initiatives.

Acknowledgement

Research, which is the basis of this chapter, was funded by the CCIAM project. It is part of a larger study on the Economic Assessment of Climate Change Impacts, Vulnerability and Adaptation in Tanzania: Case of Pangani Basin and Pemba coordinated by Sokoine University of Agriculture (SUA), Tanzania.

References


Housman & McFadden (1984)


## Appendices

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*Appendix 4.1: Correlation analysis of continuous explanatory variables*
## Appendix 4.2: Variance inflation factor (VIF) test for multicollinearity among variables included in the analysis

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Appendix 4.3: Parameter/coeficient estimates from Multinormal Logit Model (MNLM)

Note: Values in brackets are z-values.
Part 2

Forest Carbon
Assessment Strategies
Biomass and volume models for different vegetation types of Tanzania

Rogers E. Malimbwi¹, Ernest W. Mauya¹, Eliakimu Zahabu,¹ Josiah Z. Katani¹, Shabani A.O. Chamshama¹, Tron Eid², Ole M. Bollandsås², Salim S.M. Maliondo¹, Wilson A. Mugasha³, Abeli M. Masota⁴, Marco Njana⁴, Joseph S. Makero⁵, Joachim S. Mshana¹, Haruna Luganga¹, Agustino Mathias¹, Pastori Msalika¹, Juma Mwangi¹, Humphrey E. Mlagalila¹

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Abstract

Climate change and high rates of global carbon dioxide (CO₂) emissions have increased the attention paid to the need for high-quality monitoring systems to assess how much carbon (C) is present in terrestrial systems and how these change over time. The choice of a system to adopt relies heavily on the accuracy of the
method for quantifying biomass and volume as important primary variables for computing C stock and changes over time. Methods based on ground forest inventory and remote sensing data have commonly been applied in the recent decade to estimate biomass and volume in the tropical forests. However, regardless of the method, accurate tree level biomass and volume models are needed to translate field or remotely sensed data into estimates of forest biomass and volume. Therefore, the main goal of this study was to develop biomass and volume models for the forests, woodlands, thickets, agroforestry systems and some selected tree species in Tanzania. Data from destructively sampled trees were used to develop volume and above- and below-ground biomass models. Different statistical criteria, including coefficient of determination ($R^2$), relative root mean square error (RMSE %) and Akaike Information Criterion (AIC), were used to assess the quality of the model fits. The models selected showed good prediction accuracy and, therefore, are recommended not only to support the ongoing initiatives on forest C Measurement, Reporting and Verification (MRV) processes but also for general forest management in Tanzania.

1.0 Introduction

Tanzania is endowed with vast forest resources. The total forest area on mainland Tanzania is estimated at 48.1 million hectares (ha), which is 55 percent of the total land area of 88.3 million ha (MNRT, 2015). The main vegetation types include forests and woodlands. Forests include montane and lowland forests, mangroves and plantations of mainly Pinus patula, Tectona grandis and Eucalyptus spp. The woodlands are either closed or open but can also be distinguished in terms of species composition into, for example, Miombo woodlands, Acacia-Commiphora and Thickets. Woodlands occupy 44.7 million ha or 92 percent of the total forest area or 50.4 percent of mainland Tanzania whereas forests\(^1\) occupy 4.2 percent, bushland and grassland 17.2 percent and cultivated land 24.4 percent (MNRT, 2015). The cultivated land includes Agroforestry systems such as coconut and cashewnut trees-rich plantations. The total wood volume of growing stock is 3.3 billion cubic metres ($m^3$) (MNRT, 2015). About 97 percent of the total volume is from trees of natural origin and only three percent is from planted exotic tree species. About half of the total volume is found in forestry and wildlife protected areas and, therefore, legally inaccessible for harvesting (MNRT, 2015). Forests account for 11.3 percent of growing stock whereas Miombo woodlands contain 73.9 percent of the growing stock. Total forest Carbon(C) content in the country is about one billion tonnes ($t$).

\(^1\) Forests here collectively refer to Low= land forests, Montane forests, Mangroves and Plantations
The importance of forests in climate change mitigation have prompted negotiations towards a post-Kyoto agreement to include Reducing Emissions from Deforestation and forest Degradation (REDD). Subsequently, REDD+ started in the context of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol annual meeting of 2005 held in Montreal, Canada (UNFCCC, 2005). The submissions also considered whether and how incentives to reduce tropical deforestation could be included in future climate regimes. Furthermore, this has led to the discussion of how to address REDD+ in developing countries. In fact, recent policy advances include drawing lessons and experiences drawn from pilot projects at the country level that addressed REDD+.

At the core of the discussion on REDD+ is the creation of an incentive mechanism (payment) for those responsible for reducing deforestation and degradation. Establishing a REDD+ mechanism along these lines leads to numerous challenges. The basic challenge, however, is the requirement of information on changes in biomass and Carbon (C) stock of the forests at the national and regional as well as local levels. Information on such changes can be based on inventories relying on field plots only or on field plots combined with remote sensing methods. Field plots inventories for REDD+ involve the estimation of C in five Intergovernmental Panels on Climate Change (IPCC) pools of above-ground biomass (AGB), below-ground biomass (BGB), deadwood, foliage and soil organic C. Out of these, AGB and BGB are the most important pools as they are vulnerable to changes. To estimate accurately AGB and BGB, allometric models are imperative. Country-specific allometric models enable the country and forest managers to report on C estimates at higher IPCC tiers. IPCC identifies three reporting tier levels whereby tier 1 utilises global models whereas tiers 2 and 3 utilise site-specific models and information. Volume and C estimates also provide important information as a basis for implementing sustainable forest management.

Tree biomass and volume models comprise easily measureable tree variables, usually diameter at breast height (dbh) and total height (ht) that are correlated to the biomass or volume. Provided that information on individual trees is available, the use of biomass and volume models is the best option to quantifying amounts of C and volume of wood. Quantification of biomass is also essential for issues related to energy production (fuelwood and charcoal production) in conventional forest management planning. Tree volumes are also important for forest management purposes such as the assessment of growing stock, timber valuation, selection of forest areas for harvesting, and for growth and yield studies.
Tanzania has recently completed its National Forest Inventory popularly known as the National Forest Resources Monitoring and Assessment (NAFORMA) (MNRT, 2015). The inventory was based on tree measurements in field plots. The tree measurements could only be converted to biomass/C and volume estimates using appropriate allometric models. Before the implementation of this project, tree allometric models that existed in Tanzania were deficient in terms of narrow tree species coverage, narrow tree size range and narrow spatial representation (Malimbwi et al., 1994, Chamshama et al., 2004). NAFORMA was, therefore, bound to utilise these models and other general models regardless of their deficiencies.

2.0 Objectives of the study

The main objective of the study was to develop models and methods for assessing and monitoring C stocks in Tanzania required for the implementation of REDD+ initiatives at the local as well as national levels. The study developed individual tree biomass and volume models for all major vegetation types such as Miombo woodlands, montane and lowland forests, mangroves, Acacia-Commiphora, thicket and plantations of mainly Pinus patula, and Tectona grandis. Species-specific models for baobab trees and agroforestry system trees composed of mainly coconut and cashewnut were also developed. Baobab was picked from the woodlands due to its significant contributions to volume (4% of total volume in the country) (MNRT, 2015) whereas its biomass is believed to be low due to high water content.

3.0 Methodology

3.1 Study sites
The study sites were spatially distributed across the country to cover different vegetation types that exist in the country (Table 5.1; Figure 5.1).
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**Forest Plantation**

- **Pinus patula**
  - Sao Hill: 1740-2000 Dystric nitisols
  - Meru: 1700-2320 Volcanic soils

- **Tectona grandis**
  - Mtibwa: 640 Clay loamy soils
  - Longuza: 160-560 Loamy soils

**Agroforestry**

- Cashew nut: Kisarawe <400 Sandy soils
- Coconut: Kisarawe and Mkuranga <400 Mbuga and fluvisols soils

*Table 5.1: Studied vegetation types and description of the study sites in Tanzania*
3.2 Sampling procedures

Destructive sampling procedures (see, for example, Snowdon et al., 2002; Mugasha et al., 2013; Mauya et al., 2014) were adopted to collect data used for the development of AGB, BGB and tree volume models for all major vegetation types and selected species. Destructive sampling was conducted following steps described in 3.3.

3.3 Selection of the sample trees

For all study sites, the selection of sample trees was done to ensure representation of tree size and species distribution of respective sites. This selection was based on published and unpublished information from previous forest inventories. Prior to tree felling, the entire sample trees were identified for species name (local and scientific name) and tree variables such diameter at breast height (dbh), and total height (ht) were measured. Callipers and diameter tapes were used to measure dbh whereas ht was measured with Suunto and Vertex hypsometers.
3.4 Data collection and laboratory procedures for biomass determination

To obtain the relevant dataset to achieve the objectives of the study, each of the sample trees was divided into above- and below-ground parts. The above-ground part was considered as all biomass above stump height of 30 cm, was further divided into three sections, namely, the stem, branches including tops (up to a minimum diameter of 2.5 cm) and twigs (with diameter less than 2.5 cm). Stems and branches were trimmed and cross cut into billets ranging from 1 to 2.5 m in length and then weighed for green weight (see, for example, Mugasha et al., 2013, Njana et al., 2015). Two or three small samples (depending on the stem length) from stem and branches, respectively, were extracted and weighed and finally oven-dried in laboratory to obtain the dry weight. Twigs were collected in separate bundles and the green weight of each was determined. Small disk samples from each bundle were collected, labelled, measured for green weight and finally oven-dried.

For BGB, the excavation of the below-ground part of the individual tree was firstly done to ensure that all main roots initiating from the root crown were clearly visible. Then three main roots from the root crown (largest, medium and smallest in diameter) were selected and excavated (see, for example, Mugasha et al., 2013, Njana et al., 2015). These main roots were measured for diameter at the branching point from the root crown and then weighed. Three side roots were also selected from the excavated main roots and measured for diameter at the branching points from the main root and then weighed. The remaining side roots from the excavated main roots were measured for diameter at the branching point. All the main roots that were not excavated were measured for diameter at the branching point of the root crown. Then the root crown was also recorded for green weight. To obtain estimates of the dry weights of the belowground components, a minimum of two samples was taken from all main and side roots and two from the root crown. They were all weighted for green weight, labelled and oven-dried.

3.5 Computations of above- and below-ground biomass of the sample trees

For the above-ground part of the trees, we computed all the mean dry to green weight ratio (DG-ratio) for each tree section (stem, branches and twigs). The dry weight of each section was obtained as a product of mean DG-ratio and the green weight of the respective tree section. Total AGB was computed as the sum of stem, branches and twigs. For the below-ground parts of the excavated trees,
we first converted all green weights from different parts to dry weight biomass as the product of the DG-ratio and their green weights. Models developed from the excavated main and side-roots were applied to predict biomass of those parts of the root system not excavated (see, for example, Mugasha et al., 2013, Njana et al., 2015).

3.6 Data collection for tree volume
The data used for the development of AGB models was also used to develop tree volume models. This started with the computation of the volume of the individual logs obtained from the destructive sampling. The volume of each log-section (i.e. stem and branches) was calculated by multiplying the cross-sectional area at the midpoint of each log with its length. Then the total tree volume was obtained as a sum of stem and branches volumes. A detailed description is provided by Mauya et al. (2014).

3.7 Characterisation of the biomass and volume models data
The data used for developing tree biomass and volume models covered a wide range of conditions in terms of vegetation types and geographical locations. The statistical summary of the data is presented in Table 5.2:
<table>
<thead>
<tr>
<th>Vegetation type/species</th>
<th>Location</th>
<th>n</th>
<th>Min</th>
<th>Max</th>
<th>n</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mangroves</strong></td>
<td></td>
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</tr>
<tr>
<td><em>A. marina</em></td>
<td>Tanzania</td>
<td>40</td>
<td>1.1</td>
<td>70.5</td>
<td>10</td>
<td>3.0</td>
<td>38.6</td>
</tr>
<tr>
<td><em>S. alba</em></td>
<td>Tanzania</td>
<td>39</td>
<td>1.1</td>
<td>47.5</td>
<td>10</td>
<td>6.5</td>
<td>33.8</td>
</tr>
<tr>
<td><em>R. Mucronata</em></td>
<td>Tanzania</td>
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<td>1.4</td>
<td>41.5</td>
<td>10</td>
<td>1.4</td>
<td>32.6</td>
</tr>
<tr>
<td><strong>Miombo</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manyara</td>
<td>40</td>
<td>1.7</td>
<td>78.0</td>
<td>20</td>
<td>3.3</td>
<td>78.0</td>
</tr>
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<td></td>
<td>Tabora</td>
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<td>1.2</td>
<td>95.0</td>
<td>20</td>
<td>10.0</td>
<td>95.0</td>
</tr>
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<td></td>
<td>Katavi</td>
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<td>3.5</td>
<td>79.0</td>
<td>20</td>
<td>8.0</td>
<td>64.0</td>
</tr>
<tr>
<td></td>
<td>Lindi</td>
<td>47</td>
<td>1.1</td>
<td>110.0</td>
<td>20</td>
<td>6.4</td>
<td>80.0</td>
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<td><strong>Lowland and Sub-Montane</strong></td>
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<td></td>
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<td></td>
<td>Amani</td>
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<td>117.0</td>
<td>29</td>
<td>6.0</td>
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<td><strong>Thicket</strong></td>
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<tr>
<td><em>Pseudoprosopis fischeri</em></td>
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<td>1.2</td>
<td>3.0</td>
<td>30</td>
<td>1.2</td>
<td>3.0</td>
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<td><strong>Associate trees</strong></td>
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<td></td>
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</tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Acacia commiphora</strong></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kiteto</td>
<td>50</td>
<td>5.9</td>
<td>79.2</td>
<td>50</td>
<td>5.9</td>
<td>79.2</td>
</tr>
<tr>
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<td>2.5</td>
<td>30.0</td>
<td>60</td>
<td>2.5</td>
<td>30.0</td>
</tr>
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<td></td>
</tr>
<tr>
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<td>Kilosa</td>
<td>35</td>
<td>31.0</td>
<td>318.0</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
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<td><strong>Forest Plantations</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Pinus patula</em></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Meru</td>
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<td>65.0</td>
<td>50</td>
<td>4.3</td>
<td>65.0</td>
</tr>
<tr>
<td></td>
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<td>46.0</td>
<td>35</td>
<td>1.0</td>
<td>46.0</td>
</tr>
<tr>
<td><em>Tectona grandis</em></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longuza</td>
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<td>1.0</td>
<td>83.4</td>
<td>50</td>
<td>1.0</td>
<td>83.4</td>
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<tr>
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<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Kisarawe</td>
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<td>45</td>
<td>6.0</td>
<td>89.8</td>
</tr>
<tr>
<td>Coconut</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kisarawe-Mkuranga</td>
<td>18</td>
<td>19.0</td>
<td>39.0</td>
<td>9</td>
<td>22.5</td>
<td>38.0</td>
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<tr>
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<td></td>
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<td>21.0</td>
<td>40.0</td>
<td>20</td>
<td>21.0</td>
<td>37.0</td>
</tr>
</tbody>
</table>

Table 5.2: Statistics for dbh and number (n) of sample trees used in model development
*Basal area weighted mean diameter of thicket clump*
3.8 Statistical analyses

Ordinary least square regression, non-linear regression, weighted non-linear regression and nonlinear mixed effects modelling techniques were applied to develop AGB, BGB and tree volume models (see, for example, Mugasha et al., 2013; Mauya et al., 2014; Njana et al., 2015). R software (R Development Core Team 2013) and SAS software (SAS® Institute Inc., 2004) were applied during data analyses. The model development procedure started with the selection of appropriate model forms commonly used in previous studies. Similarly, forest mensuration literature was used to suggest appropriate model forms (Philip, 1983; Köhl et al., 2006;). Different model forms were tested for each forest type and study site with the aim of getting models with dbh only and models with both dbh and ht as input variables.

Regression assumptions on homoscedasticity and normal distribution of residuals were examined by means of graphical plots. In cases where these assumptions were not met, weighted regression procedures were used to account for heteroscedasticity (i.e. non constant variance). Likewise, in other studies logarithmic transformation of both response and predictor variables were applied.

Different statistical criteria were used to assess the quality of the models and to guide the selection of the best models. The criteria used included coefficient of determination ($R^2$), pseudo-$R^2$, Akaike information criterion (AIC), relative root mean square error (RMSE) and mean prediction error (MPE%). Details on how the model selection criteria were applied are available in individual studies (see, for example, Mugasha et al., 2013; Mauya et al., 2014; Njana et al., 2015).

4.0 Results and discussion

4.1 AGB models

AGB models covering different vegetation types and some species in Tanzania were developed. General site and species-specific models were developed as presented in Table 5.3. Different criteria for the assessment of model fits were used in individual studies (see, for example, Mugasha et al., 2013; Njana et al., 2015). For the Miombo woodlands, lowland and sub-montane forests, thickets and Acacia-Commiphora, the $R^2$ ranged from 0.80 to 0.97 (Mugasha et al., 2013; Masota et al., 2015; Mathias, 2015). RMSE% was used for assessing the model quality for mangroves, where the values ranged from 23.1 percent to 42.6 percent (Njana et al., 2015). The $R^2$ for the species specific models were all above 0.80, indicating that the majority of AGB variations were explained by the models. All the models developed were further evaluated over sites and diameter classes. None of the selected models produced MPE% values that were statistically significantly different from zero ($p > 0.05$). Additional tests for
model evaluations are given in the individual studies (see Table 3). Therefore, based on the aforementioned model performance statistical criteria, which are comparable to results from previous studies in tropical forests (see, for example, Malimbwi et al., 1994; Chamshama et al., 2004; Ryan et al., 2011; Chave et al., 2014; Mwakalukwa et al., 2014), the developed models can be used to estimate tree AGB with reliable precision. In addition, the developed models do not only cover a wider geographical range, but also wider ranges of tree sizes and species as than the previously reported models in Tanzania (for example, Malimbwi et al., 1994; Chamshama et al., 2004). This indicates that the models can be used over a wide range of tree sizes and sites in Tanzania.

4.2 BGB models
Models for predicting BGB were developed for all vegetation types mentioned above (see Table 5.3). The model fits for BGB were generally not as good as for the AGB models. $R^2$ for the Miombo woodlands and lowland and sub-montane forests ranged from 0.71 to 0.93 (Mugasha et al., 2013; Masota et al., 2015;). RMSE values for Mangrove tree species for the below-ground biomass models ranged from 16.8 percent to 95.1 percent (Njana et al., 2015). The BGB models were also evaluated over sites and tree sizes, and the MPE% values were not significantly different from zero ($p > 0.05$). Generally, the poor performance of the models can be attributed to methodological approaches to data collection. As not all roots were excavated and measured, the use of regression analysis in estimating the unmeasured roots might have resulted into accumulated errors (Mugasha et al., 2013; Malimbwi et al., 2016). Nonetheless, this weakness could not be avoided due to the high cost associated with total tree roots excavation. Despite the shortcomings related to the methodology applied, the models are far better than the use of biomass default values (IPCC, 2003).
<table>
<thead>
<tr>
<th>Vegetation/ species</th>
<th>Location</th>
<th>Model (^a)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AGB (kg)</td>
<td>BGB (kg)</td>
</tr>
<tr>
<td>Mangrove</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>A. marina</em></td>
<td>Tanzania</td>
<td>[0.25128 \times \text{dbh}^{2.24351}]</td>
<td>[1.42040 \times \text{dbh}^{1.44260}]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.19633 \times \text{dbh}^{2.08791} \times \text{ht}^{0.29654}]</td>
<td></td>
</tr>
<tr>
<td><em>S. alba</em></td>
<td>Tanzania</td>
<td>[0.25128 \times \text{dbh}^{2.21727}]</td>
<td>[1.42040 \times \text{dbh}^{1.65760}]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.19633 \times \text{dbh}^{2.04113} \times \text{ht}^{0.29654}]</td>
<td></td>
</tr>
<tr>
<td><em>R. mucronata</em></td>
<td>Tanzania</td>
<td>[0.25128 \times \text{dbh}^{2.26026}]</td>
<td>[1.42040 \times \text{dbh}^{1.68979}]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.19633 \times \text{dbh}^{2.10853} \times \text{ht}^{0.29654}]</td>
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</tr>
<tr>
<td>Miombo woodlands</td>
<td>Tanzania</td>
<td>[0.1027 \times \text{dbh}^{2.4798}]</td>
<td>[0.2113 \times \text{dbh}^{1.9838}]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.0763 \times \text{dbh}^{2.2046} \times \text{ht}^{0.4918}]</td>
<td>[0.1766 \times \text{dbh}^{1.7844} \times \text{ht}^{0.5434}]</td>
</tr>
<tr>
<td>Manyara</td>
<td></td>
<td>[0.1603 \times \text{dbh}^{2.3396}]</td>
<td>[0.3789 \times \text{dbh}^{1.7904}]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.1080 \times \text{dbh}^{1.9936} \times \text{ht}^{0.6628}]</td>
<td>[0.3364 \times \text{dbh}^{1.6166} \times \text{ht}^{0.2979}]</td>
</tr>
<tr>
<td>Tabora</td>
<td></td>
<td>[0.1054 \times \text{dbh}^{2.4809}]</td>
<td>[0.1849 \times \text{dbh}^{2.0318}]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.0817 \times \text{dbh}^{2.1015} \times \text{ht}^{0.6021}]</td>
<td>[\exp[-1.9534 +0.7674 \times \ln(\text{ht} \times \text{dbh}^2)]]</td>
</tr>
<tr>
<td>Katavi</td>
<td></td>
<td>[0.0739 \times \text{dbh}^{2.5764}]</td>
<td>[0.1731 \times \text{dbh}^{2.0296}]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.0474 \times \text{dbh}^{2.2239} \times \text{ht}^{0.6605}]</td>
<td>[\exp[-2.3772 +0.8094 \times \ln(\text{ht} \times \text{dbh}^2)]]</td>
</tr>
<tr>
<td>Lindi</td>
<td></td>
<td>[0.0981 \times \text{dbh}^{2.4897}]</td>
<td>[29.7026-3.6428 \times \text{dbh} +0.2738 \times \text{dbh}^2]</td>
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<td></td>
<td>[0.0669 \times \text{dbh}^{2.2770} \times \text{ht}^{0.4253}]</td>
<td>[\exp[-2.9601 +0.8862 \times \ln(\text{ht} \times \text{dbh}^2)]]</td>
</tr>
<tr>
<td>Lowland and Sub-Montane</td>
<td>Amani-Tanga</td>
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<tr>
<td></td>
<td></td>
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<td>[4.4701 \times \text{dbh}^{0.8613}]</td>
</tr>
<tr>
<td>Thicket</td>
<td>Manyoni</td>
<td>Makero et al. (in press)</td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------------------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td><em>Combretum celastroides</em></td>
<td>( =0.7269 \times \text{dbh}^{2.6710} \times \text{ht}^{0.5737} \times \text{st}^{0.2039} )</td>
<td>( =0.1006 \times \text{dbh}^{4.0062} \times \text{st}^{6.3499} )</td>
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<tr>
<td><em>Pseudoprosopis fischeri</em></td>
<td>( =0.4276 \times \text{dbh}^{2.4053} \times \text{st}^{0.5290} )</td>
<td>( =0.1442 \times \text{dbh}^{4.1534} \times \text{st}^{0.4117} )</td>
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<tr>
<td>Associate trees</td>
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<td>( =1.3803 \times \text{dbh}^{1.1671} )</td>
<td></td>
</tr>
<tr>
<td><em>Acacia - Commiphora</em></td>
<td>Same-</td>
<td>Mathias A. (2015)</td>
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</tr>
<tr>
<td>Kiteto</td>
<td>( =0.1879 \times \text{dbh}^{2.2904} )</td>
<td>( =0.3867 \times \text{dbh}^{1.6749} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( =0.1050 \times \text{dbh}^{2.0423} \times \text{ht}^{0.6205} )</td>
<td>( =\exp(-1.3847 + 0.6775 \times \ln(\text{ht} \times \text{dbh}^2)) )</td>
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</tr>
<tr>
<td>Baobab</td>
<td>Kilosa</td>
<td>Masota et al. (in press)</td>
<td></td>
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<tr>
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<td>( =2.2349 \times \text{dbh}^{1.4354} )</td>
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<tr>
<td></td>
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<td>( =0.6991 \times (\text{dbh}^2 \times \text{ht})^{0.6726} )</td>
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<td>Mugasha et al. (in press)</td>
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<td>( =0.0027 \times \text{dbh}^{3.0579} )</td>
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</tr>
<tr>
<td>Sao Hill</td>
<td>( =0.1564 \times \text{dbh}^{2.2711} )</td>
<td>( =0.1551 \times \text{dbh}^{1.7915} )</td>
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</tr>
<tr>
<td>Meru</td>
<td>( =0.0304 \times \text{dbh}^{2.7590} )</td>
<td>( =0.0018 \times \text{dbh}^{3.1697} )</td>
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</tr>
<tr>
<td>Vegetation Type</td>
<td>Location</td>
<td>Biomass Model (AGB)</td>
<td>Biomass Model (BGB)</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><em>Tectona grandis</em></td>
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<td>Mugasha et al. (in press)</td>
<td></td>
</tr>
<tr>
<td><strong>Coconut</strong></td>
<td>Tanzania</td>
<td>3.7964×ht^{1.8130}</td>
<td>13.5961×ht^{0.6635}</td>
</tr>
<tr>
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<td></td>
<td>5.2988×dbh^{-0.1829}×ht^{1.9297}</td>
<td>8.4628×dbh^{0.1689}×ht^{0.6214}</td>
</tr>
<tr>
<td><strong>Cashewnut</strong></td>
<td>Kisarawe</td>
<td>exp(-0.1684+0.8873×ln(dbh^2))</td>
<td>exp(-2.3765+0.9394×ln(dbh^2))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mugasha et al. (in press)</td>
<td>Zahabu <em>et al.</em> (in press)</td>
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</tbody>
</table>

Table 5.3: Above- and below-ground biomass models for different vegetation types in Tanzania

*AGB = Above ground biomass (kg); BGB = Below ground biomass; dbh = Diameter at breast height (cm); ht = Total tree height (m); st = Number of stems in thicket clump; ρ= Wood density
4.3 Tree volume models

Tree volume models were developed for Miombo woodlands, lowland and sub-montane forests, thickets and *Acacia-Commiphora* (see Table 4). General and some species-specific volume models were also developed for different sites (see Table 5.4). The pseudo-R² of the models ranged from 0.69 to 0.96 (Masota *et al*., 2014; Mauya *et al*., 2014; Makero *et al*., in press; Mathias, 2015). The models were evaluated by testing their performance over different sites and tree sizes, which resulted into MPE% that were not significantly different from zero (p > 0.05), thus indicating that the developed models were unbiased. The models are considered to be unique in terms of wider geographical and species coverage. For example, the models which were developed for Miombo woodland (see, for example, Malimbwi *et al*., 1994; Chamshama *et al*., 2004) covered only one site in eastern Tanzania, but the newly-developed models cover four regions endowed with abundant and diverse Miombo tree species (MNRT, 2015). Moreover, previously there were no tree volume models available for *Acacia-Commiphora* and mountain forests.
<table>
<thead>
<tr>
<th>Vegetation/ species</th>
<th>Location</th>
<th>Model</th>
<th>Source</th>
</tr>
</thead>
</table>
| Miombo woodlands    | Tanzania        | $= 0.00016 \times \text{dbh}^{3.463}$  
                     |                  | $= 0.00011 \times \text{dbh}^{2.135} \times \text{ht}^{0.5758}$     | Mauya et al. (2014)     |
|                     | Manyara          | $= 0.00005 \times (\text{dbh}^{2} \times \text{ht})^{1.013}$           |                         |
|                     | Tabora           | $= 0.00042 \times \text{dbh}^{2.19786}$                               |                         |
|                     | Katavi           | $= 0.00009 \times \text{dbh}^{2.642}$  
                     |                  | $= 0.00006 \times (\text{dbh}^{2} \times \text{ht})^{1.012}$     |                         |
|                     | Lindi            | $= 0.00016 \times \text{dbh}^{2.472}$  
                     |                  | $= 0.0001 \times (\text{dbh}^{2} \times \text{ht})^{0.9416}$     |                         |
| Lowland and Sub-Montane | Amani-Tanga    | $g \times \text{ht} \times (1.414 - 0.211 \times \ln(\text{dbh}))$   | Masota et al. (2014)   |
|                     |                  | $= \exp(-7.41201 + 2.1901527 \times \ln(\text{dbh}))$               |                         |
|                     |                  | $= \exp(-8.12477 + 1.653497 \times \ln(\text{dbh}) + 0.852048 \times \ln(\text{ht}))$ |                         |
| Thicket             | Manyoni          | $= 0.0002 \times \text{dbh}^{2.4615} \times \text{ht}^{0.9089} \times \text{st}^{0.4534}$ | Makero et al. (in press) |
|                     | Combretum celastroides | $= 0.0002 \times \text{dbh}^{2.2177} \times \text{ht}^{0.5468} \times \text{st}^{0.7903}$ |                         |
|                     | Pseudoprosopis fischeri | $= 0.0004 \times \text{dbh}^{1.5009} \times \text{ht}^{0.6419}$ |                         |
| Associate trees     | Same-Kilimanjaro | $= \exp(-8.46 + 1.82 \times \ln(\text{dbh}) + 0.49 \times \ln(\text{ht}))$ | Mathias (2015)         |
|                     | Kiteto           | $= 0.0002 \times \text{dbh}^{2.3269}$  
<pre><code>                 |                  | $= 0.00013 \times \text{dbh}^{2.1555} \times \text{ht}^{0.4352}$ | Luganga (2015)          |
</code></pre>
<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Species</th>
<th>Location</th>
<th>Volume Model Equation</th>
<th>Authors</th>
</tr>
</thead>
</table>
| **Baobab**      | Kilosa  | =0.005187×dbh^{1.5726}  
= -1.04601 + 0.56162×dbh + 0.000279×dbh^{2}  
= 2.62312 + 0.000444×dbh^{2}  
= 0.001904×(dbh^{2}×ht)^{0.714836} | Masota et al. (in press) |
| **Plantations** | **Pinus patula** | Meru | =0.0004×dbh^{2.2923}  
= \exp(-9.6383 + 0.9991×\ln(ht×dbh^{2})) | Msalika (2014) |
| **Tectona grandis** | Longuza | =0.0012×dbh^{1.9912}  
= 0.00014×(dbh^{2}ht)^{0.8793} | Mugasha et al. (in press) |
| **Agroforestry** | **Coconut** | Kisarawe and Mkuranga | =0.0347×ht^{1.1873}  
= 0.00134×dbh^{1.2295}×ht^{0.7841} | Mugasha et al. (in press) |
| **Cashewnut**  | Kisarawe | =\exp(-9.4111 + 2.6044×\ln(dbh)) | Zahabu et al. (in press) |

Table 5.4: Tree volume models covering different vegetation types in Tanzania

\(g = \text{Basal area}; \text{dbh} = \text{Diameter at breast height (cm)}; \text{ht} = \text{Total tree height (m)}; \text{st} = \text{Number of stems in thicket clump}; \rho = \text{Wood density}\)
4.4 Key lessons learnt

Normally, the development of species and site-specific models are preferred in bid to boost accuracy. However, this can hardly be achieved for the entire country such as Tanzania with not only a large geographical coverage but also with more than 800 tree species. In this study, general models that aggregate species and sites were developed and their prediction accuracy were within acceptable ranges. This implies that general models can be used in the absence of species and site-specific models.

It was further learnt that, utilising students in research projects is an effective way of facilitating capacity-building and sustaining research. In fact, the developed models reported in this chapter are based on dissertations and theses of seven MSc and five PhD students. In addition, a total of ten scientific papers have been published in peer-reviewed journals. Moreover, a book detailing the procedures and findings on allometric models has been published (Malimbwi et al., 2016).

It should, however, be noted that these studies on the construction of AGB and BGB allometric models through destructive sampling procedures are limited since they are tedious and costly and, therefore, not easily repeatable. In this regard, the support rendered by the Government of Kingdom of Norway was invaluable and the documented results will ensure their long-term and wide application.

5.0 Implications of the lessons learnt for REDD+ and climate change mitigation and adaptation in general

REDD+ involves the estimation of C in five IPCC pools of AGB, BGB, deadwood, litter and soil organic C. Out of these, AGB and BGB are the most important pools since they are vulnerable to changes. To estimate accurately AGB and BGB, allometric models are imperative. This study has developed biomass and volume models for major vegetation cover types identified in Tanzania by NAFORMA (MNRT, 2015). The developed models can facilitate accurate estimation of C stocks for the AGB and BGB. This will enable the country to report on C estimates at higher tiers, in particular tier 3². Volume and C estimates also provide important information for sustainable forest management.

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² IPCC identified three reporting tier levels where by tier 1 utilizes global models while tiers 2 and 3 utilize site specific models and information.
References


Makero, J. S., Malimbwi, R. E., Eid. T ., Zahabu E. Models predicting biomass of thickets and associate tree species in Itigi thicket vegetation of Tanzania (In press)

Makero, J. S., Malimbwi, R. E., Eid. T ., Zahabu E. Models for prediction of volume of thickets and associate tree species in Itigi thicket vegetation of Tanzania (In press)

Mathias, A., (2015). Models for estimating tree volume, above and below ground biomass for Acacia - Commiphora woodlands in Same districts. MSc thesis in Forest Resource Assessment and Management (FORAM), Sokoine University of Agriculture. pp 63


Carbon Stocks and Plant Diversity in Different Land Cover Types of Tanzania

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Abstract

Forest and woodlands are important sources of ecosystem goods and services, although quite often they are underestimated due to lack of detailed studies on specific vegetation types. The aim of this study was to quantify above-ground carbon stocks, soil carbon and carbon loss due to selective harvesting in five different vegetation types in Tanzania. In particular, the study determined tree above-ground carbon (AGC) in miombo woodlands differed considerably depending on location from 20.8 (76.33t CO2eq ha⁻¹ in the dry miombo of Mufindi to 34.2 (125.5t
CO2eq ha\(^{-1}\)) in the wet miombo of Chunya in the Lake Rukwa basin. In the moist forests on volcanic mountains, the above-ground carbon stock was 65.2t ha\(^{-1}\) (239.28t CO2eq ha\(^{-1}\)) whereas in the Acacia-Commiphora woodlands it was 12.8t ha\(^{-1}\) (46.98 CO2eq ha\(^{-1}\)) and in the mangrove ecosystem it was 40.5t ha\(^{-1}\) (148.6t CO2eq ha\(^{-1}\)). Soil organic carbon (SOC) in the moist forests was 45.0t ha\(^{-1}\) (165.2t CO2eq ha\(^{-1}\)). In the miombo woodlands, the soil organic carbon varied with location from 16.1t ha\(^{-1}\) (59.1t CO2eq ha\(^{-1}\)) in the Lake Rukwa basin of Chunya to 35t ha\(^{-1}\) (128.5t CO2eq ha\(^{-1}\)) in Hanang. In the Mangrove ecosystem, the soil organic carbon amounted to 98.6t ha\(^{-1}\) (361.9t CO2eq ha\(^{-1}\)). Woodland degradation resulting from selective logging dry miombo woodlands around Lake Rukwa basin accounts for a total carbon loss of 7.2 ± 1.0t C ha\(^{-1}\), the majority being from species that are subjected to high utilisation pressure for wood fuel and construction materials. Most of carbon in all vegetation types is concentrated in few dominant species. However, apart from miombo woodlands, whose dominant species are distinct, in other vegetation types; any specie may become dominant when favourable conditions are prevalent, makes species composition crucial in ecosystem functions such as carbon sequestration. Hence, the strategy of Reducing Emissions from Deforestation and forest Degradation, biodiversity conservation, sustainable management of forests and carbon stocks enhancement (REDD+) should consider taking on board an integrated approach to management for all ecosystem services. After all, there are substantial carbon stocks in different vegetation types in Tanzania with high potential for generating socio-economic and ecological benefits at the local, national and global levels. These results have potential implications for REDD+ implementation in different vegetation types. Thus, the realisation of income from conservation of biodiversity and enhancement of the carbon stocks can create incentives for enhancing community participation towards sustainable forest management.

1.0  Introduction

Forests and woodlands play a major role in carbon cycle (Chapin et al., 2002), with plant diversity being a key property in the functioning of these ecosystems. Generally, there are strong associations between carbon stocks and woody plant diversity (Strassburg et al., 2009; Shirima et al., 2015a). However, nearly 0.7 percent of the global tropical forest cover is lost annually due to deforestation and forest degradation linked to anthropogenic activities, which also add to about 20 percent of the global carbon emissions (Gibbs et al., 2007). From local to global scales, deforestation and forest degradation constitute a potential driver of climate change and loss of biodiversity (Strassburg et al., 2009). It was agreed in the 13\(^{th}\) Conference of Parties to the UNFCCC in Bali (2007) and the subsequent COPs that Reducing Emissions from Deforestation and Degradation (REDD) should be considered for inclusion in a post-Kyoto climate change mitigation mechanism. This performance-based system for forest carbon trading
is an international move that covers emissions from habitat change (especially the loss of carbon-rich ecosystems such as forests) in a more comprehensive agreement and provides additional incentives to countries that address REDD.

Multiple benefits such as biodiversity conservation, offsetting of future emissions of greenhouse gases and promotion of ecosystem restoration, may be realised under reducing emissions from deforestation and forest degradation, conservation of carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks (REDD+), once well-structured (Strassburg et al., 2009; Phelps et al., 2012). Furthermore, safeguards on biodiversity concerns were introduced as part of the REDD+ mechanism at the UNFCCC Conference of the Parties in Cancun to avoid unintended harm to biodiversity and ensure that REDD+ does not lead to conversion of natural forest into plantations (Murray and Jones, 2014). In this regard, REDD+ should enhance carbon stocks, motivate the conservation of natural forests and woodlands, their ecosystem services and enhance accruing environmental benefits for the human well-being.

Recent estimates by the National Forestry Resources Monitoring and Assessment (NAFORMA, MNRT, 2015) estimate the area of forest and woodlands of Tanzania mainland to stand at 48.1 million ha, 42 percent larger than what was earlier projected. The current and future land use changes depend on the past and present management options and will affect forest ecosystem functions and their ability to sustain human beings (Diaz et al., 2007). Thus, sound management of these forests can generate a number of environmental services such as water catchment, scenic beauty, biodiversity, and carbon sequestration, which in principle could be valued and paid for by various consumers (Munishi et al., 2000; Munishi and Shear, 2004; Munishi and Maliondo, 2009; Shirima et al., 2011d). There is also a growing market for forest carbon due to the increasing recognition of the role forest management plays in reducing CO2 emissions to mitigate climate change and its effects (Munishi and Shear, 2004; Munishi et al., 2010). The need for addressing REDD+ in forest carbon management is also growing and, hence, the relationship between managing for carbon stocks and other ecosystem services, such as biodiversity and water (Munishi and Shirima, 2010).

Natural forest and woodlands have complex structures in flora and fauna which, if well understood and properly managed, can provide long-term ecosystem goods and services to foster local livelihoods (Shirima, 2015b). This requires stand-based assessments of structural components such as carbon stocks, plant species diversity and composition as well as their links to ecosystem processes and functions (Shirima et al., 2015c). Moreover, additional conservation benefits for biodiversity in REDD+ require developing explicit “biodiversity-friendly” strategic methods, which spatially target interventions and finances focusing on biodiversity delivery (Phelps et al., 2012; Murray and Jones 2014).
Moreover, there is growing concern about the consequences of biodiversity loss for ecosystem functioning, including the ability of ecosystems to fix and store carbon. It is likely that the species composition in tropical forests will have strong bearing on future carbon storage (Bunker et al., 2005). Thus, we need substantially more knowledge on how species composition and diversity directly affect carbon storage in general and how such effects may vary across contrasting natural and managed forests types to optimise long-term carbon sequestration of forests.

Forests and woodlands in Tanzania contribute significantly to mitigating carbon emissions through sequestration. The 2009-2015 National Forestry Resources Monitoring and Assessment (NAFORMA) provides good and reliable data on carbon stock at the national scale in Tanzania (MNRT, 2015). However, given the scale at which NAFORMA was undertaken, the data so collected is likely to underestimate, overestimate carbon stocks of small forest project, or at the sub-national scale. In addition, there is inadequate knowledge on how the species’ composition and diversity directly affect carbon storage in general and how such effects may vary across contrasting natural and managed forest types. We quantified carbon stocks, plant species diversity and composition in five different vegetation types and across climatic gradients in Tanzania. Particular focus was given to species’ composition, richness and diversity, above-ground and soil carbon pools across different topographic, habitat types and climatic gradients. In this study, we specifically asked the following questions: 1) What is the carbon density in different vegetation types; 2) How do carbon stocks relate simultaneously to tree species composition and abundance in different vegetation types; 3) What are the main drivers that influence carbon stocks (aboveground carbon stocks) and species diversity in different vegetation types; and 4) To what extent does woodland degradation contribute to carbon emissions in dry miombo woodlands in Tanzania?

2.0 Methodology

2.1 Study Site

The field sites included several areas with different vegetation types distributed in different parts of the country. In all, 327 plots were established at different sites in five vegetation types as Table 6.1: illustrates:
<table>
<thead>
<tr>
<th>Vegetation types</th>
<th>District Names</th>
<th>Agro ecological zone</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Miombo woodlands</strong></td>
<td>Kilolo, Mufindi, Mbozi, Iringa, Kilombero, Chunya and Hanang</td>
<td>Eastern Plateau, Ruaha-Rukwa Rift zone, Northern Rift Zone and High Plains/Plateau</td>
<td>Most extensive and diverse cover type (wet &amp; dry miombo, less studied, high potential for degradation through utilization. Include old growth and regenerating stands</td>
</tr>
<tr>
<td><strong>Moist forest</strong></td>
<td>Hanang</td>
<td>Northern Rift Zone, Northern Highlands Volcanoes</td>
<td>Some knowledge on carbon storage potential though inadequate, forests on volcanic mountains poorly studied</td>
</tr>
<tr>
<td><strong>Acacia/Commiphora Woodlands</strong></td>
<td>Same</td>
<td>Eastern Plateau</td>
<td>The Somali-Masai Phytochorion. An important cover type, no carbon data on this type, high potential for deforestation and degradation through utilization for grazing</td>
</tr>
<tr>
<td><strong>Mangroves</strong></td>
<td>Rufiji</td>
<td>Coastal Plain</td>
<td>A specific cover type, inadequate information of carbon stocks and potential for degradation through utilization. Scattered data on tree volumes from NAFOMA and no data on all relevant carbon pools for REDD+</td>
</tr>
<tr>
<td><strong>Small Holder Forests</strong></td>
<td>Mufindi (Iringa) and Mbozi (Mbeya)</td>
<td>High Plains and Plateau and Eastern Plateau</td>
<td>Major land cover type and increasing in extent. Poorly studied and scanty data on potential for carbon sequestration. Important component of REDD+ rural livelihoods and rural development</td>
</tr>
</tbody>
</table>

*Table 6.1: Study locations and justification for their inclusion in the study*
2.2 Sampling Techniques/Design

The vegetation of Tanzania was stratified into unique cover types within different agro-ecological zones using the vegetation and agro-ecological zone maps available for Tanzania and expert knowledge on vegetation distribution in the country. Locations of study sites were chosen to coincide as much as possible with the REDD+ pilot sites in addition to being representative of different NAFORMA land cover types.

Except for the miombo woodlands whose two locations were sampled, one study location was established for each of the five vegetation types (see Table 6.1) to take into account topographic, rainfall and temperature gradients. A permanent plot approach was adopted to enable future monitoring of changes in carbon stocks and sequestration potential as a basis for REDD+ and the National Carbon Accounting System (NCAS-T).

Plots measuring 20m by 40m (0.08ha) (see Figure 6.1) were used. These plots are modified from the one-hectare plot methodology—a part of the global Tropical Ecology Assessment and Monitoring (TEAM) protocol (Kuebler 2006). This modification helped to make use of smaller but manageable and adequate plot sizes that can be distributed within the study sites to cover as wide a variation as possible. Each study location was stratified along an elevation gradient, and plots were established across the elevation range at about 300m intervals and from valley bottoms to ridge tops. This was undertaken to capture information on variations in carbon stocks across topographic and landscape gradients. A minimum distance of 200m between plots within the same elevation was adopted to ensure that data sampled from different plots are independent. In each plot, GPS co-ordinates were taken at the south-east corner and trees under study were marked with paint at the point of measurement to enable mapping and future monitoring. Where applicable, plots followed aspect aimed at capturing variations associated with the effects of aspect on carbon stocks and plant diversity. Plots within study sites were layed purposively to ensure wide representation of topographic variations of the site.

As smallholder woodlots differ in size, sample plots in these woodlots ranged from 20m by 20m (0.04 ha) to 20m by 40m (0.08 ha) depending on the size of the woodlot. In each location, households with woodlots were sampled randomly and each household represented a plot.
2.3 Data Collection

Two different carbon pools were assessed (above-ground and soil carbon). To secure the accurate data during collection each 0.08 ha plot was sub-divided into 10 sub-plots measuring 10m by 10m (0.01 ha). In each of the sub-plots, trees with DBH ≥ 5 cm were identified, and their Diameter at Breast Height (DBH) was measured using a diameter tape. For unidentified species in the field, specimens were collected for further identification at a herbarium. All the measured trees were assigned a unique number and tagged. A minimum of three trees of different sizes (large, medium and small) belonging to the most common tree species in the area were measured for DBH, basal diameter (bd), and total height (ht). The basal diameter for the sample trees were used to develop a basal diameter-DBH relationship and a basal diameter-height relationship, which were used to determine the DBH and height of the removed trees, respectively (Sawe et al., 2014). Furthermore, stump basal diameter and height were measured to develop diameter-height relationship model, which was used for estimating tree heights of the removed trees that were not measured for height and later removed volume and biomass. Soil samples were collected at the centre of each 0.08 ha plot from four depths, for example, 0-15 cm, 15-30 cm, 30-60 cm and below 60 cm using a soil profile pit for laboratory analysis of organic carbon.

Undisturbed soil cores were also collected for the determination of soil bulk density, which was used in the computation of soil mass from soil volume and, hence, carbon density (Munishi and Shear, 2004; Munishi and Shirima, 2010, Munishi et al., 2014). In each plot, indicators of disturbance such as stumps, grazing, fire, cultivation, charcoaling and fire wood collection were recorded.
Distances (in kms) from the nearest access road and settlements were extracted from openstreetmap (http://www.openstreetmap.org/) and used as indicators of human activity disturbance. The temperatures and rainfall were drawn from AFRICLIM, a high-resolution climate projections dataset for Africa (Platts et al., 2014). In smallholder and mangrove forests, destructive sampling was used in the development of allometric models and later used for biomass estimation.

2.4 Data analysis

Live tree above-ground biomass (AGB) in each vegetation type was computed using allometric models (see Table 2). Soil samples were analysed for soil organic carbon (in percentage) at the Department of Forest Biology Laboratory of Sokoine University of Agriculture (SUA) using wet oxidation (Black and Walker Method). The soil bulk density was used to compute the soil mass in a unit area (ha) and together with the percentage organic carbon to determine the soil carbon density per unit area in t/ha (Munishi and Shear, 2004; Munishi and Shirima, 2010; Munishi et al., 2010; Munishi et al., 2014). For analysis of degradation, the volume of the cut trees was computed from the DBH obtained from the basal diameter-DBH and height relationships of the measured stumps (Sawe et al., 2014). The above-ground biomass for each tree species was analysed using existing allometric equations and conversion of biomass to carbon by multiplying the biomass with a value of 0.47 as shown in Table 6.2 before being aggregated into carbon density (ton/ha). A multivariate approach was used to determine how carbon stocks are related to species composition and the potential drivers of species composition and carbon stocks. A response matrix was generated from tree species AGC for each vegetation type. Only species with a frequency of occurrence of greater than 5% were included in the response matrix to avoid the influence of rare species on the analysis (Borcard et al., 2011). We chose AGC over species abundance or present/absent because AGC is an important measure of resource dynamic and functioning in tropical forest and woodland ecosystems (Ruiz-Jaen and Potvin, 2011). A non-linear multidimensional scaling (NMDS), which produces an ordination based on a distance or dissimilarity matrix was used and then fitted with the drivers (such as disturbance, for example, stump counts, temperature, rainfall, distances from nearest settlements and roads) to the ordination distance matrix, with 999 permutations using function `envfit()`, vegan package in R. Direct field measurements and records of removals for different uses such as timber were used to assess forest degradation through fire wood and charcoal emissions.
<table>
<thead>
<tr>
<th>Reference Model</th>
<th>Vegetation type</th>
<th>Equation (in Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mugasha et al. (2013)</td>
<td>Miombo woodland</td>
<td>( B = 0.0763 \times \text{dbh}^{2.2046} \times \text{ht}^{0.4918} )</td>
</tr>
<tr>
<td>Masota et al. (2014)</td>
<td>Montane forest</td>
<td>( B = 0.4020 \times \text{dbh}^{1.4365} \times \text{ht}^{0.8613} )</td>
</tr>
<tr>
<td>Mathias et al. (2015)</td>
<td>Acacia-Commiphora</td>
<td>( B = 0.33285 \times (\text{dbh}^2 \times \text{ht})^{0.778} )</td>
</tr>
<tr>
<td>Lupembe et al. (2014)</td>
<td>Mangrove</td>
<td>( B = \exp(0.949 + 2.226 \ln(\text{dbh})) )</td>
</tr>
<tr>
<td>Msagati (2013)</td>
<td>Mbozi-Smallholder Pine-forests</td>
<td>( B = 0.001077 \ln(\text{dbh})^{2.459} )</td>
</tr>
<tr>
<td>Msagati, (2013)</td>
<td>Mufindi-Smallholder Pine-forests</td>
<td>( B = 0.001298 \ln(\text{dbh})^{2.295} )</td>
</tr>
</tbody>
</table>

Table 6.2: Allometric models used in estimating carbon stocks (ton ha⁻¹) in different vegetation types

\( C = \text{Carbon}, \ B = \text{Biomass} \ 
\text{dbh} = \text{diameter at breast height}, \ \text{ht} = \text{tree height} \)

### 3.0 Results and Discussions

#### 3.1 Biomass Carbon Stocks

The above-ground carbon (AGC) density in the miombo woodlands differed considerably depending on location from 20.8 (76.33 t CO₂eq ha⁻¹) in the dry miombo of Mufindi to 34.2 (125.5 t CO₂eq ha⁻¹) in the wet miombo in Chunya along the Lake Rukwa basin. Both woodlands were dominated by the genus *Brachystegia* and *Julbernardia* (see Table 3). Over 20 percent of the carbon stocks were contributed by the dominant species in miombo and *Acacia-Commiphora* woodland sites, whereas in the moist forest the dominant species contributed only 10 percent of the total carbon stock, hence showing a higher evenness in species dominance in the moist forests (see Table 4). *Julbernardia globiflora* contributed 36 percent, 24 percent and 23 percent of the total carbon stocks for all tree species in the miombo of Hanang, Mbozi and Chunya districts, respectively; whereas *Brachystegia spiciformis* contributed 31 percent, and 21 percent of the total carbon stocks for all species in the miombo of Mufindi and Rufiji districts, respectively. Similarly, Mwampashi et al. (2013) observed that *B. bohemii* contributed 60.5 percent (23.85 t ha⁻¹) of the total carbon followed by *B. spiciformis*, which contributed 15.69 percent (6.19 t ha⁻¹) and *Parinari excelsa* contributing 11.41 percent (4.5 t ha⁻¹) in Mbozi district. Munishi et al.
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(2010) reported a carbon density of 19.2 t ha\(^{-1}\) in a degraded miombo of southern Tanzania with \(B.\) spiciformis and \(J.\) globiflora contributing most of the carbon stock. Results from this study suggest that the dominance of the two iconic miombo (\(J.\) globiflora and \(B.\) spiciformis) species, which also have the largest proportion of carbon stocks, play a key role on resource dynamic and functions in the woodlands. These species have also been reported to have an advantage when it comes to resource use due to their ability to adapt to nutrient limited environments and may have negative influence on the existence of other tree species (Shirima et al., 2015e).

In the \(Acacia-Commiphora\) woodlands, the carbon density was 12.8 t ha\(^{-1}\) (46.98 CO2eq ha\(^{-1}\)). \(Acacia\) tortilis contributed 30 percent of the total AGC for all species, followed by \(Commiphora\) compestris (13.8%) and \(Acacia\) xanthophloea (13.1%). Generally, \(Acacia-Commiphora\) woodlands had the lowest AGC compared to other vegetation types, especially miombo woodlands, which could be associated with harsh conditions (i.e. limited moisture, soil nutrients and high temperatures) to allow for tree growth.

In the moist forests on volcanic mountains, the above-ground carbon stock was 65.2 t ha\(^{-1}\) (239.28 t CO\(_2\)eq ha\(^{-1}\)). Over 10 percent of the total carbon stock for all trees species was contributed by \(Mystroxylon\) aethiopicum, followed by \(Prunus\) africana (9.9%). Results from this study shows that AGC is within the ranges of carbon stock density estimates across the country for moist forest from previous studies (74 - 517 t ha\(^{-1}\); (Marshall et al., 2012; Munishi and Shear, 2004; Zahabu, 2006)). However, estimates of AGC stock from the moist forest in this study is relatively lower than other estimates from moist forest in Tanzania (174 t ha\(^{-1}\) [144.8-205.5]; (Marshall et al., 2012)) probably due to sampling bias as plots in previous study were located mainly close to the canopy forest (Marshall et al., 2012). Other possible reasons for variation in AGC across studies are the use of different plot sizes in field measurements and allometric models in the analysis. Nevertheless, forest carbon dynamics is influenced by resource variability and past disturbance (Chave et al., 2008; Lewis et al., 2009). Moreover, AGC is known to be more highly associated with tall and closed canopy trees than it is with open and stunted growth forests (Wright, 2012). This result indicates that the Hanang mountain forest has high potential for carbon storage in one of the critically endangered tree species (\(Prunus\) africana) and, hence, requires immediate conservation actions to protect such species from extinction.

In the Mangrove ecosystem, the above-ground carbon density is estimated at 40.5 t ha\(^{-1}\) (148.6 t CO\(_2\)eq ha\(^{-1}\)) whereas the below-ground carbon was about half of the above-ground estimate. \(Rhizophora\) mucronata contributed the highest (39.9%), followed by \(Avicennia\) marina (28.1%) of the AGC stock for all the tree species. The AGC estimates in the Rufiji River delta from this study are comparable to previously reported values (i.e. 49 t C ha\(^{-1}\)) in Marudu Bay.
forest (Faridah-Hanum et al., 2012), which also reported the highest (50%) contribution from *R. mucronata*. The total above-ground carbon in Mangrove is highly affected by stocking (density), basal area, and height (Suzuki and Tagawa, 1983). Similarly, Lupembe et al. (2014) has reported that there is substantial high carbon storage in the Mangrove forest of the Rufiji River delta and suggested that the Mangroves require considerable conservation efforts to maintain and enhance the existing carbon stocks.
<table>
<thead>
<tr>
<th>SN</th>
<th>District</th>
<th>Ecosystem</th>
<th>No of Plots</th>
<th>Mean AGC (t ha⁻¹)</th>
<th>Mean SOC (t ha⁻¹)</th>
<th>Tree Richness</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
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<td>Miombo woodland</td>
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<td>Moist Forest</td>
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<td>Miombo Woodland</td>
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<td>40</td>
</tr>
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<td>4</td>
<td>Mbozi</td>
<td>Small Holder Pine-Forests</td>
<td>16</td>
<td>37.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>Miombo Woodland</td>
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<td>Small Holder Pine-Forests</td>
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<td>49.8</td>
<td>-</td>
<td>-</td>
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<td>Mangrove Forest</td>
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<td>Coastal Forests</td>
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**Degradation (t ha⁻¹)**

<table>
<thead>
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<th>District</th>
<th>Ecosystem</th>
<th>No of Plots</th>
<th>Mean AGC (t ha⁻¹)</th>
<th>Mean SOC (t ha⁻¹)</th>
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<td>7.2</td>
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</table>

*Table 6.3: Average above-ground carbon stocks (t ha⁻¹) distribution and degradation in different vegetation types of selected agro-ecological zones in Tanzania*
3.2 Soil Organic Carbon stocks

Soil organic carbon (SOC) in the moist forests was 45.0 t ha\(^{-1}\), which corresponds to 165.2 t CO\(_2\)eq ha\(^{-1}\) (see Table 6.3). In the miombo woodlands, the soil organic carbon varied with location and ranged from 16.1 t h\(^{-1}\) (59.1 t CO\(_2\)eq ha\(^{-1}\)) in the Lake Rukwa basin of Chunya to 35 t ha\(^{-1}\) (128.5 t CO\(_2\)eq ha\(^{-1}\)) in Hanang. In the Mangrove ecosystem, the soil organic carbon was amounted at 98.6 t ha\(^{-1}\), an equivalent of 361 t CO\(_2\) ha\(^{-1}\).

Miombo woodland soils are an important sink of atmospheric carbon due to the presence of soil humus that stabilises soil organic carbon for a long period. This underscores the potentiality of miombo soils as one of the important strategies in mitigating climate change through carbon storage. This study, therefore, reveals that different soil types in the miombo ecosystem vary in their capacity to store carbon. Moreover, topographic features, horizon thickness and soil texture differentially influence soil organic carbon distribution. Previous study on Miombo woodlands found a significant (p < 0.05) increase in SOC with increasing elevation, horizon thickness and percentage clay, but it decreases significantly (p < 0.05) with increasing slope gradient and percentage sand (see Shelukindo et al., 2014b).

Overall, the amount of soil carbon at the surface (i.e. top 15 cm) is higher than in lower horizons. It was observed that in most of the vegetation types the amount of C at the surface (top 15 cm) is more than two times at the 30 cm depth and three times the amount below the 60 cm depths (Munishi et al., 2014). Given the high amounts of carbon at the surface horizons, vegetation disturbance may result into high carbon emissions from the soil. This justifies the argument for the conservation of intact vegetation when implementing REDD+ initiatives for areas where such drives can be practiced more beneficially.

<table>
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<tr>
<th>Districts</th>
<th>Ecosystem</th>
<th>Scientific Names</th>
<th>Carbon (%)</th>
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</thead>
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<tr>
<td></td>
<td></td>
<td><em>Brachystegia spiciformis</em></td>
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<tr>
<td></td>
<td></td>
<td><em>Diplorhynchus condylacaron</em></td>
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<td><em>Brachystegia boehmii</em></td>
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</tr>
<tr>
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<td></td>
<td><em>Pterocarpus angolensis</em></td>
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</tr>
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<td></td>
<td><em>Burkea africana</em></td>
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</tr>
<tr>
<td></td>
<td></td>
<td><em>Isoberlinia angolensis</em></td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Pseudolachnostylis maproneifolia</em></td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Brachystegia sp</em></td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lannea schimperi</em></td>
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<td>Location</td>
<td>Ecosystem</td>
<td>Species</td>
<td>Percentage</td>
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<td>-----------------</td>
<td>--------------------------</td>
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<td></td>
<td><em>Brachystegia sp</em></td>
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<td><em>Brachystegia longifolia</em></td>
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<tr>
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<td></td>
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<td><em>Combretum molle</em></td>
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<td>Species and Percentage</td>
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<td><em>Uapaca kirkiana</em> 14.4</td>
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<td><em>Julbernardia globiflora</em> 7.8</td>
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<td></td>
<td><em>Isoberlinia angolensis</em> 5.1</td>
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<td></td>
<td><em>Brachystegia sp</em> 4.8</td>
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<td><em>Brachystegia microphylla</em> 4.1</td>
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<td><em>Brachystegia manga</em> 3.9</td>
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<td><em>Monotes elegans</em> 3.0</td>
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<td><strong>Rufiji</strong> Coastal Miombo</td>
<td><em>Brachystegia spiciformis</em> 20.9</td>
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<td><em>Pseudolachnostylis maproneifolia</em> 13.4</td>
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<td><em>Brachystegia boehmii</em> 10.9</td>
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<td><em>Gaya parviflora</em> 3.8</td>
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<td><em>Diplorhynchus condylocarpon</em> 3.8</td>
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<td><em>Bobgunnia madagascariensis</em> 3.5</td>
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<td><em>Acacia tortilis</em> 30.8</td>
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<td></td>
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</tr>
<tr>
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<td><em>Acacia xanthophloea</em> 13.1</td>
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<td><em>Acacia robusta</em> 10.5</td>
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<td><em>Acacia sp</em> 6.7</td>
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</tr>
<tr>
<td></td>
<td><em>Cordia sinensis</em> 3.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 6.4: Carbon contribution by different species in different ecosystems in Tanzania*

Only species that contributed more than 3% carbon are shown
3.3 Woodland degradation and its effects

Degradation resulting from the utilisation in the southern miombo woodlands accounts for a total carbon loss of 7.2 t C ha\(^{-1}\) with the majority stemming from *Brachystegia spiciformis* and *Brachystegia boehmii*, which contributes 92.2 percent of the total removals. The major activities contributing to wood removal were charcoal-burning (86%), timber harvesting (11%), and construction materials (3%). Sawe et al. (2014) observed that harvesting in the Miombo woodlands of the Lake Rukwa basin resulted into a total loss of 4.1±0.9 t C ha\(^{-1}\), an equivalent of 15.05 ± 3.3 t CO\(_2\) ha\(^{-1}\), and was mainly caused by human-induced disturbances in their search for livelihoods. Furthermore, the large levels of harvesting in Miombo woodlands resulted into high rates of carbon dioxide emissions beyond the current tree recruitment rates, and surpassing the Mean Annual Increment (MAI) in the woodland (Sawe et al., 2014).

3.4 Tree species’ composition, richness and carbon stocks

Tree species richness differed among vegetation types (see Table 6.3). Overall, the richness was highest in the miombo woodlands compared to moist forest, *Acacia-Commiphora* and Mangrove forests. Within the miombo woodlands tree richness was high in areas along the Lake Rukwa basin (Chunya district, 76 tree species), followed by dry miombo in Mufindi district (70 tree species) and by coastal miombo (64 tree species) in Rufiji district. It appears that areas with high AGC stocks have high tree species richness especially in the miombo woodlands (see Table 6.3). Species richness is one of the structural attributes of woodland/forest ecosystems, thus maintaining and enhancing structural attributes may yield multiple benefits such as carbon, biodiversity and other ecosystem services. Shirima et al. (2014b) observed a positive relationship between above-ground carbon (AGC) and tree species richness in Miombo woodlands, arguing that this has potential implications for REDD+ implementation in different vegetation types.

Anthropogenic factors (as measured in terms of distance from settlements and road), topographic features, especially elevation, mean rainfall and temperature have a profound influence on species composition and, hence, AGC (Table 6.5). In the miombo woodlands mean annual rainfall had a significantly positive correlation with tree species composition and AGC (see Table 6.5 and Figure 6.2), whereas elevation and distance from nearest settlement have a significantly negative correlation with tree species composition and, hence, AGC (also see Table 6.5 and Figure 6.2). In the moist forests topographic features (elevation) and distance from the nearest settlement had a substantial negative correlation with tree species composition and AGC, whereas the mean annual rainfall and temperature had a positive significant correlation with tree species composition and, hence, AGC (see Table 6.5 and Figure 6.3). Shirima et al. (2015b) observed
that carbon stocks and tree diversity patterns differ among ecosystems, partly due to environmental variability (topography, soil nutrients, and elevation) and anthropogenic disturbances. Such variation affects the ecosystem functions and has consequences on suitability for human co-benefits. This suggests that tree species morphological and physiological adaptations to the environmental conditions in forest and woodlands are important to allow for the co-existence among plant species of different life forms (Gilliam and Roberts, 2003).

Most of carbon in all vegetation types is concentrated in a few dominant species; however, apart from miombo woodlands, whose dominant species are distinct, for the rest of the vegetation types, any species can become dominant so long as favourable conditions are obtainable. Although it might be argued that management for dominant species will contribute substantially to conservation of the existing carbon stocks in the Miombo, other co-benefits such as biodiversity of non-timber forest products such as medicinal plants are also crucial to people’s livelihoods and maintenance of the eco-system balance. Hence, sustainable management for REDD+ should consider adopting an integrated approach to the management for all ecosystem services from other non-dominant species. Species composition is important in forest management, especially for REDD+ because although they may not have high carbon stocks, rare species might play a greater factional roles in ecosystem such as key stones species (Graime, 1998). Focusing on REDD+ initiatives in areas with both high biodiversity and carbon stocks such as moist forest sounds ideal and can promote more opportunities for enhancing other ecosystem services (Locatelli et al., 2013). Areas with low carbon stocks but with high biodiversity such as miombo and acacia woodlands require a strategy for achieving additional gains for biodiversity (Murray and Jones, 2014) because they also tend to be under high anthropogenic pressure resulting from selective logging, charcoal-burning and grazing. Managing miombo woodlands for emission and climate change mitigation (REDD+), therefore, requires rigorous and concerted efforts to reduce anthropogenic degradation.

<table>
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<th>Vegetation</th>
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<th>NMDS2</th>
<th>r²</th>
<th>Pr(&gt;r)</th>
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</tr>
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Moist forest

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<th>Distance from nearest Road</th>
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<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 6.5: Environmental and anthropogenic factors influencing species composition as given by non-linear multidimensional scaling (NMDS) using permutation test (999) at $\alpha = 0.05$ in two vegetation types in Tanzania

Figure 6.2: Non-linear multidimensional scale (NMDs) axis showing woody species composition measured by their above-ground carbon stocks as explained by various environmental factors in moist forests in Tanzania. Only the most abundant species (occurrence ≥ 5%) were considered in the NMDS correlation biplots. Full species names and abbreviations are shown in Appendix 1 and explanations of the environmental variables are indicated in Table 5. MeanRain = Mean annual rainfall, MeanTemp = Mean annual temperatures, StumpF = Stump counts, DistSeltKM = Distance from nearest Settlement (Km), DistRoadsKM = Distance from nearest roads (Km).
**Figure 6.3:** Non-linear multidimensional scale (NMDs) axis showing woody species Composition measured by their above-ground carbon stocks and explained by various environmental factors in Miombo woodlands in Tanzania. Only the most abundant species (occurrence ≥ 5%) were considered in the NMDS correlation biplots. Full species names and abbreviations are shown in Appendix 1 and explanations of the environmental variables are indicated in Table 5. 

MeanRain = Mean annual rainfall, MeanTemp = Mean annual temperatures, StumpF = Stump counts, DistSeltKM = Distance from nearest Settlement (Km), DistRoadsKM = Distance from nearest roads (Km).

### 4.0 Conclusions and Recommendations

There are substantial carbon stocks in different vegetation types in Tanzania with a high potential for generating socio-economic and ecological value at community, national and global levels.

Efforts to manage the forests ecosystems sustainably for carbon emission mitigation will result into greater benefits for the stewards of forest conservation in Tanzania. Such move requires concerted efforts in searching for markets and assisting communities to realise the attendant tangible benefits.

Realisation of income from the carbon stocks, especially in high-degraded forests and woodlands can create a big incentive for community participation in sustainable forest management and ensure conservation of forest ecosystems, especially through PFM as a policy issue.
The information in this chapter represents a good source of data for REDD+ baseline for Tanzania with regard to Reference Emission Levels (REL) /Reference Levels, Baseline to measure changes in emissions/ removals from forest-related activities, Possible “compensation baseline” to provide financial payments for verified emissions reductions for ‘positive incentives’. Emission Factors such as carbon changes in the five IPCC pools and best estimates for both Tier 2 and 3 regarding Emission Factors, which did not exist. These achievements are important as Tanzania readies for the actual implementation of the REDD+ initiatives.

Furthermore, the monitoring of changes in carbon stocks in the permanent monitoring plots will add to the value of carbon in these ecosystems through sequestration. This will put Tanzania’s forestry upfront in the compliance with carbon markets and efforts to gain from the market.

Consequently, the policy reforms aimed at addressing carbon as an ecosystem product and service are necessary and should be adequate in terms of addressing issues of costs and benefit-sharing in forest management for carbon.

Acknowledgements

The authors would like to acknowledge the financial support received from the Royal Norwegian Government through the CCIAM Programme. We also acknowledge the assistance rendered by various people during the data collection process, with special appreciation going to Mr. Hamidu Seki, George Bulenga, John Shesighe and other field team members, who worked tirelessly to generate the data used in preparation of this chapter.

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Appendices

Appendix 1: A list of the most frequent tree species (occurrence ≥ 5%) of moist forest and miombo woodland in Tanzania. Species abbreviations used in Fig. 1 and Fig. 2 in the text.

<table>
<thead>
<tr>
<th>SN</th>
<th>Species code</th>
<th>Scientific Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ALSCH</td>
<td><em>Albizia schimperiana</em> Oliv.</td>
</tr>
<tr>
<td>2</td>
<td>CACAP</td>
<td><em>Calodendrum capense</em> (L.f.) Thunb.</td>
</tr>
<tr>
<td>3</td>
<td>CAEDU</td>
<td><em>Catha edulis</em> (Vahl) Forssk. ex Endl.</td>
</tr>
<tr>
<td>4</td>
<td>CASMA</td>
<td><em>Cassipourea malosana</em> (Baker) Alston</td>
</tr>
<tr>
<td>5</td>
<td>CEAFR</td>
<td>* Celtis africana* Burm. f</td>
</tr>
<tr>
<td>6</td>
<td>CUSHO</td>
<td><em>Cussonia holstii</em> Engl.</td>
</tr>
<tr>
<td>7</td>
<td>CUSPI</td>
<td><em>Cussonia spicata</em> Thunb.</td>
</tr>
<tr>
<td>8</td>
<td>EKCAP</td>
<td><em>Ekebergia capensis</em> Sparrm.</td>
</tr>
<tr>
<td>9</td>
<td>ERSPP</td>
<td><em>Ehretia</em> sp</td>
</tr>
<tr>
<td>10</td>
<td>EUDIV</td>
<td><em>Euclea divinorum</em> Hiern</td>
</tr>
<tr>
<td>11</td>
<td>EUNAT</td>
<td><em>Euclea natalensis</em> A.DC.</td>
</tr>
<tr>
<td>12</td>
<td>GYSEN</td>
<td><em>Gymnosporia senegalensis</em> (Lam.) Loes.</td>
</tr>
<tr>
<td>13</td>
<td>HAABY</td>
<td><em>Hagenia abyssinica</em> J.F.Gmel.</td>
</tr>
<tr>
<td>14</td>
<td>JUPRO</td>
<td><em>Juniperus procera</em> Hochst. ex Endl.</td>
</tr>
<tr>
<td>15</td>
<td>MAYSP</td>
<td><em>Maytenus</em> sp</td>
</tr>
<tr>
<td>16</td>
<td>MYAET</td>
<td><em>Mystroxylon aethiopicum</em> (Thunb.) Loes.</td>
</tr>
<tr>
<td>17</td>
<td>NUCON</td>
<td><em>Nuxia congesta</em> R. Br. ex Fresen</td>
</tr>
<tr>
<td>18</td>
<td>OLEUR</td>
<td><em>Olea europaea</em> L</td>
</tr>
<tr>
<td>19</td>
<td>POLAT</td>
<td><em>Podocarpus latifolius</em> (Thunb.) R.Br. ex Mirb.</td>
</tr>
<tr>
<td>20</td>
<td>PRAFR</td>
<td><em>Prunus africana</em> (Hook. f.) Kalkman</td>
</tr>
<tr>
<td>21</td>
<td>PRPET</td>
<td><em>Protea petiolaris</em> (Hiern) Baker &amp; C.H.Wright</td>
</tr>
<tr>
<td>22</td>
<td>PSYSP</td>
<td><em>Psychotria</em> sp</td>
</tr>
<tr>
<td>23</td>
<td>SCBMU</td>
<td><em>Sclerocarya birrea</em> multifoliolata (Engl.) Kokwaro</td>
</tr>
<tr>
<td>24</td>
<td>SCVOL</td>
<td><em>Schefflera volkensii</em> (Harms) Harms</td>
</tr>
<tr>
<td>No.</td>
<td>Code</td>
<td>Scientific Name</td>
</tr>
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<td>-----</td>
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<td>------------------------------------------------------</td>
</tr>
<tr>
<td>25</td>
<td>SESIN</td>
<td><em>Senna singueana</em> (Delile) Lock</td>
</tr>
<tr>
<td>26</td>
<td>TESIM</td>
<td><em>Teclea simplicifolia</em> (Engl.) Engl.</td>
</tr>
<tr>
<td>27</td>
<td>TUFIS</td>
<td><em>Turraea fischeri</em> Gürke</td>
</tr>
<tr>
<td>28</td>
<td>ZAXSP</td>
<td><em>Zanthoxylum sp</em></td>
</tr>
<tr>
<td>29</td>
<td>ACSEY</td>
<td><em>Acacia seyal</em> Del.</td>
</tr>
<tr>
<td>30</td>
<td>ALAMA</td>
<td><em>Albizia amara</em> (Roxb.) B. Boivin</td>
</tr>
<tr>
<td>31</td>
<td>AZGAR</td>
<td><em>Azanza garckeana</em> (F. Hoffm.) Exell &amp; Hillc</td>
</tr>
<tr>
<td>32</td>
<td>BRMIC</td>
<td><em>Bridelia micrantha</em> (Hochst.) Baill.</td>
</tr>
<tr>
<td>33</td>
<td>BRSPI</td>
<td><em>Brachystegia spiciformis</em> Benth</td>
</tr>
<tr>
<td>34</td>
<td>BRTAM</td>
<td><em>Brachystegia tamarindoides</em> Benth</td>
</tr>
<tr>
<td>35</td>
<td>BRUTI</td>
<td><em>Brachystegia utilis</em> Burtt Davy &amp; Hutch</td>
</tr>
<tr>
<td>37</td>
<td>COMOL</td>
<td><em>Combretum molle</em> R. Br. ex G. Don</td>
</tr>
<tr>
<td>38</td>
<td>COZEH</td>
<td><em>Combretum zehyeri</em> Sound</td>
</tr>
<tr>
<td>39</td>
<td>DANIT</td>
<td><em>Dalbergia nitidula</em> Welw. ex Baker</td>
</tr>
<tr>
<td>40</td>
<td>DICIN</td>
<td><em>Dichrostachys cinerea</em> (L.) Wight &amp; Arn.</td>
</tr>
<tr>
<td>41</td>
<td>JUGLO</td>
<td><em>Julbernardia globiflora</em> (Benth.) Troupin</td>
</tr>
<tr>
<td>43</td>
<td>LOBUS</td>
<td><em>Lonchocarpus bussei</em> Harms</td>
</tr>
<tr>
<td>44</td>
<td>PTANG</td>
<td><em>Pterocarpus angolensis</em> DC.</td>
</tr>
<tr>
<td>45</td>
<td>SCBMU</td>
<td><em>Sclerocarya birrea multifoliolata</em> (Engl.) Kokwaro</td>
</tr>
<tr>
<td>46</td>
<td>STRPT</td>
<td><em>Strychnos potatorum</em> L.F</td>
</tr>
</tbody>
</table>
Community Climate Change Adaptation and Livelihoods Strategies under REDD+ initiate
Climate change, non-timber forest products and livelihood of forest dependent communities
Impacts, vulnerability and adaptation in Tanzania

Augustino, S.¹, Eriksen, S.², Makonda, F.B.S.¹, Ishengoma, R.C.¹, Gillah, P.R., Migunga, G.A.¹ and Shemdoe, R.S.³

ABSTRACT

Climate change threatens the livelihood security of millions of rural Tanzanian households, which rely on natural resources; however, the extent to which the Non-Timber Forest Products (NTFPs) and communities’ livelihoods are impacted upon and are vulnerable to climate change, including the success of coping and adaptation strategies remains largely unknown. This chapter, therefore, is based on a study that assessed the current impact of climate change on livelihoods of forest-dependent communities, their vulnerability and socio-economic adaptation strategies employed in the NTFPs context of Iyondo Forest Reserve (IFR) in Kilombero district, Morogoro and New Dabaga-Ulongambi Forest Reserve (NDUFR) in Kilolo district, Iringa regions of Tanzania. Socio-economic methods taking into account the gender context, market price-based and contingency valuation, NTFPs Inventory and Forest cover change analysis
were applied to collect data. A total of 13 and 11 NTFPs and services were identified and recorded from IFR and NDUFR under the perceived climate change and variability in Kilombero and Kilolo districts, respectively. The majority of the men and women in the two study sites perceived climate to have changed as manifested by an increase in temperature and erratic rainfall, changes which affected the main livelihood activities. Forest-dependent communities in the two study areas are highly vulnerable to climate change and variability, with women, children, the elderly and the disabled singled out as the main vulnerable social groups. On the other hand, both men and women in the two study sites were found to have developed local strategies to ease the effects of climate change and variability on their livelihoods. The total economic value of NTFPs including values from other ecosystem services was found to be high, hence indicating their contribution to rural livelihood and enhanced adaptive capacity. Thus the need to develop the potential NTFPs identified for climate change adaptation by forest-dependent communities through domestication is fundamental. Furthermore, the set baseline information from this study could be used for the implementation of the existing climate change adaptation strategies in Tanzania through use of NTFPs as part of the REDD+ co-benefits.

**Key words:** NTFPs; Livelihood; Climate Change Adaptation; REDD+ Co-benefits; Tanzania

### 1. INTRODUCTION

#### 1.1 Background information

Climate change is increasingly threatening the lives and livelihoods; therefore, maximising adaptation opportunities can minimise its potentially catastrophic effects (Munang *et al.*, 2013). As the largest, most populous, and poorest country in East Africa, Tanzania has already felt the impacts of climate change and will continue to do so well into the future (Ehrhart and Twena, 2006). As a matter of fact, three quarters of the world’s poorest people (those living on less than US$2 per day) depend on the environment for a significant part of their livelihoods (WRI, 2008). In Africa including Tanzania, more than 70 percent of the population earns their living from agriculture, and a majority of the remaining population depends on the exploitation
of other natural resources through hunting, fishing and use of forest products (Enow and Muhongo, 2007) including Non-Timber Forest Products (NTFPs).

And yet, climate change threatens the livelihood security of millions of rural Tanzanian households, which rely on natural resources and rain-fed subsistence farming, especially women whose livelihoods are vulnerable to climate hazards that are expected to become more frequent as climate change accelerates (IPCC, 2001). Climate change projections for Tanzania include changing geographic and temporal patterns and intensity of drought, flooding, and seasonal rainfall shifts, with corresponding impacts on agriculture and forestry (Ehrhart and Twena, 2006; Christensen et al., 2007; URT, 2012).

Forest dependent communities in Tanzania are particularly sensitive to changes affecting forest resources because the changes may cause resource degradation and, in turn, contribute to increased vulnerability and reduced capacity to adapt to climate change (Tschakert, 2006). Although poor households are considered to be vulnerable to climate change due to their dependence for their livelihoods on natural resources and lack of access to other resources needed for adaptation, women are the main natural resource users and managers in rural Tanzania and are, therefore, likely to be disproportionately burdened by the adverse effects of climate change (Ehrhart and Twena, 2006).

Global efforts, including the Reduction of Emissions from Deforestation and forest Degradation (REDD) initiatives, have focused on developing appropriate mitigation measures to reduce the intensity and speed of climate change impacts. The need to develop adaptation strategies to cope with climate change impacts is also increasingly being recognised (Goklany, 2007; Pielke et al., 2007; Stern, 2007). Adaptation strategies that enhance the resilience of ecosystems to ensure the continued provision of goods and services can be particularly important for poor people who depend on natural resources for their livelihoods, and who tend to have low adaptive capacity and, therefore, are highly vulnerable to climate change (Adger et al., 2005; Reid and Huq, 2005; Thomas and Twyman, 2005; AIACC, 2007; Ravindranath, 2007; Eriksen et al., 2007).

According to Guariguata et al. (2008) a number of generic adaptation measures have been proposed mainly drawing on case studies conducted

**Box 7.2**

NTFPs encompass all biological materials other than timber, which are extracted from forests, other wooded lands and trees outside forests for human use (Gubbi and MacMillan, 2008)
in temperate regions (Kalame et al., 2009). On the other hand, few studies have been undertaken in tropical regions such as Tanzania (Paavola, 2008) to establish appropriate measures for coping with climate change impacts. NTFPs and REDD+ are both market-based approaches to conservation and development (Peña, 2010), but it is evident that not all the dimensions, scales and objectives are comparable. Thus, addressing the current use of forest resources including NTFPs is key to the future of Tanzania, in economic, social and environmental terms. It has been argued that failure to address the livelihood needs of local communities in the development and implementation of REDD+ strategies could seriously undermine these initiatives, vital as they may be in the long-term.

This risk will particularly be acute in the case of centrally-imposed, protection-oriented management strategies, where the right of local communities to access and manage forests for livelihood needs is restricted. For instance, where REDD+ affects firewood and charcoal availability, this could have significant distributional impacts on low income households which cannot afford other more viable alternatives (URT and UK-AID, 2011). In this regard, Bansley (2008) recognised the need to conduct adaptive capacity studies to catalyse streamlined multi-level initiatives towards adaptation strategies that could foster community livelihoods.

1.2 Rationale for the study

In the context of the increasing global focus on climate change, attention is being paid to the role of the forestry sector in contributing to and fighting the effects through the development of proper mitigation and adaptation measures. These measures also include a recent focus on opportunities for reducing greenhouse gas emissions from deforestation and forest degradation as well as sustainable management and conservation of forest resources (REDD+) in developing countries. Such activities can present both risks to and opportunities for the interests and rights of local communities in terms of access to forest products, particularly NTFPs. Climate change extreme events, for example, have been reported in Kilombero district (URT, 2012), where in 2011 floods in the Kilombero valley demolished about 663 houses and submerged 2,942 others, leaving about 9,000 households homeless. These events often tend to increase shocks and stresses for forest adjacent communities, which might imply increased reliance on NTFPs products from the forest resources to cater for basic needs in terms of food and shelter (i.e. building and construction materials).
NTFPs represent the subsistence lifelines and economic base of many forest-dependent communities and also act as buffers and safety-nets during periods of climate-induced crop failure and famine. In fact, climate change is already affecting the availability forest goods and services (Nkem et al., 2010), threatening the livelihoods as well as posing incremental impacts on local economies, food security and health (Olsson et al., 2014). The majority of rural population in Tanzania are forest-dependent relying as they do on NTFPs to sustain their livelihoods by direct use of the products such as firewood, charcoal, wild fruits and vegetables, honey and bush meat for household consumption and income generation.

The extent to which the NTFPs and forest-dependent communities’ livelihoods are impacted upon and are vulnerable to climate change is not well understood. Moreover, the success of coping and adaptation strategies to deal with climate impacts through sustainable use of NTFPs is not well and adequately documented. The high prevalence and intensity of poverty, and dependence on NTFPs in Tanzania, suggests that forest-dependent communities are likely to be vulnerable to climate change impacts. The impacts and vulnerability are higher in areas where natural forests are already facing degradation (Katoomba, 2009), as is the case in the Eastern Arc Mountains of Morogoro and Iringa regions. According to Eriksen et al. (2011), it is vital to understand the vulnerability context, including the diverse strategies through which rural populations manage social and environmental shocks and change. Furthermore, it is crucial for formal adaptation policies to support the adaptive capacity of the poor to avoid exacerbating processes generating poverty.

A project entitled *Climate Change, Non-Timber Forest Products and Livelihood of Forest Dependent Communities: Impacts, Vulnerability and Adaptation in Selected Parts of Tanzania* was conducted between 2011 and 2014 in selected forested areas of Morogoro and Iringa regions. The study was aimed at developing, enhancing and providing understanding of the ability of forest-dependent communities to respond to climate change and to reduce their vulnerability, enhance their adaptation and strengthen natural forest integrity through the development and sustainable use of NTFPs that meet gender-specific needs. The study has established baseline information to be used in promoting adaptation strategies among forest-dependent communities. These strategies are rooted in sustainable forest management principles and community-based NTFP application in addition to addressing climate adaptation and mitigation.
goals simultaneously. This Chapter presents findings generated from a research project that constitutes a timely scientific input aimed at complementing efforts towards combating climate change impacts and implementation of REDD+ initiatives.

Objectives of the study
The overall objective was to assess the current impact of climate change on livelihoods of forest-dependent communities, their vulnerability and socio-economic adaptation strategies within the context of NTFPs in Kilombero district, Morogoro and Kilolo district, Iringa regions of Tanzania.

Specifically, the project sought to answer the following key questions: (i) Which NTFPs are available from the forests and use patterns in the study areas under the current change in climate and variability?; (ii) How have the past and present change in climate impacted upon the livelihoods and NTFPs in the study areas?; (iii) To what extent are forest-dependent communities vulnerable to degradation under the changing climate?; (iv) What adaptation strategies are being and have been developed and are being used by forest-dependent communities to reduce the effects of climate change and variability on their livelihoods?; (v) What is the total economic value of NTFPs for enhancing adaptive capacity of forest-dependent communities around the study areas; and (vi) How can NTFP resources be improved in terms of supply, value addition and market promotion to enhance the income of forest-dependent communities,

2.0 METHODOLOGY

2.1 Location of the study
The study was carried out in Iyondo Forest Reserve (IFR), currently part of Kilombero Nature Reserve in Kilombero district, Morogoro region and New Dabaga-Ulongambi Forest Reserve (NDUFR) in Kilolo district, Iringa region. Whereas IFR lies between longitude 36°06’ and 36°22’ East and latitude 8°00’ and 8°16’ South, 55km west of Ifakara Town (Figure 7.1a); NDUFR lies between latitude 35°54’ and 35°57’ East and is between longitude 8°01’S and 8°06’S 60km southeast of Iringa Municipality (Figure 7.1b). Both of the selected sites are located within the Eastern Arc Mountains.
Figure 7.1: Map of the study sites in Kilombero (a) and Kilolo (b) districts, Tanzania

The choice of the study sites was based on the reported high levels of species diversity and reliance of forest adjacent communities on these forestry products for their livelihood security. Furthermore, the Eastern Arc Mountain forests are currently threatened by uncontrolled wildfires, human encroachment, illegal logging as well as slash-and-burn farming (Katoomba Group, 2009) which might undermine climate change effects mitigation through REDD+ initiatives in Tanzania. A total of six villages close to IFR, namely Mbingu, Njage, Igima, Mpofo, Mgeta and Mchombe were studied in Kilombero district. Similarly, six other villages close to NDUFR, namely Lulanzi, Ilamba, Kidabagha, Magome, Isele and Lusinga were involved in the study in Kilolo district.

2.2 Data collection approaches and analysis

Socio-economic methods (i.e. Questionnaire, PRA techniques, and Participant observations) applied within the gender context were used (Regmi et al., 2010). The sustainable livelihood approach (DFID, 2000), and forest resource assessment methods mainly NTFPs Inventory and Forest cover change analysis were the main approaches used to collect information from the study areas. Whereas around IFR a total of 108 (i.e. 65 male and 43 female) respondents were interviewed, 152 respondents were interviewed (i.e. 79 male and 73 female) around NDUFR. Socio-economic data from the two study sites were collected from households adjacent to forest reserves and key informants such as village government leaders, district forest officers and Nature Conservators. The selection of households was based on gender and proximity to the forest reserve, for example living within the 5km radius of the forests. The information collected was aimed to solicit community perceptions on climate change and its effects on their livelihoods, available NTFPs and their use pattern in the
perceived changing climate, NTFPs trading and future prospects to enhance adaptive capacity, coping strategies using NTFPs and the existing challenges in the two study sites.

Vulnerability assessment involved the use of cognitive mapping of forest adjacent households concepts through brainstorming (Downing and Ziervogel, 2004; Locatelli et al., 2008). Cognitive mapping involved a group of 15 respondents in each of the villages surveyed in the study sites, with diverse composition of men and women of different ages. Vulnerability was assessed based on the people's perception and available evidence. During the exercise, each group brainstormed the different parameters related to climate change vulnerability in terms of exposure, sensitivity and adaptive capacity. Exposure was based on local climate change perception using parameters such as temperature, rainfall, plants/animals behaviour changes, disasters, livelihood activities and other physical information. Sensitivity to climate change was perceived to be based on the effects of climate change at the local level to agriculture and food security, forest and biodiversity, settlement and infrastructure, water and energy as well as human health. Perception of the adaptive capacity was based on the impacted livelihood assets such as human, natural, social, financial and physical resources. Indicators used in assessing people's exposure to climate change included occurrence of hot and cold days, rainfall duration and intensity, frequencies of floods, dry spells, winds, and hailstones. Other indicators were prevalence of crop pest and diseases, decreased water sources in dry season, and disruption of road communication between and among villages. Indicators for assessing climate change sensitivity parameters included loss of crop production, loss of productive land, emergence of waterborne and skin-related diseases and decreased availability of NTFPs. Others were the destruction of infrastructure, loss of fresh water springs, and outbreak of pest and diseases. Adaptive capacity parameters included population of children and youths, access to health services, clean water, financial institutions, and forest products. Others were employees in public and private sectors, number of available schools, land under irrigation, and the presence of standard houses.

NTFPs resource inventory, employed concentric sample plots established along transect, the design being adopted from ANSAB (2010) with some modifications on plot size. Land use and land cover change detection was done using various algorithms available for change detection analysis using ArcView Image Analysis software (ESRI, 1996). Post-classification comparison approach was used to detect the forest cover change between 1990 and 2013 (Jensen, 1996; Mbilinyi, 2000). The change detection matrix was then processed in an intensity analysis programme (Pontius et al., 2004). Furthermore, market price-based and contingency valuation approaches were used to evaluate the NTFPs with market and non-market value, respectively. Climatic data, mainly rainfall and temperature from the Tanzania Meteorological Agency (TMA) for a span
of 30 years (1980–2010), were also used to supplement community member’s perceptions of climate change in the study area.

The quantitative and qualitative data collected were then analysed inferentially and descriptively using MS Excel and the Statistical Package for Social Sciences (SPSS Version 16) software tools. The community-based Risk Screening Tool - Adaptation and Livelihoods (CRISTAL) was also used to analyse the impacts of changing climate and vulnerability to livelihoods. Vulnerability data were analysed in the field using the variables for exposure (E), sensitivity (S) and adaptive capacity (A) before being subjected to descriptive statistics. The variables were ranked into four levels based on people’s perception and the numerical values (indices) were calculated as per Metzger et al.’s (2006) equation (1). The numerical vulnerability indices were used as basis for comparison of the vulnerability indicators in each parameter for each variable.

\[ V = E \times S \times \frac{1}{A} \]  

Where;

\[ V = \text{Vulnerability} \]

The vulnerability indices (V.I) were interpreted as follows as per Vincent (2004):
(i) \( 1 - 1.4 = \text{Low} \);
(ii) \( 1.5 - 2.4 = \text{Medium} \);
(iii) \( 2.5 - 3.4 = \text{High} \) and
(iv) \( \geq 3.5 = \text{Very high} \)

### 3.0 Results and Key Lessons

#### 3.1 Results

**Available NTFPs resources and their utilisation pattern**

A total of 13 NTFPs and services were identified and recorded from IFR under the current perceived climate change and variability. The NTFPs identified to have a potential for enhancing adaptive capacity of forest-dependent communities in the study site under the changing climate included (in the order of priorities) the following: firewood, charcoal, wild vegetables, wild fruits, thatching grass, medicinal plants, mushrooms, poles, handles, ropes, withies, honey and bush meat. The other perceived important forest ecosystem services were recreation, watershed protection, precipitation formation, biodiversity and socio-cultural values such as sacred areas.

A similar situation was found around NDUFR in Kilolo district where a total of 11 NTFPs and services were identified and recorded for enhancing adaptive capacity of forest dependent communities under the current perceived climate
change and variability. The NTFPs similarly identified to have potential for increasing forest adjacent communities’ adaptive capacity under the climate change included (in order of priorities) medicinal plants, wild vegetables, poles, firewood, charcoal, ropes, thatch grasses, honey, bush meat, wild mushrooms and wild fruits. Other perceived important forest ecosystem services were recreation, watershed protection, precipitation formation and biodiversity conservation.

In the two study sites, the use pattern for the NTFPs identified was claimed to have increased from subsistence to safety-nets in times of climatic shocks and stresses (such as floods and severe drought) to cater for food and income generation at the household level. For example, communities around NDUFR had increased their reliance on the forest for wild foods such as mushroom, wild fruits and bush meat to cater for income generation based on the frequency of visits, as reported by the Village Natural Resources committees. For communities around IFR, wild foods such as vegetables, fruits, mushroom, bush meat as well as medicinal plants and firewood were the main products to cater for both household consumption and income generation. In terms of forest services, water shortages due to drying out of rivers and streams were a problem across the two study sites. Despite the sample size being different from previously studies by Kitula (2007) around NDUFR and Kilonzo (2009) around Kilombero district, where the reported pattern of utilising the NTFPs resources was for subsistence at the household level, the findings from the two study sites seem to differ and indicate a change in the utilisation pattern at this time amidst climate change and variability.

**Climate change and variability impacts on livelihoods and NTFPs**

The majority of men and women (90%) around IFR perceived the climate to have changed and their argument were supported by climatic data from the study site, which indicate increased temperature and unpredictable rainfall (see Figure 7.2a). The households interviewed provided insights into the change in climate based on such indicators as change in rain seasons often accompanied by severe floods, increased temperature often accompanied by severe drought and increased crop pests, especially for banana and rice.
The respondents claimed that variability in climate had impacted on the main livelihood activity of their communities (i.e. agriculture in terms of decreasing crop yield due to unreliable rainfall) with minor impacts on NTFPs (i.e. whose impact was reported to be in terms of reduced seasonal availability due to increased drought). The latter claim of the reduction was in terms availability due to climate change as well as change in tenure regime (i.e. change of the IFR access under Joint Forest Management of nature reserve through the application and enforcement of more stringent rules and regulations) which has reduced forest-dependent communities’ access to NTFPs. In future, there is a need to conduct in-depth ecological studies in the forest reserve to establish whether the claimed change in NTFPs availability are due to climate variability and change or not. Based on the current study period, it was difficult to establish the forest adjacent communities’ claim.

In Kilolo district, the majority of the men and women (81%) around NDUFR perceived the climate to have changed as supported by climatic data of the site which indicate variations in rainfall patterns (see Figure 7.2b) and increase in temperature. The households interviewed in the area also understood the change in climate and based their comprehension on indicators such as change in rain seasons with shortened crop harvesting season, increased temperature, increased crop/tree pests, especially for fruits and emergence of new diseases hitherto unknown in the area for the past 30 years such as Malaria, and body rashes for children during drought.
The variability in climate was claimed to have had positive impacts on agriculture, which is the mainstay of the communities (i.e. short crop harvests allow for two cultivation per annum) and negative impacts on other livelihood options mainly in terms of communities’ health security (i.e. emergency of Malaria and body rashes during severe drought). Changes in the frequency and spread of infectious diseases are some of the most widely documented potential effects of climate change, and could have significant consequences for human health as well as economic and societal impacts (Chan et al., 1999). Climate change has also affected the abundance and geographical range of tropical disease vectors due to the rising temperatures, which impact on vector distribution, parasite development and transmission rates (Kovats et al., 2001). Climate change also directly affects disease transmission by shifting the vector's geographical range while increasing the reproductive and biting rates and shortening the pathogen incubation period (Patz et al., 1996). For NTFPs only reduced availability due to climate change and increased human disturbances in natural forests was reported. On the other hand, there could be other factors which contribute to the decline in NTFPs availability other than climate change. Therefore, detailed ecological studies are suggested in future for the two study sites to confirm what has been observed and perceived by the communities, which took part in the current study.

The current findings differ with some of the past studies which have been documented across Africa and other parts of the world. For example,
despite difficulties in establishing facts and figures on increased or decreased yield due to the perceived varying and changing climate in the two study sites, according to IPCC (2007), climate change has already been reported to have affected agriculture in developing countries. The findings are more or less similar to what the IPCC (2007) has described in relation to the likelihood of worsening climate change impacts in future. Also, Rosenzweig and Tubiello (2007) have pointed out significant impacts on crop yields and productivity due to changes in temperature, precipitation, water availability, salinity and the proliferation of pollinators, pests and diseases. It has also been argued that the climate change impacts have not been uniform as they vary across regions and in some cases require a number of different adaptation strategies (Berry et al., 2008). This argument is similar to what has been observed in NDUFR, Kilolo district where the change in temperature seem to have brought positive changes to communities since they can now cultivate short crop varieties twice per year than once as it used to be in the past 30 years.

Under the changing climate, rising temperatures were reported to change the geographical distribution of disease vectors, which are migrating to new areas and higher altitudes. It has been reported (Boko et al., 2007) that, the migration of the Malaria mosquitoes to higher altitudes may expose large numbers of previously unexposed people to infection. In the densely-populated East African highlands of Tanzania, there are already reported incidences of Malaria epidemic, especially in the highland areas that were traditionally mosquito and malaria-free (Yanda et al., 2006; URT, 2009; Wandiga et al., 2006) such as highland areas of Tanga, Kilimanjaro, Iringa, Kagera and Mbeya. All these studies support the situation of emerging Malaria incidences among forest-dependent communities in Kilolo District.

According to the URT (2012), climate change impacts on forest ecosystems and biodiversity are expected to vary depending on the vegetation type. The common impacts on all forests types include loss of biodiversity, disappearance of wildlife habitats, increased risk of bush fires, limited availability of forest products (both timber and non-timber products) and ecosystem shift (e.g. forest to woodlands or woodlands to grasslands).

**Climate change vulnerability in the study sites**

During Data collection, the respondents brainstormed on the different elements related to climate change vulnerability, and clustered them into exposure, sensitivity and adaptive capacity groups. Whereas exposure
included parameters such as temperature, rainfall, plants/animals behaviour changes, disasters, livelihood activities and other physical information, sensitivity included parameters such as agriculture and food security, forest and biodiversity, settlement and infrastructure, water and energy as well as human health; and adaptive capacity based on livelihood assets information both human resource, natural, social, financial and physical. Results from IFR in Kilombero district revealed that forest dependent communities were very highly vulnerable to climate change and variability impacts (Overall Vulnerability Index = 4.02) (see Table 7.1a), with women, children, the elderly and the disabled claimed to be particularly vulnerable social groups.

<table>
<thead>
<tr>
<th>Village</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Adaptive capacity</th>
<th>Vulnerability Index (V.I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mbingu</td>
<td>2.49</td>
<td>2.91</td>
<td>1.80</td>
<td>4.02</td>
</tr>
<tr>
<td>Igima</td>
<td>2.28</td>
<td>3.07</td>
<td>1.93</td>
<td>3.63</td>
</tr>
<tr>
<td>Njage</td>
<td>2.33</td>
<td>2.99</td>
<td>1.63</td>
<td>4.32</td>
</tr>
<tr>
<td>Mchombe</td>
<td>2.5</td>
<td>3.07</td>
<td>1.93</td>
<td>3.97</td>
</tr>
<tr>
<td>Mngeta</td>
<td>2.36</td>
<td>3.02</td>
<td>1.5</td>
<td>4.75</td>
</tr>
<tr>
<td>Mpofu</td>
<td>2.25</td>
<td>3.04</td>
<td>1.27</td>
<td>5.38</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>2.37</strong></td>
<td><strong>3.02</strong></td>
<td><strong>1.68</strong></td>
<td><strong>4.35</strong></td>
</tr>
</tbody>
</table>

*Table 7.1a: Climate change vulnerability assessment for IFR communities*

A similar observation was made for NDUFR in Kilolo district where forest-dependent communities were found to be highly vulnerable to climate change and variability (Overall Vulnerability Index = 3.29) (see Table 7.1b), with women, children, the elderly and the disabled also being the most vulnerable social groups.

<table>
<thead>
<tr>
<th>Village</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Adaptive capacity</th>
<th>Vulnerability Index (V.I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magome</td>
<td>2.94</td>
<td>2.26</td>
<td>2.16</td>
<td>3.08</td>
</tr>
<tr>
<td>Isele</td>
<td>2.33</td>
<td>2.54</td>
<td>1.83</td>
<td>3.23</td>
</tr>
<tr>
<td>Kidabagha</td>
<td>2.75</td>
<td>2.33</td>
<td>1.8</td>
<td>3.56</td>
</tr>
<tr>
<td>Lusinga</td>
<td>2.8</td>
<td>2.04</td>
<td>1.9</td>
<td>2.97</td>
</tr>
<tr>
<td>Ilamba</td>
<td>2.97</td>
<td>2.11</td>
<td>1.73</td>
<td>3.62</td>
</tr>
<tr>
<td>Lulanzi</td>
<td>2.8</td>
<td>2.21</td>
<td>1.88</td>
<td>3.29</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>2.77</strong></td>
<td><strong>2.25</strong></td>
<td><strong>1.88</strong></td>
<td><strong>3.29</strong></td>
</tr>
</tbody>
</table>

*Table 7.1b: Climate change vulnerability assessment for IFR communities*
It can be noted that vulnerability was higher for communities around IFR than NDUFR in Kilombero and Kilolo districts, respectively, with low adaptive capacity, probably due to variations in forest resources management with NDUFR communities having formal access to forest products, hence reducing their sensitivity to climatic hazards. The low adaptive capacity of forest dependent communities was due to inadequate social and financial institutions that help to minimise the effects stemming from climate change hazards in addition to supporting local coping strategies.

Furthermore, the sensitivity to climate change and variability had impacts on IFR communities, especially on livelihood sectors such as agriculture (e.g. loss of crops and productive land decline in crops yield due to floods and drought); NTFPs and biodiversity (i.e. decrease in availability and enhanced forest fire); health (i.e. eruption of diseases like malaria, cholera and typhoid).

According to Guernier et al. (2004) Africa is vulnerable to a number of climate-sensitive diseases such as malaria, tuberculosis and diarrhoea. In this regard, future climate variability is likely to interact with other stresses and vulnerabilities such as HIV/AIDS and conflict and war (Harrus and Baneth, 2005), hence resulting into increased susceptibility and risk to infectious diseases (e.g. cholera and diarrhoea) and malnutrition for adults and children (WHO, 2004).

**Climate change adaptation in the study sites**

Around IFR both men and women (95% of the 108 respondents) have developed local strategies to cushion the effects of climate change and variability on their livelihoods through cultivation of short crop varieties, increased reliance on NTFPs for food, health and income security (90%), keeping environments clean and conserving forest resources for future. Similarly, in NDUFR, both men and women (90% of the 152 respondents) have developed and adopted various strategies in agriculture, forestry (increased reliance on NTFPs) biodiversity conservation and water resources management to cope with the prevailing situation.

Rosenzweig and Tubiello (2007) reported adaptation options to range from relatively inexpensive changes, such as shifting planting dates or switching to an existing crop variety, to much more costly measures including the development of new crop varieties, increasing chemical and other inputs and irrigation systems, depending on the region and available resources. These measures are similar to some of the adaptation strategies which have been observed in the two study sites of Tanzania.
For example, crops diversification was noted in the two study sites as one of the coping strategies where local communities in Kilombero switched from the normal paddy cultivation to sesame and cocoa. Similarly in Kilolo, communities switched from cultivating long maize varieties to short varieties as well as sweet potatoes and vegetable cultivation in valley bottoms due to increased temperature, which allows for early crop maturity. Despite the switching observed it is difficult at the moment to correlate the findings with the existing climatic data in the area. Thus in future studies could be done to establish such a correlation and provide requisite proof.

Despite crop diversifications and ability to cultivate twice in the study area, the communities’ adaptive capacity was still low since. As Flanagan et al. (2011) have argued, adaptive capacity is a function of socio-economic factors, technology and infrastructure. And yet, the majority of forest-dependent communities around NDUFR remain poor, have limited technology for utilising in harnessing effectively the natural resources available including NTFPs. These could probably be some of the factors contributing to what was observed in Kilolo district.

According to Leavy and Lussier (2008), crop diversification and mixed cropping are also being used in Brazil and Ghana to increase the likelihood of at least one crop surviving and produce a harvest while at the same time providing increased income when both crops flourish. The most common adaptation strategies used by farmers in South Africa and Ethiopia include the use of different crop varieties (Bryan et al., 2009). Also adopting new crops and varieties has also been an important aspect of the recovery from adverse weather ravages related events in Zimbabwe (Chigwada, 2005). Furthermore, UNEP-WCMC (2009) argues that the options for adaptation in agriculture may be include: (i) changes in the locations of cultivation (i.e. opening new areas for cultivation); (ii) changes to the crops cultivated, including substitution by new crops, new varieties and crop diversification; and (iii) changes to agricultural practice, including irrigation and soil management regimes and the use of agricultural inputs. This case could also apply to communities in Kilolo and Kilombero districts in Tanzania.

**Total economic values of NTFPs and harvesting modalities for sustainability under a changing climate**

Whereas in IFR, the total economic value of NTFPs including values from other ecosystem services mainly water, socio-cultural values, recreation
and biodiversity conservation was estimated at TZS 20, 523,361,460, in NDUFR the value was TZS 19, 658,280, both at a discount rate of 10 percent. For the two study sites, firewood was found to contribute highly in terms of total economic value of NTFPs similar to a study that was carried out by Schaafsma (2012) in the Eastern Arc Mountain Blocks.

The TEV obtained provides an indication of how NTFPs could contribute to communities’ livelihoods as part of the forest ecosystem services and as per the magnitude of the economic loss that households would bear if NTFPs collection would be banned in the study sites (Schaafsma, 2012). Results, on the other hand, could probably imply that the high contribution of NTFPs for forest-dependent communities observed in terms of subsistence and income under the changing climate might influence their adaptive capacity if the resources are developed for them to explore full potentials, particularly when other forest ecosystem services are available. The realisation of NTFPs benefits to communities’ livelihood under the current perceived change in climate seem to be hampered by change in management regimes whereby most of the reserved forests with utilisation aspects are turned into nature reserves with total restrictions. This has already happened to communities around IFR in Kilombero and may hinder their efforts to cope with the prevailing climate change effects. This argument is supported by the observation made by Schaafsma et al. (2014), who pointed out that, considering the relative NTFPs contribution which varies across income groups and is higher for the poorer part of the population, any policy that restricts forest access and NTFPs collection is likely to hit the poorest the hardest. Furthermore, the authors suggested the need for developing financial schemes in an equitable manner to compensate the losers from conservation efforts and enable poor households to benefit from sustainable trade in forest products, especially the NTFPs. The suggestion provided could probably apply to the IFR adjacent communities who are losers at the moment from the Kilombero Nature Reserve. One of the options of compensating losers is to support communities in their efforts to domesticate potential NTFPs and/or initiation of alternative income generation activities.
Inventory results from IFR and NDUFR have revealed a decrease in the abundance of NTFPs, especially for species with multiple uses and higher demand such as mushroom and bush meat. This view is supported by the forest dependent communities’ perceptions on decreased availability of potential NTFPs for food and income in respective seasons: they confirmed the existing common pool resource problem. Whereas minimal disturbances was noted in IFR in terms of NTFPs harvesting modalities due to restricted access, in NDUFR much disturbances were observed due to poor harvesting modalities such as debarking of trees for medicinal plants and setting up of many local traps for bush meat hunting. Informal discussion with forest dependent communities revealed that there had been high disturbances in the past five years resulting from high pressure for communities to access NDUFR for multiple uses. Agreements were then signed by surrounding villages for total restrictions to harvest forest products until further notice. The agreements, however, have been poorly reinforced as for some villages encroachment is business as usual and threatened the future sustainability of NDUFR and its biodiversity. All in all, it is difficult to link what forest adjacent communities’ perceived in terms of NTFPs decrease to climate variability and change. Thus, an in-depth ecological study will be required for the forests in the two study sites.

Forest cover change analysis in IFR from 1990 to 2013 (see Figure 7.3a,b) revealed the following: (i) Bushed grassland decreased by 111.2 ha (0.3%) which is equivalent to a decrease of 4.8 ha per year. These were abandoned cultivation fallow which after upgrading the forest reserve to nature reserve (particularly to IFR) the protection increased and some of these changed to other cover types which are forests, wooded grassland and woodland). (ii) Forest increased by 1,341.2 ha (3.9% increase), which is equivalent to an increase of 58.3 ha per year. Forest increase may be due to the establishment of the nature reserve, increasing protection e.g. decreased bushed grassland mentioned above. (iii) Riverline grass portrayed no significant change. (iv) Wooded grassland increased by 3,795.1 ha (11%), which is equivalent to an increase of 165 ha per year (some went into other cover types which are forest and woodland). (v) Woodland decreased by 5,025.1 ha (14.5%), which is equivalent to a decrease of 218.5 ha per year (part of the cover changed into wooded grassland and forest).
In Kilolo district, forest cover change analysis in NDUFR (Figure 7.3c, d) from 1990 to 2013 revealed the following: (i) Bushed grassland increased by 7 ha (173.8% increase) which is equivalent to increase of 0.3 ha per year. Large part in the patches is covered by tall grass, the vegetation which develops on gullies. (ii) Forest area increased by 13.4 ha (0.4% increase), which is equivalent to an increase of 0.6 ha per year. (iii) Open woodland decreased by 20.4 ha (68.8%), which is equivalent to a decrease of 0.9 ha per year. Limited change was associated with decreased human activity in the forest and the establishment of woodlots and agroforestry in the neighbouring community. This was also linked with the HIMA project and other environmental conservation projects interventions in the area.

Generally, the NDUFR portrayed limited changes compared to IFR. This could be attributed to farming practices of the neighbouring community. The neighbouring areas are practicing agroforestry and have woodlots enabling them to fetch firewood and timber from their own farms. The situation is different for IFR where the main farming practice is monoculture with only paddy and banana plantations.
Improved supply, value addition and market promotion for NTFPs

From the results in the two study sites, NTFPs supplies seem to have been dwindling not only due to impacts of climate change and variability but also due to change in tenure regimes. Whereas in IFR the change from a joint managed forest reserve to nature reserve was an obstacle, around NDUFR in Kilolo district, access to the reserve was hindered by high disturbances in the reserve resulting into the halting of utilisation activities. To improve supply there was a need to build capacity of forest-dependent communities in domestication of NTFPs. Therefore, two scenarios emerge. In Kilombero for communities around IFR sensitisation and capacity-building in terms of training communities to engage in agroforestry practices (Figure 7.4a) was emphasised so as to improve the supply of NTFPs, especially firewood which was among the priority products and agricultural productivity. Around NDUFR in Kilolo district, on the other hand, after prioritisation of NTFPs, capacity-building in terms of training and promoting village groups to engage in mushroom domestication (see Figure 7.4b) was done for income generation and food.

![Figure 7.5: Agroforestry nursery in Kilombero (a) and mushroom cultivation in Kilolo (b) districts](image)

All in all, the promotion of simple technologies such as agroforestry and mushroom domestication to provide alternatives to wild harvested NTFP products was aimed at building capacity and enhancing the forest-dependent livelihood adaptive capacity to offset stresses and shocks emanating from the climate change and variability effects. Capacity-building in this regard was done in a gender sensitive manner by training community groups comprising of women and other vulnerable social groups as well as men.

It has been argued (FAO, 2007; Ravindranath, 2007) that, forest communities whose reliance on the wild resources is high are often the poor members of the society with a low adaptive capacity. In fact, when access to forest products such as NTFPs becomes marginalised, vulnerability of the poorest people increases (Eriksen et al., 2005; Paavola, 2008). Forests, on the other hand, can provide ‘safety-nets’ during periods of food shortage, as well as form an important venture that contributes to food security (Kalame et al., 2009; Nkem et al., 2007).
According to Verchot et al. (2005), agroforestry can improve biophysical resilience and promote income diversification; it is one of the most promising options for helping communities adapt and become resilient to the impacts of climate change. Kandji et al. (2006) asserts that agroforestry can also serve as an important role in climate change mitigation by enhancing carbon stocks within the agricultural landscape. Therefore, through agroforestry local communities might be able to diversify income, improve crop productivity and reduce their vulnerability to climate change effects.

3.2 What are the key lessons

The project findings show that climate change and variability has already impacted on the main livelihood of forest dependent communities, and to a lesser extent on the availability of NTFPs. This is evidenced by the existing climatic information of the two study sites as supported by the perceptions of forest adjacent communities. In this regard, local communities perceived the change and varying climate using indicators such as unpredicted rainfall, increased temperature and associated events, for example, severe floods, severe drought and emerging human and crop diseases. Since the current findings are based on average monthly rainfall and temperature data from meteorological stations, there is a need in future to prove the community perceptions on the changing climate in the two study sites by utilising daily climatic data which could provide a composite picture on the seasonal shifts, including the onset and cessation of rainfall as well as temperature increase. Furthermore, there is a fundamental need to develop the NTFPs and capture their full potential in terms of value chain to increase income and enhance climate change adaptation by forest-dependent communities.

Forest-dependent communities are also aware of the change and effects and have, therefore, developed local mechanism to cope and adapt with the variability and change. The research has also enhanced the forest-dependent communities’ understanding of climate change and adaptation issues including REDD+ as their training on NTFPs provided a link between climate change and REDD+. Through such training, local communities have also increased their understanding of the potentials of NTFPs for climate change adaptation in terms of income, food and health security. These findings are crucial to the implementation of the National Forest Policy (1998) on promoting sustainable forest management under the changing climate and variability.
It has been learnt further that, the forest-dependent communities coping strategies are rather weak and largely ineffective. As such, they will require government interventions to strengthen them. Moreover, climate change adaptation in Tanzania using the forestry sector is possible through the development of NTFPs among the forest-based enterprises; however, it will require multi-stakeholders’ efforts to offset challenges to the development of priority NTFPs for adaptation in the study sites. According to Munang et al. (2013), harnessing the adaptive forces of nature is economically viable and effective to combat the impacts of climate change.

4.0 Implications of lessons learnt for REDD+, climate change mitigation and adaptation

Findings of this study provide baseline information for implementation of the National REDD+ Strategy (2013) through use of the NTFPs part of the REDD+ co-benefits. The strategy stresses the need to invest in sustainable forest based enterprises to create more employment opportunities, especially for marginalised groups in the forest sector using NTFPs, and in turn improve households’ nutrition and economy of forest dependents. Moreover, crucial to the NAPA (2007) in Tanzania where the use of NTFPs as potential adaptation activities in the forestry sector is more emphasised in terms of: (i) promotion of alternative sources of energy for both domestic and industrial use; (ii) utilisation of appropriate and efficient technologies to reduce use of wood; (iii) enhancement of Participatory Forest Management through benefit-sharing from forest resources; and (iv) ex-situ conservation of important plant genetic resources. According to Gimay et al. (2013) who support the findings from this study, REDD+ has the potential of simultaneously contributing to climate change mitigation and poverty alleviation, on the one hand, and conserving biodiversity and sustaining vital ecosystem services, on the other hand. NTFPs and REDD+, which both focus on achieving forest conservation and development through market-based approaches, are important for enhancing rural livelihoods and poverty alleviation. Therefore, integrating NTFPs with REDD+ can potentially increase income opportunities of the local communities living adjacent to forests.
5.0 References


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Striking a balance between intensification and environmental sustainability under smallholder maize and rice cropping systems in Tanzania

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Abstract

Maize and rice constitute 50 percent of dietary energy of Tanzanians. Smallholder farmers produce 90 percent of these crops. Productivity is low due to low soil fertility, low use of agricultural inputs because lack of capital, knowledge and extension services. Future food demand for the increasing population can either be met by increasing cultivated land or through intensification of agriculture. The first option can lead to the destruction of vegetation cover, loss of biodiversity, forests, reduce ecosystem services and depletion carbon stocks and, therefore, undesired. The second option is to impart knowledge on improved agricultural practices to smallholder farmers. To spearhead the second option,
the public-private partnership (PPP) was initiated by two public universities (Sokoine University of Agriculture, Tanzania, and University of Life Sciences, Norway) and two multinational companies one dealing with fertiliser (YARA) and another with crop protection (SYNGENTA). The PPP carried out a study over four seasons (2011-2014) which was aimed at demonstrating sustainable intensification of maize and rice production in smallholder farmers’ fields. The study was carried out in 10 villages, five in Morogoro and another five in Njombe region. Soil fertility status was determined before two treatments were imposed on each farm, being farmers’ practice (control) and improved agriculture practices. Grain and crop residue yields were measured and nutrients content in soils and plant tissues were collected for analysis. Soils were acidic with low plant nutrients (N,P,K,Mg,S,Cu and Zn). Maize and rice grain yields at 14 percent moisture content ranged from 2.5 - 5.4 t/ha for the farmers’ usual practice to 6.6 - 8.5 t/ha for improved practice, respectively. Maize-stover and rice-straw ranged from 2.11 - 9.13 t/ha for farmers’ usual practice to 5.33 - 15.4 t/ha for improved practice, respectively. It can be concluded that family food demand can be met without expanding the cultivated area through environmentally-friendly agricultural intensification and, hence, conserve forest carbon stocks, reduce emissions from forest degradation and enhance forest carbon stocks by releasing more farmland for fruit, fodder and timber tree growing in the process. This approach can contribute to accruing benefits of REDD+ among smallholder farmers.

Key words: sustainable intensification, increased land productivity, improved agricultural practice, farmer’s practice, carbon sink, reduced emission

1. Introduction

Maize and rice are the most widely grown and consumed cereal crops in Tanzania accounting for 31 and 13 percent, respectively, of the total food production in the country (WEMA, 2010). Maize in particular accounts for 75 percent of all cereals consumption. It is also a cash crop in some parts of the country. The per capita consumption of maize and rice is about 74.5 and 16.5 kg/person/year (FAOSTAT 2012 and PASS 2012), respectively.

Nearly 90 percent of the two cereal crops are produced by small-scale farmers. Food production under smallholder farmers is constrained by factors such as inherently low fertile soil, unfavourable climate conditions, poor infrastructure and low use of farm inputs due to lack of capital and skills, which lead to low crop yield and nutrient mining.

Thus, challenges to producing adequate food to meet population demand should be dealt with closely. By 2010 the cultivated areas and productivity of maize and rice were about 3 million ha at 1.5 t/ha and 1 million ha at 2.3 t/ha, respectively (MAFC, 2010). These levels could meet the demand of the two crops.
for the current 45 million people. Given the projected increase in population in Tanzania from 45 million people in 2010 to 83 million in 2030 and 137 million in 2050, the corresponding demand for food crops such as maize will pose a major challenge for the country. At the current yield levels, the cropping area of maize would need to be doubled by 2030 and tripled by 2050 to meet the soaring demand. Doubling maize yields (3 t/ha), however, would at least entail keeping the maize area stable until 2030, and at an average national maize yield of 5 t/ha. This situation would even last until 2050. Figure 8.1 show the cropping area required to produce sufficient maize domestically for the growing population until 2050 under the assumption that malnutrition will be eradicated by 2050 and the nutrition pattern will not change (FAOSTAT, 2012):

![Figure 8.1: Current trends of maize area, production and yield in Tanzania (FAOSTAT, 2015)](image)

The conversion of non-agricultural land such as forests or savannah into cropland should be avoided as much as possible because it has significant consequences in terms of loss of biodiversity and natural carbon stocks. Globally, the loss of carbon due to land-use change (LUC) is responsible for about 10 percent of the total emissions of greenhouse gases (Tubiello et al., 2015). The concept of sustainable intensification, which entails production of more food from the same area of land while reducing associated environmental impacts, is of particular importance (Johnston, 2011; Beddington et al., 2012; Mtengeti et al., 2015).

The constraints for improving productivity of these crops under smallholder farmers are: i) inadequate use of inputs because of high input prices, farmers’ lack of the purchasing power for inputs, insufficient knowledge on the effects of inputs on crop production and how to use them appropriately; ii) inadequate access to information and extension services; and iii) erratic rainfall and frequent prolonged drought periods as part of the effects of climate change.

To achieve sustainable intensification to meet an increasing demand for food by
an increasing human population in the country, smallholder farmers, therefore, require full knowledge on how to improve maize and rice productivity (i.e. knowledge of all inputs and how to use them appropriately). However, the provision of discrete technological information on inputs and how to use them appropriately will not provide sustainable profit margins that are necessary to motivate poor smallholder farmers to adopt improved agricultural practices (Foster and Rosenzweig, 2010).

Thus, appropriate improved agricultural practices package on how to intensify crop production should strategically incorporate efficient agronomic practices such as soil fertility management, weed and pest management, and use of improved crop seed varieties. These three agronomic practices, however, require capital to acquire them and skill to apply them properly. As such, a strong partnership between public technical advisory services and agro-input dealers should serve as the right vehicle for enhancing sustainable intensification among smallholders’ crop fields. Towards this end, a public-private partnership (PPP) comprising two public universities (Sokoine University of Agriculture and Norwegian University of Life Sciences) and two international agro-input companies (Yara, an international fertiliser company and Syngenta, an international plant protection company) was initiated in December 2010. The project was implemented from 2011 to 2014. The aim of this PPP was to test whether agricultural intensification through improved agronomic protocols can be compatible with environmental sustainability while simultaneously improving the productivity and profitability at the farm level and eventually reducing expansion of cultivatable land and improving forest conservation.

This chapter presents the results and discussions of a four-year project on environmental and climate compatible agriculture project (ECCAg) which sought to strike a balance between intensification and environmental sustainability under smallholder maize and rice cropping systems in eastern and southern agro-ecological zones of Tanzania.

2.0 Materials and Methods

2.1 Description of the study sites

Maize crop trials were established under smallholder farmers in Njombe district and at a Sokoine University of Agriculture (SUA) farm in Morogoro district (see Table 8.1). Njombe district is located in the Southern Highlands of Tanzania at 1700 to 1800 masl and experiences a unimodal type of rain from late November to April. The total annual rainfall amount is 1000 to 2000 mm. Temperature ranges from 22 to 30°C maximum and 15 – 20 °C minimum. Soils are highly weathered acidic with low fertility, high Phosphorus fixation and
very low organic matter (Mtengeti et al., 2015). The study was conducted in four villages of Njombe district, namely Kichiwa (1796 masl and S 09°01.063, E 034°52.170), Matiganjola (1791 masl and S 09°13.883; E 034°53.452), Welela (1793 masl and S 09°01.233; E 034°48.233) and Ibumila (1819 masl and S 09°06.620, E 034°50). The Sokoine University of Agriculture farm, on the other hand, is located along the western foots of the Uluguru Mountains and receives an average annual rainfall of 800 mm. The farm is 540 masl and S 06°50.870; E 037°39.270 with a temperature range of 20 to 33°C. The soil is alluvium derived from intermediate metamorphic rock from Uluguru Mountain and is classified as Isohyperthermic, very fine kaolinitic kanhaplic Haplultult (Soil taxonomy) or Chromic Acrisol, according to the World Reference Base resource (Szilas, 2002; Msanya et al., 2003).

Rice trials were established at smallholder farmers’ field at Dihombo village (360 masl and S 06°15.749; E 037°32.357) and Dakawa Rice Research Institute farm (370 masl and S 06°25.236; E 037°32.476) in Mvomero district and at Mkula village (300 masl and S 07°48.826 E 036°54.700) in Kilombero district (see Table 8.1). These rice growing areas are floodplains of Wami and Ruaha rivers, respectively, and have vertisols, fluvisols and complex vertisols and fluvisol (Msanya et al., 2003). The average annual rainfall in these bimodal rainfall rice growing areas is 1,000 mm and the temperature range is 24 to 32°C.

<table>
<thead>
<tr>
<th>Region</th>
<th>District</th>
<th>Villages</th>
<th>Crops</th>
<th>Trials</th>
<th>Altitude (masl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morogoro</td>
<td>Mvomero</td>
<td>Dihombo</td>
<td>Rice</td>
<td>1</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dakawa</td>
<td>Rice</td>
<td>2</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DRRI*</td>
<td>Rice</td>
<td>1</td>
<td>366</td>
</tr>
<tr>
<td>Kilombero</td>
<td></td>
<td>Mkula</td>
<td>Rice</td>
<td>1</td>
<td>290</td>
</tr>
<tr>
<td>Morogoro</td>
<td></td>
<td>SUA#</td>
<td>Maize</td>
<td>1</td>
<td>550</td>
</tr>
<tr>
<td>Njombe</td>
<td>Njombe</td>
<td>Ibumila</td>
<td>Maize</td>
<td>1</td>
<td>1820</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kichiwa</td>
<td>Maize</td>
<td>1</td>
<td>1798</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Welela</td>
<td>Maize</td>
<td>1</td>
<td>1793</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Matiganjola</td>
<td>Maize</td>
<td>1</td>
<td>1791</td>
</tr>
</tbody>
</table>

Table 8.1: Locations and crops involved in demonstration trials
*DRRI (Dakawa Rice Research Institute); #SUA (Sokoine University of Agriculture)
2.2 Treatments

Two treatments were included in each farmer’s field. For the farmers’ practice (FP), the farmer decided based on the agronomical practices and inputs applied whereas the Yara/SUA/Syngenta (YSS) agronomic practice was based on soil analysis and crop-specific nutrient requirements according to the amount and type of fertiliser and plant protection demand applicable at different stages of growth (see tables 8.2 and 8.3). Maize trials were planted at the beginning of the long rain season in December in Njombe and March in Morogoro for the three consecutive years of this study. Spacing was 90cm by 30cm for long maturing maize variety (120-150 days) in Njombe and 75cm by 30cm for medium maturing variety (90-110 days) in Morogoro. Rice trials were planted twice per year at Dihombo and Mkula in August and March and harvested in December and June, respectively. At Dakawa Rice Research Institute, rice was planted only once in March and harvested in July. Rice in all trials was planted at 20cm by 20cm.
<table>
<thead>
<tr>
<th>Activities</th>
<th>Inputs</th>
<th>Farmers’ Practice (FP)</th>
<th>Period of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed treatment</td>
<td>Apron Star at 10g/4kg seed</td>
<td>no seed treatment</td>
<td>Seed preparation during planting</td>
</tr>
<tr>
<td>1st Fertiliser application</td>
<td>Yara mila cereal @ 142 kg/acre.</td>
<td>(DAP) @ 25 kg/acre.</td>
<td>During Planting</td>
</tr>
<tr>
<td>Pre-emergence Herbicide application</td>
<td>Primagram Gold 1.2lts/acre</td>
<td>No application. But 1st weeding 3rd week after planting</td>
<td>Just after planting</td>
</tr>
<tr>
<td>1st Insecticide application</td>
<td>Karate 5 EC for control of stalk borers @160mls/acre.</td>
<td>Karate 5 EC for control of stalk borers @160mls/acre.</td>
<td>3rd week after planting If symptom of attack occur</td>
</tr>
<tr>
<td>2nd Fertiliser application. Sprayed on the leaves</td>
<td>Yara Vita Trace™ BZ @ 800g/acre</td>
<td>No application</td>
<td>3rd week after planting (4 – 6 leaves)</td>
</tr>
<tr>
<td>3rd Fertiliser application</td>
<td>81kg/acre Yaramila Cereal</td>
<td>Application of Urea fertiliser @ 50kg/acre</td>
<td>5th week after planting (Knee height)</td>
</tr>
<tr>
<td>4th Fertiliser application</td>
<td>21kg/acre Yaramila Java</td>
<td>No application</td>
<td>7 weeks after planting (Tasseling)</td>
</tr>
<tr>
<td>2nd Insecticide application</td>
<td>Karate 5 EC @ 160mls/acre</td>
<td>No application</td>
<td>8th week after planting</td>
</tr>
<tr>
<td>Herbicide application</td>
<td>Gramoxone @ 500mls/acre</td>
<td>Weeding by use of draft animals</td>
<td>10th week after planting</td>
</tr>
</tbody>
</table>

1. Yara mila cereal = 23N - 10P(O)<sub>3</sub> - 5 K<sub>2</sub>O - 2MgO- 3S - 0.3Zn
2. Yara Vita™ Trace™ BZ = 5N – 7.5 P<sub>2</sub>O<sub>5</sub> – 5 K<sub>2</sub>O – 5MgO – 5S – 5Zn – 5Bo – 0.1Cu – 0.1Fe – 0.1Mn – 0.1Mo
3. Yara Mila Java = 22N – 6 P<sub>2</sub>O<sub>5</sub> – 12K<sub>2</sub>O – 2CaO – 1MgO – 3S – 0.2Bo – 0.2Zn

Table 8.2: Inputs application for maize in YSS and Farmers’ practices (treatments)
<table>
<thead>
<tr>
<th>Activities</th>
<th>Inputs</th>
<th>Period of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed treatment</td>
<td>Apron Star at 10g/4kg seed</td>
<td>no seed treatment</td>
</tr>
<tr>
<td>Fertiliser application in rice nursery</td>
<td>Yara mila Cereal 3 kg/100m²</td>
<td>Fertiliser application (Urea @ 1kg/100 m²)</td>
</tr>
<tr>
<td>Herbicide application</td>
<td>Touchdown Forte @ 1lt/acre</td>
<td>No treatment</td>
</tr>
<tr>
<td>1st Fertiliser application</td>
<td>Yaramila cereal @ 81kg/acre</td>
<td>No application</td>
</tr>
<tr>
<td>Herbicide application</td>
<td>Solito 320 EC @ 600mls/acre</td>
<td>Hand weeding</td>
</tr>
<tr>
<td>2nd Fertiliser application on the leaves</td>
<td>Yara Vita™ Tracel BZ @ 800g/acre</td>
<td>Urea @ 50kg/acre</td>
</tr>
<tr>
<td>3rd Fertiliser application</td>
<td>Yara mila Java @ 100 kg/acre</td>
<td>No fertiliser</td>
</tr>
<tr>
<td>4th Fertiliser application</td>
<td>Yara Liva Nitrabor @ 25 kg/acre</td>
<td>No fertiliser</td>
</tr>
<tr>
<td>Insecticide application</td>
<td>Karate 5 EC @ 160mls/acre</td>
<td>Application of Karate 5 EC @ 160mls/acre</td>
</tr>
<tr>
<td>Fungicide application</td>
<td>Artea 330 EC @ 200mls/acre</td>
<td>No application of fungicide</td>
</tr>
</tbody>
</table>

1. Yara mila cereal = 23N - 10P<sub>2</sub>O<sub>5</sub> - 5 K<sub>2</sub>O - 2MgO- 3S - 0.3Zn
2. Yara Vita™ Tracel BZ = 5N – 7.5 P<sub>2</sub>O<sub>5</sub> – 5 K<sub>2</sub>O - 5MgO - 5S - 5Zn - 5Bo - 0.1Cu - 0.1Fe - 0.1Mn - 0.1Mo
3. Yara Mila Java = 22N - 6 P<sub>2</sub>O<sub>5</sub> - 12K<sub>2</sub>O - 2CaO - 1MgO - 3S - 0.2Bo - 0.2Zn
4. Yara liva Nitrabor = 15.4 N - 25.5CaO - 0.3Bo

Table 8.3: Inputs application for rice in YSS and Farmers’ practices (treatments)
3.3 Farmers’ Field Days

Farmers’ field days were held before every harvest when the crops were just mature enough but not yet dry enough to harvest. All the farmers, village leaders and extension staff in the villages were invited to the farmers’ field days. The aim of the farmers’ field days was to show how effective the improved crop production practices were compared to the normal farmers’ production practices. Usually on the farmers’ field days the contact farmer in the presence of the researchers would explain step-by-step how she/he used improved crop production practices. Farmers’ field days were chosen as the most cost-effective method of providing training in agricultural technology since the invited farmers or communities could see the performance of the crops under improved agronomic practices. The farmers’ field days were also used to encourage invited farmers to adopt technologies that had been adopted by their fellow farmers to good effect.

1.4 Harvesting and plant and soil sampling for chemical composition analysis

Each treatment plot in each farm was demarcated into three sub-plots during crop harvesting period. Two sampling units were then located at the middle of each sub-plot, hence making a total of six sampling units per treatment. Maize sampling units were 4m long lines and rice sampling units were 1m². The farmers continued to harvest their crops after sampling. After each crop sampling, two soil samples at 0-20 cm and 20-40 cm depth were collected for physical and chemical property analysis. The soils, crop residues (maize stover and rice straw) and grains samples were sent to the Research Centre Hanninghof, YARA International, Duelmen, Germany for analysis of macro and micro nutrients. This analysis helped to understand the influence of improved plant nutrition on the chemical composition of the maize and rice grain and also to calculate nutrient removal with crop harvest. Crop agronomic data recorded for maize were spacing of plants, number of plants per 4m row (sampling unit), plant height, cob weight, cob length, grain yield (t/ha at 14 % MC), grain-specific weight (1000 seed wt), stover biomass (t DM/ha) and weed biomass/sampling areas. For the rice crop, the parameters recorded were the number of plant/m², number of tillers/m², tiller height, number of panicles/m², grain yield (t/ha at 14 % MC), grain-specific weight (1,000 seed wt), and weed biomass/m². In this chapter, however, only the productivity and profitability, impact of agricultural intensification on environmental sustainability and lessons and implication for REDD+ will be discussed.

3.5 Data analysis

The crop harvest data was handled and analysed using Excel and a t-test was used to check whether the difference between improved (YSS) and farmers’ (FP) practices was significant. The soil fertility status was interpreted using a

4.0 Results and Discussion

4.1 Crop productivity

Maize yields increased on average over three seasons and all trial sites by 83 percent, rice yields by 16 percent. The yield increased because of the effective and balanced management of nutrients accompanied by crop protection application safeguarding crops from pests and disease. Throughout the experimental period, maize grain yields were significantly (P < 0.05) higher under improved agricultural practices than under the farmers’ usual practice (see Table 8.4).

<table>
<thead>
<tr>
<th>Villages</th>
<th>2011</th>
<th></th>
<th></th>
<th>2012</th>
<th></th>
<th></th>
<th></th>
<th>2013</th>
<th></th>
<th></th>
<th></th>
<th>2014</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>YSS</td>
<td>FP</td>
<td>YSS</td>
<td>FP</td>
<td>YSS</td>
<td>FP</td>
<td>YSS</td>
<td>FP</td>
<td>YSS</td>
<td>FP</td>
<td>YSS</td>
<td>FP</td>
<td>YSS</td>
</tr>
<tr>
<td>Ibumila</td>
<td>3.81a</td>
<td>0.85b</td>
<td>2.9a</td>
<td>2.54a</td>
<td>4.29a</td>
<td>1.11b</td>
<td>3.63a</td>
<td>3.29a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kichiwa</td>
<td>7.13a</td>
<td>4.19b</td>
<td>6.28</td>
<td>NR</td>
<td>7.90</td>
<td>6.21</td>
<td>8.71a</td>
<td>5.33b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matiganjola</td>
<td>NR</td>
<td>NR</td>
<td>6.72a</td>
<td>2.53b</td>
<td>5.57a</td>
<td>2.29b</td>
<td>3.34a</td>
<td>1.56b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUA</td>
<td>NR</td>
<td>NR</td>
<td>6.16a</td>
<td>3.38b</td>
<td>5.89a</td>
<td>4.80b</td>
<td>5.57a</td>
<td>4.61b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welela</td>
<td>NR</td>
<td>NR</td>
<td>6.07a</td>
<td>1.80b</td>
<td>9.28a</td>
<td>3.16b</td>
<td>7.77a</td>
<td>3.77b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8.4: Mean marketable maize grain yield (t/ha) at 14% moisture content

NR = Not recorded. Means of YSS and FP in the same village and year with different superscripts are significantly different at P < 0.05 according to t-test (two tails)

Highest yield increases were achieved in maize at sites where the FP treatments received the lowest inputs of fertiliser, representing the actual situation in many smallholder maize farms in Tanzania. The average national maize yield in 2013 was 1.3 t/ha (FAOSTAT, 2015). Under farmers’ practice in maize plots, fertilisers were applied between 0 and 46 kg N/ha, 0 and 11 kg P/ha and no other nutrients such as K, Mg, and micronutrient are applied in their plots. The YSS plots, on the other hand, received between 110 and 166 kg N/ha, 30 kg P/ha, 33 kg K₂O/ha and Mg, S and micronutrients such as Zn and B were also applied.

Results of the field trials show that it is possible to increase productivity
considerably under the given soil and climatic conditions and thus meet the house food requirement and have a surplus for sale to meet fertiliser and other domestic costs. Intensification of major staple food production among smallholder farmers can, therefore, lead to environmental sustainability through the reduction of cultivatable areas and thus reduced forest degradation and deforestation and enhance carbon stocks but reduce carbon emission. Farmers’ practice on rice sites was already more advanced with higher fertiliser inputs application than on maize sites and, therefore, leading to high yields when compared to the national average of 2.3 t/ha (Figure 8.2). This could, however, be a particular case for those study areas. In fact, in the study area, some farmers had adopted parts of the YSS protocol much more quickly than anticipated as soon as they saw the significant yield improvements of rice in the first season. Since the FP plots with maize are more representative of typical farming practice in Tanzania than the ones for rice, the following results for profitability and environmental impact focus on the maize trials.

Figure 8.2: Marketable grain yield of maize and rice in the trials (average over all sites and years)

4.2 Profitability
Income and expense data were gathered following each season to calculate profitability. For maize, the sharp increase in marketable grain with YSS treatment increased household income and the profit was nearly three and seven times higher at Welela and Matiganjola villages on average for 2012 and 2013 (see Figure 8.3). Ibumila village with soil pH 4 (Mtengeti et al, 2015) had a loss in farmers’ practice treatment. However, moderate application of nutrients in combination with good soil conditions as evidenced at Kichiwa and SUA led to comparable profitability between YSS and FP.
Consumption of maize and rice grain in Tanzania is estimated at 74.5 and
16.5 kg/person/year (FAOSTAT, 2012; PASS 2012). Thus a family of six people will require about 447 and 99 kg/household/year, of maize and rice grain, respectively. Therefore, a yield of 5.9 t/ha and 7.5 t/ha of maize and rice, respectively, will not only improve household food security but also tremendously improve household income through the sale of surplus grain, thus increasing the purchasing power for agro-inputs in addition to enhancing the standard of life for the household. This tangible benefit can also reduce pressure on the forest through charcoal-burning and extraction of timber for sale to meet the household’s cost of living.

Furthermore, we saw instances of income diversification through planting of additional cash crops such as fruit and timber trees on the farm, or purchasing of livestock such as poultry. As part of a livelihood impact assessment, farmers responded that they spent part of their added income on children’s education and improving their homes. At a scale, such income creation would stimulate local economies to the benefit of wider rural communities.

Figure 8.3: Profitability of the YSS and FP protocols (average of 2 seasons)
4.3 Environmental impact

To understand and describe the environmental impact of the tested cropping systems, we applied a framework of environmental indicators that cover impacts on climate, soil, water, and biodiversity (see Figure 8.4 below).

![Figure 8.4: Framework to measure and evaluate environmental parameters](image)

**Climate**

Green House Gas (GHG) emissions were calculated for each practice using a Life Cycle Assessment based carbon footprint calculation methodology, which includes emissions from the production and transportation of farm inputs (fertiliser, plant protection, and seeds), on-farm energy use, nitrous oxide ($N_2O$) emissions from soil, and carbon loss from land use change. Compared to FP, the GHG emissions per hectare increased with the increased use of farm inputs such as mineral fertiliser required in the YSS practice. However, this effect is smaller when looking at emissions per tonne of production.

The low yields with current farmer practice, however, lead to continuous expansion of cropping area to keep up with the increasing demand for food crops. The carbon losses associated with such land use change (e.g. converting savannah or scrub land into arable land) lead to a substantially higher carbon footprint per unit of grain versus the YSS practice. If GHG emissions from such potential land use change are considered according to a methodology suggested by IPCC (2007), the carbon footprint of FP is between four and 12 times greater than that of the YSS protocol (see Figure 8.5).
Soil impacts have been investigated in different ways. Soil samples were taken at the beginning of the project and after each harvest to analyse crop nutrients and other parameters such as soil pH and organic matter content as reported by Mtengeti et al. (2015). The measurement of nutrient contents in harvested grain and straw enabled an analysis of the input-output balance of plant nutrients, which is an important parameter for the sustainability of crop production.

It should be noted that the initial soil properties before experimentation in maize sites showed low to very low pH (ranging from 4.2 – 4.7 in Njombe study sites) and deficiency of various plant nutrients (e.g. phosphorus, sulphur, boron, and zinc) on almost all sites (Mtengeti et al., 2015). The YSS practice addressed this problem by including multiple macro-, secondary-, and micro-nutrients as indicated in Table 2. Additionally, the highly weathered soils in Njombe region can benefit from any application of on-farm organic material available such as manure and crop residue to improve soil structure and recycling of plant nutrients. The YSS treatment produced more plant residues available for soil improvement and nutrient recycling (see Table 8.5).

<table>
<thead>
<tr>
<th>Villages</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>YSS</td>
<td>FP</td>
<td>YSS</td>
<td>FP</td>
</tr>
<tr>
<td>Ibumila</td>
<td>7.3a</td>
<td>2.7b</td>
<td>7.3a</td>
<td>7.1a</td>
</tr>
<tr>
<td>Kichiwa</td>
<td>10.9a</td>
<td>7.7b</td>
<td>15.4</td>
<td>NR</td>
</tr>
<tr>
<td>Matiganjola</td>
<td>NR</td>
<td>NR</td>
<td>14.2a</td>
<td>4.84b</td>
</tr>
<tr>
<td>SUA</td>
<td>NR</td>
<td>NR</td>
<td>11.63a</td>
<td>6.2b</td>
</tr>
<tr>
<td>Welela</td>
<td>NR</td>
<td>NR</td>
<td>11.16a</td>
<td>3.0b</td>
</tr>
</tbody>
</table>

NR = Not recorded. Means of YSS and FP in the same village and year with different superscripts are significantly different at P < 0.05 according to t-test (two tails).

Table 8.5: Maize stover yield (without grain) (t/ha) from 2011 to 2014
Total shoot removal (i.e. grain and stover or straw) showed a negative nutrient balance for N and K (see figures 8.6 and 8.7). Removal of the whole above-ground crop residue and grain can lead to nutrient mining and negative impact on the environment (FAO, 2016). Under smallholder farmers, crop residues are used to feed animals. It is common practice in Tanzania for animals to graze freely in farms after crop harvest. Even when a farmer does not keep livestock, the neighbours’ animal will graze in his/her farm. This practice should be discouraged because it leads to land degradation, hence a negative impact on sustainable agriculture.

Evidence from the current study reveals a large proportion of crop nutrients found in crop residues i.e. maize stover and rice straw. Results in figures 8.5 and 8.6 indicate that the total shoots (grain and stover) have large amounts of potassium and nitrogen, hence their removal from the farm can lead to negative nutrient balance even where balanced fertilisers were applied adequately under the YSS (improved agriculture practices). Phosphate fertilisers are not removed in large quantity due to high fixation in soil and due to low plant uptake of the nutrient (Weil and Brady, 2007). Globally, about 31, 26, and 154 percent of N, P, and K, respectively, of the fertiliser consumption in 1998 were found in crop residues (FAO, 1999). Throughout the tropics, there is little recycling of crop residues in the field. These are either harvested for fuel, animal feed, or bedding or burned in the field (FAO, 1999). Negative nutrient balance from total removal of grain and crop residues revealed in the current study can be used to raise awareness on the fact that crop residue incorporation into the field is crucial even when balanced and adequate fertilisers are applied.

Figure 8.6: Nutrient balance NPK (kg/ha) in maize fields in 2014. Negative N and K in both YSS (improved practice) and FP (Farmers practice by total removal of grain and crop residues of maize)
Figure 8.7: Nutrient balance NPK (kg/ha) showing negative balances of N and K in both YSS (improved practice) and FP (Farmers practice) by total removal grain and crop residues of rice in 2012.

Water

Weather stations at two of the sites enabled the measuring and assessing of water use across the treatments. All the maize sites were rain-fed so yield increases were achieved with no additional water. A full water footprint analysis, according to Global Water Footprint Assessment Standard (Hoekstra et al., 2011), was performed for one site and one season. Figure 8.8 shows the water footprint per tonne of maize grain, which was 50 percent higher in the farmers’ practice treatment compared to YSS. In the YSS treatment a small N surplus is responsible for a grey water component of the water footprint. Moreover, under the YSS in total the available rain water was utilised more efficiently than under the farmers’ practice, for example, the former produced “more crops per drop of water” than the latter.
Biodiversity was assessed in different ways in the project: in-field, on-farm, and in terms of land-use efficiency. In-field biodiversity was evaluated by tracking the number of invertebrates and earthworms on the plots, counting the number and variety of weeds, as well as analysing the microbial biomass of soil samples from several sites. Biodiversity of the whole farm was recorded by creating biodiversity maps of each of the sites. In-field biodiversity assessments showed fewer species of weeds and insects on YSS plots due to the crop protection treatment applied. In the areas immediately surrounding the growing area, biodiversity remained unchanged. On-farm biodiversity improved with YSS practice use, as increased yields and additional income made several farmers plant perennial trees and thus increased carbon stocks on their farms instead of degrading the land.

Farmers’ practice required twice as much land area to produce a tonne of maize grain as the YSS treatment. This is, of course, simply the reverse for the yield data. The improved productivity does not only provide more output for the farmer and more food for society but also removes pressure for further land use change, thus enabling preservation of biodiversity and carbon stocks at the landscape level.

5.0 Lessons and Implication for REDD+

This study has been shown that intensification of crop production results into an increased productivity per unit area, thus enabling more flexibility in land use such as planting of forests and increasing biodiversity. It has been estimated that land use change, including deforestation and forest degradation, accounts for 12-29 percent of the global greenhouse gas emissions (Fearnside, 2000). For this reason, increased agricultural productivity through intensification as this study has revealed can enhance the reduction of emissions from land use change and should be considered to be essential in achieving the objectives of the United Nations Framework Convention on Climate Change (UNFCCC) especially for smallholder farmers who produce 90 percent of the maize and rice crops in Tanzania. As the rural poor are the most susceptible to adverse effects of climate change, reducing deforestation through agricultural intensification provides an opportunity to simultaneously tackle the problem at its source whilst helping to foster resilience of those most vulnerable to climate change. This is because forests provide essential ecosystem services including carbon storage, emissions offsetting, health (through disease regulation), livelihoods (providing jobs and local employment), water (watershed protection, water flow regulation, and rainfall generation), food, and nutrient cycling and climate security. Therefore, agricultural intensification under smallholder crop production system seems to comply with REDD+ (reducing emissions from deforestation and forest degradation) incentives through increased household food and income security. In the study areas, sustainable agricultural intensification saved enough land
around the smallholder farmers for alternative uses such as planting fruit, fodder and timber trees and, thus, complying with REDD+ initiatives, specifically on enhancing forest carbon stocks and reducing emissions from deforestation for fuel, house construction and fodder for their livestock (Peskett *et al*., 2008). Improved water flows from forest conservation have enabled smallholder farmers in one of the study villages in Njombe district to start fish farming to improve household food quality and income. This is also a potential benefit accruing from REDD+ brought to the study area through striking a good balance between agricultural intensification and environmental sustainability.

### 6.0 Conclusions

A balanced supply of plant nutrients can increase maize and rice yields and farm profitability substantially. Improved agricultural practices are important to ensure high productivity of the existing cropland in the long-term. This will reduce the expansion of cultivatable land to meet food demand and, thus, saving forests and water resources to contribute viably and substantially to REDD+. The potential impacts on climate, soil, water and biodiversity from agricultural intensification need to be assessed and monitored in a consistent and transparent manner so as to evaluate the sustainability of intensification measures. Generally, this study has demonstrated that improved agricultural practices increased crop yields substantially and can reduce the need for arable land expansion and potentially help avoid GHG emissions. Moreover, total removal of crop residues either through burning or grazing animals shows negative nutrient balances, hence signifying nutrient mining and loss of farm productivity. Furthermore, less water per tonnage of maize produced is possible when improved agricultural practices are applied compared to the current smallholder farmers’ low input agricultural practices.

### Acknowledgements

The authors would like to thank the Sokoine University of Agriculture (Morogoro/Tanzania), the University of Life Sciences (As/Norway), Syngenta and Yara Tanzania, which were all part of the public-private partnership. They allowed their staff to carry out this study for four years. The authors are also thankful to NORAD for a substantial funding of this study.
References


Implications of Potential REDD+ Initiatives on Smallholders’ Livelihoods through Access to Land in Singida and Manyara Regions
Mapping and Assessment of Challenges and Opportunities

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Abstract

This chapter is based on a study that was carried out in five villages of Singida rural district, namely Nduamughanga, Mughunga, Unyampanda, Pohama and Ngimu, which are located adjacent to Mgori Forest Reserve. Data collection involved the analysis of Landsat images over the study area. In all, five scenes from different years—1990, 2000 and 2010—were used to generate landuse cover maps necessary to establish changes over 20 years. Primary data were collected through focus group discussions (FGDs), key informant interviews
and household surveys and transects walks in the selected villages in study areas. Remote sensing analysis shows that, woodland had decreased by 53.8 percent in a period of 10 years from 1990 to 2010 as bushland increased by 22.9 percent. On the other hand, agricultural land increased by 4.8 percent due to the expansion of crop land as community livelihoods depended on agriculture by between 65 and 70 percent. Livelihood analysis shows that there was reduced access to livelihood assets, especially natural assets as a result of the conservation initiative. The communities in the study area reported that they paid for conservation more than the accruing benefits gained from the forest in terms of income. About 90 percent of communities in Mgori observed that mitigations through REDD+ initiatives, if introduced, could create serious challenges for smallholders due to restrictions imposed on access to land for other uses such agriculture. The respondents claimed that restrictions attributable to conservation (environmental income) increased income inequality. The inequality, as measured by the Gini coefficient, increased significantly without recourse to environmental income in Mughunga (0.1), Ngimu (0.01) and Pohama (0.01). Generally, without environmental income, the overall Gini coefficient decreased to 0.08 units. The study, therefore, recommends that Mgori Forest Reserve needs to be well-managed and placed under REDD+ initiative to contribute to climate change mitigation and fostering of community livelihoods.

1.0 Introduction

1.1 Background Information

Pressure on land in Tanzania is increasing as rapid population growth coupled with the expansion of protection areas raises a number of challenges in land uses including conflicts and over-utilisation of resources. In fact, more than 40 percent of the land area in Tanzania is under some form of conservation regime (Benjaminsen and Svarstad, 2010a). Environmental protection intervention through the expansion of conservation areas such as wildlife conservation and creation of agricultural corridors have been reported to accelerate land use conflicts in the country (Abdallah et al., 2014). As REDD+ is being introduced in Tanzania, there is need to rethink how a balance can be struck between mitigation and other land uses among local communities.

Rationale of the Study

Tanzania has piloted REDD+ countrywide. Preparatory steps have included the launching of the National Carbon Monitoring Centre. Generally, there is a possibility of larger REDD+ implementation in Tanzania. Therefore, REDD+ intervention should be seen in a broader regional context to avoid adverse effects on smallholders’ access to resources and, hence, on their livelihoods. This chapter focuses on Singida region, particularly Singida rural district. The study on which it is based examined the implications of REDD+ initiatives
for smallholders’ access to land. The analysis also took on board the gender dimensions of these challenges. Strategies to meet challenges of access to land and resources for smallholders were identified in relation to livelihood security and gender equity (Schalatek, 2009). In this regard, the chapter generates knowledge on the importance of addressing the challenges of access to land and resources for smallholders as the REDD+ implementation comes knocking in Singida region.

Tanzania has embarked on a national REDD+ programme to meet its obligations of managing its forests sustainably while responding to poverty reduction initiatives. In fact, the Tanzania government envisages to participate in REDD policy and in its development and inclusion into UNFCCC. However, to make suitable decisions on land uses for climate change adaptation and mitigation initiatives, knowledge is required on the legal status of the land (various protected areas or village land, etc), types of vegetation cover (forest categories, farm land, etc) and types of present uses (food cultivation by smallholders and large estates, land leased by foreign companies for food, pastoral uses, etc). And yet, today only partial data covering some of these elements at the regional level in Singida is available. Hence, there is a need to bring these various elements together to provide a better analysis of the main types of land uses and conflicts that REDD+ might face. This chapter, therefore, provides, among other things, tools for assessing the potential social impacts of different land areas for REDD+ implementation.

The study was based on the conceptual framework of political ecology (Forsyth, 2003; Adger et al., 2001; Benjaminsen et al., 2009; Benjaminsen and Svarstad, 2010b). The approach builds on political economy, on the one hand, and cultural or human ecology, on the other. Current political ecology usually focuses on power relations pertaining to land and environmental management. The analysis can be made from the local via the national to the global level, and on inter-linkages between these levels. Power relations studies can also reflect issues of land tenure and access to land rights and how they manifest from a gender perspective (Palmer, 2010). They can also reveal poverty and its relations to gender-based discrimination in communities under patriarchal values. Some of the shortcomings can be seen in the current land policies such as the Land Act (1999). For example, the Land Act of 1999 recognises the presence of idle land within village boundaries and labels such land as general land. This labelling has created conditions that favour land investment within village boundaries, which in turn limits land accessibility for community members in the villages (Abdallah et al., 2014). Consequently, the introduction of REDD+ initiatives under these circumstances may pose an added challenge to women’s rights in terms of their access to land and tenure unless they are addressed in a concerted manner at the conception of the REDD+ initiative.
2.0 Objectives of the study
The overall objective of the study was to provide and understand the implication of REDD+ for smallholders’ livelihoods with regard to access to land. The project had five specific objectives but only three of the discussed in this paper are:

1. To examine the potential areas for REDD+ initiatives in the context of the existing land uses and projected land use changes;
2. To assess the challenges and opportunities REDD+ may present on livelihood security through changes in access to land for smallholders;
3. To recommend different strategies for meeting the challenges identified.

3.0 Methodology
This section briefly describes the study area, briefly maps out the land use cover change and describes the process of collecting both secondary and primary data as well as the interpretation and analysis procedure.

3.1 Location of the Study
The study was carried out in Singida region because of the area’s significance in relation to the Participatory Forest Management (PFM) implementation, land use conflicts and REDD+ initiatives. In Singida rural district, the research project was undertaken in five villages of Nduamughanga, Mughunga, Unyampanda, Pohama and Ngimu, which are located adjacent to Mgori Forest Reserve (see Figure 1).
3.2 Mapping of land use changes

Mapping of land use change was achieved by interpreting and analysing Landsat images that cover the study area. Specifically, five scenes of 1990, 2000 and 2010 years were analysed. These images were used to analyses the land use situation (Majule et al., 2012).

3.3 Primary and Secondary Data

Secondary data were collected through documentary review. In this regard, different similar studies conducted in Tanzania and elsewhere were reviewed. The review covered different research reports and other documented materials available including journal articles, books, proceedings, relevant thesis and dissertations. Primary data were collected through: i) Stakeholders’ workshops; ii) in-depth interviews held with key informants at the district and village level; iii) focus group discussions (FGD) with 15 selected village community members in five villages surrounding Mgori Forest; and iv) household survey covering 150 sampled households drawn from the five study villages surrounding Mgori Forest. Simple random sampling was used to draw household for taking part in the survey with a semi-structured questionnaire. This sampling method gave
every household had an equal chance of being selected (Kothari, 2004). The methodology used in data collection and analysis is quite similar to the one reported by Lema and Majule (2009) and Kimayo (2012). A transect walk helped to validate some information generated during FGDs and on land use images analysis. Household data were coded, captured into SPSS spreadsheet and Microsoft Office Excel 2007, analysed to generate descriptive statistics and presented in tabular form. On the other hand, based on the information required in this chapter, household data validated critical information generated during the FGD. Data from FGDs and transect walk, on the other hand, werecorded, entered into a computer using the IBM Statistical Package for Social Sciences (SPSS) version 20...

4.0 Results and Key Lessons Learnt From the Study

4.1 Social characteristics
Most of the villages in Mgori were established as Ujamaa villages in 1974 as part of the implementation of villagisation programme in Tanzania. The indigenous ethnic group, which dominated in most villages, was the Nyaturu. Others were Sandawe, Mbungu, Mang’ati, Mbulu, Kimbu, Gogo and a few Nyiramba. Most of the villages had three main social economic groups determined by their wealth, namely the Mghware in Nyaturu (the affluent), the Bahubahub in Nyaturu (the middle class) and Mtuki/Mruki in Nyaturu (the poor). On average, the proportion of well-to-do people was around 10 percent whereas the middle class accounted for 50 percent and the poor for 40 percent. These proportions are similar to those reported by Kangalawe et al. (2005). A very strong network existed among the three main wealth groups and this formed a very strong relationship between them similar to one reported by Lema and Majule (2009).

4.2 Main socio-economic activities
The main socio-economic activities in most of the villages that surround Mgori Forest is agriculture (see Table 9.1) mainly in form of subsistence and rain-fed farming. During this study, several social and environmental challenges, such as lack of productive seeds, attack by pests and diseases, poor and declining soil fertility and frequent drought associated with seasonal climate variability, were reported. Major crops grown were maize, sorghum, millet, cassava and bulrush millet. Due to the existence of potential natural vegetation in this area, perennial crops introduced include cashew, avocado and mangoes in a bid to improve livelihoods of the communities in the area. The second main activity across the villages was livestock-keeping which provides income and food to the community in addition to meeting the cultural demands of the
area, particularly the payment of the bride-price. The villagers mostly keep local breeds as livestock. The main challenges of livestock activities in the areas were found to be poor productivity, lack of veterinary services to conquer diseases and pests affecting production and productivity. The villages surrounding Mgori Forest generally expected much of their livelihoods to depend on the use of natural resources from the Mgori village land forest reserves. However, due to an effective conservation and management of resource, only less than 10 percent use of such resources for all villages was reported (see Table 9.1) in all cases of lumbering, charcoal-burning and firewood gathering. In this regard, the insignificant collection of resources from the forest indicates that conservation through the CBFM was working and this created right conditions for effective REDD+ implementation.

<table>
<thead>
<tr>
<th>Economic activities</th>
<th>Nduamghanga</th>
<th>Unyampanda</th>
<th>Ngimu</th>
<th>Pohama</th>
<th>Mughunga</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural production</td>
<td>70</td>
<td>65</td>
<td>70</td>
<td>60</td>
<td>68</td>
</tr>
<tr>
<td>Livestock keeping</td>
<td>20</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Small business</td>
<td>03</td>
<td>05</td>
<td>04</td>
<td>05</td>
<td>04</td>
</tr>
<tr>
<td>Crafting</td>
<td>02</td>
<td>-</td>
<td>04</td>
<td>02</td>
<td>02</td>
</tr>
<tr>
<td>Beekeeping</td>
<td>02</td>
<td>05</td>
<td>1.5</td>
<td>03</td>
<td>02</td>
</tr>
<tr>
<td>Lumbering</td>
<td>01</td>
<td>03</td>
<td>01</td>
<td>01</td>
<td>02</td>
</tr>
<tr>
<td>Charcoal-burning</td>
<td>01</td>
<td>03</td>
<td>01</td>
<td>01</td>
<td>01</td>
</tr>
<tr>
<td>Firewood gathering</td>
<td>01</td>
<td>-</td>
<td>02</td>
<td>02</td>
<td>01</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 9.1: Main socio-economic activities per village (%)

4.3 **Patterns of land-use/cover changes over 20-year period (1990-2010)**

Different land use and cover types were found to exist at Mgori Forest and the surrounding villages as presented in figures 9.2 and 9.3. The major land cover types identified as presented in Table 9.2 are similar to those reported for Tabora region by Majule et al. (2011). In the context of REDD+, the area in the 1990s was largely covered by Miombo, which store large amounts of measured carbon stock and, hence, can potentially mitigate climate change impacts as compared to other types of forest cover (Mwakisunga and Majule, 2012). However, the changes observed in the woodland area (see figures 9.2, 9.3, 9.4) indicate that the ability of Mgori Forest to sequester carbon might have been reduced due to deforestation and degradation of the Miombo woodlands in the area.
<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>1990</th>
<th>%</th>
<th>2010</th>
<th>%</th>
<th>1990-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bushland</td>
<td>6305</td>
<td>17.1</td>
<td>13642</td>
<td>40.0</td>
<td>+23.0</td>
</tr>
<tr>
<td>Cultivated Land</td>
<td>909</td>
<td>02.5</td>
<td>02678</td>
<td>07.3</td>
<td>+04.8</td>
</tr>
<tr>
<td>Grassland</td>
<td>0000</td>
<td>0</td>
<td>01207</td>
<td>03.3</td>
<td>+03.3</td>
</tr>
<tr>
<td>Rock Outcrops</td>
<td>0089</td>
<td>00.2</td>
<td>00000</td>
<td>0</td>
<td>0 0</td>
</tr>
<tr>
<td>Settlement</td>
<td>0000</td>
<td>0</td>
<td>00045</td>
<td>0.12</td>
<td>+0.12</td>
</tr>
<tr>
<td>Swamp</td>
<td>0351</td>
<td>0.95</td>
<td>01059</td>
<td>2.87</td>
<td>+1.92</td>
</tr>
<tr>
<td>Thicket</td>
<td>0000</td>
<td>0.00000</td>
<td>08873</td>
<td>24.04</td>
<td>+24.0</td>
</tr>
<tr>
<td>Woodland</td>
<td>29249</td>
<td>79.3</td>
<td>09399</td>
<td>25.5</td>
<td>-53.8</td>
</tr>
<tr>
<td>Total area</td>
<td>36903</td>
<td>100</td>
<td>36903</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

*Table 9.2: Land use/cover changes between 1990 and 2010 in Mgori Forest*

*Figure 9.2: Land use and cover in Singida rural district in 1990*
Figure 9.3: Land use and cover in Singida rural district in 2000

Figure 9.4: Land use and cover in Singida rural district in 2010
Table 9.2 illustrates that a significant land use and cover change had taken place despite the implementation of the CBFM initiatives in the area. For example, the area under woodland covered 29,905 ha in 1990 and by 2010 this area had shrunk to only 9,399 ha of land, indicating land degradation and its conversion to other uses. Table 9.2 also shows that there had been a significant increase in Bushland area (by 23%) and this may indicate that once woodlands are degraded through deforestation and degradation of bushland subsequently emerges. Similar results have been reported for woodlands in Tabora region (Majule et al., 2011).

The changes observed have implications for community livelihoods and ecosystems by affecting a balance between ecosystem service provision and community demands as described within the context of ecological gradients. In general, woodland decreased by 53.8 percent over the last 20 years (see Table 9.2), indicating that this might compromise the REDD+ initiatives once allowed to continue unabated. Since most of the woodlands appeared to have been converted to bushland or thickets, opportunities for reversing the situation once REDD+ was in place had been created. This would not comprise much the agricultural land as a change to cultivated land was not that significant. Although food was not reported to be a challenge, improving productivity of agricultural land would further balance the food demand to allow other benefits to flow from REDD+ as the population grew. Other land uses had remained almost the static and one should not expect much change under the REDD+.

4.4 Future land use and cover change and implications for REDD+

In general, Majule et al. (2012, 2014) have established that deforestation was associated with the expansion of bushland, agricultural activities and population growth, which also lead to the expansion of human settlements. Transitional land cover change detection showed a change of individual land cover types by determining the difference of land cover in subsequent years (Majule et al., 2015). Under this analysis, it was difficult to see directly what had contributed to the change. Abdallah et al. (2012), on the other hand, noted that pressure on land around Mgori Community Based Forest Management increased due to population growth and so had the demand for cultivating drought-resistant crops (e.g. finger millet).

As the analytical data presented in Table 9.3 illustrated, the land under Mgori Forest in 2000 had to a large proportion (61.45%) been covered by woodland, suggesting that carbon concentration in that area was high. This further suggests that this area was rich in biodiversity including wildlife (Abdalah et al., 2012). Other land cover types in 2000 were thickets (12.53%), bushland (12.18%)
and cultivated land (5.35%) with land under settlement accounting for the least 
(at 0.0) After only 10 years, land under woodland decreased with a significant 
increase of land under thickets and bushland, which indicates a grave case of 
deforestation. The projected land use cover are also presented in Table 9.3 
have also been reported by Majule et al. (2014). In this regard, the woodland 
is projected to decrease by 2020 to cover only 16.49 percent from 61.45 in 
2000 and would remain the same in 2040. Land covers predicted to increase 
are those for bushland, agriculture and thickets. Based on the projected land 
use cover changes as presented in Table 9.3, it is apparent that there is a need 
for effective REDD+ initiatives to be in place in Mgori Forest to forestall some 
of the projected negative impacts and sustainably manage the natural resources.
<table>
<thead>
<tr>
<th>Land cover (per ha)</th>
<th>2000</th>
<th></th>
<th>2010</th>
<th></th>
<th>2020</th>
<th></th>
<th>2030</th>
<th></th>
<th>2040</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area</td>
<td>%</td>
<td>Area</td>
<td>%</td>
<td>Area</td>
<td>%</td>
<td>Area</td>
<td>%</td>
<td>Area</td>
<td>%</td>
</tr>
<tr>
<td>Bushland</td>
<td>04744</td>
<td>12.18</td>
<td>13675</td>
<td>35.11</td>
<td>11410</td>
<td>29.29</td>
<td>11409</td>
<td>29.29</td>
<td>11413</td>
<td>29.30</td>
</tr>
<tr>
<td>Cultivated land</td>
<td>02083</td>
<td>05.35</td>
<td>02688</td>
<td>06.90</td>
<td>03970</td>
<td>10.19</td>
<td>03967</td>
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<td>03966</td>
<td>10.18</td>
</tr>
<tr>
<td>Grassland</td>
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<td>00.38</td>
<td>01209</td>
<td>03.10</td>
<td>00684</td>
<td>01.76</td>
<td>00687</td>
<td>01.76</td>
<td>00679</td>
<td>01.74</td>
</tr>
<tr>
<td>Seasonally inundated</td>
<td>01133</td>
<td>02.91</td>
<td>01056</td>
<td>02.71</td>
<td>01236</td>
<td>03.17</td>
<td>01235</td>
<td>03.17</td>
<td>01235</td>
<td>03.17</td>
</tr>
<tr>
<td>Woodland</td>
<td>23937</td>
<td>61.45</td>
<td>09399</td>
<td>24.13</td>
<td>06422</td>
<td>16.49</td>
<td>06420</td>
<td>16.48</td>
<td>06426</td>
<td>16.50</td>
</tr>
<tr>
<td>Thicket</td>
<td>04880</td>
<td>12.53</td>
<td>08852</td>
<td>22.72</td>
<td>13107</td>
<td>33.65</td>
<td>13109</td>
<td>33.65</td>
<td>13107</td>
<td>33.65</td>
</tr>
<tr>
<td>Settlement</td>
<td>00000</td>
<td>00.00</td>
<td>00045</td>
<td>00.12</td>
<td>00102</td>
<td>00.26</td>
<td>00103</td>
<td>00.26</td>
<td>00102</td>
<td>00.26</td>
</tr>
<tr>
<td><strong>Total Area</strong></td>
<td><strong>38952</strong></td>
<td><strong>100</strong></td>
<td><strong>38952</strong></td>
<td><strong>100</strong></td>
<td><strong>38952</strong></td>
<td><strong>100</strong></td>
<td><strong>38952</strong></td>
<td><strong>100</strong></td>
<td><strong>38952</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Table 9.3: Projected land use cover change at Mgort based on analysed data*
4.5 Implications of REDD+ project for community livelihoods

Livelihoods of the majority of the communities living in villages surrounding Mgori Forest depend on agriculture for their livelihood (see Table 1). In this case, there is a significant change in the size of agricultural land area at the expense of woodland (see Table 3) As Abdallah et al. (2012) have noted, the introduction of REDD+ in the area should be handled in a broader context to avoid adverse effects that could be imposed on the smallholders’ access to resources and, hence, severely affect their livelihoods.

The subsequent section presents opportunities, challenges and lessons learned from this study.

4.5.1 Opportunities

There were a number of livelihood opportunities that were identified by communities living adjacent to Mgori Forest. These include increased availability of non-timber forest products, mitigating effects of greenhouse gases, increased income for the communities, conservation of land and forest biodiversity, improvement of social services and increase in employment opportunities and reduced poverty. These are briefly described in the sub-sections that follow:

4.5.1.1 Increased availability of non-timber forest products

REDD+ entails reducing emission from deforestation and forest degradation as well as conservation of natural resources. Results from the FGDs show that when the forest was put under REDD+ communities felt that different non-timber forests vital to their livelihood would increase in terms of quantity and quality. FGD participants mentioned honey, traditional fruits and vegetables (mushrooms) as Non-Timber Forest Products (NTFPs) that were going to increase under sustainable conservation.

4.5.1.2 Mitigating effects of greenhouse gases

FGDs revealed that communities had high awareness of climate change and forest as sinks of the GHGs. Forests and woodlands were known already by communities for enabling a conducive environment such as conserving water and ecosystem integrity. Trees were also known by communities for their ability to fix carbon and, hence, reduce the emission of GHG. Communities living in villages surrounding Mgori Forest also reported that when REDD+ was introduced communities would benefit by selling carbon. Also through water conservation by trees, drought was going to be reduced and this could result into increased crop and livestock production. This observation was also in broad agreement with what was seen in privately-owned forests in Singida the research team had visited.
4.5.1.3 Increased income for communities
Through increased wild animals and other natural products as well as increased biodiversity tourist activities could be established, which could in turn attract tourists to the area. Such a development together with the harvesting and sale of different products could bring about income to the communities and local governments. On the other hand, because REDD+ would involve carbon trade, the payment accrued for the communities could increase their income and also increase opportunities for further investment in new areas.

4.5.1.4 Conservation of land and forest biodiversity
REDD+ entails conservation and this means that the Forest will already be under proper land use plan. Land in this case will be protected from degradation, which could eventually lead to an increase in biodiversity and richness in species found in the areas. Consequently, both timber and non-timber forest products could increase and community needs on natural products would be met.

4.5.1.5 Improvement of social services
REDD+ can potentially bring income to the communities in the area to change their lifestyle. To accommodate such changes, social services would be required as more people would be going to the area. Also, good roads would be required. Health services and water services were also likely to improve. The improved socio-economic setup could also attract banking services to the area.

4.5.1.6 Increase in employment opportunities and reduced poverty
In general, improvement registered for social services in the area as the forecasting above illustrates, different employment opportunities could emerge in the area and this together with other benefits mentioned earlier could bring about poverty reduction in the area. In this regard, poverty reduction could occur as income earning mounted, which could potentially address the problem of the livelihoods of the people in the area in addition to increasing their purchasing power.

4.5.2 Challenges
In spite of the number of potential gains and opportunities that could accompany REDD+ for communities living adjacent to Mgori Forest, there are also some challenges that are likely to emerge. The challenges have also been identified by the communities. These challenges include changes in land tenure and land compensation, threats from wild animals, limited access to forest products and increased poaching activities are discussed accordingly.

4.5.2.1 Changes in land tenure and land compensation
Through a stakeholders’ consultation workshop held in Singida, discussions with representative community members and key informants fears emerged that
their land would be grabbed by whoever was going to implement the REDD+ programme in Mgori Forest. This reason was based on their previous experience whereby community land had been taken away. It was, however, clearly elaborated to them that this was not the case with REDD+ since its benefit were clearly elaborated and was not designed to alienate local community from the land as it sought to turn them into partners in forest and land conservation without necessarily compromising their livelihoods.

4.5.2.2 Threat from wild animals
Mgori Forest has a number of wild animals. These include elephants, lions and monkeys, which pose threats to both human life and their property, in particular crops and livestock. This was an issue of concern to the communities and one control mechanism had been to clear some parts of the forest. On the other hand, with effective conservation, they feared that the elephant population was likely to increase and with it the damage to the field crops was likely going to increase, hence affecting yields and food security in the area. The communities also feared threats wild pigs and birds including qualea qualea, which could flourish as their habitat improved and these could threaten the livelihoods of communities in the area.

4.5.2.3 Limited access to forest products
Many communities believed that access to different forest products would not be easy to them because of restrictions that might be imposed under REDD+. This, however, might not be the case because under REDD+ there was room for sustainable use of natural resources.

4.5.2.4 Increased poaching activities
From consultations with stakeholders and FGDs conducted with village communities, it emerged that REDD+ would lead to an increase in the number of wild animals in the area. Therefore, poaching was likely to increase and this would add a burden to the local authorities in an attempt to control poaching.

4.5.3 Key lessons
Strategically, it has been learnt that Mgori Forest remains a potential site for the REDD+ initiatives whose implementation depends on participatory forest management regime. The area of the forest has a potential for participatory training in natural resources management, particularly on wildlife, honey keeping, research and other uses.

Agriculture is still the major source of livelihood for the majority of communities adjacent to Mgori Forests. It has been established that there is a need for strengthening the capacity of communities to manage various land uses including the ones set for conservation while responding to REDD+ initiative. For example, cropping patterns, management practices, fertility and water management are
both important when it comes to fostering livelihoods and income generation. However, currently there is no consistency and synergies at the village levels when it comes to the implementation of various laws and policies pertaining to the conservation of Mgori Forests. This anomaly, to some extent, results into the degradation of resources due to agriculture.

5.0 Implications of lessons learnt for REDD+, climate change mitigation and adaptation

It has been established that at Mgori Forest in Singida rural district was being managed through four major zones, namely: i) The use one zone for different purposes; ii) The beehive-keeping zone; iii) The wildlife reproduction zone; and iv) The control zone. According to Kasebele (2013), these zones particularly for reserved forest were found to store significant carbon stock due to forest management which has positive impacts on climate change mitigation. On the slopes of Mount Rungwe in Mbeya, similar observations on carbon stock were made by Mwakisunga and Majule in 2012. Mitigating effects of greenhouse gases while ensuring an increase in income of local communities also continue providing education to the communities on the importance of sustainable conservation of the natural resource base.

Securing land tenure rights of local communities around the forest area are crucial since it significantly reduce poverty and conflicts over resource uses. Indeed, this issue of land tenure is important in sustainable management of natural resources. On the whole, the introduction of REDD+ to the area should be handled in a broader context to ensure there are no adverse effects associated with the smallholders’ access to resources to avoid impairing their livelihoods.

6.0 References


Part 4

REDD+
Governance Process in Tanzania
Lessons Learned from REDD+
Pilot Projects in Kondoa and Rungwe Districts, Tanzania

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Abstract

Reduced deforestation and forest degradation ‘plus’ the role of conservation, sustainable management of forests and enhanced carbon stock (REDD+) has been singled out as one of the core strategies against climate change. At the same time, forests offer important livelihoods. To acquire experience on how to establish REDD+ ‘on the ground’, REDD+ pilot projects were established in Tanzania. The pilots were expected to provide valuable insights on many issues that will likely be encountered by both the government and local communities as REDD+ develops to assist in future REDD+ initiative. This study was conducted to draw lessons from two REDD+ pilot projects in Kondoa and Rungwe districts in Dodoma and Mbeya regions, respectively. Structured questionnaires for households with both closed and open ended questions were used to collect socio-economic, institutional and livelihoods-
related information. Participatory rural appraisal (PRA) techniques, participant
observation and focus group discussions (FGDs) were also employed. Results
show that land and forests are the main livelihood assets in the two pilot
project areas. Although REDD+ was generally accepted by most communities
in the pilots, there were some levels of scepticism based on their past land use
history. For example, the introduction of REDD+ in Kondoa faced rejection
from some villages due to fears over land grabbing and exclusion from forest
access. On the contrary, villages which depend solely on state-owned forests did
not object to REDD+ as they are used to resource use exclusion mechanisms
from such tenure systems. Assessment of the trial payments showed that most
of the people would consider stopping deforestation and forests degradation
if they get compensation relative to the losses of income they will encounter.
Communities prefer payments in form of community investments rather
than paying cash to individuals. It was observed as well that at the local level
parallel governance structures for REDD+ have increasingly become a source of
intra-village conflicts. In fact, the livelihood of the poor inhabitants is directly
hooked to surrounding forests and natural services with growing future needs
of land per household that threaten the future of REDD+. On the other hand,
land use plans go through a relatively too long process and are costly. Thus, the
government should consider preparing plans for all villages to reduce the costs
of planning for natural resource management and use.

**Key words:** Climate change, REDD+ architecture, Livelihoods, Tanzania.

### 1.0 Introduction

Reduced deforestation and forest degradation ‘plus’ the role of conservation,
sustainable management of forests and enhanced carbon stock (REDD+) has
been singled out as one of the core strategies against climate change (IPCC,
2007; URT, 2009). At the same time, forests offer important livelihoods. In
Tanzania, forests have been estimated to contribute 1.9 percent of the Gross
Domestic Product in 2006 (FAO, 2009). The sector also provides employment
to about three million Tanzanians through forest industries, government forest
administration as well as self-employment in forest-related activities (MNRT,
2008). However, the real value of forest resources is grossly underestimated
in official statistics due to unrecorded fuel-wood and other forest-related
products for direct consumption by households (URT, 2011). Vedeld *et al.*
(2007) document that forest incomes are typically about 20 percent of the total
household income in the rural south.
Notwithstanding their contribution to the national and local economies, Tanzania’s forests face enormous challenges, including deforestation and forest degradation. Tanzania is reported to be twelfth among countries with the largest forest loss per year in Africa (Murray and Olander, 2008; Vatn et al., 2009). Deforestation and forest degradation take place in both reserved and unreserved forests, but are more pronounced in the latter (Mwakalobo et al., 2011; URT, 2013). Forests in the general land are de facto under open access characterised by insecure land tenure and lack land use plans. Typically, shifting cultivation, annual wild fires, uncontrolled harvesting of fuel-wood, poles and timber, and heavy pressure for conversion to other competing land uses, including agriculture, livestock grazing, expansion of settlements, and industrial development degrade these forests (Blomley and Iddi, 2009; Zahabu, 2008). The rate of deforestation in Tanzania is estimated at between 130,000 and 500,000 hectares per annum (Zahabu, 2008). Deforestation has been magnified by limited human capacities and financial incentives and the government’s inability to institute effective management plans for ensuring active and sustainable forest management in the country (Blomley et al., 2008; URT, 2009).

Zahabu (2008) reports that the current rates of deforestation and forest degradation in Tanzania result into high CO₂ emissions estimated to be in the order of 126 million tonnes per annum. Recognising its significant contribution to global carbon emissions, Tanzania, with support from the Norwegian government, developed a REDD+ Framework in 2009 (URT, 2009) and a National REDD+ Strategy in 2013 (URT, 2013a), which provide a direction for future REDD+ implementation in the country. However, it remains unclear how Tanzania will participate in REDD+ initiatives in terms of what options the country will offer and the attendant costs of these options.

To acquire experience on how to establish REDD+ ‘on the ground’, a number of REDD+ pilot projects have been established. Despite most of them developing rather slowly, they are expected to provide valuable insights into many salient issues that likely be encountered by both the government and local communities as REDD+ develops. Furthermore, they will serve as valuable test cases for a full national programme regarding the engagement of stakeholders, the understanding of potential effects on livelihoods, the realisation of challenges related to necessary clarification of property and land use rights and the development of benefit-sharing mechanisms (Jagger et al., 2009; Sills et al., 2009; Van Bodegom et al., 2009). Hence, they provide valuable information on the suitability and implications of various solutions supporting the design of an effective and equitable future REDD+ mechanisms.

This chapter is aimed at providing such insights based on the data collected from two of Tanzania’s REDD+ pilot projects based in Kondoa and Rungwe districts. The focus is on potential livelihood consequences, tenure issues, local
perceptions of REDD+ and REDD+ payments. Finally, an analysis of the implementation status of REDD+ in the two pilot projects is made, including some emerging land use conflicts in relation to the introduction of REDD+.

2.0 Materials and methods

2.1 Location of Study Sites

The Rungwe pilot area is located on Mount Rungwe Nature Reserve in Rungwe district, Mbeya region. The pilot project in Kondoa District is located around Kolo Hills Forest Reserves, Dodoma region (Figure 10.1). The sites were selected on the basis of their differences in ecology, forest management regimes and cultural conditions.

Rungwe district lies between 8°30’ and 9°30’ S and 33° and 34° E. It consists of 30 villages and has a total population of 307,270 people. The Nyakyusa and Ndali are the main indigenous ethnic groups accounting for more than 70 percent of the population. The other ethnic groups in the area include the Nyiha, the Nyamwanga, Bungu, Safwa, Kinga, Hehe and the Sukuma. The pilot project in Rungwe district covers four areas—Mount Rungwe Nature Reserve, Livingstone Nature Reserve, Kitulo National Park and Mbizi Forest Reserve. The present study was conducted around Mount Rungwe Nature Reserve. The project is run by the Wildlife Conservation Society (WCS).

Kondoa district, on the other hand is one of the five districts of Dodoma region. The district lies between latitudes 4°10’ and 5°44’ South and longitudes 34°54’-36°28’ East (Mung’ong’o, 1995; Mung’ong’o et al., 2004), 5° 0’ S and 35° 45’ 0 E. It consists of 34 villages with a total population of 269,704, according to the 2012 National Population Census (URT, 2013b). The Rangi and the Sandawe are the major ethnic groups accounting for about 80 percent of the populations in the district (Mung’ong’o et al., 2010). Other groups include the Alagwa (also known as Aasi), the Burunge, the Gorowa (or Fyome), the Nyaturu and the Barabaig. REDD+ is being tested at the Salanka, Isabe and Kome Forest Reserves on the Irangi Hills and Irangi Escarpment, which together make up the so-called Kolo Hills Forest Reserves. The African Wildlife Foundation (AWF) is responsible for the implementation of this REDD+ pilot.

The study was conducted in ten villages—five in each district. In Rungwe district, the study villages covered Ndala, Kibisi, Kabale, Ikama and Katumba whereas in Kondoa district it covered Mnenia, Bereko, Kikore, Gwandi and Haubi.
2.2 Data Collection

The study employed a combination of quantitative and qualitative techniques for data collection. The aim of the combination of techniques was to triangulate the sources of data and facilitate the validation of data through cross-verification from more than two sources (Mikkelsen, 1995; Luoga et al., 2006). Household survey was conducted through the administration of structured questionnaires for households with both closed and open ended questions designed to collect socio-economic, institutional and livelihoods data at the time of the introduction of the pilot projects, for example, in 2011. A total of 200 households were involved in this part of the study in the Kondoa and 198 respondents in Rungwe.

On the other hand, the study employed some Participatory Rural Appraisal (PRA) techniques such as participant observation and semi-structured interview. The semi-structured interview were organised through Focus Group Discussions (FGDs) and Key Informant Interviews (KII). These techniques were useful in capturing some in depth and controversial information which could otherwise not be captured through the use of a structured questionnaire. As some livelihoods are based on illegal activities, there were some clear uncertainties related to the data acquired, especially those from the questionnaires. Therefore, information from focus group discussions and key informant interviews were used to supplement the information from questionnaires. Both pilot projects were later
revisited at least once each year to gather lessons from time to time and also for self-monitoring. It was necessary to collect continuous lessons on stakeholders’ engagement, potential effects on livelihoods, the realisation of challenges related to necessary clarification of property and use rights and the development of benefit-sharing mechanisms. At this time, interviews with various resource persons such as representatives from the NGOs running the projects, district officials and representatives of village governance bodies, for example, village councils and natural resource management committees were undertaken.

### 2.3 Data Analysis

The IBM Statistical Product and Service Solutions (SPSS) version 20 was used to analyse quantitative livelihood data. Qualitative information captured through participant observation, semi-structured and unstructured interviews, on the other hand, was subjected to content analysis. In this analysis, the components of verbal discussions held with key informants were analysed in detail, whereby recorded dialogue with respondents was broken down into smallest meaningful units of information (Kajembe, 1994; Mbeyale, 2009).

### 3.0 Results and discussion

#### 3.1 Role of Forests in Rural Livelihoods

Forests were generally treated as a major livelihood asset in both pilot project areas. At the same time, lack of clear land tenure and land use plans were found to be critical barriers for REDD+ implementation as observed from the very beginning of the pilot projects. Table 10.1 gives an overview of the main livelihoods in Rungwe and Kondoa pilot villages, respectively. Certainly, there are substantial uncertainties involved.

<table>
<thead>
<tr>
<th>Source of income</th>
<th>Pilot areas</th>
<th>Rungwe District (N=198)</th>
<th>Kondoa District (N=200)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>USD</td>
<td>%</td>
<td>USD</td>
</tr>
<tr>
<td>Forest income</td>
<td>365</td>
<td>15.7</td>
<td>211</td>
</tr>
<tr>
<td>Crop</td>
<td>1423</td>
<td>61.1</td>
<td>617</td>
</tr>
<tr>
<td>Livestock</td>
<td>316</td>
<td>13.6</td>
<td>283</td>
</tr>
<tr>
<td>Other income</td>
<td>224</td>
<td>9.6</td>
<td>222</td>
</tr>
<tr>
<td>Total</td>
<td>2328</td>
<td>100</td>
<td>1333</td>
</tr>
</tbody>
</table>

*Table 10.1: Income per household and category for Rungwe and Kondoa districts (N=398)*

*Source: Survey Data (2011)*
There is substantial internal variation in the income, with the largest variation found in Rungwe. Here the richest 1/3 had income that was about 70 times that of the poorest 1/3. In Kondoa the levels were 9:1. Crop income dominated in both districts, with forest income accounting for about 16 percent of the total income in both pilot areas. Whereas a substantial fraction of crop income in Rungwe was cash income (91 %), it was much lower in Kondoa (42 %). Certainly, Rungwe district has very favourable conditions for crop production. In both cases, almost all income from forests was for subsistence.

Generally, forests play three roles in the economy of rural households, namely supporting current consumption, safety netting and serving as an out-of-poverty pathway (Luoga et al., 2006). Table 10.1 covers only the former, and it does so only partially. In other words, it does not capture the role forests play as fallow land for agricultural expansion. Moreover, it does not explicitly show the importance of forests in the livestock economy—grazing—or the role for NTFPs for subsistence. It was found to be too difficult to obtain meaningful data on these aspects. Based on the household survey data we can, however, add the following information:

- In Rungwe, about 6 % of present households were ‘a bit’ too ‘quite’ dependent on clearing forests for agricultural expansion of. In Kondoa, the figure was 11 %, including also some ‘very’ dependent responses. The data does not, however, say anything about the situation for the establishment of new households.

- In Rungwe, 4 % mentioned dependency on forests for grazing. In Kondoa, the figure was 14.5 %.

When interpreting the above data, one must be aware that the government forest reserves were largely closed for farming activities by the surrounding communities from the time they were established. Some of the communities had no other forests available. In Rungwe, the main forest was turned into a nature reserve in 2009, implying that use for farming was no longer allowed. It should also be added that there were many trees in the agricultural landscape, including those in the ravines along water streams and rivers, even though, some of these trees were also protected.

In Kondoa, closing off the forests to grazing has been a policy since the 1980s. This was the outcome of the Tanzania government’s effort to rehabilitate the degraded land through the Land Rehabilitation Programme for Dodoma Region known as HADO in Kiswahili, which stands for Hifadhi Ardhi Dodoma, and it was launched in 1973 (Garrett and Emmanuel, 2010). The programme was supported financially by the Swedish International Development Co-operation Agency (SIDA) with aim of rehabilitating soils and forest areas in Dodoma. It is, however, clear that we faced under-reporting regarding the use of forest...
resources as people were afraid of telling the full story under the present legal situation. This conclusion is based on data derived from the FGDs.

Forest income, as reported in Table 10.1, concerns mainly fuel-wood. The data show that this is the main source of energy in both study sites. Assessment of the most important source(s) of energy for cooking shows that 98 percent of the households in Rungwe used wood as their main source of fuel. It was learned that fuel-wood from tree plots on the households’ own land was by far the most significant as 69 percent of the households had this as their primary source of fuel-wood. On the other hand, about 14 percent of the households depended on bought fuel-wood as their major source, whereas 11 percent depended first-of-all on wood collected from forests around the household landscapes and only one percent reported collecting wood from REDD+ pilot forests. The fact that the main forest was a forest reserve turned into a nature reserve is the most plausible explanation behind the low level of reported fuel-wood consumption in the pilot project area.

Also, in Kondoa District, 97 percent of the households used wood as a main source of energy for cooking and lighting. The results show that wood was collected from different sources and that 45 percent of the households collected firewood from the forests in the landscapes around the settlements. The primary source for 24 percent was the REDD+ pilot forests. For 16 percent own tree plots were the most significant whereas nine percent of the respondents depended first-of-all on locally bought firewood. Although fuel-wood dominated heavily as source of energy in both pilots, it was only in Kondoa that the REDD+ forests seemed to play a significant role currently in supplying fuel-wood.

3.2 Land Tenure and Rights to Forest Resources

Land tenure is one of the principal factors affecting the manner in which land is managed and the way accruing benefits are shared. The legal basis for land tenure in Tanzania is derived from two basic laws that were passed in 1999, namely the Land Act No. 4 of 1999 (URT, 1999a) and the Village Land Act No. 5 of 1999 (URT, 1999b). These laws state that all land in Tanzania is public, as it is held in trust for all the citizens by the president. The president delegates the power to designate, adjudicate and modify land tenure status to the Commissioner for Lands (URT, 1999a).

According to the Land Act No 5 of 1999, ‘land’ includes the surface of the earth and the earth below the surface and all substances, buildings and other structures permanently affixed to land—except minerals and petroleum forming part of or being below the surface. The Village Land Act also adds a claimer that
‘naturally growing things’ are an integral part of the land. Trees are, therefore, regarded by law as fixtures/naturally growing on land surface (URT, 2009). This interconnectedness seems to imply that carbon property rights would correspond closely with land rights.

Although it is a trust-based system, land tenure in Tanzania can best be described by legal pluralism where traditional systems operate in parallel with the formal legal system. People may have informal use rights that sometimes are viewed locally as comparable to a property right. Hence, there is a lot of tenure insecurity. Land tenure insecurity may result into a number of environmental problems, including forest degradation and deforestation (Kissinger et al., 2012; Robinson et al., 2011; Broegaard, 2005). Broegaard (2005) argues that tenure security is vital in determining people’s investment behaviour. Lack of clear land tenure and land use rights may become a critical barrier to REDD+ initiatives and their success (Harvey, 2010).

This issue is magnified by the fact that land is the major asset for households in the study areas. For example, it is a basis for incomes from crops, forests and livestock-keeping. Concerning property and use rights to the land and its resources, there is a clear distinction between land for agriculture and forest land. Even though REDD+ focuses on forests, understanding the overall tenure situation is important.

### 3.2.1 Agricultural Land

In both sites, most of the agricultural land is privately-owned through ‘traditional’ arrangements – see Table 10.2. However, a substantial part of the land is on general land, whereby tenure is not clear, thus creating land tenure insecurity. It was learned that individuals acquire agricultural land mainly through inheritance, buying or through allocation by village governments.

<table>
<thead>
<tr>
<th>Tenure regimes</th>
<th>Percentage (%) of ownership in the pilot areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rungwe District (N=192)</td>
</tr>
<tr>
<td>Private ownership</td>
<td>82</td>
</tr>
<tr>
<td>(most on general land)</td>
<td></td>
</tr>
<tr>
<td>Common ownership</td>
<td>16</td>
</tr>
<tr>
<td>State ownership</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Table 10.2: Perceived status of agricultural land ownership in Rungwe and Kondoa districts
Source: Survey Data (2011)*
As emphasized in Section 3.0, agricultural expansion depends at least partly on converting forests into agricultural land. This represents a great challenge for REDD+ as halting this process is rather difficult. Halting such expansion will depend on the acceptance among local communities since influencing agricultural expansion is very difficult if controlled only from outside. Certainly, compensating for lost income opportunities may help. What are needed are substitutes for the ‘lost’ land. In this regard, money offers a capacity to buy these substitutes or alternatives. It does not, however, by itself ensure the availability of substitutes such as fertilisers, for example. Moreover, fertilisers are also complements to land. Hence, despite effective compensation, the conversion pressure may not be reduced if local communities do not accept that conversion of forests into agricultural land is wrong.

3.2.2 Forest Land
Tanzania Mainland has a total of 33.428 million ha of forest land out of which 16 million ha comprises reserved forests, two million ha are forests in national parks and 15.4 million ha are unprotected forests located in the so-called General Land (URT, 2013). As already indicated, most of the forests in Tanzania are under government ownership through forest reserves and general land institutions. Forest reserves are partly under central and partly under the local governments. Some public forests are also under more strict protection. These include nature reserves and national parks. There are, however, also some forests that are under private and communal ownership as detailed below.

3.2.2.1 Forests under private tenure regime
Forests under private tenure regime are owned by individuals with rights that exclude others from the use of the forest resources (URT, 1998). The amount of forests under private ownership is small, and dominantly takes the form of woodlots in between agricultural fields. The study shows that 38 percent of the households in the Rungwe pilot project site owned woodlots/forests privately. In Kondoa, the equivalent was only nine percent. The different levels were related to differences in history. In Rungwe, a substantial part of the forests are found in the Mount Rungwe Forest Reserve, currently a Nature Reserve. These changes in status have imposed relatively stricter resource use controls to the surrounding communities. As a result, most of the households have established woodlots in the agricultural landscape as an alternative way of ensuring the availability of the necessary sources of energy. As we shall see later, both the WCS and the district authorities in Rungwe have constantly promoted such a development.

The low number of woodlots in Kondoa, on the other hand, could be attributed to less strict regulations of forest reserves regarding fuel-wood collection and reluctance of the local community to adopt environmental conservation technologies due to bad experiences with the SIDA-initiated HADO (Hifadhi
Ardhi Dodoma) project interventions in the 1980/90s. The approaches which were adopted by HADO project during the implementation were claimed to be top-down and technocratic, hence resulting into low acceptance by the community because it necessitated the community to reduce their economic activities, for example, reduce livestock, move shifting cultivation, which had a negative impact on their livelihoods (Garrett and Emmanuel, 2010).

Private ownership of forests does not automatically ensure the right-to-use the resources. In Tanzania, the extraction of forest resources even in private forests including timber and poles demands a legal permit from the government. Nevertheless, the majority of the private forest owners (87 % in Rungwe and 93 % in Kondoa, respectively) stated that they had user rights for all resources in the forests they owned. This conflicting understanding of the rights to forests situation is very typical in Tanzania, and it creates a great challenge for REDD+.

3.2.2.2 Government forests

Forests in Rungwe district are mainly under the central and/or local government authorities. According to the District Natural Resources Officer (Mr. Chibwaye, Pers. Comm.), there is a mixture of plantation and natural forests in the district. The plantations include Kiwira, which covers about 2,634 ha, owned by the central government and four other softwood plantations covering an area of 60 ha, each owned by the District Council. There are also numerous privately-owned softwood plantations around the district covering about 46,000 ha. On the side of natural forests, there were seven proposed village forest reserves which covered from about 2-640 ha. These forests were Kinyala, Swaya, Nkunga, Ilima, Milima Mbambo and Kipapa. But none of these forests are found in the study villages. With regard to natural forests owned by the central government, a total of 11 forest reserves ranging from about 45 - 855 ha exist in the district. These include Mount Livingstone, Mount Rungwe, Sawago, Kitweli, Masukulu, Kyejo, Isaka, Nyiru Bamboo and Kyosa-Rungwe reserves.

The findings show that respondents in the study villages had no user rights over the resources in the government forests. Access restrictions were strengthened as the two forests in the area—Mount Rungwe and Livingstone—acquired the status of ‘nature reserves’ which by design have stricter access rules than forest reserves. The contribution of the Mount Rungwe Nature Reserve to the livelihoods of local communities was, thus, heavily constrained by the prevailing state tenure regime and exclusive state management. In other forests with a normal status of a ‘reserve’, access was rather loose. Information from forest officers revealed, for example, that the extraction of forest resources was restricted to particular forest products. These products included dead wood for energy purposes and a variety of non-timber forest products (NTFPs). It was also found that non-destructive activities such as traditional rituals and medicinal plants were also allowed in the nature reserves.
In Kondoa, 50 percent of the respondents reported to have user rights to resources in government forests of Salanga, which is under the central government, and Isabe, which belongs to the District Council. Together these forests covered an area of about 18,000 ha which were under the management of the REDD+ pilot project. These forests were managed through the Joint Forest Management (JFM) system. This system involved local communities in the management and use of government forest resources. According to the feasibility studies for REDD+ interventions in the area (CAMCO, 2010), there was a possibility of the pilot project to cover up to 22,000 ha of land. This would include state-owned forest reserves, community forests and private forests.

Though being more exhaustive than in Rungwe, the user rights in government forests were here also restricted to some products. This was because in government forests under the JFM regime, the government retained most of the managerial responsibilities either through exclusive control, or by granting limited user rights. The rights include non-commercial use rights and permits to hunt and gather dead wood and NTFPs. Monela et al. (2000) reported that lack of property rights for the local communities residing around forest reserves in Tanzania was a major obstacle to the extraction of forest resources, which discouraged them to get involved in forest conservation in the longer run. This observation is relevant to the current situation in both study sites.

On the other hand, studies have shown that JFM may offer improvement in forest management as compared with exclusive state management. Kajembe et al. (2003), for example, argue that JFM is likely to improve livelihoods of forest adjacent communities through the introduction of alternative income generating activities. Furthermore, a comparative study carried out by Blomley et al. (2008) in six forests under JFM and six under exclusive state management found that JFM forests had better forest conditions than the state-managed forests. Because of the positive impacts that are being seen regarding livelihoods as well as emission reductions, there is growing interest in using participatory approaches as an institutional framework for REDD+ in Tanzania (Zahabu, 2008).

### 3.2.2.3 Community forests

Results of the study also show that there are community or village forests in both study areas. A substantial part of these forests were under Community-Based Forest Management (CBFM). However, no data existed on the size of these forests. In the case of Kondoa site, five villages (Kisese Sauna, Mitati, Mkurumuzi, Kikore and Madege) out of 21 under the pilot project had community forests under CBFM, meaning that most communities still depended on the state-owned forests for their energy supply. Analysis of user rights for villages with forests under village land but not on CBFM status show that nearly every household had access to these forests provided they followed proper procedures of securing
access permission from relevant authorities. Such authorities included the Village Natural Resources Committees.

The autonomy of local communities’ in the management of forest resources had increased accessibility to resources and improved forest conditions. Hence, the majority of the households (76% and 80% in Rungwe and Kondoa sites, respectively) were satisfied with the rules that governed the use and management of the community forests. This could be attributed to the fact that the local communities were involved in making the rules that govern and manage the forests, including the perceived appropriateness of conflict resolution mechanisms.

The general perceptions of the forest managers in the study sites was that greater tenure security and institutional autonomy of forests under CBFM contributed to more effective management. This observation tallies well with findings from elsewhere in Tanzania. For example, a study by Persha and Blomley (2009) in the forests of Usambara Mountains in Tanzania found fewer incidences of disturbance in forests under CBFM than those under JFM which were better than those under exclusive state management. Moreover, the study by Zahabu (2008) conducted on strategies to involve forest communities in global climate policy found that community forests were more effective in ensuring carbon storage and sequestration than unmanaged forests, which supports the view that CBFM could be a good strategy for REDD+.

### 3.3 Piloting REDD+

Communities in both pilot projects were aware that climate was varying and changing. Many of the people could tie the changes to the rise in temperatures, unpredictable precipitation patterns, as well as increased crop and livestock diseases. The results further show that most of the people understood the role that forests play in regulating micro climates as well the overall global climate. However, it was surprising to note that 72 percent and 68 percent of community members in Kondoa and Rungwe, respectively, considered REDD+ as ‘business as usual’ initiative concerning forest management. The negative perception of REDD in the two study sites was historically determined through the previous forest conservation initiatives and land tenure situation in Tanzania. For example, in Kondoa district the past negative experiences from HADO have made people to equate REDD initiatives with being pushed away from their land. It was further revealed that communities participating in REDD+ activities were sceptical about positive social benefits from the initiative. On the other hand, the Mount Rungwe pilot project negative experience to the people on the way the forest was upgraded to Nature Reserve (NR). It is clear that the upgrading of Mount Rungwe to nature NR was an effort from WCS who are the key implementers of REDD+ project. In the process of gazetting
the NR, some people lost pieces of land and access to the resource which they used to have prior to the gazette-ment. In addition, in the Mt Rungwe pilot area it was quite clear that people were scared of REDD+ initiatives believing that it was administered by the Tanzania National Parks (TANAPA), which is unpopular among the local people in the project site.

On the aspect of the present tenure situation in Tanzania, where poor people have limited access and ownership to land, the findings show that people were worried that the REDD+ initiatives might increase tenure insecurity, hence making poor local people vulnerable to dispossession of land. This was attributed to the probability of increasing land values due to a growing carbon market. This might also create a conflict of interest on the priority use of land by prioritising tree-planting over food production. Given the shortage of land facing most of communities in the pilot sites, landless people were worried about not being able to hire land or borrowing land in near future since all the land would be planted with trees.

Apart from concerns raised on the individual/private lands, the study also revealed related concerns about local use rights in government forests, both in general land and forest reserves. This challenge was raised in the Mount Rungwe pilot project site since in this site the REDD+ pilot project was implemented in the National Park/Nature Reserve where there is no access and user rights at all. If these lands were set aside/protected for carbon storage according to REDD+, who should be the beneficiary of the compensation? Is it the owner (the state) or the communities surrounding the Forests? A detailed discussion on these challenges will be provided in the subsequent sections.

### 3.3.1 Implementation Status

Both piloting NGOs—the AWF in Kondoa and the WCS in Rungwe—have their main experiences in wildlife conservation. REDD+ as a new concept presents a big challenge for both when it comes to the issue of competence. In this regard, we note that the pilot projects are oriented and organised quite differently as discussed below.

#### 3.3.1.1 The Kondoa REDD+ pilot project

As informed by AWF (Matilya, pers. comm.), the establishment of the project started with a launching in Kondoa town in 2010 whereby village and ward leaders and officials from the District Council and representatives of NGOs that operate in the area attended. In all, 21 villages that surround Kolo Hill Forest Reserves were invited to join the REDD+ project. Of these, 19 villages agreed to participate whereas two declined. Several others hesitated at the beginning but later agreed to jump onto the bandwagon. Scepticisms arose from several issues, including fear over land grabbing and exclusion from the use of forests, especially for grazing (Matilya, pers. comm.). The pilot focused on establishing
alternative livelihoods and the necessary institutions and organisations to make REDD+ initiatives feasible. In so doing, AWF engaged with the District Council, the communities (through their village councils) and consultants.

A core component of this pilot project was the establishment of land use plans (LUPs) for the participating villages. LUPs were expected to specify borders between villages and define uses for different land uses, including setting aside land for productive and protective purposes. According to the Land Use Planning Act (URT, 2007), land use planning at the village level should be done in accordance with the Participatory Village Land Use Planning (PVLUP) guidelines of 2010 (URT, 2010).

The Enactment of the Land Act Cap 113 (1998a) and the Village Land Act Cap 114 (1999a) and Regulations form a basis of land administration and management whereas the Enactment of the Environmental Management Act Cap 191 (2004) and the Land Use Planning Act Cap 116 (2007) are the basis for the harmonisation towards effective planning and management of land and its natural resources. Following this harmonisation, Village Councils may divide village lands into three categories: communal land, which is shared by a large number of individuals within the village and may include pastures, forests or other areas with natural resources; occupied land, which is used for housing, cultivation and businesses, and managed by individuals or families; and future land, which is set aside for future use by individuals of the community. The Act further allows village governments to enter into agreements with enterprises that invest in and provide resources for improving the well-being of villagers.

AWF argued that they did not have the necessary land use planning competence and, hence, they engaged the National Land Use Commission to undertake land use planning. The discussions with the DNRO for Kondoa (Mr. Mvungi, pers. comm.) revealed that LUP was going rather slowly due to the necessarily rigorous process involved in the preparation and approvals at different levels. This lengthy process delayed the implementation of subsequent activities, including the introduction of PFM initiatives. By the end of 2013, however, all 19 villages involved had finished the process of making their land use plans. The plans were by then at different levels of approval, though. Thirteen out of 19 villages were participating in the Joint Forest Management programmes of their surrounding state-owned forests. These forests included Salanga and Isabe Forest Reserve. The villages benefiting from this arrangement included Bereko, Bukulu, Filimo, Humai, Itundwi, Kandaga, Kolo, Kwadinu, Mapinduzi, Masange, Masawi, Mnenia and Salanka.

The importance of land use planning for village land management has been emphasised in the Village Land Act No 5 of 1999 such that it is now obligatory for every village to prepare a land use plan. The land use planning Act No 6 of 2007 further elaborates that obligation by establishing the village council as the planning authority.
The other six villages operated CBFM on forests earmarked during land use plans. These villages included Madege, Kikore, Mkurumizi, Mitati and Kisese Sauna. According to Matilya (pers. comm.), most processes for completing the management of the forests under JFM arrangements were had been the final stages of approval by the end of 2014. For example, a joint Committee on Environmental Management in the two responsible divisions of Bereko and Kolo had developed bye-laws which had been approved by all village governments and, subsequently, by the District Council. With regard to the CBFM process, three villages out of six had approved their forest management plans by end of 2013 and subjected them to different stages of approval at the district level. The other three villages were working on finishing their management plans which were expected to be finalise and subsequently approved by the end of 2014 (Matilya, pers. comm.).

3.3.1.2 The Rungwe REDD+ pilot
The pilot project in Rungwe less focused on engaging villagers. Instead, it was primarily concerned with four outputs: a) establishment of baseline estimates for carbon; b) participatory monitoring and capacity-building; c) development of a leakage remedial and monitoring framework; and d) improvement of livelihoods, including fuel-wood availability for local people (Chibwaye pers. comm.). on the basis of this orientation, the Rungwe pilot project can be described as ‘conservation without compensation’. Although there was some focus on livelihoods, for example, supporting communities in bee-keeping and establishment of woodlots, these interventions were not directly linked to the REDD+ project which exclusively concentrated on the Mount. Rungwe Nature Reserve. Here measuring carbon and building monitoring capacity were the core elements. Parallel to this, it was observed that the WCS avoided raising unnecessary expectations among the local communities due to uncertainties surrounding the REDD+ payment mechanisms. Moreover, their strategy towards communities was mainly concerned with raising awareness on the perceived conservation benefits. It should be noted here that WCS’ main capacity lay in the natural sciences where it believed that sustainable forest conservation should be done by facilitating non-forestry livelihood pathways and not through compensatory payments. Hence, land use planning was not an integral part of the strategy for this pilot area (Mpunga, pers. comm.).

Regardless of the WCS’ downplaying of the component of compensation to the communities, it was learned that people were informed through various sources that REDD+ in a way meant ‘payments for foregone opportunities’ (Chibwaye, pers. comm.). This might have serious negative implications in future if the WCS went on to stick to the ‘don’t pay’ approaches as they could lose trust among the local communities. After all, village representatives had been following up the matter informally with the district authorities
and other stakeholders regarding the issue for compensation for various effects stemming from such a project. On the other hand, if payment were to be effected during the pilot project and then cease thereafter for whatever reason, the future of conservation could also be compromised. Either way, some clear path ought to be charted with clear community participation.

3.3.2 Emerging conflicts in the pilot sites

3.3.2.1 Emerging conflicts in the Kondoa site

The main conflict in Kondoa district concerned future access to forest resources pertaining especially for grazing land. People in Kondoa had negative past experiences from the HADO project whereby one of the measures was destocking. People with large herds of livestock were forced to reduce the number of animals, which forced some households to migrate to other areas (displacement) to look for grazing land. In this regard, the FGDs revealed substantial dissatisfaction with HADO. People did not sympathise with the aims of the project as they strongly believed it simply invited opposition. As a result of the HADO experience, many people in some parts of the Kondoa project area tended to equate REDD+ initiatives with being again pushed away from their land. Furthermore, the FGDs revealed that many people saw little prospects for positive social benefits accruing from the latest initiative.

The situation varied quite considerably across the villages, though. First, it was noted that while the AWF tried to involve 21 villages in the pilot project, two of these villages (Kisesedisa and Itololo) were quite negative from the onset and decided not to endorse REDD+. None of these villages had village forests, for example, they depended solely on adjoining government forests for resources, including pastures. The issue was also rather tense even in villages beyond these two, especially those with community forests that could be incorporated into the CBFM regime, as it constituted a new management regime. As a result, Mitati village decided not to approve the land use plan and was, therefore, automatically removed from the project as land use was one of the participation criteria. The village simply opposed inclusion of their village forest into REDD+. During a meeting with village representatives at Bereko—including representatives from the village council, land use and environmental committees—it was observed that there were quite distinct differences in views among the participants. Whereas the secretary of the Environmental Committee strongly advocated for conservation, including destocking, others voiced that REDD+ would result into greater problems not least regarding restricted access to pastures. Again it was noted that all the forests surrounding the village were government forests.

For the evaluation of the text, note that this village was not among the three villages hesitating to endorse REDD+. 
Hence, many villagers emphasised the issue of land scarcity and the fact that they had no forests on their own whose use they could control.

The negative experience with the HADO project was again emphasized. It was noted, though, that REDD+ was better in that it engaged local communities. It was also further observed that REDD+ rules being developed for this village seemed to include some rights to grazing in government forests. Hence, rule formulation was sensitive to local needs whereas the limits imposed were sensitive to the carrying capacity of the forests, implying tentatively five herds per household. Some herders had many more, some as many as 20-30 animals.

In another village—Mnenia—the views concerning REDD+ were quite different. From the meeting representatives from the same committees as in Bereko it was evident that there was clearly less land scarcity, and that the village had its own forest. In the process of endorsing REDD+, some worries were nevertheless voiced even here. However, when people learned that they could get permits for collection of fuel-wood and building materials, the villagers accepted to participate. Nevertheless, two strategies were under development to reduce dependence on forests—these were tree planting/wood lot creation and zero grazing. A tree planting group run by women was established and it had set up a tree nursery and a wood lot demonstration plot. Concerning grazing, the villagers planned to close forests for grazing and establish a grazing area to be used in the rainy season. In the dry season, plant residues would be used. It was generally noted that there was no clear pressure to keep forests open for grazing and that the REDD+ rules for this village did not include rights to a certain level of grazing in forests.

During a discussion with key informants at the district level it was established that the district authority was worried about the long-term sustainability of the Kondoa REDD+ project. They noted that it was run by an NGO and using a lot of external consultants in establishing the pilot. The study noted also that there could be some validity to the argument based on the criteria required to make the project sustainable. To ensure the long-term sustainability of the REDD+ piloted project and to restore the lost hope of the local communities on the sustainability of the donor-funded project, involvement of key actors in the whole process of project design and implementation becomes important within the district, particularly at the grassroots level.

### 3.3.2.2 Emerging conflicts in the Rungwe site

A major issue in Rungwe was the relationship between the local communities and the Nature Reserve (NR). The NR was established on the basis of an initiative by WCS. In gazetting the NR, some people lost pieces of land and access to the resources which they used to have prior to the gazette-ment. Although the
laws, especially the Wildlife Conservation Act No. 5\(^5\) (URT, 2009b), Wildlife Policy (URT, 1998b) and the Resettlement Policy Framework (URT, 2003) grant local communities the right to be compensated for losses following increased protection status, in practice these compensations are typically low. They do not acknowledge all prior uses and sometimes the affected people are not even paid. As the REDD+ project focused exclusively on carbon sequestration in the NR, local communities had no way of linking this to the recourse and demand their part of the potential compensation that would exclusively go to the state.

Two things were observed, however, which could be done to handle the matter fruitfully and reveal the best practices for REDD+ implementation. First, the establishment of JFM could be a way to include local communities in the REDD+ endeavour. This could be accompanied by compensation and introduction of new income opportunities to re-address (some of) what may be seen as injustices made when establishing the NR. It was clear that some households had to give up their potential areas for expanding farming activities which were included into the forest boundaries. Although WCS management acknowledged the proposed solution during key informant discussions with the project team, they indicated that they had neither the legal competence nor the practical experience to engage in this matter. In a way the proposed solutions were contrary to their philosophy of conservation. Their interest lay in having total conservation without compensation. The findings illustrate that organising REDD+ pilot projects via conservation NGOs in Tanzania restricts the establishment of a true image regarding how the matter should be handled, since the kind of issues to be implemented in the pilot project to test for best practices might be overlooked or completely ignored by concerns and interests of NGO.

Secondly, the way the issue of compensation in relation to government forests/protected areas is treated, may be very important for the legitimacy of REDD+ both nationally and internationally. Focusing on the latter, it may be problematic for REDD+ if national distribution of internationally-created REDD+ resources is not based on rules that are acceptable. Hence, Tanzania needs to urgently start a process on how to handle compensation issues in the case of forest reserves and protected areas. At the same time, if the international community demands that payments should only be for additional carbon sequestered, compensation

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5 According to the Act No.5 Cap. VIII Section 71.–(1), the Minister may in public interest and after consultation with the Minister responsible for finance, make regulations specifying the amount of money to be paid as a consolation to a person or groups of persons who have suffered loss of life, livestock, crops or injury caused by dangerous animals: whereas subsection (2) stipulates: ‘Without prejudice to the provisions of subsection (1), the Minister shall make regulations prescribing the payment of consolation money to any person for injury sustained, death or destruction of his crops caused by dangerous animals, provided that in relation to destruction of crops, no payment shall be made in excess of five acres’. 
to local communities for losses incurred before REDD+, may not be accepted. These issues demand clarification also at the international level.

Given the form of the Rungwe pilot project, the involvement of local communities was minimal. The villages in the area had established environmental committees a few years before the REDD+ project started. In a meeting with such a committee at Ndala, it was confirmed that though the committee was established by the village council, the WCS was influential in promoting for increased conservation. The study observed that members of the committee also advocated for the goal of environmental protection in a broader sense, for example not only to emphasise on water conservation but also to address climate issues.

At the same time, it was clear that some of the strategies adopted by the environmental committee created frosty relationships with other community members. For example, the protection of forests in ravines and along streams created rifts. In this regard, the study observed the development of a schism between the committee and ‘ordinary’ villagers. ‘What is really in it for us?’ the villagers asked. They emphasized the fact that those who gained from what they did were mostly downstream energy plants.

Finally, in the Mount Rungwe pilot area it was clear that people were also scared of REDD+ initiatives as they misconceived it to be administered by the Tanzania National Parks (TANAPA) operating with fully armed patrols. This misunderstanding could be attributed to the fact that the Kitulo National Park under TANAPA surveillance is rather close to the Mount Rungwe pilot project area. Although that TANAPA is only responsible for the management of the national park, conservation activities in nature/forest reserves are also conducted in collaboration between TANAPA and forest officers. Furthermore, forest patrolling is conducted outside the reserves where it is difficult to distinguish sources of forest resource extraction. It was reported that any person caught by TANAPA harvesting valuable forest resources, including timber and poles, from Rungwe Nature Reserve was fined up to Tsh 50,000. Logs and all working gears were also confiscated.

Discussions with the Katumba village chairperson (Mkomwa, pers. comm.), disclosed that TANAPA restricted villagers not only from extracting forest resources but also from accessing the parks for cultural activities. As a matter of fact, local people noted that TANAPA had two faces—a friendly one emphasising co-operation with communities and a draconian one rigidly enforcing laws. Although law enforcement is the primary role of this authority, many people thought it sent out mixed signals to the communities. Moreover, TANAPA was a very centralised institution far-removed from participatory method that REDD+ is supposed to engender. As a result, it was very unpopular among local communities in this area.

It was observed that the introduction of tea and coffee plantations since the
colonial era was a major cause of land inadequacy in the Rungwe district. Discussions with the villagers revealed that before independence, tea was produced in estates which were owned by foreigners and all tea-related matters were handled by the then Tanganyika Tea Board. Smallholder tea farming began during the 1960s. In 1968, the Tanzania government initiated a full-fledged smallholder tea development programme whereby the Tea Ordinance Act (Cap 291) was amended and the Tanganyika Tea Board was replaced by the Tanzania Tea Authority. Under this ordinance farmers were not allowed to change tea estates into other land uses such as replacing tea with other crops with higher market demand. This situation has obstructed the diversification of land uses in the area. It has also created uncertainty on the adoption of the REDD+ due to potential loss of tenure security.

3.3.3 Community perceptions on trial payments

The study also explored the villagers’ views on payments/compensations. The data show that most of the people would consider stopping deforestation and forest degradation on condition they received compensation relative to the losses of income they would encounter. According to Figures 10.2 and 10.3, the responses in this regard were quite similar in both areas: Villagers preferred actions through the community rather than payments to individual households.

![Figure 10.2: Types of compensation that people prefer for them to stop forest clearing in Rungwe District (N = 130)](source: Survey Data (2011))

6 Tea was introduced in Tanzania by German settlers at the Agricultural Research Station at Amani, Tanga, in 1902. It was introduced at Kyimbila in Rungwe District, Mbeya region in 1904. Commercial production began in 1926 and increased considerably after World War II, when the British took over tea plantations.
Looking at what explains the variation in distributions, the ordered probit regressions model was adopted for each payment option and site. The predictors variables were ‘sex’, ‘age’, ‘education level’, ‘the individual’s level of trust in other people in the village’, ‘distance to nearest forest’, ‘family income’ and ‘family size’. The aim was to check the most important predictors of the payment options reported by the respondents. From these analyses, one factor stands clearly out in all cases. That is ‘trust’. High levels of trust in co-villagers reduced systematically the probability of high score on ‘individual payments’ whereas it was opposite for all community actions. The variable was highly significant with \( P \) values ranging from 0.000 - 0.002 in most options except one where \( P \) was somewhat higher (0.04). This result implies that without a high level of trust even the proposed community compensation might not benefit every individual. The latter is concerned with ‘individual payments’ in Rungwe.

The results show that in Kondoa, ‘distance to nearest forests’, ‘family income’, being ‘female’ and ‘education level’ all influenced positively the probability of scoring high on ‘individual payments’. ‘Education level’ also influenced positively the probability of supporting the solution ‘alternative sources of livelihoods’ in Kondoa (\( P=0.05 \)). In Rungwe, ‘family income’ influenced negatively the probability of scoring high both on ‘alternative sources of income’ and ‘better social services in the community’ (\( P \) values being 0.01 in both cases). Hence, higher income seems to point towards wanting individual payments (Kondoa).

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7 Variables are ordered with increasing \( P \) values – \( P=0.002 \) in the case of distance till nearest forest till \( P=0.087 \) in the case of education level.
or not favouring community action (Rungwe). Otherwise there was no clear picture that emerged in the analysis regarding this aspect. On the other hand, there was variation in the views for both districts. Hence, whatever measures are undertaken, some conflicts should be anticipated.

4.0 Conclusion and Recommendations
Experience from REDD+ pilot projects reveals that there is a very high level dependency on forest resources by the communities surrounding them. However, the level of dependency in Kondoa was higher than in Rungwe primarily because most of the households in Rungwe own some woodlots through which they can access some products for fuel and timber. Although some households in Rungwe still depended on natural ecosystems for earning their living, the transformation of two forest reserves into nature reserves and the upgrading of Kitulo Game Reserve into a national park both signified imposition of restrictions on community access to some forest products that they hitherto used to get. In this regard, the local believe that the introduction of REDD+ would further increase resource scarcity in the area. The general assessment shows that land ownership in both study areas was mainly private.

The introduction of REDD+ seems to depend largely on the completion of land use plans, especially in Kondoa where AWF had set it as a criteria for inclusion of a village into REDD+. However, the process was rather slow due to its long approval processes. As a result, it delayed the implementation of some REDD+ activities such as setting up of REDD+ forests, implementation of trial payments and the implementation of participatory resource assessments. Although REDD+ piloting is based on the community sensitisation and promotion of private engagement in conservation, the situation in Kondoa is more on the PFM mode of arrangement. The assessment has shown that tenure security and institutional autonomy of the CBFM are prerequisites in securing community livelihoods, especially now when the tenure of carbon is uncertain.

Based on the early experiences from the study sites, it can be concluded that for successful REDD+ projects, both social and environmental benefits should be considered during the designing and implementation of the projects. The study further suggests that promoting successful REDD+ initiatives entails early engagement of the communities and their political figures from establishment and subsequent implementation is equally important.

As the Rungwe pilot project involved a relatively higher status level of protected forests, it is important that community management programmes are introduced to ensure that community livelihoods are not compromised in the name of environmental conservation. Actually, the Rungwe project could be used as a ‘test ground’ for how carbon projects in protected areas could be designed so that
they can ensure poverty alleviation. Currently, there is no strategy developed in Tanzania on how income from carbon credits from government-owned forest lands should be distributed. As a result, most of the NGOs piloting REDD+ have decided to exclude reserved forests to maximise community incentives through village/community forests.

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REDD+ readiness in Tanzania
Assessing the financial Accountability mechanisms at the Local Government level

By Henry Chalu, Razack Lokina, Agnes Mwakaje & Desmond McNeill

Abstract:

REDD+ has a potential of contributing to reducing poverty, combating global warming, and conserving biodiversity. Amongst its challenges is the issue of governance. The issue of governance arises as one of the crucial actors in REDD+ implementation are local government authorities (LGAs). The LGAs are crucial for not only ensuring regulations are followed, but also in ensuring that REDD+ finances are used to improve welfare of the adjacent communities and conserve forests. Nevertheless, a question that has not been addressed by many previous studies in REDD+ is whether the LGAs have the capacity to handle REDD+ money (in other words financial readiness for REDD+ implementation). This chapter, therefore, argues that addressing the LGAs financial readiness for REDD+ implementation needs to focus on financial accountability mechanisms in these LGAs. It is based on a study that analyses the availability and effectiveness of such mechanisms in LGAs to manage REDD+ money. Theoretically, the study builds on the literature on accountability and REDD+ finances focusing analytically on two aspects: tools (disclosure reports and performance assessment and evaluations), as well as process mechanisms
(participation, self-regulation and social auditing). This study draws data from four districts in Tanzania: Kigoma, Kilosa, Kilwa and Kisarawe, based on documentary review, interviews and focus group discussion. The data, though varying between districts, reveal limitations in LGAs' capacity to implement REDD+. LGAs were also found to have hitherto played a very limited role until now compared with NGOs, while on the other hand for the NGOs to operate efficiently to some extent are on LGAs.

**Keyword:** Reducing Emissions from Deforestation and Degradation (REDD+), LGAs, forest conservation, financial accountability, REDD+ finances, social auditing, strategic accountability

1.0 Introduction

Reducing Emissions from Deforestation and forest Degradation (REDD+) initiatives are crucial not only for conserving biodiversity and combating global warming but also in contributing to the reduction of poverty and achievement of sustainable development (Atela et al., 2014; Ebeling and Yasué, 2008; Groom and Palmer, 2012; Mwakaje et al., 2010; Peskett et al., 2008; Peskett et al., 2006a, 2006b; Pinho et al., 2014; Somorin et al., 2014). Although these studies have underscored the potential of REDD+ in poverty alleviation and achievement of sustainable development, they have recognised the importance of several factors which can make REDD+ meet desired objectives. According to Peskett et al. (2008) there is a need to take into account issues such as the provision of information, upfront finance and use of mechanisms to reduce costs, and technical assistance to LGAs, in addition to strengthening local legal institutions as well as ensuring accountability and transparency in REDD+ processes are an integral part of the conservation initiatives. Indeed, for REDD+ to be successful in both conserving the forest and enhancing human development, governance and institutional issues are important ingredients.

Resolving the accountability and transparency issues as part of good governance can help to address barriers to small producers such as lack of certainty and predictability, potential high transaction costs for REDD+ implementation as well as minimising risks (Peskett et al., 2006a). According to Ebeling and Yasué (2008), countries with high REDD+ potential but scoring low in the governance index may not be better placed to benefit from REDD+. Also Somorin et al. (2014) analysing the governance structure of REDD+ in Cameroon found that one of the challenges is defining the roles of various actors (for example, the civil society and the private sector) from designing institutional rules and guidelines to building an existing governance goals for REDD+.

As McNeill (2014) observes, when REDD+ was created it created an impression that it will be cheap and easy to implement but the opposite has been found to be true. This complexity threatens to reduce the potential benefits to the
poor and minimise the achievement of long-term objectives of projects. Some of the challenges are described in Peskett et al. (2006b) and also by Somorin et al. (2014). Although the issues these authors identify are pertinent to REDD+ implementation, they focus only to a limited extent on good governance as it relates to REDD+. Despite the increasing recognition of the importance of governance issues in the implementation of REDD+ (see Ebeling and Yasué, 2008; Hobley, 2007; Mwakaje et al., 2010; Peskett et al., 2008; Somorin et al., 2014), the focus has mostly been on broad, macro level issues (such as implementation at the national level, and the involvement of civil society and donor organisations in policy formulation) (see, for example, Hobley, 2007). There appears to be little attention paid to the role of local government authorities (LGAs), one of the crucial institutional set-ups in most countries where REDD+ is implemented, in enforcing financial accountability as it relates to project implementation. Few studies have focused on LGAs’ involvement in REDD+ and climate change in general (Bulkeley and Kern, 2006; Pacheco, 2003). But to ensure that REDD+ implementation is successful there is a need for focus to be directed towards LGAs. As Bulkeley and Kern (2006) point out, the successful implementation of the climate change programme requires the enhancement of the capacity of LGAs. Although governments have generally been implementing decentralisation policies, these policies have their own challenges, which have not been sufficiently addressed. Decentralisation to the LG level may not necessarily lead to better outcomes for the poor or better resource allocation LG institutions may exploit the poor just as much as the central government (Hobley, 2010). He one might also add than systemic financial regulation and accountability problems even at the LG level when not addressed might affect the operations of REDD+ in their respective areas with far-reaching consequences. In fact, these threats create limitations which may ultimately affect not only the management of forest resources (Pacheco, 2003) but also sustainable conservation of these resources. More specifically, they can have negative consequences on the finances generated through REDD+ due to a lack of appropriate measures to ensure that the money generated contributes to conserving biodiversity as well as human development. Literature shows that limited capacity at the LGAs level can create numerous problems such as corruption, low accountability, lack of transparency, low participation, elite capture and minority marginalization (Tanzania National REDD+ Strategy, 2010).

As Hobley (2007) contends, LGAs dealing with forests tend to be accountable to the central government authorities rather than to the local people, hence limiting the effectiveness of participatory forest management (PFM) in place. This problem can be attributable to lack of financial resources and capacity as identified by Burgess et al. (2010) and Mwakaje et al. (2010). One of the consequences of lack of financial resources and capacity at LGA level is that most projects become donor dependent or implemented by NGOs. This
tends to increase upward accountability and reduce downward accountability. Although upward accountability is important, too much of it at the expense of downward accountability may reduce projects to top-down initiatives. As found by Agyemang et al. (2009) that top-down initiatives may be unaware of local conditions, with the consequence that projects may not be sustainable because of weak local support.

Studies conducted on the financial aspects of REDD+ so far have focused mainly on issues such as sources of finance for REDD+; money, costs and benefits; payments mechanisms; and financial incentives of REDD+ initiatives (Griffiths, 2007; Mwakaje et al., 2010; Ogonowski and Enright, 2013; Hobley, 2007; Peskett et al., 2008). The aspect of financial accountability has been given limited attention, although most of these studies show that there are some weaknesses in financial accountability in REDD+ implementation and particularly at the LGAs level. For example, Hobley (2007) recognises the limited effectiveness when money is devolved at the local level and particularly if that money is distributed to non-representative groups. Likewise Ebeling and Yasué (2008) found that weak financial accountability can make it difficult to ensure that REDD+ money is passed on to benefit rural areas in addition to supporting conservation initiatives. Here financial accountability is not only linked to compliance (that LGAs account for the money according to the law) but also to the performance of REDD+ (i.e. economy, efficiency and effectiveness) to achieve long-term objectives. As Peskett et al. (2008) argue, REDD+ projects can only be successful at the local level, if financial accountability mechanisms of LGAs are effective and LGAs can handle effectively REDD+ money. This is an issue that deserves greater attention: Do the LGAs have adequate financial accountability mechanisms to manage REDD+ money if they get it? Are the LGAs ready to handle REDD+ money and achieve the set objectives?

This study attempts to answer these questions by examining financial accountability mechanisms available in Tanzania’s LGAs. After all, lack of financial accountability mechanisms may encourage large amounts to be misused or distributed outside the governing structure, hence leading to corruption of local leaders (Hobley, 2007). Following decentralisation there are some forests under the control of the LGAs (see, for example, Mwakaje et al., 2010; Pacheco, 2003) which may serve as a source of money to the LGAs as well responsibilities to ensure that some money is invested back into conserving biodiversity. According to Peskett et al. (2008), REDD+ is potentially considered to involve a large sum of financial resources for the protected areas. Much more specifically, this study seek to assess the capacity of the LGAs and their institutions in managing forest resources and implementation of REDD agenda; establish the relative financial contribution from forest-related resources (such as charcoal, timber, logs and so on) accruing for LGAs (from the village to the district level); and to identify factors that hinder or support effective financial accountability at the LGA level. On the whole, the study seeks to establish a clear understanding of the
roles of LGAs in fostering financial prudence and accountability relation to REDD+ initiatives to make governance and transparency an integral part of the sustainability of these initiatives at that local level. In this study, therefore, we seek to address the following primary question: To what extent are current financial accountability mechanisms in LGAs adequate for managing REDD+ money? We address this question by first by reviewing the roles of LGAs in relation to forest management and REDD+ initiatives; second, by reviewing financial accountability mechanisms available and their relations to the REDD+ initiatives. Third, by outlining the methodology and provide results from our qualitative studies of three REDD+ projects in Tanzania. Finally, by discussing our findings and providing conclusions.

2.0 REDD+, LGAs’ roles and financial accountability: frameworks for understanding

This section reviews various financial accountability mechanisms and develops a conceptual framework based on Ebrahim (2003). Even though this framework was identified by Ebrahim (2003) to apply to Non-Governmental Organisations (NGOs), in our view those categories are relevant for LGAs for a number of reasons. First, the mechanisms take into account the expanded form of financial accountability, which includes compliance and performance aspects. As Rabrenović (2009) argues, financial accountability does not only deal with verification of legality and regularity of financial accounts, but also with making sure that there was value for money in the use of resources. Second, the categories also reflect adequately good practices for public environmental expenditure management (PEEM) as developed by the OECD. According to OECD (2007), the good practices cover three key areas: environmental effectiveness, budgetary good practice (fiscal prudence) and management efficiency. Third, the settings of LGAs have multiple sources of accountability hence the framework can help in identifying various sources of accountability for LGAs. As Barr et al. (2009) contend, LGAs are one of the state agencies that may be required to handle REDD+ money in terms of managing finances and administering revenues, dealing with corruption and fraud and protecting assets, monitoring, reporting and verifying financial transactions, aligning incentives, ensuring accountability and distributing benefits equitably.

2.1 The REDD+ context in Tanzania: an institutional framework and roles of LGAs

Forest management is increasingly becoming a popular issue among policymakers, academics and even local people. Apart from conserving the environment as a natural resource (Robinson and Kajembe, 2009; Lokina and Robinson,
people can now generate income and even earn their livelihoods from managed forest. Recognising these benefits from forest products to the local communities, studies have focused on the management of forest and harvesting of forest products. For example, Mustalahti and Lund (2010) found that communities in Tanzania could generate substantial benefits from the utilisation of forest products once PFM is implemented adequately, though its implementation has been slow, especially in areas with high forest resources. It was noted, however, that the introduction of PFM in Tanzania has imposed new restrictions on the communities’ access to forests, which is likely to affect where people extract forest products (Robinson and Kajembe, 2009; Lokina and Robinson, 2009). As a result, while the objective of the participatory forest management is to protect forests, including ecosystems and biodiversity, restricting access for the local community to these resources might negatively affect them and, hence, create resistance, even if alternative income generating activities may be introduced with participatory forest management (Robinson and Kajembe, 2009).

Points raised by Robinson and Kajembe (2009) on the issue of resistance from the local community to PFM are connected with the earlier findings by Ylhäisi (2003) on ways in which different land ownership models affect forest management in terms of environment conservation. Ylhäisi (2003) claimed that local people’s participation is important for forest management through community-based management. According to Ylhäisi (2003), the government and forest officials have to realise that for effective forest management there is a need to listen to local people. Kihiyo (1998) adds an important aspect of the role of government organs (be they central or local) in forest management. This aspect has not been addressed clearly by most of the previous studies. Limited literature such as Blomley and Ramadhani (2005) attempted to address the role of various levels of government in forest management. To address that Blomley and Ramadhani (2005) contrast two approaches to participatory forest management through joint forest management (JFM) and Community-Based Forest Management (CBFM). JFM takes place on land reserved for forest management such as National Reserves and Local Government Reserves. Also, JFM, which is formalised through a Joint Management Agreement, indicates the responsibilities of villages, district councils and relevant sector Ministry. On the other hand, CBFM takes place on village land whose schemes are managed by village councils. For these two approaches to participatory forest management, Blomley and Ramadhani (2005) argue that there is a need to build government structures by transforming government institutions and building the capacity of LGAs to respond effectively to the demand of PFM. These views are consistent with earlier arguments by Mowo, Mwihomeke and Mzoo (2002) to the effect that forest management efforts have not been successful for failure to take into account local communities as an important cog in the whole forest management exercise.
Much of the literature in Tanzania focuses on two issues: community participation in forest management through PFM and local community access to forest products. In the literature, success of the PFM is typically judged by the level of local community involvement and benefits of extraction from the forest. However, the question which has not been addressed has to do with the benefit to the local community where access to forest is restricted or incentives provided to the local communities adopted to keep the forest. As Robinson and Kajembe (2009) point out, the restrictions to forest are likely to invite resistance from the local community, especially if necessary incentives are not forthcoming. For the local community and LGAs, who are beneficiaries of the forest products, to participate in the forest protection, there is a need for a different source of income to sustain the livelihoods at the household level and provide funds at the LGA level.

Zahabu et al. (2005) reviewed the benefit sharing mechanisms of forest management in Tanzania and proposed payment for environmental services (PES) including carbon sequestration, biodiversity conservation, watershed protection and landscape beauty. Although these environmental services are necessary for forest management at the local level, there is no market for the services. In this regard, the government would have to create some market to reflect the value of the public good. For example, according to Zahabu et al. (2005), the beneficiaries from environment services, such as watershed management may include hydroelectric facilities, clean irrigation and domestic water user. Under this arrangement, the urban people would pay for environmental services to respective LGAs. Another important consideration is that LGAs are using taxes from forest products as a major source of revenue, so that changing the approach to support environmental efforts would definitely change their approach to revenue generation. As Zahabu et al. (2005) note, since the financial capacity of these government institutions is very limited there is a need to explore possible financial mechanisms for compensating environmental protection. This problem is also identified by the REDD+ initiative in Tanzania in its brochure entitled ‘Tanzania’s National REDD-Readiness Programme’, which identifies one of the challenges as developing flows of benefits of maintained forest under local management.

2.2 Financial accountability mechanism in LGAs and their implications on REDD+ money: a theoretical perspective

Although there is now substantial literature on payment for on environmental services (PES) elsewhere in the world, there is much less information, or discussion, on the role of the LGAs in the marketing of environmental services. As Lokina and Robinson (2009) have argued, for PES to succeed, there is a need
to bridge the interest of various groups such as landowners, villagers, and other beneficiaries. Here, LGAs would have a crucial role to play. However, despite the importance of LGAs in the management of community affairs, including land and forest, the literature on PES largely ignores them.

Financial accountability is concerned with ensuring that public money has been used in a responsible and productive way. According to Rabrenović (2009), this does not only involve verification and regularity of financial accounts, but also making sure the value for money has been achieved in the use of resources. This is an expanded view of financial accountability, which is consistent with Ebrahim (2003) as well as Najam (1996). Studies focusing on financial accountability examine how financial management systems help to improve governance and accountability in the public sector organisations. However, Premchand (1999) has noted some gaps in existing financial accountability mechanisms. First, access to financial information by public does not allow detailed scrutiny of that information. Second, annual accounts and related data show overall results without identifying factors contributing to specific actions. Third, compliance does not mean that objectives of the budget policies have been achieved or that there is a better service delivery. Fourth, the audit focus has been more on financial control process and not on efficiency or service delivery (Premchand, 1999). This implies more emphasis on financial audit than on operational audit, hence reducing the importance of value for money. These gaps show that financial accountability has focused more on the external perspective of accountability. This has reduced the main objective of financial management in public sector organisations of ensuring that resources are utilised to achieve organisational objectives. One of the key resources of the LGAs is forests. These forests serve different roles, which are significant to the economic and social well-being of the people. Likewise, the importance of the forests has been growing due to its role in reducing carbon emissions particularly of greenhouse gases. As one of the key resources, forests also need to be subjected to financial accountability mechanism. Since the existing financial accountability mechanisms have their own limitations as Premchand (1999) has pointed out, it is crucial to assess a practical financial accountability models existing in LGAs and the support for REDD+ readiness which will help the LGAs to generate benefits from the forests while providing services to conserve those forests. Establishing practical models can also facilitate the flow of the REDD funds to LGAs and to those involved with forest conservation.

To assess financial accountability mechanisms in LGAs to support REDD+ projects, we used Ebrahim (2003) and OECD’s PEEM in this study as framework as summarised from Agyemang et al. (2009) as Table 11.1 illustrates:
<table>
<thead>
<tr>
<th>Tool mechanisms</th>
<th>Disclosure reports</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Concerned with upward to funders and oversight agencies and downward (to a lesser degree) to clients or members who read reports. Focus on short term results. Ensure accountability by presence of well-functioning oversight by regulatory agencies. Mechanisms to deal with corruption, fraud and protection of assets. In REDD+, this is expected to be concerned with the availability of control mechanisms to ensure that forest funds are not misappropriated and used for forest conservation.</td>
</tr>
</tbody>
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| Performance assessment and evaluations | Concerned with upward to funders and downward to communities/beneficiaries. Assess whether and to what extent goals and objectives have been achieved. Evaluation has the potential for facilitating broader organisational change, particularly through capacity building and organizational learning. This will include assessment reports and evaluation report. In case of REDD+ this is associated with Monitoring, reporting and verifying financial transactions, the aim is to ensure that reduction of emissions is adhered. |

<table>
<thead>
<tr>
<th>Process mechanisms</th>
<th>Participation</th>
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<tbody>
<tr>
<td></td>
<td>Concerned with both downward to communities and internally dealing with LGAs units themselves. Participation will take on board issues such as community consultations and dialogue, informal reporting and participatory review of reports. In REDD+ this is concerned with aligning incentives i.e. aims to provide incentives to reduce deforestation and forest degradation. Also concerned with the distribution of REDD+ benefits equitably.</td>
</tr>
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</table>

| Self-regulation | Concerned with LGAs themselves as a sector and to communities and donors. Aim to build public confidence particularly on projects being implemented and accomplishments required objectives. This item also involves networks and membership in different associations. Development of standards or codes of behaviour and performance. Useful to help LGAs deal with the problem of public trust and also allow them deal with sector-wide problem. |

| Social auditing | Concerned with both downward and upward to stakeholders. Valuation of social, environmental and ethical performance. Promote longer-term planning and become adopted sector-wide. In case of REDD+ this may be considered under building on steps forward, avoiding steps backward. |

Table 11.1: Financial accountability mechanisms framework
Source: Adapted from Agyemang et al. (2009)
The framework divides the financial accountability into main two categories: tool mechanisms and process mechanisms. According to Ebrahim (2003), tool mechanisms refer to those discrete devices or techniques used to achieve accountability and are usually applied over a specified period. These include disclosure reports as well as performance assessment and evaluations.

The tools mechanisms are more concerned with compliance or functional accountability. According to Najam (1996), functional accountability deals with accounting for resources given, the use of resource as well as immediate impacts of resource use. In this regard, functional accountability tends to be more of upward accountability and short-term (Ebrahim, 2003). For the LGAs, the functional accountability will involve being accountable to the central government and donors for the funds received and ensure that they are not misappropriated (Agyeman, et al., 2009). As Table 10.1 illustrates, the tool mechanisms has two financial accountability mechanisms: disclosure reports and performance assessment and evaluations. On the other hand, performance assessment and evaluations are concerned with both upward and downward accountability by assessing the extent to which project goals and objectives are achieved. In case of this study which deals with REDD+, the first dimension helps us to analyse the availability of control environment to ensure that forest funds are not misappropriated. Under the second dimension (i.e. performance assessment and evaluations), the mechanisms in REDD+ are associated with monitoring, verifying and reporting financial transactions to ensure the aim of reducing emissions is achieved. According to Agyemang et al. (2009), assessments are usually done at the mid-way whereas evaluations are usually done at the end of the project. The performance assessment and evaluations can also be used by funders to determine the future requirements of funds. In this situation, performance assessments and evaluations enforce upward accountability.

Process mechanisms are concerned with broad perspective and emphasise course of action rather than end-results (Ebrahim, 2003). As such, process mechanisms are considered under what is called “strategic accountability” (Connelly and Gangloff, 2011). The importance of strategic accountability is shared by Phillips and Connell (2003) who identified five important advantages: considering decisions as important issues of strategy; measuring actions with bottom line results; helping logical movement from one issue to another; discipline and methodology as well as continuous cycle for improvement. Cavill and Sohail (2007) consider strategic accountability to be associated with organisations focusing on how they perform their activities in relation to their mission. Process mechanisms are, thus, generally more broad-based and multifaceted.

In the process mechanisms, there are three financial accountability mechanisms: participation, self-regulation and social auditing. As Table 10.1 illustrates, participation is concerned with involving beneficiaries in decisions about the
project (Agyemang et al., 2009) and this can be in the form of community consultation, dialogue, informal reporting and participatory review of reports (Ebrahim, 2003). In case of REDD+, we consider participation to be crucial because it will enable stakeholders to identify the incentives or benefits available, hence reduce deforestation and degradation. Various studies show that, for increased success in environmental management, REDD+ implementation and climate change, participation of various stakeholders is crucial because it will increase the knowledge base and cultivate a sense of ownership (Bleaney et al., 2010; Brockhaus and Di Gregorio, 2014; Brockhaus, Di Gregorio, and Carmenta, 2014; Reed, 2008). Although these studies have addressed the participation issue, many of them have not taken participation as one of the components of strategic accountability. Likewise, many of them have taken a community perspective and not an organisational perspective. As a result, LGAs as part of REDD+ implementation are not clearly considered. These LGAs have a complex model because, on the one hand, they are supposed to facilitate community involvement in REDD+ projects, but on the other, they are expected to be involved in those projects in a similar way to communities. As Phelps, Webb and Agrawal (2010) have argued, decentralisation of forest management has been done by the central government to reduce costs and increase efficiency to respond to local demands. This has—potentially at least—increased the role of LGAs which may include providing incentives to reduce emissions and social services and rural development, negotiating with stakeholders as well as brokering carbon deals (Phelps et al., 2010). Brown, Seymour and Peskett (2008) contend that through LGAs, REDD+ can potentially help to improve the generation of revenue from forests as well as make the community benefit and achieve governance through participation. Even though participation is good, there are some limitations that curtail the influence of participation on the overall achievement of emission reductions. Wollenberg (2009) identify limitations such as the problem of aggregating diverse interests to produce a single decision, participants not knowing until the meeting and being biased in favour of conveners. In this regard, Wollenberg (2009) seems to encourage voluntary participation to engage participants in a more fruitful and meaningful way. In case of REDD+ it was considered that LGAs have mechanisms to encourage voluntary participation of communities and other stakeholders.

Another financial accountability mechanism under the process category is self-regulation, which is aimed at increasing credibility and accountability (Agyemang et al., 2009). Ebrahim associates self-regulation with organisational efforts to develop standards or codes of behaviour and performance. To Ebrahim (2003), self-regulation provides organisations with a complementary path that allows them to address directly their own problems and, at the same time, retain their integrity, consequently improving their public image and enhancing performance in the process. In this study, self-regulation was considered to be concerned with LGAs themselves as a sector and their responses to communities
and donors. The aim is to help build public confidence towards environmental projects implemented by LGAs. In case of environmental management, there are number of studies which have been conducted with a self-regulation perspective. Ostrom (2005), using conventional theory of common-pool resources, considers self-regulation (under self-governance the term she has used) to be more likely to occur when the forests are salient to users; when users have common understanding; and when users have autonomy to make their own rules. The importance of the capacity to make own rules reflect the LGAs settings in Tanzania. In the former, if the LGAs find that forest resources are important to enable them to address the roles given by the central government, the LGAs will be inclined to create self-regulatory mechanisms to ensure that forest resources contribute to community development. In the latter scenario, the LGAs have some power to create their laws (i.e. bye-laws) which basically are part of the self-regulatory mechanism. These self-regulation mechanisms, which may go beyond those set by central government, may increase LGAs’ readiness for REDD+ funds management.

The last financial accountability mechanism under process category is social-auditing. According to Ebrahim (2003), social-auditing is concerned with a process whereby the organisation assesses, reports and improves upon its social performance and ethical behaviour. This can be achieved particularly through dialogue with stakeholders. Berthin (2011) considers social auditing as an accountability mechanism where citizens mobilise to evaluate or audit government performance and policy decisions. This rests on the premise that when government officials are watched and monitored, they feel greater pressure to respond to their constituents’ demands and have fewer incentives to abuse power. Henriques (2001) considers social auditing to be made of four building blocks: disclosure, external verification, stakeholders and indicators. According to Henriques (2001), social auditing has been associated with environmental reporting, which is consistent with the views provided by Deegan (2002), Gray (2000) as well as Owen (2008). Although these studies have considered social auditing as an issue which can influence the effectiveness of environmental management, and how organisations behave towards stakeholders, most of these studies have dealt with the private sector. Almost none has considered LGAs forest and climate change management. In this study, we considered social auditing as a part of financial accountability mechanisms concerned with the capacity of LGAs to provide a forum for fostering dialogue with different stakeholders.

Thus, at the local level, LGAs in Tanzania can potentially play an important role in the implementation of REDD+, but it remains unclear what their specific role is going to be as far as the REDD+ funds are concerned. At present, in Tanzania, LGAs are weak relative to national government—both in terms of human and financial resources. Despite the efforts to reform LGAs through devolution of power, LGAs still face a financial crunch (on average LGAs
generate less than 20% from own sources) due to lack of predictable sources of revenue; poor utilisation of financial resources and lack of a clear analysis on how financial resources are utilised.

From the data available at the district level, there is limited or no information on revenue from forest at the village level. Lack of information complicates the financial accountability mechanism at the grassroots level because the community is not informed about the financial benefits and losses from forests. For example, several questions may be asked such as: How much revenue from forest was collected at village level? Out of the collected revenue, how much are fines from legal activities and how much was from fines imposed on banned activities? How much of the revenue collected at the village level was remitted to the district level and how much was received from the district level? These questions lead to the central question on REDD which is: How can the REDD funds be handled at LGAs so as to make sure that the objectives of REDD are achieved? For LGAs to play a valuable role in REDD+ it is pertinent that there is an effective financial accountability mechanism in place.

3.0 Methods

3.1 Research strategy and sample

This study adopted a qualitative approach to addressing the research question. This approach enabled the researchers to have an in-depth understanding of the subject matter by focusing on few individuals or cases. Also, the qualitative approach recognises the fact that the researcher is an instrument of the study (Chism, Douglas, and Hilson, 2008). According to Morse (1998), the qualitative approach offers a particular and unique perspective that presents more aspect of reality than other approaches. Hence, it was deemed appropriate for this type of study, which was exploratory in nature because of limited studies conducted so far. Although the qualitative approach has limitation since it cannot take a large sample. Consequently, this limitation reduces statistical generalisation. However, its strength is in achieving analytical generalisation, which is crucial in exploratory studies (Yin, 2003). Analytical generalisation is achieved through triangulation of methods (Mathison, 1988; Patton, 2002) and application of theoretical framework, which forms a basis for analysis (Maxwell, 2005; Miles and Huberman, 1994).

The study utilised purposive sampling in selecting officials from LGAs and NGOs dealing with REDD+ as well as people from community villages where REDD+ projects are implemented. Using different participants helped the study to achieve triangulation, which also helped to reduce bias in the study (Oliver and Victor, 2006).
The sample involved four LGAs in which REDD+ projects are being implemented: the districts of Kigoma, Kilosa, Kilwa and Kisarawe. In this sample, two of the LGAs were those covered by the Controller and Auditor General (CAG)’s performance audit report on management of forest harvesting of 2012 (Kigoma and Kisarawe), and two districts, which were not (Kilosa and Kilwa). Choosing contrasting cases helped to reduce the selection bias (Collier and Mahoney, 1996). In each LGA, participants were drawn from district officials, NGOs, villages and community based groups.

3.2 Procedures

In this study, data were collected using three techniques: semi-structured in-depth interviews, focus group discussion and documentary review. Semi-structured in-depth interview helped us to obtain information on the actors’ experience and knowledge on REDD+ implementation issues, REDD+ money as well as financial accountability mechanisms at LGAs. In the case of focused groups and in-depth interviews, these took place between June and December 2012. The focused groups involved 7-10 participants and lasted about an hour-and-half and two hours long. These focus group discussions drew participants from members of forest conservation groups. The focus groups discussions were guided by topics such as the current status of REDD+ implementation, mechanisms for distribution of REDD+ funds, money expected to be received and how has been received. Other topics were forest coverage, role of LGAs in the implementation of REDD+, institutional set-up for handling REDD+ funds, involvement of local companies in the forest conservation accountability and transparency of REDD+ funds. These topics were based on the theoretical perspective of the study, which divided the issues into five financial accountability mechanisms: disclosure, performance assessment and evaluation, participation, self-regulation and social auditing.

The semi-structured interviews were carried out mainly with LGAs officials and NGOs officials dealing with REDD+ implementation in those four districts. As Reja et al. (2003) have argued, open-ended questions help to generate qualitative information because they discover responses that individuals give spontaneously and avoid bias that may be caused by suggested responses to individuals. As result, some studies have considered open-ended questions to be more reliable and valid (Bengston, Asah, and Butler, 2010) than closed-ended ones. A number of studies in forest management and REDD+ have used open-ended questions for similar and other reasons such as allowing for detailed and qualitative understanding of forest owners motivations as well as helping to avoid “priming effects” (Bengston et al., 2010). In this study, using open-ended questions helped us to generate greater understanding. Interviews with the officials lasted for between 45 minutes and an hour. However, the interviews with the NGO officials took a much shorter time than those of LGAs officials. In this case, the interviews with NGOs officials were between 20 and
40 minutes. The main reason for this is that not all questions were relevant to NGO officials. The interviews explored the implementation status of REDD+, mechanisms for funds distribution, institutional set-up for handling REDD+ money and other forest funds, forest covers in the district, contribution of forest in district own sources of funds, as well as their views on how REDD+ money should distributed. The interviews, like proceedings from focus group discussions, were recorded using notebook and then transcribed. Transcripts were analysed and coded in accordance with the main themes of the theoretical framework of this study. In the first phase, one researcher highlighted words or phrases from the data and located to critical themes. After that, members of the research team held regular discussion to relate those points to a particular theme. The third phase involved one researcher connecting themes and finding links in the data and providing illustration of the final themes. These coding and final themes were checked by the most senior researcher to ensure that the coding had been done correctly and the pattern of the data are logically connected. The themes were divided into three categories: LGAs involvement, LGAs readiness and financial accountability mechanisms. The financial accountability mechanisms were divided into the categories developed by Ebrahim (2003)—see Table 10.1. These were summarised for LGAs used in this study. In addition, the data analysis involved LGA profile; REDD+ profile and profile of the respondents. For LGA profile, this involved the details about villages and REDDS+ coverage. On the other hand, the respondents profile covered the nature of type of the respondents in data collection. The use of predetermined themes helped to generate the perspective of the study. However, when we continued with the analysis more terms and themes became apparent, which is consistent with Moorefield-Lang (2010).

4.0 Results

The findings are presented according to three analytical typologies: (i) LGAs involvement; (ii) LGAs readiness for REDD+; and (iii) Financial accountability mechanism, which is further divided into tool mechanisms and process mechanisms. The tool mechanism was divided into disclosure reports and performance assessment and evaluations. On the other hand, the process mechanism was divided into participation, self-regulation and social auditing.

4.1 LGA involvement in REDD projects

Based on CAG report of 2013, the LGAs have mainly six functions and operational objectives (CAG, Report 2013).

(a) To maintain and facilitate the maintenance of peace, order and good governance within their areas of jurisdictions
(b) To promote the social welfare and economic well-being of all persons within their areas of jurisdictions.
(c) To further the social and economic development of their areas of jurisdiction.
(d) To strengthen meaningful decentralisation in political, financial and administrative matters relating to the functional powers, responsibilities and services at all levels of LGAs.
(e) To promote and ensure democratic participation in and control of decision making by the people concerned.
(f) To establish and maintain reliable our source of revenue to enable them (LGAs) perform their funding effectively and to enhance their financial accountability.

LGAs thus have a responsibility to being involved in a wide range of activities in their areas of jurisdictions. Their involvement can be either directly, whereby the LGAs themselves become one of the main actors (either by themselves or by co-operating with other actors), or indirectly whereby various actors seek approval from the LGAs to facilitate their activities. For NGOs to access REDD+ communities, for example, they will need the approval of the LGAs. This was observed in one of the LGAs whereby one NGO official argued: “The NGO cannot access village government and the Village Environment and Natural Resources Committee without going through the LGA official channels.”

These functional and operational objectives indicate that the role of LGAs in ensuring that projects are implemented relate both to their social and economic benefits.1 Thus LGAs have a role to play in REDD implementation and ensuring its success. This is supported by the following explanation provided by the Kigoma District Environmental Management Officer (DEMO).

The LGA is involved by ensuring that its officials get training on matters relating to REDD+. Such training is provided with assistance from NGOs. NGOs dealing with REDD+ provided reports to the District Executive Directors. However, because the District (LGA) does not have the co-ordination capacity, this has raised some concern with councillors on the benefits of these NGOs to the people. To address this issue, the District had discussion with NGOs implementing REDD+ to ensure that their activities are co-ordinated.

The same situation of LGA involvement was observed in Kilwa district. MPINGO (NGO), which deals with REDD issues in Kilwa reported that the district do participate for several reasons: “Employees of the district are working with the villagers within the same area where MPINGO is operating. Likewise, MPINGO is working with village Natural Resources which also works with the district.”

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1 See Local Government (Distinct Authority) Act No. 7 of 1982 (which was revised in 2000) Section III(I) and Section III (I)
The involvement of LGAs is on both practical and legal basis. According to legal basis, there are by-laws governing the implementation of forest project. These Bye-laws have to be approved by the Regional Consultative committee (RCC). Practically, the LGAs are involved to create an enabling environment for villages to access requisite services, for facilitation of activities, for conflict resolutions and for settling village borders dispute as well as controlling of wild animal intrusion. The involvement of LGAs has been captured by the following views as provided by the MPINGO project official in Kilwa:

The District Council (LGA)’s input is clearly needed for very vivid reasons. First, it enables the NGO to access villages. Without LGA’s support, NGOs cannot easily access villages as the system is well linked to LGA leadership. Second it facilitates activities because LGA officers are acceptable to village, especially the District Executive Director, Community Development Officer, Forest Officers, and so on. Third, the LGA help in conflict resolution because many village border disputes can be resolved through LGA leadership. Also, the invasion of wild animals in the project area such as elephant can only be controlled by the LGA because it has the mandate to call on the necessary state machinery to intervene.

The LGAs officials recognised this crucial role and broadly endorsed the involvement of LGAs in REDD+ projects. They viewed that REDD+ will not be successful if the LGAs are not involved. As one LGA official explained: LGAs do co-ordinate almost everything. They provide guidelines and direction about forest management. For example, mining activities have huge impact and foment conflicts, which LGAs have to resolve. This happens even when initially the LGAs were not involved. Participation in forest management would be very difficult without the involvement of LGAs (District Treasurer – DT).

In summary, both LGAs and NGOs recognise the important role the LGAs play; and yet the NGOs provided training to the LGA officials on matters relating to REDD+, but when it came to issues of funding for REDD+ effectively bypassed the LGAs.

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2 Regional Consultative Committee (RCC) is the organ created by the Regional Administration Act of 1997. The RCC is made up of a mixed composition of both political and administrative leader from the region. The main function of RCC as per section 9 of the Act is: [T]o consider and provide advice, to any interested party on economic and development affairs...to monitor and ensure the co-ordination of the overall economic development in the region.
4.2 LGA financial accountability mechanism

(a) Tool Mechanisms

Disclosure reports
Disclosure reports help to ensure accountability, both upwards and downwards, by presence of well-functioning oversight bodies as well as in dealing with corruption, fraud and protection of assets. The findings indicate that all the four LGAs have been submitting their financial reports to CAG for auditing purposes. The CAG has been providing opinions on these audited reports. In addition, CAG reports and responses from the LGAs are submitted to the Local Authority Accounts Committees (LAAC), which is an oversight body at that level. Such checks can help achieve good financial accountability by fostering transparency. However, the achievement of financial accountability through transparency is constrained by the LGA setting and their relationship with the Central Government. For example, in case of development fund, these funds are disbursed directly to the villages and are very difficult to be accounted for at the district level. In this regard, one District Treasurer argued:
Although we boast of transparency, there are structural problems. Because the district receives money for various development activities and they are channelled directly to villages/communities, when it comes to reporting the district has to prepare reports since it has the responsibility to manage those funds. Why don’t these villages prepare their own reports? The villages are the ones which are given the money directly, have their own signatories, and have capacity. In my view, they can manage the money to achieve the required objective (District Treasurer -DT).

This view was supported by a Village Executive Officer (VEO) who confirmed that the villages do receive funds directly from the Central Government and had the capacity to report because regulatory procedures allow them:
Transparency in financial management in villages is very important. Once we receive the money, we have to inform the people and we are required to show how we have spent the money. We prepare monthly financial reports which are critically presented to the Village Committees and Village Councils. After that the reports are submitted to Ward Development committee (WDC) and then to District Council (VEO)

Performance assessment and evaluations
This is aimed to assess whether and to what extent the stated goals and objectives of the project have been achieved. In the REDD+ projects, this will involve monitoring, reporting and verifying of financial transactions related to the forest money. Our observation from the four LGAs indicates that performance evaluations are done through different reporting mechanisms, which are legally grounded. For example, the LGAs are required to prepare and submit quarterly
reports to the central government. According to a District Planning Officer (DPO), monitoring and evaluation is done on a quarterly basis in case of engineering works whereas the monitoring and evaluation is done at any time when payment is required.

However, the LGAs do not always report everything in the quarterly reports. For example, the LAAC report of 2007/2008 of Kigoma found that the LGA had not taken any action against a salt producing (mining) company, which was using wood for energy, hence destroying the forest cover. In Kisarawe, the CAG report shows that the LGA did not submit FMP to the Ministry, hence making it difficult to do evaluations.

(b) Process Mechanisms

Participation
Participation takes on board issues such as community consultation and dialogue, informal reporting, and participatory review. Under REDD+, this is concerned with aligning incentives to curbing deforestation and forest degradation. It also considers the distribution of REDD+ benefits equitably. It was observed that of the four LGAs, Kigoma and Kilwa were found to be strong in ensuring participation whereas Kisarawe was the least. One District Treasurer interviewed emphasised the importance of their role: Effective participation in the forest management requires LGA involvement. People cut trees or sell charcoal because they want to generate income. The LGA needs to find alternative income generating activities as well as alternative energy sources (District Treasurer).

Similarly, the District Forest Officer (DFO) said: Even if the government can take REDD+ money it should have the responsibility to create a mechanism to incentivise those who protect the forest. One way could be establishing forest conservation co-operatives such as JUWAMA. However, there is a need of building the capacity and providing technical knowledge to ensure that they are managed efficiently. Thus, REDD+ money can be applied similar to TASAF model. In this model, forest co-operatives will have their own bank account and request funds from District (District Forest Officer).

And a participant in FGD spoke on in similar vein with regard to incentives: How can we encourage members of JUWAMA who are charcoal dealers to protect forest? There is a need for compensation and giving them alternative income generating activities to do. We do not need political plans; we need business plans (FGD Participant).

It was noted that the REDD+ programme is too dependent on NGOs. For example, in Kigoma, most of training has been financed by Jane Goodhall
Institute. As a result, at the district level, awareness of REDD+ is very low as opposed to the village where it is very high. A similar situation unfolded in Kilwa where REDD+ project is implemented by an NGO (MPINGO). However, unlike in Kigoma, here the NGO’s proposal was submitted and discussed at the district level. Training was also extended to the district officials, councillors and committee members on forest conservation and REDD+ projects. As one village government leader explained: “Prior to REDD+ we made losses, we thank MPINGO because now we know our rights and the value of our forests and we will no longer be cheated” (Village Executive Officer - VEO). On the whole there was satisfaction with this arrangement, and other areas could pick a leaf from this experience.

In Kisarawe, the situation was different because the participation had been conducted through SACCOS and other environmental groups (i.e. Maendeleo – 30 members, Kumekucha – 30 members as well as Chenu SACCOS – 30 members). The majority of the members in these groups were women. In addition, in Kisarawe, we observed individuals who are dealing with forest projects on their own. One person, who was considered successful had 20-acre plot with 4,500 trees, from which he could be earn about Tshs 1.5 million per teak when sold at the local market. But similar to other LGAs, the issue of alternative income generating activities was considered important for the local government’s successful participation. The alternative income generating activities identified include poultry farming, modern animal husbandry as well as small processing industries to create employment. This is consistent with the views provided by one of the participants in the focus group discussion: Once the LGA receives funds in case of REDD+ money, it can be channelled to the community projects to create incentives to protect forests. The TASAF model can be used. However, for the TASAF model to work, then Villages should be given power to identify their priorities on forests management and project implementation (FGD – Participants).

Self-regulation
The aim of self-regulation is to build public confidence on projects being implemented. It can be achieved through networks, development of standards as well as good performance. In case of the development of standards, the LGAs visited at the time had no FMP and did not have bye-laws covering forest harvest practices. However, in Kigoma there is REDD+ district team and there is an inter-village forest management organisation called Jumuiya ya Watunzaji wa Msitu wa Masuto-Ugalla (in short JUWAMA), which works as a team. JUWAMA was more effective than the district team because it received money from an NGO, and was more independent. However, in the case of contractual arrangements JUWAMA involves the LGA. Several of the district staff interviewed believed that REDD+ funds should be channelled through the LGA. For example, one observed:
In my view since the district is involved so much, I think REDD+ money should go through the same channel as the development fund. Considering the way the development fund is being handled, there is going to be no problem with handling REDD+ money (District Environmental Management Officer -DEMO).

According to DFO in Kigoma, the huge expectation of getting money (REDD+ money) made several people form their own community-based organisations (CBOs) waiting for when the carbon business would materialise for them to reap dividends: “So awareness campaigns and trainings are necessary to manage their expectations” (DFO). These views are also shared by FGD participants as one of them put it:

There is a need of proper regulations for the flow of REDD+ money. The money should not go to individual members of associations because the leaders are misusing the money. The money should go to the village government and then to the group and not individuals (FGD Participant).

In Kisarawe, the presence of unregistered SACCOS that provide financial services for alternative income generating activities exposes the need for the LGA to enact bye-laws and put in place other requisite guidelines. These documents are required to ensure that these unregistered groups will not misuse money. This need was underscored by a respondent from a conservation unit based in Kisarawe: “The LGA should put in place policies to ensure that officials responsible for forest visit the villages regularly as well as provide effective training and seminars particularly to SACCOS.”

In Kilwa, in particular, some efforts in this regard have already been taken. Training has been conducted for a few villages and officials, but even here the knowledge on REDD+ and carbon business was found to be still limited. For example, before training people thought the government first wanted to grab their land for carbon business. In fact, respondents in Kilwa proposed three alternative models for channelling and disbursing REDD+ money: (i) investing in production activities that village co-operatives may use as credit for villages; (ii) channel through LGA using the TASAF model; and (iii) distribute the money directly to individuals. In the last model, the LGA can provide financial guarantee as collateral.

**Social auditing**

Social auditing is concerned with the valuation of social, environmental and ethical performance. Other observation, for example, in Kilwa shows that there are many actors for REDD+; however, their efforts are not clearly co-ordinated by the LGA. Likewise, there were challenges because LGAs officials were found to be to be sceptical about carbon emissions trading and raised a number of questions about the certainty of such trading. To them it was more of a myth
that a reality. Moreover, in Kilwa it was also established that REDD+ was not on the villages’ priority list submitted to the district level.

In Kisarawe, a respondent cited a number of potential barriers to successful REDD+ projects such as over-population, limited resources from the government and limited alternative energy source. In addition, a number of respondents indicated that REDD+ needs to be infused with business and entrepreneurial activities. For business, problem such as lack of business competence, lack of entrepreneurial acumen, lack of business skills as well as poor group management need to be addressed. This sentiment also emerged in other study areas. As a DEMO from Kigoma pointed out:

The central government should come up with proper strategic plans to conserve forest which may include subsidies to both rural areas such as forest subsidies and urban centres such as gas companies to reduce the high demand for charcoal.

4.3 LGAs Readiness for REDD Projects.

Using data from CAG reports and annual reports of the four LGAs, we extracted information on the readiness of these local authorities in terms of the profile as presented in Table 2. For revenue, it was found that all LGAs visited depend very heavily on the central government for funding (the most dependent on central government coffers of the districts was Kigoma with an average of own sources revenue amounting to a paltry 3.4% the least was Kilosa with own sources accounting for approximately 6%). Generally, these LGAs were found to collect very little from forest products. Kilwa (1.9%) and Kigoma (1.6%) are the LGAs with the highest own revenue generated from forest product sources. Kisarawe collects nothing from forest products whereas Kilosa collects only a measly 0.3%. The forest products, therefore, make very limited contribution to LGAs’ revenue.

To assess the capacity of LGAs to handle external sources of funding, this study reviewed four items: auditor’s expert opinion (auditor’s report) in the annual report; the auditor’s report on forest management conducted in 2012; efficiency of internal control systems of the LGA; and the LGA’s efficiency in the utilisation of Participatory Forest Management (PFM) funds. The annual report audit remarks were either ‘adverse’, ‘qualified’ (i.e. minor, not major
criticism) or ‘unqualified’ (satisfactory). In all, the LGAs got 18 unqualified opinion, four qualified opinion and two adverse opinions out of 24 opinions. This indicates that the LGAs generally had a strong fiscal management. Of the local governments under review, Kisarawe was found to be leading in this aspect with all opinion being in the type of unqualified, followed by Kigoma (5 unqualified and 1 adverse). Kilosa was the least in financial management with two unqualified, three qualified and one adverse opinion.

In addition, we also reviewed the CAG report on Forest Management conducted in 2012. This report covered only two LGAs: Kigoma and Kisarawe. For these two LGAs, the auditor’s findings showed that at the time of audit, the LGAs did not have approved Forest Management Plans as reported thusly:

- It was found that some districts have issued harvesting licences, transit passes even in the absence of approved Forest Management Plans and Annual Harvesting Plans (NAO, 2012).

- ...Ministry (MNRT) needs to ensure that [the] harvesting of forest products follows approved Forest Management Plans. MNRT should therefore stop districts without approved Forest Management Plans from using harvesting permits.

- ...this means that they (LGAs) had no information about the available harvestable forest stock so as to set the harvesting limit for ensuring [the] sustainability of the forest resources (NAO, 2012).

In other words, despite not having approved FMP, the LGAs continued sanctioning the harvesting of forest resources by issuing permits. According to the NAO Report, the harvesting was based on the recommendation of the National Forest Inventory Report of 2005. This report shows maps of districts with locations of different forests, list of forests and their areas, tree species, timber species, stocking levels, tree volume (both total and harvestable) and general forest quality. The major limitation of these maps is that they were not revised to reflect the actual situation on the ground, hence creating conditions

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3 According to the CAG Report, an audit opinion expresses whether or not the audited financial statements have been prepared consistently following appropriate accounting policies and procedures, as well as relevant legislations and regulations. Unqualified opinion is issued when CAG is satisfied with LGAs’ financial statements. In fact, this is one of the indicators of best financial management practices in LGAs: qualified opinion is issued when there is disagreement with management or limitation of scope is not so material. Qualified opinion is one of the indicators of better financial management in LGAs. On the other hand, adverse opinion is issued when disagreement with the LGAs management has a material and pervasive effect on the financial statements of LGAs being audited. Getting adverse opinion reflects worst financial management practices in LGAs. As such, audit opinion is one of the indicators for LGAs’ accountability in terms of using funds generated from different sources.
for over-harvesting of forests and their products. Similarly, the top-down approach has reduced the extent of participation, as observed by one of the FGD participants in Kigoma.

Village Environmental Committees (VEC) are responsible for forest security. In each Mtaa [street level administrative unit], there are two members of VEC. But limited awareness on forest management issues makes only few people participate in forest conservation (Focus Group Participant – Kigoma).

Other issues on the LGA readiness involved their efficiency of the LGAs’ internal control systems and efficiency in the utilisation of participatory Forest Management (PFM) funds. In case of control system, the study here sought to establish whether the LGAs have adequate mechanisms to protect REDD+ money if they were provided with it. Using CAG reports for the period of six consecutive financial years (2007/2008 to 2012/2013), it was found that two LGAs (Kilosa [82.9%] and Kilwa [74.3%]) had major weakness in their control systems compared to Kigoma (41.4%) and Kisarawe (47.3%). Weaknesses in control systems may create a leakage of funds, and reduce accountability. For example, our interviews in Kilwa (covering four villages of Nairokwe, Liwiti, Kisangi and Kikole) found that in these villages revenue from the Village Forest Reserves is retained at the village level by 100 percent. However, the District Forest Officer had no clue on how these funds are spent at the village level. This builds a case for strong internal control systems. This need was also raised in Kigoma where different interviewees harped on it. To them the existing financial management system in the LGAs was not that efficient and recommended the adoption of the TASAF model⁴ which they deemed appropriate. As one of them proffered:

Applying the TASAF model would be very helpful because communities play a role of accountants and verifiers. TASAF only checks the procedures whether they are followed or not. For example, if it is concerned with the protection of forest against fire, TASAF will check whether the kilometres offered are OK. TASAF does not go with projects but the projects implemented are those identified by the communities themselves (TASAF District Co-ordinator).

Similar views were provided by the FGD participants in one of the village in Kigoma and their Village Executive Officer (VEO). In this regard, one FGD participant said:

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⁴ According to TASAF model, projects are identified and implemented by the communities. The funds flow directly to the communities who will have a bank account. TASAF officers at the district level are only charged with responsibilities of co-ordination. No leakage of funds is allowed.
We think the TASAF model is appropriate because it will help us identify priorities, form committees which are not inside the government. These committees will make follow-ups on the implementation of REDD+ money (FGD participant).

And the VEO chipped in to shed more light on the appropriateness of the TASAF model:
I think the TASAF model is much better than the O & OD model for a number of reasons. People themselves participate; they form committees; they purchase materials; and they supervise the operating. Also, the budget is sufficient and village council only forms committee to supervise the project (VEO-Songambele).

On the utilisation of PFM funds, the capacity of the four LGAs ranged from 66.7 -100 percent, indicating an adequate capacity to utilise funds (If the LGA was not mentioned in the CAG report that it has underutilised these funds, then efficiency was considered to be 100%). The PFM fund was introduced by the government following the enactment of Forest Act of 2002. This Act provides a clear legal basis for LGAs, communities, groups or individuals to own, manage or co-manage forests under a wide range of conditions. In this regard, LGAs are required to be more efficient in utilising those funds because they have more responsibilities to manage forests by making bye-laws and Forest Management Plans.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>KIGOMA</th>
<th>KILOSA</th>
<th>KILWA</th>
<th>KISARAWE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of revenue in terms of own source (2010/11-2012/13)</td>
<td>3.4</td>
<td>5.9</td>
<td>3.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Revenue from central government (%)</td>
<td>96.6</td>
<td>94.1</td>
<td>96.4</td>
<td>96.1</td>
</tr>
<tr>
<td>Revenue from forest (%) (in relation to own source)</td>
<td>1.6</td>
<td>0.3</td>
<td>1.92</td>
<td>0</td>
</tr>
<tr>
<td>Auditors opinion (2008/9 -2012/13)</td>
<td>5 unqualified 1 qualified</td>
<td>3 qualified 2 Unqualified 1 Adverse</td>
<td>5- Unqualified 1- Adverse</td>
<td>6 - Unqualified</td>
</tr>
<tr>
<td>Auditors report on forest management (2012)</td>
<td>No Forest management Plan (FMP) only draft 2012</td>
<td>Not conducted</td>
<td>Not conducted</td>
<td>No approved Forest Management Plan (FMP) only draft in 2010/2011</td>
</tr>
<tr>
<td>Efficiency of internal control systems for all years)</td>
<td>12 issues out of 29 found to be inefficient i.e. 41.1%</td>
<td>29 issues out of 35 found to be inefficient i.e. 82.9%</td>
<td>26 issues out of 35 found to be inefficient i.e. 74.3%</td>
<td>17 issues out of 36 found to be inefficient i.e. 47.3%</td>
</tr>
<tr>
<td>Efficiency in utilisation of Participatory Forest Management (PFM) funds Average</td>
<td>100%</td>
<td>87.3%</td>
<td>66.7%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 11.2: LGAs’ indicators for REDD+ readiness
Source: CAG and LGAs reports from 2008/2009-2012/2013
5.0 Discussion and Conclusion

This study has explored views and experiences of LGAs in terms of their REDD+ readiness with regard to fostering financial accountability mechanisms. Using a qualitative approach, we have highlighted a range of issues that are crucial for REDD+ readiness and financial accountability mechanisms and the role of the LGA in this matrix. In our views, the issues identified in this study need to be taken into account when designing intervention strategies to protect forests and reduce carbon emissions and ensure that LGA play an active role in fostering financial accountability at the grassroots level where the REDD+ are carried out.

In the case of involvement, the findings indicate that the LGA structure allows them to get involved in REDD+ projects from the village level to the district level. The LGAs are involved for both legal and practical reasons. The legal structure requires LGAs to get involved because of administration and approval purposes of REDD+ projects. The legal basis helps to create a conducive environment for efficient and effective implementation of the projects. The REDD+ projects are large and involve a number of actors with diverging agendas and interests and hence need a legal basis. The legal basis helps them to set contractual arrangements as well as the basis for conflict resolutions. The importance of legal basis also arises because REDD+ has generated substantial financial supports from donors and multilateral agencies, which generates wide interest from politicians and other powerful actors who will want to dominate the REDD+ initiatives. Brockhaus et al. (2014) contend that in REDD+ actors co-operate and conflict in the network structure, build coalitions and try to control information and even the flow of finances. Thus the involvement of LGAs can help in policy formulation and implementation at the local level, hence improve governance for REDD+ projects. However, the issue is whether the legal settings make LGAs involvement effective. The findings from the four LGAs indicate rather limited legal guidelines to support LGAs’ involvement in REDD+. The existing legal framework covers normal operations of the LGAs without specifically addressing the issues related to REDD+ and forest management. Lack of strong legal settings for REDD+ projects makes it difficult for LGAs to provide adequate support to the villagers even on issues relating to financial administration and accountability. Similarly, survey results by Angelsen et al. (2012) affirm that villagers depend on government for legal advice when the agreements are signed about the information on REDD+. This is an area where LGAs can play an active role.

For practical purposes, LGAs seem to be involved because they can provide access to group communities. Most of the group communities respect LGAs leaders at all levels. As such to make REDD+ a success, NGOs and donors were obliged to involve LGAs leaders. This involvement is, however, not mandatory hence it is beyond the legal-based aspect of involvement. For those LGAs, which consider that REDD+ will be beneficial to them they are expected to embrace it more
than those which consider it to be less beneficial. The benefits here must not be limited to financial ones, but must also include biodiversity and livelihoods.

In case of financial accountability situation in the four LGAs, we assessed using tools and process mechanisms. The results indicate the presence of strong disclosure reports as financial accountability mechanisms compared to performance assessment and evaluations. For example, the results indicate that all the LGAs sampled have been submitting their financial reports to CAG for auditing purposes. These reports together with the auditor’s response are also submitted to the oversight organ of the parliament for scrutiny. This implies that, if LGAs are going to receive REDD+ money, there is a system of checks and balances to ensure that the funds are used properly. But are these checks and balances effective and efficient? The results indicate limited evidence to support that because of two issues. Instead, the relationship between LGAs and the central government, as well as the limited capacity and regulatory procedures particularly at the village level need to be sorted out. The relationship between central government and LGAs provides unclear levels of authority between district offices and village offices. As result, the likelihood of not accounting for funds that are allocated directly to the villages is high. There is consequently an increasing likelihood of misappropriation of funds. The implication for REDD+ money is that if they are disbursed directly at the village level they may not be reflected appropriately in the distinct accounts. Also, because of limited financial management capacity at the village level, there is a likelihood of the REDD+ money being misused or even misappropriated or diverted to other unbudgeted for use. But this does not mean that sending REDD+ money through district offices will be automatically translated into proper utilisation. It will require a proper model or framework which can integrate both financial management and REDD+ objectives. According to several respondents, the TASAF model was considered to be appropriate for handling REDD+ money at the grassroots level.

For performance assessment and evaluations, it has been observed that, although it is legally grounded, it is not always complied with. One reason for limited compliance could be a lack of standardised format and guidelines for performance assessment and evaluations. It was observed that, in some cases, it is done on quarterly basis and in other cases only at the time of payment. Another reason could be lack of funds to protect forest (this applied for forest management plan). As result, the LGAs did not have performance assessment and evaluation activities. This implies that for REDD+ money to be able to achieve the intended objective financial monitoring and evaluation activities should be included in the project.

For the second category which is process mechanisms, this study used three items: participation, self-regulations and social auditing. The results present
a mixed picture with some LGAs having stronger participation than others. Those LGAs with alternative income generating activities (i.e. environmental friendly business activities) were found to have stronger participation than those which do not have. Likewise, it was observed that participation was higher in LGAs with NGOs which are visible than those without visible NGOs. But in those LGAs with strong NGOs much of REDD+ knowledge and training were conducted at the village level and not at the district level. As such, participation is very strong at the village level but weak at the district level. Although this has advantage of ensuring those who are directly affected by the project objectives do participate, it has its own limitation. One limitation is that the district office is the one with resourceful people and policies; hence leaving them out at institutional level tends to reduce the effectiveness of PFM as well as the development of FMP.

In case of self-regulations, the aim was to assess the development standards or codes of behaviour and performance to ensure that the LGAs generate trust from the public. The results reveal weak self-regulatory mechanisms for all the LGAs sampled. The weaknesses included lack of bye-laws covering forest harvest practices. The major plausible reasons include too much donor-dependence, hence the LGAs lacking initiatives, for REDD+ oriented projects. Donor dependence also created huge expectation that money will be flowing to the community, which resulted into the formation of CBOs. This process consumed much time of the LGAs without focusing on developing appropriate bye-laws and standards for forest management as well as for carbon business. In addition, standards are required for proper financial management of REDD+ money, which are not there—indicating a possibility of a problem of distribution once the money starts flowing in.

The last part of process mechanism used in this study is social auditing. The results indicate limited social auditing practices for forest management in LGAs. There are a number of reasons for poor social auditing. First, there are many actors dealing with REDD+ in LGAs without clear co-ordination. As it has been argued in the previous paragraph, several donors may be involved in the same issue at LGAs. As a result, it is difficult to co-ordinate their activities. Second, LGAs officials are sceptical about the carbon business and the REDD+ as whole. As such, REDD+ is not part of the LGAs’ priority areas and let alone part of their plans.

In case of REDD+ readiness, which is the overall concern of the study, we assessed the outcomes of involvement and financial accountability mechanisms in the LGAs sampled. The aim was to assess the preparedness of LGAs to handle the money generated from external sources. To achieve this objective, we used CAG reports and other reports. The results indicate that the capacity of the LGAs to generate own revenue is very limited and most of their revenues comes from
the central government. On the one hand, the over-dependence on external financing indicates that the LGAs have financial accountability mechanisms to satisfy the external funders hence indicating that REDD+ money can be handled appropriately. This is also evidenced by good reports from auditors (majority of LGAs are getting good reports from auditors). Likewise, when the assessment is done using efficiency in utilisation of PFM we see that the majority of the LGAs are utilising these revenues efficiently. However, the external financing from the government is not voluntary, which means even if the LGAs do not have effective financial accountability mechanisms, the central government may be required to fund them. This will be contrary to REDD+ money because they are given for specific objectives, hence if they want be used accordingly there is a possibility for funders to withdraw their funds. This is also evidenced by limited efficiency in internal control systems and lack of approved FMP. Some LGAs are inefficient whereas others are efficient, but there is no evidence to indicate that the LGAs which are inefficient or lack financial discipline were penalised by having revenue deduction.

In conclusion, the study argues that REDD+ can be successfully implemented if the challenges facing it are addressed. Amongst its challenges is the issue of effective financial accountability, monitoring and checks and balances at the grassroots where the REDD+ initiatives are likely to be undertaken. In fact, the LGAs are crucial for not only ensuring regulations are followed, but also in ensuring that REDD+ finances (money) are used to develop people and conserve forests. Nevertheless, the question which has not been addressed by many previous studies in REDD+ is whether the LGAs have the capacity to handle REDD+ money (in other words financial readiness for REDD+ implementation). As such, this study assessed the financial readiness of these LGAs for the REDD+ by looking at their involvement, financial accountability mechanisms and REDD+ readiness per se. In case of involvement, legal and practical factors should be considered to ensure that LGAs are prepared for REDD+ projects. For the financial accountability mechanisms, using Ebrahim (2003) categorisation, we can see that the LGAs are not similar as far as effectiveness of financial accountability is concerned. However, the study considers that there is a need to improve performance assessment and evaluations, self-regulations and social auditing for the REDD+ money to be handled appropriately under the aegis of the LGAs which facilitates many activities at the local level where REDD+ initiatives are likely to be anchored. For the REDD+ readiness, there is a need to improve on areas such as revenue from forest, forest plans and internal controls. If the LGAs will not generate adequate revenue from forests, the incentives for the LGAs to participate in REDD+ money will be reduced and, consequently, increasing the possibility of project failure.
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The influence of certification on community forest management
Implication of Forest Stewardship Council (FSC) standards’ implementation for REDD+ pilot project villages in Kilwa, Tanzania

Kalonga, Severin1* and Kulindwa, Kassim2

Abstract
Forest Stewardship Council (FSC) forest management certification standards have been promoted to maintain and support the enhancement of forest ecosystem integrity, including forest structure and biodiversity conservation. However, little has been done to evaluate its influence on community forest management. Through socio-ecological system conceptual framework, this chapter presents findings of a study that assessed the performance of a set of FSC-certified forests under village management supported by Mpingo Conservation and Development Initiative (MCDI) and compared them with the performance of similar non-certified forests/villages in Kilwa district, Tanzania. The MCDI is one of the non-governmental organisations (NGOs), which implemented the Reduction of Emissions from Deforestation and Forest Degradation (REDD+) pilot project in Kilwa using the FSC approach. Results show that forest certification
is significantly and positively related to forest governance implementation, forest structure and biodiversity indicators in FSC-certified forests/villages. This result suggests that forest certification may have a positive influence on the enhancement and maintenance of forest ecosystem integrity. However, the empirical evidence in this study is limited in both space and time due to small sample size used and short time of FSC implementation in Kilwa by MCDI. Yet results show differences between FSC-certified and non-certified forests/villages (identified as REDD+ pilot projects) by encouraging the involvement of villagers in sustainable forest Management (SFM) for green growth and economy. Despite its limitations, this study constitutes one of the first examples of a field-based study that compares some of the ecological effects of FSC-certified with non-certified forestry in the tropics. In this regard, it contributes some key lessons and implications for future REDD+ implementation and adds to the existing limited empirical evidence on the performance of forest certification in tropical Africa and other tropical regions. It also provides some of the data that can inform decision making on investments in forest management and certification. Moreover, the findings can serve as baseline data for conducting proper assessment of the impacts of forest certification at both the temporal and spatial scales.

1. Introduction

1.1 Background

Tropical forests provide a variety of valuable ecosystem services such as biodiversity, carbon sequestration, water cycling and scenic beauty (Gardner et al., 2009; Sasaki et al., 2011; Sell et al., 2007). The forests of Tanzania, like other tropical forests, are species-rich and contribute to local economies in terms of timber and non-timber forest products (Owino, 2003). They also contribute to the long-term social and economic development goals and play a vital role in addressing the Millennium Development Goals (Gondo, 2010), and, specifically, in ensuring environmental sustainability (Sebukeera et al., 2005). Unfortunately, deforestation and forest degradation reduces each year the capacity of these forests to provide these ecosystem services (Gondo, 2010, FAO, 2010). Causal factors include uncontrolled human activities such as illegal logging, wildfires and conversion to agriculture land and grazing areas (see, for example, FAO, 2006, 2010).

Since the early 1990s, there has been a marked increase in the number of tools and instruments available to reverse uncontrolled human activities with far-reaching environmental implications through the application of sustainable forest management (SFM) practices. These tools seek to manage forest resources and forestlands sustainably to meet the social, economic, ecological, cultural
and spiritual needs of the present and future generations (FAO, 2006). Some tools and instruments that were developed and promoted include reduced-impact logging techniques, codes of practice for forest management and forest harvesting, and the creation of model forests (Dennis et al., 2008). These tools catered for SFM implementation and monitoring at the policy level, whereby many countries, including Tanzania introduced new forest policies and pieces of legislation to protect forest resources through improved management (Cashore et al., 2006).

Irrespective of the ample institutional and legal frameworks and ongoing SFM initiatives, these frameworks have failed to yield adequate positive biophysical and associated socio-economic benefits for both immediate and wider communities (Hamza and Kimweri, 2007; Petersen and Sandhövel, 2001). This is because illegal exploitation of forest resources has continued unabated the regulations and (rather weak) enforcement not withstanding (Milledge et al., 2007; German et al., 2010), primarily because the initiatives in place do not effectively and efficiently meet the primary objective of SFM (see, for example, Blomley et al., 2010; Gondo, 2010). Further research has revealed a complex, yet fragile relationship between forests use and the natural functioning of forest ecosystems (Cashore et al., 2006). So far, some scholars (see, for example, García-Fernández et al., 2008; Radachowsky et al., 2012) have suggested that the most successful incentives for SFM in the tropics appear to be forest certification. Forest certification is one of the approaches that aim at improving forest management practices through independent assessment of a forest management on the ground using specified social, ecological and economic criteria or standards (Elliott and Hackman, 1996).

Forest management certification is gradually becoming a standard requirement for timber suppliers and timber markets to many developed-country markets. Some of the world’s leading environmental groups in the early 1990s formed forest certification schemes, including Forest Stewardship Council (FSC) to develop forest management tools for promoting SFM initiatives to re-address the relationship between forest use and the natural functioning of forest ecosystems (see, for example, Auld et al., 2008; Cashore et al., 2006; Marx and Cuypers, 2010).

According to FSC, it is widely accepted that forest resources and associated lands should be managed to meet the social, economic, ecological, cultural and spiritual needs of present and future generations. Furthermore, growing public awareness of forest destruction and degradation has led consumers to demand that their purchases of wood and other forest products will not contribute to this destruction but rather help to secure forest resources for the future. In response to these demands, certification and self-certification programmes of wood products have proliferated in the marketplace (FSC, 1993). Although
certified forest management for multiple outcomes has become a mainstream concept in forestry and advocated to serve this purpose, its implementation and performance on the ground remains contentious (see, for example, Foster et al., 2008; Poulsen and Clark, 2010). Generally, there is dearth of quantitative empirical studies to substantiate the performance of forest certification globally (see, for example, Blackman et al., 2014; Blackman and Rivera, 2010, Cubbage et al., 2010; Sheil et al., 2010; van Kuijk et al., 2009), particularly in Africa, including Tanzania.

1.2 Rationale for the study
The motivation for this study is to contribute to knowledge on qualitative evidence about the performance of forest certification in meeting SFM precepts with regard to balancing the social and economic needs of the people without compromising ecological stability in human-dominated landscapes. The rationale of the study is to assess whether the certified forests in Kilwa do contribute more significantly to the health of the forests and improvement of livelihoods of communities than non-certified forests, which are under REDD+ pilot projects.

2.0 Objectives of the study
The main objective of this study was to assess whether and to what extent FSC-certified forest management fulfils its own goals of enhancing ecosystem integrity. To assess the performance of forest certification, the study employed a comparative (cross-sectional) study among forest management regimes (FMRs). This comprised FSC-certified forests under the Community-based forest management (CBFM), for example, communal regime, REDD+ pilot projects non-certified forest under village land (the “de facto” open access regime) and the state forest reserves solely managed by the state (the state regime) in Kilwa district, Tanzania. The variables for assessing the influence of forest management interventions on forest structure and biodiversity were identified through a social-ecological system framework. To achieve this assessment, the study was guided by the following specific objectives: 1) to assess the influence of forest certification on enhancing forest structure integrity; and 2) to evaluate the influence of certified forest management in conserving tree species richness, diversity and density.

3.0 Study sites and methods

1.1 Study Sites
The study was conducted in Kilwa district in Lindi region (see Figure 12.1). Kilwa district is almost an ideal place for the assessment of the “concept of forest certification” because the area has both certified (FSC) and non-certified
forests (non-FSC). The forests were FSC-certified in 2009, whereas the first intervention with auditors started in 2007 (for more details see MCDI’s certification reports: info.fsc.org). Therefore, this case can demonstrate how forest certification performs on the ground compared to non-certified forests.

The district is located between 8°15’-10°00’S and 38°40’-39°40’E with an area of 13,347.50 km². It has a coastal climate with a mean annual temperature ranging between 22°C and 30°C with 98-100 percent humidity and a mean annual rainfall of 1,034mm (KDC, 2008). The study area falls on the western part of Kilwa, which is characterised by Miombo woodlands with some patches of coastal forests, and north Zambezian undifferentiated woodlands and wooded grassland (see, for example, Lillesø et al., 2014). Presently, these woodlands are heavily influenced by informal economic activities such as logging and pit-sawing (KDC, 2011) and they are everywhere threatened by an ever-increasing demand for farmland, fuel-wood and charcoal production (Burgess and Clarke, 2000).

Six forests and four villages adjacent to these forests were chosen for this study (see Figure 12.1, tables 12.1a and 12.1b). Kikole and Kisangi are FSC-certified community forests under CBFM. Likawage and Mchakama forests (which were identified as REDD+ pilot projects at the time of fieldwork) were still under the open access regime without certification and Mitarure and Rungo forests are state forest reserves under state management without certification.

Figure 12.1: Location of study sites in Kilwa district, Tanzania
<table>
<thead>
<tr>
<th>Villages</th>
<th>Year Registered</th>
<th>Population, 2010 (number)</th>
<th>People per ha of forest</th>
<th>Distance to market centres (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kikole</td>
<td>1974</td>
<td>1,395</td>
<td>3.1</td>
<td>15</td>
</tr>
<tr>
<td>Kisangi</td>
<td>1996</td>
<td>924</td>
<td>0.5</td>
<td>10</td>
</tr>
<tr>
<td>Likawage</td>
<td>1974</td>
<td>5,994</td>
<td>0.4</td>
<td>13</td>
</tr>
<tr>
<td>Mchakama</td>
<td>1992</td>
<td>1,435</td>
<td>0.5</td>
<td>5</td>
</tr>
</tbody>
</table>

*Table 12.1a: Villages' description*

<table>
<thead>
<tr>
<th>Forests</th>
<th>Area (ha)</th>
<th>Current forest management regime</th>
<th>Forest management certification</th>
<th>Forest legal status</th>
<th>Forest management and harvesting plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kikole</td>
<td>454</td>
<td>CBFM</td>
<td>FSC, 2009</td>
<td>Village Land Forest Reserve</td>
<td>Mandatory VNRC</td>
</tr>
<tr>
<td>Kisangi</td>
<td>1,966</td>
<td>CBFM</td>
<td>FSC, 2009</td>
<td>Village Land Forest Reserve</td>
<td>Mandatory VNRC</td>
</tr>
<tr>
<td>Likawage</td>
<td>17,000</td>
<td>Open access</td>
<td>Non-FSC</td>
<td>Village General Land Forest</td>
<td>Mandatory VNRC/KFO</td>
</tr>
<tr>
<td>Mchakama</td>
<td>3,000</td>
<td>Open access</td>
<td>Non-FSC</td>
<td>Village General Land Forest</td>
<td>Mandatory VNRC/KFO</td>
</tr>
<tr>
<td>Mitarure</td>
<td>60,484</td>
<td>State</td>
<td>Non-FSC</td>
<td>State Forest Reserve</td>
<td>Mandatory KFO</td>
</tr>
<tr>
<td>Rungo</td>
<td>22,586</td>
<td>State</td>
<td>Non-FSC</td>
<td>State Forest Reserve</td>
<td>Mandatory KFO</td>
</tr>
</tbody>
</table>

VNRC = Village Natural Resource Committee  
KFO = Kilwa District Forest Office

*Table 12.1b: Forests' description*
1.2 Methods

1.2.1 Research design
A mixed methods research design (see Creswell, 2013; Lund et al., 2014) was used to evaluate the influence of forest certification on enhancing the ecosystem integrity in the six forests under review and their four adjacent villages (see Figure 12.2). To minimise confounding factors, the forests and villages included were chosen based on their similarities in biophysical and socio-economic attributes, so that the influence of management intervention could be assessed. The selection of each village and forest pair was based on their proximity to each other. An attempt was made to maximise the distance between the certified and non-certified forests and villages but within the same agro-ecological zone and similar vegetation types. Biases introduced by interaction effects were minimised by not selecting villages managing FSC-certified forests that shared a border with villages managing non-certified forests to strengthen the assumption of a relationship between one village and one forest per pair. The assumption here was that there was no influence between them and they could be investigated as independent study sites. Since no data were available to compare the before and after situation, differences were assessed through a cross-sectional study, by comparing the FMRs at the same point in time.

To check whether the differences observed might have happened even without forest certification, we used a retrospective quasi-experimental design (Schreckenberg and Luttrell, 2009) as a form of space-for-time substitution (Hargrove and Pickering, 1992). Similarities were maximised between the certified and non-certified groups by selecting proxy variables that helped reduce observable biases and systematic differences. Two types of counterfactuals were employed, controls in space (forests) and controls in time (recall within communities), to determine reasons behind forest structure differences among the FMRs (see Schreckenberg and Luttrell, 2009). The state forest reserves served as a control group and FSC-certified forests and village ‘general land’ forests served as treatment groups. In this spatial design, the FSC-certified group was compared to non-certified, so that similar values of several proxy variables could be controlled for (see, for example, Strauss and Corbin, 1996). A time dimension factor (control in time, i.e. temporal design) was built into the research methods through the participatory rural appraisal (PRA) and household survey questionnaire, focusing on assessing changes related to forest management interventions. Respondents were asked about perceived changes to the biophysical and socioeconomic aspects in the present situation compared to the time before the inception of forest certification.

To assess the influence of forest certification, it would be optimal to compare FSC-certified CBFM to non-FSC-certified CBFM forests (see Table 12.1b;
Figure 12.1), and the inclusion of non-FSC-certified CBFM forests in the sample would have been ideal, but no non-FSC-certified CBFM forests with similar vegetation types in the same agro-ecological zone were available. Nevertheless, the pre-assessment of forest management before the certificate was granted to Kilwa communities showed that the forests identified for certification suffered similar managerial problems as other forests in the area, such as lack of selective harvesting to enhance/maintain ecosystem integrity (see Soil Association, 2007).

1.2.1.1 Sampling procedure
Forest structure and biodiversity aspects: Stratified systematic sampling design was used. The stratification criterion was ‘FMRs’, which resulted into three strata: 1) FSC-certified community forests - treatment; 2) non-FSC-certified ‘de facto’ open access forests - treatment; and 3) non-FSC-certified state forest reserves - control. A reconnaissance survey based on between plot variability and the forest area was first undertaken to determine the statistically required number of sample plots per forest. For all the forests, the first plot was located randomly at 100m from the boundary of the forest. Using Global Positioning System (GPS), subsequent plots were located systematically at 500m, 1,500m, 1,000m, 2,000m and 1,500m intervals along transects for Kikole, Kisangi, Likawage, Mchakama, Mitarure and Rungo forests, respectively. The distance between transects varied from 500m to 5,000m depending on the size of the forest and the required number of sample plots. Some 131 temporary concentric circular sample plots of 20m radius (0.126 ha) with subplots of 1m radius (0.0003 ha) were established.

Forest governance aspects: The sampling frame for the household surveys was stratified by wellbeing. A participatory wellbeing ranking was, therefore, first carried out in a village assembly in each village, facilitated by the research team, whereby the households were categorised into three groups according to wellbeing (rich, middle and poor). The rankings were carried out using criteria established by the villagers themselves, including a combination of food security, landholding, education level of family members, social status and recognition, and physical assets. Households were then sampled in approximate proportion to the size of each wellbeing category.

Participants in the PRA, as key informants, and in focus groups were identified from an updated village register under the guidance of Village Councils (VCs) and Village Natural Resources Committees (VNRCs). The size of focus groups ranged from 6-12 people. To avoid dominance during the discussion and to allow the villagers to talk freely, the leaders were interviewed separately and requested to leave the PRA exercise soon after their interviews. The PRA data were collected to complement the more quantitative variables collected during interviews and to better qualify the strengths and possible constraints of forest governance and institutions at the village, community and government levels.
Overall, the PRA provided a reasonably accurate overview of the prevailing socio-economic, ecological and institutional conditions in the study villages within a relatively short time.

### 1.2.2 Data collection

**Forest structure and biodiversity indicators' data**

For all trees in a plot, diameter at breast height (dbh) for trees with dbh ≥3 cm was recorded. In addition, two sample trees in each plot, for example, the first and second nearest tree to the plot centre, were selected for measurements of basal diameter (30 cm from ground), dbh and total tree height. A count of seedlings ≤10 cm tall was also carried out from plots of 1 m radius (0.0003 ha). Tree species identification was done in the field by a botanist. Unidentified species were collected, pressed and then taken to the herbarium in the Department of Botany, University of Dar es Salaam, for identification. The identification was done by matching with herbarium specimens by using Flora of Tropical East Africa (see Edmonds, 2012).

Stumps and fire incidences were also recorded from all 20 m radius plots. Basal diameter was recorded for all stumps ≤5 years old. The age of stumps was assessed by local informants based on the colour and degree of decay of the cut surface, combined with their knowledge on whether harvesting activities had recently taken place in the respective forests. Proportion of area burnt (percentage) was also recorded for each plot. Other information recorded at the plot level included distances (in kilometres) to access roads and nearby towns, elevation that were captured using GPS.

**Forest governance indicators’ data**

Qualitative (PRA) and quantitative (household survey) approaches (see Creswell, 2013) were used for data and information collection in the four villages. For the PRA, focus group discussions and key informants interviews were carried out using meetings and semi-structured interviews, respectively. The PRA data included the prevailing forest governance conditions including history of forest management and resources use patterns, forest policies, laws and regulations, such as forest bye-laws, and forest management plans.

The household surveys were conducted using structured questionnaires. A total of n = 176 households (n = 44 per village) were surveyed to provide quantitative data on household’s knowledge and implementation of forest governance, for example, about access to forest resource use, the role of relevant institutions, and forest resource governance.

### 1.2.3 Data analyses

**Forest Structure Indicators**

Data analyses involved the estimation of the following forest structure indicators:
Stem density (N/ha), basal area (m$^2$/ha), volume (m$^3$/ha), and number of seedlings (N/ha). Human forest use indicators estimates included stump density (N/ha) and associated volume (m$^3$/ha), as well as proportion of area burnt/ha. To estimate dbh for the trees that were cut down (stumps) for estimating volume (m$^3$/ha), dbh - basal diameter equations were developed per forest from the sample trees. A local volume model using dbh, as independent variable developed by Mauya et al. (2014) for Lindi Miombo woodlands, was used for the volume estimate. The variations in forest structure and human forest use indicators among the forests were tested in pairs (pairwise comparison) using Bonferroni t-test (see Holland and Copenhaver, 1988). To assess the influence of FMRs in enhancing forest structure, the generalised linear model (GLM) was used to establish the relationships between human forest use indicators (response variables), such as stump volume and fire incidences, and the FMRs (forests) as categorical explanatory variables (with six levels: Kikole, Kisangi, Likawage, Mchakama, Mitarure and Rungo). The GLM was employed using a quasipoisson family to take care of non-normally distributed data (see Crawley 2013), which was the case for the present dataset. Spearman rank correlation test was used to measure the direction and the strength of the relationships between the plot level human forest use indicators (stumps, fire and distances) and forest structure indicators. All these statistical analyses were conducted in R statistical data analysis programme, version 3.0.1.

**Forest biodiversity indicators**

Biodiversity indices including tree (adult and seedling) species richness, diversity and density were estimated as proxies for forest biodiversity indicators (see Kindt and Coe, 2005). There are often correlations between species richness, diversity and density (Hooper et al., 2005; Magurran and McGill, 2011; Rosenzweig et al., 2011). However, they can be differently affected by human activities (see, for example, Balée, 2014; Folke et al., 2004; Hooper et al., 2005; Krebs, 2001) and it is, therefore, relevant to include all three in the analyses. In addition, the relationship between the number of species observed and the number of individuals in a sample is non-linear, which confounds direct analyses of species per individual ratios from samples of different sizes (Sheil et al., 1999). Species richness as the total number of species observed per plot (Magurran and McGill, 2011) and rarefied species richness were estimated. The rarefied species accumulation curves (with 100 permutations, based on significance level of $\alpha = 0.01$) were used to compare richness among the forest management regimes. Species density ($c$), an environmental indicator which is useful in comparing forests of different areas, was estimated using the equation, $c = s/A^z$ (see Rosenzweig et al., 2011). The $s$ is species richness and $A$ is the total sampled area. Plot number per forest was used as a proxy for forest area (see Rosenzweig et al., 2011). The $z$ is a parameter which accounts for the curvature of species-area-relationships (SAR) (Magurran and McGill, 2011, Guilhaumon et al., 2010), and a value of $z = 0.2$, which is recommended for many tropical ecosystems
was used for this study (see, for example, Magurran and McGill, 2011). Species diversity was estimated using *Fisher's alpha* diversity index (Magurran, 1988) as $\alpha = n(1-s)/s$, where $s$ is species richness, $n$ is the number of individuals. The index is a measure of diversity that takes into account variability in stem number (Beck and Schwanghart, 2010) due to human intervention (Balée, 2014). To estimate the biomass of removed trees (stumps biomass), dbh for the trees that were cut (stumps) were estimated from dbh-basal diameter equations developed by Kalonga *et al.* (2015) for every forest. A local biomass model using dbh as an independent variable developed by Mugasha *et al.* (2013) for Lindi Miombo woodlands was used for biomass (t) estimation.

Data analyses were preceded with data exploration using a protocol developed by Zuur *et al.* (2010) to establish appropriate statistical tools to be applied for the analyses. Cleveland dotplots were used to inspect the variables for outliers. No outliers were detected. Pair plots and variance inflation factor (VIF) of three (3) were used to assess collinearity whereas multi-panel scatterplots were used to visualise relationships. Furthermore, relationship between response and explanatory variables were examined using GLM.

The species richness, diversity and density of the different forest management regimes were first visualised using boxplots. One-way ANOVA, followed by Post hoc test for multiple comparisons (Tukey Honestly Significant Differences/HSD) were used to test for differences between parametric variables. For non-parametric variables, the Kruskal-Wallis/Bonferroni t-test was used.

Due to collinearity, distances to nearby town and village variables were not included in the GLM analyses. Response variables in the models were species richness, diversity and density of adult trees and seedlings. The explanatory variables were elevation; forest management regimes, i.e. FSC-certified community forests, open access community forests (OCF) and state forest reserves (FRS); distances to access road; main road; stump biomass and fire (i.e. area burnt), with two-way interactions of all variables. Models were fitted separately for each response variable. The GLM with *quasipoisson* distribution was used to model the relationship between human forest use variables and adult tree species richness and density among the forest management regimes. The GLM with Gaussian distribution was used to model the relationship between human forest use variables and tree diversity. The GLM with *poisson* distribution was used for seedling species richness and diversity, whereas *quasipoisson* distribution was used for seedling density.

Full models were fitted initially and then simplified by backwards selection using stepwise procedure to eliminate the insignificant variables basing on Akaike's Information Criterion (AIC) for gaussian models. Drop one procedure was used for *poisson* and *quasipoisson* models by manually removing insignificant variables
basing on $p$-values to get the final models. All these analyses were done in R version 3.2.0 (R Core Team, 2015) employing vegan (Oksanen et al., 2013), MASS (Venables and Ripley, 2002), and visreg (Breheny et al., 2014) packages. A $p$-value ≤ 0.05 indicated statistical significance.

**Forest governance indicators**
The variations in forest governance indicators among FMRs from household survey data were analysed using the Statistical Package for Social Science (SPSS), version 20.

### 4.0 Results and key lessons from the study

#### 4.1 Results

Results show that forest structure and human forest use indicators that varied among the forests (Table 12.2). Stem density (N/ha), basal area (m$^2$/ha), volume (m$^3$/ha) were significantly larger in Kisangi and Mchakama than in the other forests. Although seedling density (N/ha) in Kikole and Mchakama was higher than in the other forests, they were not significantly different from them. Stump density (N/ha) and fire (area burnt/ha) were significantly larger in Mitarure than in the other forests. Also stumps’ volume (m$^3$/ha) was higher in Mitarure than in the other forests, but insignificant.

Analyses by means of GLM, with stumps’ volume as a proxy for harvesting rate (human forest use) show that there was an effect in Mitarure ($p = 0.0500$) and Rungo ($p = 0.0434$). Meanwhile, there was no effect on the other forests. Fire showed an effect in Likawage ($p = 0.0121$), Mitarure ($p = 0.0038$) and Rungo ($p = 0.0010$), but no effect in the other forests.

Forest governance and institutions indicators show that, more people living adjacent to the FSC-certified community forests were aware of the forest bye-laws in addition to being receptive to them, as compared to those living adjacent to the non-FSC forests (see Table 12.3). Those living adjacent to the FSC-certified community forests were also more motivated to implement SFM and had a more positive attitude towards forest governance than those living adjacent to non-FSC forests.
森林结构指标:

<table>
<thead>
<tr>
<th>指标</th>
<th>Kikole</th>
<th>Kisangi</th>
<th>Likawage</th>
<th>Mchakama</th>
<th>Mitarure</th>
<th>Rungo</th>
</tr>
</thead>
<tbody>
<tr>
<td>树木 (N/ha)</td>
<td>841^A ± 98</td>
<td>1 385^B ± 154</td>
<td>633^A ± 70</td>
<td>1 434^B ± 149</td>
<td>739^A ± 82</td>
<td>461^A ± 55</td>
</tr>
<tr>
<td>基木面积 (m²/ha)</td>
<td>11.0^A ± 1.2</td>
<td>16.6^B ± 1.6</td>
<td>7.7^A ± 0.7</td>
<td>21.4^B ± 1.9</td>
<td>9.9^A ± 0.9</td>
<td>7.4^A ± 0.9</td>
</tr>
<tr>
<td>体积 (m³/ha)</td>
<td>100.8^A ± 25.7</td>
<td>167.4^B ± 42.7</td>
<td>74.4^A ± 19.8</td>
<td>228.2^B ± 52.5</td>
<td>93.0^A ± 19.6</td>
<td>74.1^A ± 24.6</td>
</tr>
<tr>
<td>种苗 (N/ha)</td>
<td>12 009^A ± 3 728</td>
<td>6 897^A ± 3 206</td>
<td>5 040^A ± 2 756</td>
<td>12 732^A ± 5 474</td>
<td>6 543^A ± 4 161</td>
<td>6 476^A ± 2 660</td>
</tr>
</tbody>
</table>

森林使用指标：

<table>
<thead>
<tr>
<th>指标</th>
<th>FSC</th>
<th>Non-FSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>树桩 (N/ha)</td>
<td>0.0^A ± 0.0</td>
<td>0.9^A ± 0.6</td>
</tr>
<tr>
<td>树桩 (m³/ha)</td>
<td>0.0^A ± 0.0</td>
<td>0.7^A ± 0.5</td>
</tr>
<tr>
<td>火灾 (Area/ha)</td>
<td>0.014^A ± 0.007</td>
<td>0.034^A ± 0.011</td>
</tr>
</tbody>
</table>

Table 12.2: Forest structure and human forest use indicators among the forests.

Values after ± are standard errors of the means at 95% confidence interval
The same superscript letters in the same row denote mean values which do not differ significantly from each other at α = 0.05 level.

Table 12.3: Forest governance indicators (%) among FSC and Non-FSC villages forest management in Kilwa (n = 44 per village)
Some 14,346 individual trees were recorded from 188 species, 115 genera and 42 families. Dominant species were *Grewia conocarpa* K. Shum and *Diplorhynchus condylocarpon* (Müll. Arg.) Pichon, while *Combretum, Grewia*, and *Fabaceae, Combretaceae* were dominant genera and families, respectively. No introduced species was observed, as all of them were endemic/core species. There were differences in adult tree and seedling species richness, diversity and density (see Figure 12.3A-F) among the FMRs. Adult tree species (see Figure 12.3A) richness was higher in FSC-certified forests and significantly different ($F_{2, 128} = 60.5, p = 0.0000$) from open access forests (OCF) and state forest reserves (FRS). Diversity (see Figure 12.3B) was higher in FSC-certified forests and significantly different ($F_{2, 128} = 40.62, p = 0.0000$) from OCF and FRS. Similarly, density (see Figure 12.3C) was also higher in FSC-certified forests and significantly different ($F_{2, 128} = 21.26, p = 0.0000$) from OCF.

Seedling species richness was high in FSC-certified forests and slightly significantly different ($KW = 7.6216$, $df = 2$, $p = 0.0221$, Fig. 12.3D) from OCF and FRS. Diversity and density did not differ among forest management regimes (see Figure 12.3E, F).

![Figure 12.2: Adult tree (A-C) and seedling (D-F) species richness, diversity and density among FMRs, which are FRS, FSC-certified forests, OCF. FRS stands for Mitarure and Rungo forests, FSC stands for Kikole and Kisangi forests and OCF stands for Likawage and Mchakama forests as detailed in Figure 12.1 and Table 12.1b.](image-url)
Analyses by means of GLM, with reference to FRS, adult tree species richness, diversity and density significantly decreased with the distance to the main road, whereas interactions between forest management regimes and distance to the main road showed that species richness, diversity and density significantly increased with distance to main road in the OCF. The interactions between forest management regimes and distance to access road showed that species richness, diversity and density significantly decreased with distance to access road in the OCF. The interaction between forest management regimes and stumps biomass (i.e. harvesting intensity) showed that species diversity significantly increased with harvesting intensity in the FSC-certified forests (see Figure 12.3).

Seedling species richness, diversity and density were generally negatively related to fires (i.e., fire significantly decreased seedling species richness, diversity and density in all the forest management regimes). On the other hand, species richness and diversity were significantly and positively related to management intervention (i.e., human forest use) in FSC-certified forests and OCF, respectively; however, they had insignificant relationship with species density in both FSC-certified and OCF regimes. Species diversity significantly decreased with distance to access roads, whereas interactions between forest management regimes and distance to access road showed that species richness and density significantly decreased with distance to access road in OCF (see figures 12.4 and 12.5).
1.2 Key lessons from the study

**Forest structure**
In general, the FSC-certified community forests exhibit the best forest structure (i.e. high stem density, basal area and volume), followed by OCF (non-FSC) which are under REDD+ pilot projects and FRS (non-FSC) with the poorest structure. The possible factors explaining the differences observed could include a combination of human forest use, such as harvesting levels and fire incidences, access and forest governance. The PRA information on historical forest management and use reveal that OCF and FRS are more affected by human forest uses when there are more illegal activities.

**Forest biodiversity conservation**
The harvesting intensity is lower in the certified forests and higher biodiversity than in the non-certified forests possibly due to effective implementation of forest management planning and practices in FSC-certified forests such as
selective harvesting based on species density, size and age. Thus, the low intensity of human forest use, combined with supporting measures such as monitoring and proper calculation of annual allowable cut (AAC) and forest fire control in community FSC-certified forests in Kilwa suggests that there is an effective implementation of forest management plans. In this regard, human activities here are regulated compared to in non-certified forests, which lack effective implementation of forest management plans.

5.0 Implications of lessons learnt for REDD+, climate change mitigation and adaptation

This book chapter highlights the fact that FSC forest certification standards may help to enhance forest structure and conserving biodiversity. The differences in forest structure and biodiversity indicators among the FMRs indicate that human forest uses and inadequate forest governance implementation are major causes of resource depletion and deterioration in these forests. Appropriate approaches are, therefore, required that balance management/conservation and local communities’ needs through ‘adaptive management’ to minimise unsustainable human forest uses. REDD+ is one of these approaches.

There is parallelism between the FSC standards and the National REDD+ social and environmental safeguard standards in achieving SFM, with the aim of meeting communities’ socio-economic needs without compromising the forest ecosystem’s integrity. Most of the REDD+ activities from pilot projects in Tanzania are currently taking place in non-certified forests. The REDD+ safeguard standards are forest-related and not standalone initiatives, and REDD+ is an integral part of SFM. However, the National REDD+ safeguard standards, which guide the implementation of REDD+ activities, pose some implementation impediments, as they do not have international credibility (Nordeco and Acacia, 2014). The incorporation of the REDD+ safeguard standards into the National FSC draft standards, which have clear intents and grounded norms and international credibility, will add clear operational value to the implementation of the REDD+ safeguard standards in Tanzania, whereby they will gain international recognition and credibility. The REDD+ activities in Tanzania will be eligible to access international markets for carbon trading and operational funds from international financial institutions such as the World Bank for activities implementation.

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Governance structures for REDD+
Experiences from Tanzania

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Abstract

This chapter discusses national governance structures for REDD+ in Tanzania. It also documents experiences from REDD+ pilot projects and discusses what findings from these imply for the national REDD+ strategy. The present strategy is advocating a national/fund whereas NGOs favour a market solution. Our research shows that establishing REDD+ will demand substantial developments in local land/forest governance structures including clarifying property rights and developing management plans. Capacities and competences at district,
but also at national levels are weak. There are also important challenges related to ensuring participation and handling of conflicts that REDD+ implies. In this regard, a ‘fund’-based model seems favourable to ensure democratic accountability as well as national capacity building and avoidance of leakage. However, Tanzania’s public administration faces serious problems regarding transparency and managing of decentralisation. Thus, involving NGOs in the REDD+ Fund will help enhance openness. Moreover, learning from their experiences with engaging local communities in REDD+ is also helpful in making decentralisation effective.

1.0 Introduction

Establishing REDD+ demands the creation of new governance structures—i.e., institutions and actors—to manage forest resources. When the international engagement for REDD+ ‘took off’ at the UNFCCC COP at Bali in 2007, it was believed to be a cheap mitigation strategy (Stern, 2006) and fairly simple to introduce. According to the Norwegian Prime-Minister Stoltenberg, “The technology is well known and has been available for thousands of years. Everybody knows how not to cut down a tree” (Statsministerens kontor, 2007). And yet, experiences regarding establishing REDD+ governance structures in various countries have shown that it is demanding. REDD+ is based on the idea of paying forest owners for increased storage of carbon (Angelsen, 2008). It is technically challenging to establish the basis for such payments—e.g. measuring carbon stocks, clarifying property rights and creating institutions for payments. It is also politically demanding to handle the various conflicts of interest involved and to choose and establish systems for administering REDD+.

In this chapter, we have two objectives. First, we clarify which national governance structures have been advocated for REDD+ on mainland Tanzania and what overall direction that has taken. Second, we document experiences from REDD+ pilot projects and discuss what findings from these imply for the national strategy. One pilot project is in Kilosa district. The Tanzania Forest Conservation Group (TFCG) administers this project in cooperation with the Community Forest Conservation Network of Tanzania (MJUMITA)2. The second is in Kondoa district. The African Wildlife Fund (AWF) manages the project.

1 We thank Maria Nantongo, Cecilie Dyngeland, Elvis Mosi, Irina Pleva and numerous research assistants for participating in the collection of data from Tanzanian REDD+ pilots included in this chapter.

2 A membership organisation for village inhabitants. MJUMITA works in close relationship with TFCG.
2.0 Establishment of REDD+ governance structures – the key issues

REDD+ involves changes in the way forest resources are perceived, used and governed. A new ‘product’ is created—that of storing carbon. CO₂ from deforestation comprises about 12-15 percent of total global emissions. Hence, decreasing deforestation creates value in the sense of reducing climate change. At the same time, deforestation is a result of the existing institutions and the motivations they create for economic actors. Reduced deforestation therefore demands changes in the institutions governing forest/land use.

Institutions are ‘rules’ (North, 2005). They are conventions, norms and legal rules directing action, defining what is appropriate and meaningful action (Scott, 2014; Vatn, 2015). A key concept here is the resource regime. It includes which rights and responsibilities different actors have to resources such as property or use rights. It also concerns the rules established for the interaction between actors—e.g., whether it is based on trade, command or co-operation. Important also are institutions governing the political process—the institutions governing the processes that define the resource regimes.

Institutions form and are formed by actors. The governance structure as understood here (Vatn, 2015), therefore, also include the actors involved—economic, political and civil society actors. These actors are defined by the rights and responsibilities that they hold regarding access to resources—the resource regimes—and the political processes forming these regimes—the political institutions.

REDD+ implies a series of governance related questions. There are issues regarding how to raise and distribute funding, how to define who has rights to forest resources (especially carbon), how to motivate involved actors to reduce deforestation and forest degradation, and how to administer the system (see also Angelsen, 2009; Lederer, 2012). This regards the overall legitimacy of the systems created including whose rights should be protected. It regards, however, also more technical issues regarding how to organise payments, how to measure carbon stocks, and how to ensure additionality and avoid leakage. This is all about the creation of new institutions and probably also about defining new actors.

A key issue in REDD+ is clarification of rights. Most tropical forests are under legal pluralist regimes. Forest dwellers may have customary (use) rights whereas the state holds formal property rights by declaration (Sunderlin et al., 2012; Larson et al., 2013). In such situations, rights are typically contested. This becomes a special challenge in the case of REDD+ as defining a ‘right to carbon’ appears in an institutional landscape where the rights to land and trees are contested.
Rights should be defined in a legitimate way. Legitimacy may be defined as ‘due process’, as following the process of law. This definition does not however capture the quality of the decision: that the law itself may be viewed as unfair or inconsistent. More recent literature on legitimacy, therefore, distinguishes between input and output legitimacy (see e.g., Bäckstrand, 2006). The former concerns the acceptability and appropriateness of policy processes both on the grounds principle and the treatment of the interests involved. Issues such as responsibility, participation, transparency of the process and the accountability of decision-makers to wider constituencies are key (Vatn and Vedeld, 2013).

Output legitimacy regards obtained results. The literature tends to emphasise aspects such as effectiveness, efficiency and equity (Angelsen, 2008, 2009). Whereas effectiveness in our case regards the capacity to raise funds, reach carbon sequestration goals through ensuring additionality and avoiding leakage, efficiency regards cost-effectiveness, including transaction costs. The REDD+ literature refers finally to co-benefits emphasising both equity issues/poverty reduction and biodiversity protection.

Establishing REDD+ governance structures ‘in a good way’ is demanding and will typically take place in rather weak institutional environments. Moreover, it may demand profound changes in local practices (Hiedanpää and Bromley, 2014). Also, the financial basis is not clear. Today funding for REDD+ mainly comes from a few donor countries, with Norway being the most prominent even in the context of Tanzania. In fact, there is yet to be an agreement at the international level to create a global structure that facilitates the future financing of REDD+. Hence, countries face great financial risks when they invest a lot in capacities to support REDD+ (Mustalahti et al., 2012).

3.0 Methods
This chapter is based on data gathered under the CCIAM project ‘REDD Architecture in Tanzania: Assessment of REDD options for Livelihood Security and Sustainable Development’. Supplementary data were collected under the project ‘Poverty and sustainable development impacts of REDD architecture: Options for equity, growth and the environment’ led by IIED3 and the project ‘Man and forests – an evaluation of management strategies for reduced deforestation and forest degradation’ led by Noragric, NMBU4.

3 International Institute of Environment and Development (London). The project was financed by Norad.
4 Norwegian University of Life Sciences (Aas, Norway). The project is funded by the Norwegian Research Council.
Regarding data sources, we have interviewed key informants at the national, district and village levels, people representing the Tanzanian government, the REDD+ Task Force, district (forest) officers, village executives and NGOs. At the village level, we have also acquired data from household heads and male and female focus groups. Finally, we have used printed sources including Tanzania’s policy documents, materials from NGOs and material from research conducted by others that supplements our own data. Data were collected in the 2010-2016 period, hence, from the time REDD+ pilot projects were introduced in the villages, through to after the pilot projects were terminated.

4.0 Overall governance structures for REDD+ in Tanzania

In the literature on REDD+ governance, there is a distinction between a ‘market’ and a ‘fund’ based approach, for example, between compliance and donor-based funding. Highlighting markets reflects a trend towards more use of markets both in general (e.g., Pierre and Peters, 2000) as well as in the case of forests/REDD+ (e.g., Corbera and Brown, 2010; Okereke and Dooley, 2010). Markets are expected to yield less bureaucratic, more adaptive and innovative solutions. An alternative to this neo-liberal trend emphasises the fact that a contracted state reduces accountability, results in losses of communication channels between the state and its citizens, and leads to more patchy and unreliable service delivery, as well as more power to less accountable local elites. Issues around markets and fairness are also emphasised (Pierre and Peters, 2000; Okereke and Dooley, 2010).

It has been argued that to create enough resources to make REDD+ effective, a (global) compliance market is necessary. Donor-based financing will be too small (e.g., Karousakis and Corfee-Merlot, 2007; Saunders et al., 2008). However, as Vatn and Vedeld (2013) argue, by establishing a global REDD+ fund having the power to issue REDD+ credits to actors/firms under compliance, there will be no significant difference between the two models regarding the capacity to raise money.

The choice of national REDD+ structures in Tanzania must be understood in this wider context. The short story is that the Tanzania government prefers a type of fund-based solution established within the state structure whereas the NGOs have favoured a more market-oriented solution reserving state engagement mainly to monitoring—what they call a ‘nested approach’. Below we describe the process regarding the establishment of a national REDD+ strategy for Tanzania, the decisions regarding relevant property rights, and finally the decisions made regarding the overall governance structure for REDD+. 
4.1 The process of establishing the Tanzania REDD+ strategy

The National Strategy for REDD+ (URT, 2013) describes the planned REDD+ governance structure. This document exists in two publicly available drafts—URT (2010) and URT (2012). The Vice President’s Office (VPO) has been responsible for formulating the strategy. Early in 2009, an interim National REDD Task Force (NRTF) was established to oversee the implementation of technical and operational issues in relation to REDD+ readiness, including serving as the secretariat for producing the national REDD+ strategy. From the outset, the NRTF included six members—three from the VPO and three from Forest and Beekeeping Division under the Ministry of Natural Resources and Tourism (MNRT/FBD). Later the same year, a representative of the government of Zanzibar was included. In 2012, the number of ministry representatives was expanded to 12 and involved ministries covering agriculture, energy, etc. A member from civil society was also included5.

Two main forms of communication with the wider group of stakeholders were established. First, there was a series of awareness raising drive and consultative meetings organised regionally that included NGOs, regional, district and local representatives (URT, 2010:13). According to the Forest Carbon Partnership Facility (2014), seven such meetings have been held. Second, the various drafts of the national REDD+ strategy were shared with key stakeholders to invite comments and inputs (URT, 2012).

Although there have been civil society consultations, NGOs involved in forest management have criticised the process for being slow and increasingly closed/c centred on the NRTF. According to Rantala and Di Gregorio (2014), NGOs organised public protest events. They also commented on various REDD+ documents. This way, they established themselves in the policy arena and obtained the position in the NRTF. Looking at the various versions of the REDD+ strategy, some influence from this coalition is observable, as we will discuss later. It is notable that NGOs dominantly are national and international organisations involved in nature resources management and protection, for example, AWF, MCDI, MJUMITA, TaTEDO, TFCG, and WCS. MJUMITA is the only organisation having a local membership base.

4.2 Rights to carbon

A key issue in the above debate regards the rights to carbon and hence to REDD+ carbon sequestration payments. In practice, this concerns what (bundle of) rights villagers have to the forests they use. The Land Act (URT, 1999a) defines three main categories of land: reserved, village and general land. Reserved land covers

5 Mr. Charles Meshack, Executive Director of TFCG
statutorily protected land such as national parks and wildlife reserves. It also includes land for harvesting resources by the state and districts—the so-called production forests. The Act stipulates that village land is “land declared to be village land under and in accordance with section 4 of this Act and includes any transfer land transferred to a village” (URT, 1999a: Section 2). On the other hand, general land “means all public land which is not reserved land or village land and includes un-occupied or unused village land” (URT, 1999a: Section 2). The Village Land Act defines, however, general land as “all public land which is not reserved land or village land” (URT, 1999b: Section 2).

According to the Land Act, village land has therefore to be declared (‘formalised’) whereas the Village Land Act includes also customary ownership. Using the former definition, the amount of forests on general land is about 54 percent of all forests (URT, 2012). According to the definition of the Village Land Act as calculated by the Ministry of Lands and Human Settlement Development (URT, 2011), the size is only two percent. The difference stems from what is considered village land, which in the latter source is defined as 70 percent.

As the government is responsible for general land, which definition is used has implications for who is eligible for REDD+ payments and for establishing leasing contracts with investors, etc. on large forest areas. It is notable that the Land Act will prevail if in conflict with other laws (URT, 1999a: Section 181). In fact, the Tanzania RPP and drafts of the REDD+ strategy based their estimates on the definition of the Land Act. This has been contested by NGOs such as the Tanzanian Civil Society Organisations (2010), TFCG and MJUMITA (2011), and Tanzanian Civil Society Organisations (2012).

In its second draft of the REDD+ strategy, the government acknowledged that there is “insecurity with the general lands stemming from the definition… There is little doubt that this definition raises concern of freeing ‘surplus’ land from villages, including forest lands, for external investors” (URT, 2012:25). In the final REDD+ strategy, however, the government shifted its position and defined general land de facto in line with the provisions of the Village Land Act (URT, 2013), while again including the above text from the 2012 draft on general lands.

Another issue regards the rights of local communities in reserved forests (state-owned). According to the principles of participatory forest management (URT, 2002), villagers may participate in the management of forest reserves through joint forest management. The REDD strategy states that “Joint Forest Management (JFM) is currently a strongly favoured approach to the management of state owned forests, with management responsibilities and returns divided between the state and the communities adjacent to the forest” (URT, 2013:11). Although almost 13 percent of reserved land on mainland Tanzania was under the JFM
by 2008 (op.cit.), TFWG (2010) states that no guidelines for revenue sharing under the JFM has yet been released. In fact, the REDD+ strategy does not clarify the issue. It just notes that “cost-benefit sharing mechanism under JFM (is) still not fully operational” (URT, 2013:11).

4.3 Overall REDD+ governance structure

4.3.1 Responsible authority
The governance structure as specified in the REDD+ strategy—“the institutional structure for REDD+ implementation and reporting”—is complex (URT, 2013:22). It has been made part of the overall climate change governance structure. This is similar to ambitions of countries such as Brazil, while deviating from countries such as Indonesia and the Democratic Republic of the Congo that have established a separate REDD+ agency or Nepal whose REDD+ is under the responsibility of the Ministry of Forests and Soil Conservation (Vatn et al., 2013).

There seems to have been some issues in the early stages, though. According to Manyika (pers. comm.), there were three options for organising REDD+: a) under the VPO including the Department of Environment; b) under the Prime Minister’s—now under the President’s—office as responsible for local government; or c) under forestry administration (MNRT/FBD). Option b) was soon discarded. Regarding the choice between a) and c) the issue seems to have prevailed for a while. A memorandum of understanding regarding REDD+ was signed in 2009 between UN-REDD and the MNRT/FBD establishing the latter as the REDD Focal Point of Tanzania. In the end, the argument that REDD+ should be part of the overall climate strategy of the country seems to have won. In this regard, the VPO/Department of Environment was made the main responsible body. Ningu (pers. comm.) emphasised that there was really no doubt, as climate policy was the responsibility of the VPO/Department of Environment.

4.3.2 Three key issues on REDD governance structure
Regarding the presentation and evaluation of the REDD+ governance structure, we will focus on three issues. First, we look at the strategy for channelling REDD+ funds to eligible receivers. Second, we briefly cover the system for monitoring, reporting and verification (MRV). Finally, we include key points regarding the conditions for participation of villages in REDD+.

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6 It is notable that the REDD+ strategy does not refer to a ‘REDD+ Focal Point’, being the international standard, but ‘National Climate Focal Point’.
The REDD+ strategy specifies a national REDD+ Trust Fund to “consolidate and distribute funds to different stakeholders based on efforts in implementing REDD+ strategy. It will operate at the national level. The fund will observe issues of transparency and accountability. Also, the performance of past forest revenue management systems, benefit sharing and incentive schemes will be assessed to provide lessons for REDD+” (URT, 2013:20-21).

The fund solution has been criticised by the coalition of NGOs. They have favoured a nested model underscoring the fact that communities should be allowed direct access to REDD+ markets (e.g.; Tanzania Civil Society Organisations, 2010; Tanzania Civil Society Organisations, 2012). A key motivation for this alternative was a distrust in the government’s capacity to ensure that resources would reach the forest communities where REDD+ action would be undertaken (Tanzania Civil Society Organisations, 2012; Rantala and Di Gregorio, 2014). It is also notable that TFCG— the most active NGO— together with MJUMITA has engaged itself in establishing a ‘carbon enterprise’ to support villagers trading carbon not least by pooling supply and offering support in negotiations. Hence, an alternative national model to a state-based system could be foreseeable.

According to Manyika (pers. comm.), the issue of establishing a national fund created heated debates at both the stakeholder meeting held in Kibaha in 2009 and at an ‘extended’ task force meeting held in Tanga in 2011. According to him, representatives of, for example, the UN-REDD supported the NGOs’ emphasis on the need for a transparent system that is inclusive and adheres to good governance practices. Experiences with corrupt public practices are key here (see also Section 5). Representatives of the government emphasised that NGOs do not have the national coverage, and that there will be serious problems with leakage, that REDD+ must balance against development needs and that there are several risks involved in embarking on a market/project based governance structure (op.cit.). Certainly, if TFCG/ MJUMITA were successful in creating a nationwide carbon enterprise, this could challenge the role of the state as a responsible for country-wide land use planning.

The NGOs acknowledged some of the challenges of a market-based system with price fluctuations and higher implementation costs than a single national approach (e.g., TFWG, 2010). They still supported a market-oriented strategy as they believed it would raise more funds and because the large risks local communities face regarding getting their fair share in a state based payment system.

The REDD+ strategy also somewhat presents a caveat on the part of the government. First, the strategy notes that while the fund-based solution is favoured, “the on-going global processes through UNFCCC will inform the
appropriate financing mechanism” (URT, 2013:17). Second, the strategy realises that sustainable forest management has not been “fully realised due to among others poor governance at local as well as district, regional and national levels” (op.cit:19), referring to corruption, elite capture, minority marginalisation, low accountability, inadequate transparency and weak law enforcement. According to the Strategy, REDD+ must offer benefits to villagers, or they may “withdraw their co-operation” (op.cit:10). Observing this is one thing, being able to reform public systems duly is another. REDD+ could offer enough resources also to make reforms of relevant public systems possible. Great uncertainties prevail, however.

In relation to this, it is notable that the management of the fund and how resources would be channelled down to the local level is left without any clarification in the strategy. Indeed, the roles of various actors at the national level are not specified and there are no principles clarifying how funds should be managed. The overall structure is very complex adding a REDD+ Fund to a structure including all three systems of relevance for REDD+, for example, the environmental administration, the forest sector, and finally the regional administration and local government under the President’s Office. The district natural resource and forest offices are actually under this latter jurisdiction. What role each administration is supposed to play is not discussed.

A second key issue concerns the system for MRV. The REDD+ strategy envisaged the establishment of a National Carbon Monitoring Centre (NCMC). This was a less conflictual topic than the one regarding the REDD+ Fund management. Certainly, some NGOs such as TFCG argued that the nested approach should include local monitoring and that this data could be fed into a national system (Manyika, pers. comm.). According to Rantala and Di Gregorio (2014), NGOs accept that there has to be a national accounting system. Establishing NCMC has, nevertheless, been slow. It took time to decide who should host the centre. In 2012, the VPO decided that it should be hosted by Sokoine University of Agriculture (SUA). The decision was, however, announced first in March 2013 (Ngaga, pers. comm.). This delay seems to relate to the uncertainty regarding the funding of NCMC. The Tanzania government has been reluctant to establish the centre before financing was more secure. Given the slow developments of the international structure for REDD+, this has been a serious limitation (Norad, 2013).

Finally, the format for village/forest community participation is a very important aspect of REDD+ in Tanzania. There seems to be no conflict regarding the importance of Participatory Forest Management (PFM) as a basis for REDD+ either in the form of Community-Based Forest Management (CBFM) or through JFM. The government/REDD+ strategy and the NGOs both emphasise PFM.
However, the functioning of PFM may be different if part of a ‘market’/‘nested’ or ‘fund’/‘national’ model.

The legal basis for PFM is found in the Forest Act of 2002 (URT, 2002). The REDD+ strategy sees PFM as “by far the most promising option for restoration of the large areas of degraded land in Tanzania” (URT, 2013:13). Moreover, it is stated that “To improve governance at local level that will eventually facilitate sustainable PFM, the village institutions need capacity development in areas such as planning, mobilisation, finance management, good governance, and lobbying” (op.cit.:19).

Hence, the government acknowledges that it has been demanding to establish PFM. In the case of CBFM, NGO representatives have claimed that this is due to lack of recognition of village land and that the process is too complex and formalistic (e.g.; TFCG and MJUMITA, 2011; Rantala and Di Gregorio, 2014). The government acknowledges that the process is slow stating that “access to REDD+ finances through fund based financing arrangements could facilitate and speed up this process” (URT, 2013:xv). So, according to the government, REDD+ may offer resources to do what one has already decided, but failed to accomplish.

### 5.0 Establishing REDD+ at the local level

Section 4 has raised several issues regarding the REDD+ governance structure with implications for local communities. In this section, we will try to shed some further light on these by documenting experiences from the establishment of two REDD+ pilots—the TFCG/MJUMITA pilot in Kilosa and the AWF pilot in Kondoa, both funded by the Norwegian government. After situating the two pilots, we briefly cover the following topics:

- The process of introducing REDD+ at village level
- The establishment of village forest governance structures
- The payment to villagers for REDD+ efforts

These processes cover the main steps of the pilot developments. Both pilot projects were based on the national systems for PFM. In the Kilosa case, only CBFM was involved as all forests were on village land. In Kondoa, JFM was the dominant strategy.\(^8\)

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7 Some of the data presented here have already been published in Mosi (2013), Vatn et al. (2013); Dyngeland et al. (2014); Kajembe et al. (2015)

8 All pilots in Tanzania were funded by the Norwegian government and administered by NGOs. The choice of NGOs can largely be explained by the fact that at the same time as the pilots were initiated, there were issues raised regarding mismanagement of funds previously transferred from the Norwegian government to the MNRT.
5.1 Kilosa and Kondoa before REDD+

The Kilosa pilot borders the Eastern Arc mountain range and is dominated by Miombo woodlands and sub-Montane forests. Although there are forest reserves and national parks in Kilosa, TFCG selected villages to participate in REDD+ that have forests only on village/ general land. The main loss of forests in the area took place in the colonial era – especially due to establishment of large sisal plantations. Recent key drivers of deforestation have been clearing for (subsistence) agriculture, charcoal production, firewood collection, timber extraction and bush fires (Hall et al., 2009). None of the villages had been involved in PFM at the time the pilot started.

The Kondoa pilot is in the Kolo hills, central Tanzania. More specifically, it is concentrated on villages surrounding the Salanga (central government) and Isabe (local government) forests reserves. Miombo woodlands dominate. Drivers for deforestation are similar to Kilosa though grazing also plays an important role in the Kondoa pilot area. Between 1973 and 1996, SIDA, in co-operation with Tanzania authorities, had ran a project in the area called Hifadhi Ardhi Dodoma (HADO) focusing on reducing erosion through destocking. It was a controversial and quite top-down oriented project. The government continued the project but at a much-reduced level after SIDA had stopped its engagement (Sweti, pers. comm.). Finally, AWF started introducing PFM in villages in Kolo hills already from 2007.

5.2 Introducing REDD+ in Kilosa and Kondoa

Introducing REDD+ started in both districts by the NGOs approaching the districts. This took place in 2009. After both districts endorsed REDD+, a process was initiated where villages were visited to enquire if they were interested in joining REDD+. First, meetings were held with village councils. Later, village general assemblies were held where the villages decided whether they wanted to engage in REDD+. TFCG also included a meeting with villagers at sub-village level before the general assembly was convened. About 20 percent of those with the right to vote attended these meetings (Forrester Kibuga et al., 2011; Matilya, pers. comm.; Pima, pers. comm.). Representatives both of the NGO and the district attended meetings, informing about REDD+ and its implications. Although the climate dimension was explained, REDD+ was nevertheless mainly coached in a more familiar way – that of resource conservation.

In the case of Kilosa, all 13 villages invited endorsed REDD+. One village—Munisagala—opted out at a later stage, as there were opposition building up in the process of land use planning (see below). A study undertaken in five of

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9 There was also a 14th village – Masugu. TFCG decided not to include it due to its incorporation into Kilosa town.
the villages in Kilosa in 2013—Chabima, Dodoma Isanga, Ibingu, Ilonga and Kisongwe (see Mosi, 2013; Vatn et al., 2013)—documented that villagers were quite happy with the project and how it was introduced (N=125). Whereas the majority (72%) were ‘positive’, the minority (21%) were ‘very positive’. The rest were mainly ‘indifferent’ while very few were ‘negative/very negative’. The main reason for being positive was a felt need to conserve forests, as they were perceived to be in a bad state. People were in general also happy about the information offered. Although the overall impression is that meetings were dominated by TFCG, district representatives and village leaders, our data show that questions were raised and disagreements voiced. Some villagers feared that villages might lose their land. These issues came also through in focus group discussions, typically referring to previous experiences with ‘land grabbing’. Some villagers felt that it was difficult to voice disagreements. Internal conflicts over land use also appeared. We will return to that topic in the section on land use planning. In relation to the above, one should note that TFCG seems to have emphasised mainly the gains from REDD+, both carbon payments and gains from conservation, agricultural development, etc. Risks were not emphasised and it seems to have been assumed that REDD+ would be able to cover lost income from reduced access and use of forest resources.

Introducing REDD+ in Kondoa seems to have been more conflictual than in Kilosa. Some 21 villages situated around the Salanga and Isabe forests reserves were invited. There was strong resistance against participating in REDD+ in five of these: Kisese-Sauna, Kisese-Disa, Mapinduzi, Mitati and Itololo. Political conflicts—the opposition dominated in some of these villages and REDD+ was seen as government related—and high forest dependence are among important explanations (Kasisi, pers. comm.; Matilya, pers. comm.; Mvungi, pers. comm.). In the end, Kisese-Disa and Itololo did not embark on REDD+. Mitati opted out in the process of land use planning. Here there were strong opposition at the general meeting called to discuss the land use plan. The meeting ‘turned chaotic’ and AWF/the district representative had to leave. It should also be mentioned that one village, Puhi, was not paid because the village did not comply with the rules defined. The REDD+ forest was highly degraded. In some of these cases, there were local actors—often leaders—that went against REDD+ and AWF. It seems like they had personal interests in maintaining the status quo, possibly because they had substantial interest in, for example, charcoal burning.

This situation also resulted into lower appreciation of the REDD+ project among Kondoa villagers than those from Kilosa. We made interviews in altogether seven villages (early 2014). Four of these were engaged in REDD+ (Kolo, Mnnenia, Mapinduzi and Masange). The three other villages were Kisese-Disa (not involved), Mitati (withdrew in the land-use planning process) and Puhi (did not comply). People in the first four villages were actually slightly more
positive than the villagers interviewed in Kilosa (N=121). In the three other villages, about 40 percent were negative/very negative (N=90).

In both Kilosa and Kondoa, some villagers stated that they did not feel free to accept/reject REDD+ - as voiced by 13 percent and 18 percent in Kilosa and Kondoa, respectively (based on the total sample). Judging from the figures, it should be noted that it may have been very difficult to oppose REDD+ as it was backed by the district and village leadership in most villages. Moreover, information was almost without exception coming from the pilot organisers that obviously depended on the success of REDD+. Finally, the focus group data from Kilosa reflected somewhat more discontent than interviews with household heads. The issue most emphasised regarded the level of payments. We will return to this.

5.3 Establishing village forests and land use plans

As already emphasised, both TFCG and AWF based their projects on participatory forest management. Establishing CBFM focused on the demarcation of a village forest reserve, a land use plan, a forest management plan and attendant bye-laws. If a village land certificate did not exist, demarcating village borders needed to be undertaken before these processes could start. PFM is assumed to be both initiated and led by the district but administered by a Village Natural Resource Committee (VNRC) in each village.10 According to the guidelines (MNRT-FBD, 2007), a participatory resource assessment forms the basis for developing plans and enacting bye-laws. The latter must be presented to the village council and assembly for endorsement before it goes to the district and later to the National Land-use Commission for formal approval.

The Kilosa pilot seems to have followed these guidelines. Members to VNRCs were elected already at the first village assembly meeting.11 None of the villages had land certificates, so that had to be initiated. Thereafter, reserved forests were demarcated and village forest management plans and bye-laws were created. Management plans and by-laws typically vary across villages depending on a given situation. Bye-laws define utilisation that do not demand prior permission; utilisation demanding permit but no payment; utilisation demanding permit with payment; and finally activities not allowed. Farming, grazing and setting fire within forest reserves are generally not allowed. In many cases, village bye-laws also prohibit timber harvesting and charcoal burning, whereas some villages demarcated areas for both protection and utilisation and seem to have allowed (sustainable) charcoal burning and timber harvesting against a paid permit in utilisation zones.

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10 A village land-use planning committee under the VNRC was also involved.

11 According to the law, each village should already have such committees. They were, however, not functioning at the time REDD+ was introduced.
The process was not without problems. We note three main issues. First, border conflicts between two of the ‘REDD+ villages’ and between a ‘REDD+ village’ and another village were observed. Second, there were conflicts regarding the relocation of people within the village forest reserve as settlements there became illegal. Finally, there were conflicts especially between charcoal-burners and other villagers regarding the size of the forest reserve and its regulations, as charcoal burning would be restricted. According to Pima (pers. comm.), some people claimed that TFCG was taking their land. This created distrust, although accusations diminished over time as TFCG showed that this was not their intention. In the focus group discussions, people noted that conflicts were largely resolved through mediation and explaining the importance of forest conservation.

As already mentioned, one village—Munisagala—opted out at the stage of land-use planning. According to Enos (pers. comm.), the fear of losing land was strong. There was also an issue regarding the proposal in the land-use plan to establish a common cemetery.

It is notable that the process of getting land certificates has been slow. According to Pima (pers. comm.), TFCG/MJUMITA went on establishing land use plans without, for example, waiting for the time-consuming formal approval of village borders from the national authorities. They did so to complete the pilot project within a given timeframe. By 2015, only two villages in Kilosa had received such certificates. The rest are awaiting signatures from the Commissioner of Land.

In Kondoa, all the villages seem to have land certificates from 2007 (Kasisi, pers. comm.). However, regimes had to be created for JFM and CBFM. Of the 19 villages engaged from the beginning, 12 had no village forests but bordered the Isanga or Isabe forest reserves. Five villages had only village forests whereas one village had forests under both regimes.

The creation of land-use plans/forest management plans and bye-laws seems to have followed the same system as in Kilosa. Land-use planning was in practice not led by the district, though. Instead, AWF engaged the National Land Use Commission as the district was found to have too little technical competence (Matilya, pers. comm.).

A main difference from Kilosa was the establishment of JFM. It implies that management responsibilities and returns are shared between the state and the communities adjacent to the government forest. As emphasized in Section 4, no resolution had so far been made regarding the benefit sharing under JFM, heavily restricting the functionality of the regime. Clarifying this, therefore, became a key issue in Kondoa. The forest reserves were gazetted long ago—Salanga in 1941 and Isabe in 1954. The JFM process followed the standards for PFM.
regarding the making of a forest management plan and bye-laws. That is, since there are two government forests and 13 villages involved, AWF, the district and Tanzania’s Forest Service (TFS)\textsuperscript{12} drafted one management plan and one set of bye-laws for both forest reserves. This draft was discussed with the VRNC in each village. The final draft was then submitted to each village council and taken to the general assembly for approval. The final document was signed by TFS, the district and a representative of JUHIBEKO, an association formed with representatives from the 13 villages (Kasisi, pers. comm.).

The JFM agreement allows free collection of non-timber forest products such as wild fruits and mushrooms. Collection of firewood and grazing (in defined periods) is allowed with a valid paid for permit. The number of animals per household is limited to four oxen. Farming, hunting wild animals, timber lumbering and charcoal burning are prohibited. The same goes for mining, collection of medicinal plants, destruction of water sources and removal of soil humus. Most of the villagers were familiar with these rules as they pretty much reflected already the existing restrictions as the forest was a catchment as opposed to a utilisation reserve. Certainly, the rules were weakly enforced and so in that sense REDD+ seems to have made a difference.

Regarding the rules for benefit sharing, AWF proposed that 80 percent should go to JUHIBEKO and 20 percent to the district and Tanzania Forest Service (TFS) for their respective areas. This proposal was contested, as TFS demanded a bigger chunk of the stake. According to Jalabai (pers. comm.), it wanted a 60-40 sharing rule. Communities mobilised and in the end the agreement between JUHIBEKO on the one side and TFS and the District Council on the other—signed in 2015—became 80-20 (Kasisi, pers. comm.).

Regarding conflicts, the toughest ones surfaced at the start of the REDD+ process. The ‘stage’ of land-use planning seems to have been less conflictual, except in the cases of Mitati and Puhi. None of these villages was adjoining the forest reserves and hence may have had more to lose/less to gain. This is in some way also confirmed by the fact that Kisese-Disa and Itololo—the two villages bordering the forest reserve that did not engage in REDD+—have now approached the district enquiring about the possibilities to participate in the established JFM system. Kisese-Disa actually signed the JFM agreement in December 2015 (Kasisi, pers. comm.). As the JFM agreement regards all forests in the reserves, the rules also apply for Kisese-Disa and Itololo. Hence, joining implies possible gains, with no extra costs, except that signing the agreement may make the village representatives feel more responsible for their village abiding by the rules.

\textsuperscript{12} TFS was established in 2010. It took over the responsibility of managing central government forests from MNRT/FBD.
5.4 Payment systems

Finally, with regard to the payments, both TFCG and AWF undertook so-called trial payments; however, they were organised in different ways. TFCG/MJUMITA made payments based on ‘mimicking’ a performance-based system including estimated amounts of reduced CO₂ emissions per ha for each type of forest valued at the present market price for CO₂. The latter was quite low at the time. A leakage factor included was related to how much forests there were in the village outside the village forest reserve. This system determined the total payment for each village. Regarding the rules for internal distribution at village level, TFCG/ MJUMITA developed three options regarding payments from which the villagers could choose: a) a system with individual payments; b) payments made to community development projects; and c) payments to the natural resource committee for protection projects (TFCG and MJUMITA, 2012). The first option included the possibility that the village assembly would decide on a certain fraction of the individual dividend to be retained by the community for use in community projects.

Regarding individual payments, the proposal was that they should be equal across individuals, that is, limited to a maximum five persons per household. The argument was that forests were communal. Meshack (pers. comm.) moreover clarified that payments according to individual opportunity costs went against local norms. Charcoal producers were perceived to be taking too large a share of a common resource. We note that this solution was also much less costly to administer than a system based on individual opportunity costs. Although the latter is the ‘ideal’ of a performance-based REDD+, such a procedure would easily have consumed all the money available for payments.

Most village assemblies chose the individual payment option with a fraction kept for community projects. Some decided, however, to keep the fraction for community projects with TFCG until they had sorted out internal governance issues. Some villages with low total payments chose a method without individual payments. It is notable that TFCG and MJUMITA seem to have favoured the first option, as it was believed to increase the sense of community-wide ownership over forests and ensure transparency (Pima, pers. comm.). The rules—formulated as REDD+ payment bye-laws—seem not to have been much contested. The level of payments, that is an average of about 10,000 Tsh (5 USD) per person, was however creating discontent. It seems significantly below expectations (Dyngeland and Waized, 2013). We also observed a sub-village at

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13 The money still came from the payment issued to the pilot by the Norwegian government.
14 It should be noted that in our analyses of preferred options for REDD+ payments made in 2010 – i.e., before REDD+ was instituted, villagers in Kilosa (N=180) seem to have favoured community projects rather than payments to individual households (Movik et al., 2012). The evaluation report of REDD+ pilots in Tanzania by NIRAS states that the TFCG/MJUMITA payment model was popular (NIRAS 2015)
Lunenzi that did not get any payments as it was too far away for them to attend the payment meeting. Added to payments, there were some training, etc. for new or improved income-generating activities such as intensified agricultural practices, beekeeping and chicken rearing. This was also part of a strategy to increase income as well as to reduce pressures on forests.

The most novel part of the TFCG/MJUMITA pilot was the establishment of a so-called ‘carbon enterprise’, functioning within MJUMITA. The idea was to build an organisation with competence to trade carbon credits at international markets including a structure that could aggregate emission reductions across villages to increase volumes and reduce transaction costs (TFCG and MJUMITA, 2012). It also includes validating, monitoring, reporting and verification components (Meshack, pers. comm.). The carbon enterprise has so far not been able to enter the international carbon market. Accessing it seems to have been demanding (see also NIRAS, 2015).

AWF put much less emphasis on payments than TFCG/MJUMITA. According to Matilya (pers. comm.), it was not included in their original plan. The main strategy was to invest in changed/new practices such as agriculture that is more intensive, more energy effective stoves, bee keeping, and brick making. Certainly, it has been a challenge that the resources set aside for this made it possible to only reach a rather small fraction of the inhabitants.

In the end, AWF re-budgeted and was able to make a trial payment. Payments were made to village councils through JUHIBEKO who kept 15 percent. AWF paid based on rule compliance and the size of ‘REDD+ forests’. The area of the state forest reserves was divided equally between the 13 participating villages. Here the payments varied between 6.9 and 4.9 million Tsh per village\(^\text{15}\). These resources were allocated to different community projects as decided at general village assemblies (Kasisi, pers. comm.). Payments to ‘CBFM villages’ were made based on similar rules.

### 6.0 Discussion and Conclusion

This chapter demonstrates that Tanzania faces some serious challenges and dilemmas in its process of establishing well-functioning REDD+ governance structures. Starting with the present REDD+ strategy, we have first-of-all observed difficulties related to defining clear responsibilities within the government. It actually involves three subsystems: a) the governance structure for climate policy; b) the sector competencies – e.g., forestry, agriculture and energy; and c) the system for local government.

\(^{15}\) Which is lower than in Kilosa – as calculated per person
Although all may have to be involved, a clear definition of responsibilities is lacking. Second, data from the pilots under review show that it is demanding to create rights and management rules ensuring reduced deforestation and next link payments to the villages where gains are obtained. A national/fund based model will similarly demand clarification of rights, effective procedures to motivate behavioural change and measure impacts. Inadequate capacity in an underfinanced natural resource sector at district level stands out. Capacity problems are observed also at the national level as illustrated by the slow process of gazetting village forests in Kilosa. Finally, the challenges regarding elite capture and corruption will demand much investment in transparent systems regarding resource transfers.

Given all these issues, would a system based on markets and projects managed by NGOs (or other intermediaries) fare better? The most important issue here is that of accountability. Making national policies dependent on organisations that are not part of the general system of democratic control is problematic. Although such control at present seems weak in Tanzania, this is not an argument for discarding accountability issues. To do what may seem easiest now is problematic in the longer run regarding strengthening democratic processes and political accountability. In relation to that, we note that the NGOs involved have—with one exception—no membership base. In that respect, they lack legitimacy as representing the interests of the civil society. Their legitimacy is based mainly on their capacity to engage local people in the process and to deliver good outputs. In the case of single projects, political accountability may not be a big issue. NGOs may at present be more effective and inclusive than the state. AWF and TFCG probably are, and their experiences may be important for building better engagements between districts and villages. Nevertheless, creating a REDD+ strategy for a whole country based on NGOs and market transactions is problematic in accountability terms.

Another aspect regards the ineffectiveness of a project/market oriented system to handle leakage. Our two cases only shed indirect light on this issue but we observed problems with leakage even within villages, hence raising a question about what authority an NGO-based system will have to handle situations where, for example, bye-laws are not respected and need to be enforced.

Concerning competence and capacity, we have noted that districts are weak. REDD+ could bring resources to strengthen them but this depends on the future scale of REDD+. It also depends on the selected governance structure. There is no mechanism in an NGO-based scheme that ensures expanded and maintained competence. Whereas a state is a ‘permanent’ structure, NGOs come and go. In Kondoa, it was mentioned that the district had problems with sustaining competencies because of fluctuating incomes that donor projects typically deliver (Kasisi, pers. comm.).
Emphasising these challenges and dilemmas, we note that observations from the two pilots presented in this chapter illustrate the importance of acting inclusively and transparently at the local level. Although there were issues such as NGO one-sidedness regarding the emphasis on gains with REDD+, challenges regarding making REDD+ processes inclusive, low payments as well as issues regarding corruption, elite capture or mismanagement of resources did not come through. Moreover, relying on NGOs does not represent a guarantee here as two of the nine REDD+ pilots were terminated due to irregularities or weak performance (NIRAS, 2015). Nevertheless, there are some clear lessons to be learnt from the Kilosa and Kondoa REDD+ pilots regarding not least ways to ensure transparency. We also note that AWF and communities in Kondoa managed to make an important step forward concerning benefit sharing in JFM.

From the perspective of deliberative democracy, processes should be bottom-up (e.g., Mustalahti and Rakotonarivo, 2014). Although we are very much in support of this, insufficient local empowerment and capacity makes it difficult to accomplish. Moreover, certain issues are of such a character that it is hard to foresee that they could start locally. REDD+ seems to be such a case. That does not imply that it has to be top-down. Certainly, there is room for active participation. The two pilots have illustrated both inherent challenges and opportunities. Demanding no conflict cannot, however, be a measure of success. Any change in governance systems—be it at local or national level—will create conflicts as interests are challenged and the distribution of costs and benefits is shifted. We observe that the conflicts the pilots created, to a large an extent, were between local interests and less between local communities and the NGOs.

So, what should Tanzania do regarding the establishment of REDD+ governance structures? Without any breakthroughs for REDD+ internationally, the resource base for REDD+ in Tanzania will not be there. Under the present circumstances, our assessment of the experiences points towards developing a national system. It demands that the international structure facilitates national funding of REDD+ through a compliance-based system or a global carbon tax, as well as donations. As such, we would advise to choose a structure based on a national REDD+ Fund, with power to allocate resources directly to the owners of forests and in the case of villages via the districts. This solution will demand wide representation of relevant ministries on its board to ensure co-ordination with, for example, sector policies. Establishing a fund will in itself imply increased transparency compared to ordinary budget allocations. It would nevertheless be wise to include representatives from NGOs to strengthen even further transparency. Although unusual for public bodies, we find it a reasonable solution to handle some of the dilemmas mentioned above. REDD+ could offer resources to strengthen

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16 The UNFCCC COP21 in Paris did not offer any such development. At the same time, REDD+ financing is still a key issue on the agenda of climate finance.
the capacity to manage forests at the local level as well as compensate village communities for their loss of livelihoods. It will however not be as cheap as we were made to believe in Bali. It will not be simple either. Although ‘everybody knows how not to cut down a tree’, cutting trees is a crucial element of people’s livelihoods – not least in Tanzania.

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Economics of REDD+
Implementation
The opportunity cost of reducing deforestation in Morogoro Region and its policy implications

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Abstract

Knowledge of the opportunity cost of reducing deforestation can help to evaluate the economic feasibility of the climate change mitigation mechanism known as REDD+. This chapter presents findings based on a study that was aimed at estimating the opportunity costs of not converting Montane forest and Miombo woodlands into croplands in Morogoro region in Tanzania. Data came from 250 households in seven villages. Opportunity cost (USD ha⁻¹) was calculated as the net present value (NPV) of agricultural rent and forest revenue during land clearing, minus net returns from sustainable wood harvest. The CO₂ price required to offset the opportunity costs (USD tCO₂e⁻¹) was further calculated as the opportunity costs divided by the corresponding reductions in carbon stock. The results show that at a 5.3 percent discount rate, the median opportunity cost (USD ha⁻¹) of not clearing and cultivating the Montane forest were similar to that of the Miombo woodlands. It ranged from 1,482 to 4,660 for the villages around the Montane forest and from 1,289 to 5,006 for the villages surrounded by Miombo woodlands. The median CO₂ price (USD tCO₂e⁻¹) was, however,
significantly higher \( (p < 0.001) \) for the villages in Miombo woodlands \( (7–39) \) than for villages around the Montane forest \( (1–3) \). This implies that reducing deforestation through REDD+ is relatively cheaper in the Montane forest than in Miombo woodlands. Thus, reducing deforestation of the Miombo woodlands, the country’s main vegetation type, would require very high compensation levels. After all, creating a financial incentive for those who clear and degrade forests lies at the core of REDD+. Establishing such mechanism is a major challenge for the REDD+ strategy of Tanzania. REDD+ is probably not sufficient to significantly affect deforestation in Tanzania. Broader policies of land tenure reform, agricultural development and urban energy supply might be required to slow the destruction of such low-density vegetation.

1.0 Introduction

REDD+, which stands for Reducing Emissions from Deforestation and Degradation plus enhancing forest carbon stocks, sustainable management and conservation of forests in developing countries, is a climate change mitigation mechanism developed under the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC 2010). The mechanism is structured as a compensation-based system through which governments in tropical developing countries receive payments from greenhouse gas (GHG) emitting countries based on their achievements in reducing deforestation or forest degradation (reducing emissions of carbon dioxide \( (\text{CO}_2) \), or enhancing forest carbon stocks (increasing sequestration of carbon). The level of compensation depends mainly on the opportunity costs of reducing deforestation or degradation, or enhancing forest carbon stocks. Other costs associated with the implementation of the REDD+, which also determine the magnitude of the compensation levels, include the implementation costs and transaction costs.

Opportunity costs refer to the net benefits forgone for not deforesting (preventing conversion of forestland to other land-uses, particularly to agriculture) or degrading forests (preventing non-sustainable wood harvest). Such costs may be calculated for individual landowners/users, for districts or nations. When the analysis is made for a district or a nation, one would generally assume that there are possibilities of substitution. If a particularly valuable forest environment is protected, some less sensitive forest area may be cleared instead. If deforestation is not allowed, more intensive cultivation of the existing cropland may compensate for some of the loss of opportunity. The original idea of the REDD+ policy was that opportunity costs to forest owners/users should be compensated to avoid or reduce deforestation and forest degradation without affecting the livelihoods of local communities. Opportunity costs can, therefore, be seen as payments required for compensating individuals for their forgone benefits. In this chapter, we will discuss costs and benefits of deforestation from the point-of-view of farming families in Morogoro region/province. In other words, we
do not attempt a comprehensive cost-benefit analysis of deforestation, or forest conservation, seen from the point-of-view of the Tanzanian state, or nation, or from a global perspective. Our analysis may contribute some points of interest to more comprehensive evaluations, but there are several issues connected to forest conservation and rural development that we have not dealt with here. In fact, many costs and benefits of forest management can hardly be valued in monetary terms, and some aspects of forest use are highly political.

Opportunity costs of not converting forests to cropland vary greatly, depending on the types of farming systems and crops. Opportunity costs of small-scale subsistence farming systems are usually very low several studies (see, for example, Bellassen and Gitz 2008; Olsen and Bishop 2009) have illustrated, compared to the cost of paying a landowner/user to not convert forests to large-scale commercial agriculture such as palm oil production (Butler et al., 2009) or soybean cultivation (Kindermann et al. 2008). Opportunity cost estimates also vary depending on the types of forests and biomass density found within the same forests. Opportunity costs estimated for countries of moist tropical forests with carbon densities of greater than 200 tC ha$^{-1}$, for example, Brazil (Olsen and Bishop 2009), Cameroon (Bellassen and Gitz 2008), Guyana (Osborne and Kiker 2005), and Indonesia (Yamamoto and Takeuchi 2012) are very small: they are below USD 5 tCO$_2$ −1. On the other hand, opportunity costs estimated for dry tropical forests, such as those of Tanzania in which carbon densities are less than 100 tC ha$^{-1}$ (Munishi et al., 2010) are relatively high, more than USD 5 tCO$_2$ −1 (e.g., Merger et al., 2012). Moreover, significant variations in the opportunity cost values between protecting relatively intact forests and of protecting degraded forests of the same type have been reported (e.g., Olsen and Bishop, 2009). Other factors that affect opportunity cost estimates include variations in assumptions regarding the cost of labour (mainly family labour), the discount rate, time horizon, the degree of access to forests permitted after the implementation of the policy, and how net costs of conversion are treated (Grieg-Gran, 2008; Karky and Skutsch, 2010). This indicates the need for site-specific opportunity cost estimates to provide realistic information on REDD+ costs. Merger et al. (2012) have pointed out that a bottom-up approach that considers spatial variation in economic and ecological conditions provides substantial economic information on REDD+. Moreover, an estimation of opportunity costs is an important step towards providing baseline information on the economics of deforestation and forest degradation and on the financial incentives required to reduce them.

When we attempt to establish a market for environmental services such as carbon sequestration, a mechanism for exchange of goods and services against money is required. This mechanism needs a certain level of trust and reliability among trading parties. In the case of REDD+, we may imagine two ways of trading: purchase or rent. For the purchase market, carbon offsets are measured as amounts
of carbon sequestered in biomass and soils during year $t$. For the rental market, carbon offsets are measured as the stock of carbon present in biomass and soils at the end of year $t$. The presence of *ex-ante* costs to develop baselines and predict outcomes of alternative land uses, as well as the fixed and annual costs of certifying carbon offsets, means that landholders, particularly smallholders, are unlikely to participate in the carbon market directly as individuals. Their participation needs to be mediated by aggregators that pool a number of individual farmer contracts into a “carbon project”. Pooling a large number of contracts allows aggregators to gain economies of scale and manage risk (Cacho *et al.*, 2013). Consequently, we may consider a “farm-gate” price of carbon sequestration received by individual actors in Tanzania and other tropical countries that is lower than the price applied in international transactions between states in the North and states in the South. A wedge of transaction costs will be driven between the national and the local price of carbon. Pearson *et al.* (2014) have shown that including transaction costs could increase the carbon price necessary to cover REDD+ costs by up to 30 percent.

**2.0 Methodology**

**2.1 Study site description**

The study was conducted in Morogoro region, Eastern Tanzania. As this work was part of the strategic intervention project of the Climate Change Impacts, Adaptation and Mitigation (CCIAM) research programme, the project management selected the study region, district and wards. Within the wards, seven villages that represented two agro-ecological zones, two vegetation types and different farming systems, as apart from experiencing a relatively high rate of deforestation, were selected systematically. The availability of secondary data necessary for the study was also one of the criteria for selecting some of the villages. Three of the villages, namely Kunke, Maseyu and Mlimbilo, are located at an average altitude of 400 m.a.s.l., hereafter referred to as the lowland zone. The remaining four villages, namely Ng’ungulu, Nyandira, Tchenzema and Vinile, are located between 1,000 and 2,700 m.a.s.l., hereafter referred to as the highland zone. These two agro-ecological zones comprise two distinct vegetation types: Miombo woodlands in the lowland zone and Montane forest in the highland zone. Miombo woodland, a collective name for woodlands dominated by species of the genera *Brachystegia*, *Julbernardia* and *Isoberlinia*, covers about 51 percent of Tanzania’s total land area and 93 percent of the country’s forests and woodlands (MNRT, 2015). Montane forest covers less than one percent of the country’s total land area, but has a relatively much higher density of biomass per unit area. The Montane forests also support many endemic and threatened species and are part of internationally recognised biodiversity hotspots (Burgess *et al.*, 2007).
Kunke and Mlimbilo are located in Mtibwa ward, 120km north of Morogoro town whereas Maseyu is located in Gwata ward, 50km east of Morogoro town along the Dar es Salaam-Morogoro highway, next to the Kitulangalo forest reserve (KFR) (Fig. 14.1). The three villages surround a community-based conservation area known as Wami Mbiki WMA (see Figure 14.1). Ng’ungulu, Nyandira, Tchenzema, and Vinile are located in Mgeta division, about 200km west of Dar es Salaam, on the south-western side of the Uluguru Mountains, next to the Uluguru South nature reserve (USNR) (see Figure 14.1). The inhabitants of the seven villages generally depend mainly on agriculture for their livelihoods. In the lowland zone, they cultivate crops for subsistence (maize and millet) and for the market (rice, sesame, and sugarcane). They are also highly dependent on the surrounding Miombo woodlands, both for their own consumption (firewood, fruit and vegetables, and wood for poles) and for commercial purposes (charcoal). In the highland zone, on the other hand, they practice intensive small-scale farming of both subsistence crops (maize and pulses) and cash crops (vegetables), and rely mainly on family members for labour. They also depend on the adjacent nature reserve for firewood, fruits, herbs, and other non-wood forest products.

![Figure 14.1: Map of the study area, Tanzania (a), Morogoro region (b) and study villages (c). KFR: Kitulangalo Forest Reserve, USNR: Uluguru South Nature Reserve, WMA: Wami-Mbiki Wildlife Management Area.](image-url)
2.2 Data collection

We obtained most of the data used in this study through a household survey (Araya and Hofstad, 2016). In addition, various secondary sources were used. About 10 percent of the total households in each village were represented in the survey. Consequently, data were collected from 112 households randomly selected from the four villages in the highland zone, and 119 from the three villages in the lowland zone. Basic demographic information, data on characteristics of farming plots, crop production, forest resource use, as well as information relating to costs and revenues associated with crop production and forestry activities, local prices of all inputs and outputs, and cost of labour were obtained using structured questionnaires. Further information was collected through focus group discussions.

2.3 Methods

2.3.1 Estimating opportunity cost of avoiding deforestation

Opportunity cost estimates will depend on the rules that will be applied following the implementation of the REDD+ policy. For simplicity, we assumed that deforestation should stop immediately, while wood harvesting could continue in a sustainable way. Here we defined sustainable harvest as the mean annual increment (MAI) of the forest or woodland under consideration. We, therefore, estimated the Opportunity costs (USD ha⁻¹) of stopping conversion of the two vegetation types considered in our study as the NPV of agricultural rent and forest revenue during land clearing, minus the net returns from sustainable wood harvest. The CO₂ price required to offset the opportunity costs (USD tCO₂e⁻¹) were further calculated as the opportunity costs divided by the corresponding reductions in carbon stock.

2.3.2 Estimating costs and benefits of deforestation and subsequent cropping

All benefits and costs to local farming households associated with deforestation and subsequent cultivation were identified, quantified and valued. The benefit items of deforestation (conversion of forestland into cropland) are crop produce and wood obtained during land conversion. Deforestation also encompasses the cost of land clearing. The costs of crop production included the cost of seeds, fertilisers, pesticides and fungicides, labour required for different activities, and transportation to the local market. Data on crop production came from 606 sample plots owned by the 231 households considered. The estimation was based on the major crops grown at each village.

We assumed wood obtained during clearing to be used for charcoal production in the lowland zone and for poles, timber and tool handles in the highland zone. Wood extracted for making different products is considered to be a free good,
Charcoal production requires labour (mainly family members) for different activities such as felling and crosscutting of trees, log piling, stacking, and loading and unloading charcoal kilns. Similarly, the production of logs and timber requires labour (mainly hired) for different activities. The current average standing volumes of the woodlands on public land and the woodlands in the KFR are 14m³ha⁻¹ and 65m³ha⁻¹, respectively (Zahabu, 2008). The MAI of the woodlands around the study villages is estimated to be 2.9 Mg ha⁻¹ for re-growth Miombo and 3.7 Mg ha⁻¹ for old-growth Miombo (Ek 1994), equivalent to a volume of 3.41m³ha⁻¹ and 4.35m³ha⁻¹, respectively, using a 0.85 conversion factor from biomass (tonne) to volume (m³) (Malimbwi et al., 1994). Tree species used for charcoal-burning represent 40 percent of the standing volume. In the Montane forest, timber-producing species account for about 25 percent of the total average standing volume (319m³ha⁻¹). Tree species important for making poles and tool handles accounted respectively for 11 percent and 16 percent of the total average tree density (539 stem ha⁻¹)(FBD, 2010). Timber volume was estimated using 63 percent log recovery and 30 percent timber recovery (Muthike et al., 2013). The collection of firewood from the reserve is assumed to be less or equal to the MAI of the forest and, therefore, sustainable harvesting means only the collection of firewood (For details of the economic parameters that are used in this analysis, see Araya and Hofstad, 2016).

2.3.3 Cost-Benefit analysis

Cost-Benefit analysis was used to estimate the opportunity costs of not converting forestland into cropland. The costs and benefits were valued using local market prices. We applied three different wage rates to family labour: (1) the reported wage rate in the study villages (hereafter referred to as the “village wage rate”); (2) the minimum wage rate for agricultural labour in Tanzania ("minimum wage rate"); and (3) a wage rate equal to zero (“zero wage rate”) which assumed an opportunity cost of labour as zero. Cost-benefit flows were discounted to provide an estimate of the NPVs of clearing and cropping. The discount rate used in this estimation is a real interest rate, r (5.3 %), estimated by adjusting the nominal discount rate (12 %) for inflation (6.4 %) (BoT, 2011). Assuming that the present agricultural practices are sustainable and that the relative prices of products and factors are constant, the NPV was calculated as annual net benefits (NBs) divided by a constant discount rate. Sensitivity of results to changes in discount rate was analysed.

2.3.4 Estimating emissions of CO2 due to deforestation and subsequent cropping

Estimation of opportunity costs in terms of USD tCO₂e⁻¹ required data on the amount of carbon released into the atmosphere from clearing of each vegetation types. This information was gathered from various sources (Munish and Shear, 2004; Zahabu 2008, FBD 2010, Munishi et al., 2010; Ryan et al.,
2011; Shirima et al., 2011; Willcock et al., 2012). Accordingly, the amount of carbon released into the atmosphere because of land conversion ranges from 35 t ha\(^{-1}\) (128 tCO\(_2\)e ha\(^{-1}\)) for the Miombo woodlands on public land to 55 t ha\(^{-1}\) (202 tCO\(_2\)e ha\(^{-1}\)) for the woodland in forest reserves, whereas it is 467 t ha\(^{-1}\) (1715 tCO\(_2\)e ha\(^{-1}\)) for the Montane forest.

### 2.3.5 Data analysis

Of the 606 sample plots, 593 were used for analysis after the data were cleaned. The remaining plots were omitted from the analysis due to incomplete information (e.g., because crops had not been harvested). Profitability on many plots was low whereas profitability on a few plots was high. Therefore, to avoid the problem of non-normality a Kruskal-Wallis test was used to detect statistically significant differences in the median NPVs of crop production as well as the median compensation estimates between the two agro-ecological zones and among the study villages within the zones. Non-parametric multiple pair-wise comparisons between different parameters were made using Tukey’s test and t-tests, with a significance level of \(\alpha = 0.05\). The statistical software, R version 3.0.1 (R Core Team 2013) was used for analysis and SigmaPlot version 11 (Systat Software Inc 2008) was used for plotting.

### 3.0 Results and discussion

#### 3.1 Agricultural rent, opportunity cost of stopping deforestation, and REDD+ payments

Agricultural rent (see Figure 14.2) was the dominating factor in determining the opportunity cost of stopping deforestation. At 5.3 percent discount rate, the median opportunity cost of not converting forestland into cropland ranged from 1,482 - 4,660 USD ha\(^{-1}\) in the highland villages. In the lowland villages, it was in the range of 1,289 - 4,932 and 1,363 - 5,006 depending on the biomass density of the woodland to be converted (see Table 14.1). The estimated opportunity costs per hectare were in a similar range in both agro-ecological zones. The median required price of CO\(_2\), REDD+ payments (USD tCO\(_2\)e \(^{-1}\)), to offset these costs were, however, significantly (p < 0.001) higher for the villages in the lowland zone than the villages in the highland zone. It ranged from 10 - 39 USD tCO\(_2\)e \(^{-1}\) and 7 to 25 USD tCO\(_2\)e \(^{-1}\) to protect the current carbon stocks in degraded and relatively intact Miombo woodlands, respectively, and 1 - 3 USD tCO\(_2\)e \(^{-1}\) in the Montane forest. The estimates were significantly higher when the cost of farmers’ own labour was not taken into account in NPV calculations (see Table 1). In contrast, the estimates decreased significantly when the discount rate was increased to 10 percent (see figures 14.3 and 14.4).

The variation in the required REDD+ payments between the two agro-ecological
zones were due to the pronounced differences in biomass (carbon) density between the two vegetation types. The variation between villages in the same agro-ecological zone was, however, due to the choice of crop types attributed to both agro-ecological conditions and market access.

The results also reveal that depending on the wage rates applied, sustainable annual wood harvest could offset up to 45 percent and 55 percent of the estimated total median opportunity costs of protecting the Miombo woodlands and the Montane forest, respectively. This would secure carbon stocks at present level in the forest. However, if wood harvesting were also banned, biomass and carbon would be accumulated in the forest for some time since the forest, particularly the Miombo woodlands are hardly at their maximum density at present. Some buyers of REDD+ credit might insist that such accumulation should be part of the environmental service paid for. They may also not trust that wood harvest would be limited to sustainable levels and, therefore, insist that all wood harvests should cease. In such cases, our results indicate that the REDD+ payments required to offset opportunity costs would be about 50 percent higher than those reported above.

Figure 14.2: The median NPV (USD ha⁻¹) of crop production by crop type (a, b), village (c, d) from the lowland zone (a, c), and the highland zone (b, d); the lower and upper error bars represent the first and third quartiles, respectively. M: maize, Mi: millet, P: pulses, R: rice, S.C: sugarcane, Se: sesame, V: vegetables
Source: Araya & Hofstad (2016)
<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Village</th>
<th>Minimum wage rate</th>
<th>Village wage rate</th>
<th>Zero wage rate</th>
<th>Opportunity costs (USD ha(^{-1}))</th>
<th>REDD+ payment (USD tCO(_2)e(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Miombo</td>
<td>Kunke</td>
<td>4,916</td>
<td>5,006</td>
<td>5,631</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Maseyu</td>
<td>1,824</td>
<td>1,363</td>
<td>2,860</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Mlimbilo</td>
<td>2,452</td>
<td>2,633</td>
<td>3,177</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Degraded Miombo</td>
<td>Kunke</td>
<td>4,866</td>
<td>4,932</td>
<td>5,490</td>
<td>38</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Maseyu</td>
<td>1,775</td>
<td>1,289</td>
<td>2,719</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Mlimbilo</td>
<td>2,402</td>
<td>2,559</td>
<td>3,036</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Montane forest</td>
<td>Ng’ungulu</td>
<td>1,823</td>
<td>1,580</td>
<td>3,991</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Nyandira</td>
<td>4,791</td>
<td>4,660</td>
<td>6,277</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Tchenzema</td>
<td>1,965</td>
<td>1,482</td>
<td>5,397</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Vinile</td>
<td>2,287</td>
<td>2,067</td>
<td>5,156</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

*Table 14.1: Opportunity costs of stopping conversion of forestland into cropland and the required REDD+ payments to offset those costs (r = 5.3 percent p.a.) Source: Araya & Hofstad (2016)*

*Figure 14.3: CO2 prices required to offset the opportunity costs of stopping deforestation at the seven villages, considering positive opportunity cost of labour.*
4.0 Policy implications

4.1 Where should REDD+ projects be targeted?

Our results may not be directly applicable to the setting of compensation levels for REDD+ in Morogoro region or in Tanzania, but we think they might have some implications for policies on forests in climate change mitigation. The results clearly indicated where to target REDD+ projects. We note that opportunity costs per tonne of CO$_2$e are much lower in the Uluguru Mountains than in the lowland. This is due to the much higher biomass density in the Montane forest than in the Miombo woodlands. This conclusion probably holds for the whole of the Eastern Arc of Mountains (EAM). Large parts of this mountain range are protected as nature or forest reserves. Most of the Montane forest outside of the reserves is already cleared or seriously degraded (Green et al., 2013). However, degradation continues within the reserves, caused both by wood exploitation and by cropping. According to our results, effective protection of the existing reserves in the EAM would be a highly efficient way of limiting emissions of CO$_2$. Moreover, we note significant differences in agricultural rent depending on land productivity and market access. This applies also to within agro-ecological zones, particularly in the lowland areas. Cropping of sugarcane and paddy were particularly profitable. Where such crops can be cultivated, the opportunity costs of reducing deforestation are very high. Protecting open woodlands from cultivation in such places is, therefore, not a cost-effective climate change mitigation policy.

4.2 Who should be compensated and how?

At the core of the discussion on REDD+ is to create a monetary incentive to those responsible for reducing deforestation and degradation. REDD+, therefore,
represents a new way of thinking compared with both traditional development aid and forest conservation. The key is to establish performance-based systems, where payment is made to those who produce ‘certified emission reductions’ from reduced deforestation and degradation or enhanced forest carbon stocks. Carbon credits can become a new cash crop for Tanzania and its population, produced locally and sold globally. Establishing a payment mechanism along these lines is the major challenge for the REDD+ strategy of Tanzania. It requires detailed information on changes in the carbon stock of forests, appropriate incentives given to decision-makers to undertake activities that reduce deforestation and degradation, and that the flow of information and incentives are embedded within a set of effective institutions to ensure good governance.

Our analysis of agricultural rent shows a high variation of NPV estimates among farming households. The majority of farmers earned little income from the cultivation of crops, and only a few were able to make high profits. This has an implication for the REDD+ payment design. It shows that separated payment system, where each landowner/user receives just his/her opportunity cost might be required. Different payment systems have different cost implications. Wertz-Kanounnikoff (2008) indicates that separated payment system is considered to be a more cost-effective than the uniform payment system, where every landowner/user receives the same amount of compensation.

Table 14.2 provides an overview of different REDD+ payment systems and their strengths and weaknesses. Skutsch et al. (2014) distinguishes between input- or output-based payment systems. Under an input-based system, the buyer pays for activities (e.g. planting, or harvest control) aimed at carbon sequestration or storage in trees. Under an output-based system, however, the buyer pays for verified sequestration of carbon, or reduced emissions of CO₂.

Payment of REDD+ monetary incentives may be feasible in certain locations under favourable conditions. One condition is that forest vegetation is intact, and another is that cropping would not be very profitable after forest clearing. However, there are quite a few institutional obstacles to be considered (Dokken et al., 2014; Dyngeland, Vedeld, and Vatn, 2014). One such consideration is whether payment should be input- or output-based. If we aim for an output-based system, some monitoring system must be put in place to quantify the change of biomass in trees from one period to the next. For such a system not to be overly expensive, one may think of implementing the kind of village monitoring system advocated by Mukama, Mustalahti, and Zahabu (2012). However, the input-based system has been favoured in most practical situations in Tanzania. Planting trees on marginal lands where opportunity costs are low is the favoured input paid for (Movik et al., 2012). Such REDD+ projects are surprisingly similar to communal or individual woodlot projects that were implemented already in the 1970s (Kowero and Temu 1985; Skutsch, 1985; Kihiyo, 1996).
| Criteria  | Output based benefit distribution | Input based benefit distribution |  |
|-----------|-----------------------------------|---------------------------------|  |
| Strengths | Baselines                          | Economic efficiency             |   |
| Simple    | Individual baseline needed         | Baseline not required           |   |
| Baselines | parcel-based measurement           | Only pay for added carbon       |   |
| Political issues | Merit-based equity | Right-based equity | Forest ownership is often collective and confused in many deforesting countries |
| Efficiency | performance                         | Forest owners                   | No payments to actors outside forests |
| Others    | Poverty-based equity                | Others                          | Payments can be made to actors outside forests |
| Data      | Accuracy requirements               | Transaction cost                |   |
| Source:  | Source: Skutsch et al. (2014)      |                                 |   |

Table 14.2: Strengths and weaknesses of output- and input-based benefit distribution systems under national REDD+.
When forest ownership is collective, and user rights are diffuse, paying individuals or co-operatives to stop deforestation or forest degradation is difficult. Unruh (2008) mentions five aspects of African land tenure that complicate the setting up of a payment system for forest protection: 1) disconnect between customary and statutory land rights; 2) legal pluralism; 3) tree planting as land claim; 4) expansion of treed areas in smallholder land use systems; and 5) the difficulty of using the ‘abandoned land’ category. In this regard, Unruh (2008) observes, *The pervasiveness of these tenurial issues means that the prospects for successfully implementing afforestation and reforestation projects in Africa are in reality quite weak. The current project approach to carbon storage in Africa needs to be significantly realigned with African reality in order for sequestration expectations to be practical.*

Because paying farmers to stop clearing forest, which *de facto* does not belong to anybody, is even more risky, most REDD+ schemes and projects in Africa are now directed towards tree planting or protection of degraded lands. You can pay people for planting trees (the risk of failure is with the buyer), or you can punish people who continue degrading protected land, but a farmer will hardly stop clearing open access forests because of an insecure future payment.

For village forests, the appropriate recipient might be the village council or the natural resource council. The problem is, nevertheless, that this might be a too large a unit to create the more individual or household oriented incentives often needed. Community-based organisations are, therefore, an alternative, and so is direct payment to individuals.

In the case of central forest reserves, the owner is the state, and the management under Forest and Beekeeping Division, Ministry of Natural Resources and Tourism, and therefore a possible recipient of payments. The baseline should, however, be zero decline in biomass and one might, therefore, argue that “one should not be paid for what one is supposed to do anyway”. The actual situation is, however, often degradation and encroachment and illegal uses. We would argue for a pragmatic approach, with partial payment to both District Forest Offices and to the adjacent villages.

The last category is the general or public land, which is *de facto* open access in large tracts of the country. The puzzling fact is that this is the largest forest category (about 57% of total forest cover), the one where most of the deforestation and degradation occur, but where introduction of a remuneration mechanism is most challenging. It would be difficult to introduce a payment mechanism without first addressing the tenure situation of the public forestland. A general strategy would be to move public forests to the management of villages (or communities), private individuals, or the state. Districts have a responsibility for general land within their boundaries, and one can envisage a system where they are given incentives to manage general lands more sustainably. However, capacity constraints may make the handing over to communities or the private sector more effective.
Land use plans for villages have been a requirement for establishment of village forest reserves. This is a reasonable basic principle, but the situation in many rural villages is highly dynamic (Hofstad and Sankhayan, 2010). The Wami-Mbiki WMA is part of a land-use plan for many villages (Kunke is one of them) that was made in 1999. When we visited Kunke in 2013, farming families had opened up new cropland and settled inside WMA quite recently, and many people transported charcoal out of the area. This observation illustrates that with high population growth, unaltered cultivation techniques, and plenty of fertile woodland, land-use plans quickly become outdated.

Some concerns have been raised regarding to what extent can REDD+ payments be handled by Village Councils or Village Natural Resources Committees, and that it should be handled at a lower geographical unit. One may easily imagine the overwhelming data collection and reporting requirements of an output-based system to serve individual communities or hamlets all over Tanzania. Such a disaggregated system can only be implemented in a small number of districts and villages for the time being.

It may be argued that a payment system for REDD+ cannot solve institutional problems of corruption and skewed income distribution at the district and village level in Tanzania. One may have to accept the institutional conditions of rural Tanzania as they are, and implement a REDD+ system within the existing setup. In that case, deforestation and degradation data at the district level may be sufficient. District Councils may be charged with finding suitable systems for distributing REDD+ payments. Additional processes would be needed to make income distribution accountable and just within districts (Angelsen and Hofstad, 2008).

Monetary incentives alone are not enough to mitigate deforestation and forest degradation. Successful mitigation of climate change may require additional initiatives to generate employment opportunities for rural people. REDD+ is probably not sufficient to affect significantly deforestation and degradation of Miombo woodlands that have already been subjected to exploitation. Broader policies of land tenure reform (Kajembe et al., 2012), agricultural development (Arndt et al., 2012), and urban energy supply (Mwampamba, 2007; Treiber, Grimsby, and Aune, 2015) might be required to slow the destruction of low-density vegetation. Furthermore, the existing farmlands are not well-utilised; there is an opportunity to intensify cropping rather than expanding extensively cropped areas.
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Governance structures, transaction costs and incentives for managing REDD+ initiatives in Kilosa District, Tanzania


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Abstract

This chapter is based on the findings of a study that was conducted to examine community perceptions, governance structures, transaction costs and incentives for the management of REDD+ initiatives in Kilosa district where REDD+ piloting was on-going. The study covered a total of six out of 16 pilot villages (Kisongwe, Nyali, Mfuluni, Chabima, Munisagara and Lunenzi) in the district. The study deployed a range of methodologies including household questionnaire survey, focused group discussions, interviews with key informants and literature review. For the questionnaire survey, a total of 180 households were randomly
selected from the six villages, 30 households from each village. The findings reveal that 70 percent of the respondents in the study area have positive perceptions about REDD+ initiatives and high expectations. On the other hand, awareness on the restrictions imposed in terms of forest utilisation to facilitate REDD+ was relatively low. The study also found that, although REDD+ activities largely operate within the existing institutional frameworks at both the district and village levels, there is an emergence of hybrid institutions consisting of representatives from all the key actors in managing the REDD+ initiatives. Such institutions included the Project Advisory Committee at the district/national level and the Village Land Use Management team at village level. These institutions facilitate participatory management of the REDD+ initiatives in the study area. The analysis reveal that, estimated total transaction costs were TZS 2 704 ha-1 yr-1 equivalent to USD 1.7 ha-1 yr-1. The results show that, the IRR is 49.34 % higher than the World Bank rate of 15% and the BOT rate of 20.6 % implying that the project is efficient hence, worthwhile undertaking. Furthermore, the study reveals that both tangible and intangible benefits have been realised at the community level as well as by individual households. These benefits have served as incentives in propelling REDD activities in the area. The study recommends continued nursing of emerging institutional structures by the existing institutional frameworks to avoid the creation of parallel institutions. The study also recommends the scaling up of incentives in terms of magnitude and coverage.

1.0 Introduction

1.1 Background

One of the main challenges in achieving sustainable livelihoods and economic development for developing countries, including Tanzania is climate change. There are a number of global and national efforts to address the problem including adaptation and mitigation activities. In the forestry sector, conceptualisation of Reducing Emissions from Deforestation and Forest Degradation (REDD+) constitutes sets of initiatives aimed at addressing aspects of climate change adaptation and mitigation. REDD+ is a mechanism under the United Nations climate change strategy to reduce greenhouse gas emissions that are negatively impacting the global environment. It is essentially a vehicle to reward financially developing countries for their verified efforts to reduce emissions and enhance removals of greenhouse gases through a variety of forest management options (UNFCCC, 2008). In developing countries the arrangement requires the establishment of governance structures at the national, district and local levels that minimise transaction costs while providing necessary incentives for sustainable forest management.
For successful REDD+ regimes, national governments need to guarantee that forests remain intact and standing on a permanent basis. This outcome is more likely to occur through fair and effective treatment of resource, land ownership and land use rights; benefit sharing; monitoring, reporting, and verification (MRV); access to information; and guarantee of public participation in REDD+ activities (Ivan and Maryanne, 2009; Oliver and Wollenberg, 2010). These aspects cannot be realised without good governance. As such, effective implementation of REDD+ calls for broad-based institutional reforms in the area of governance, tenure, decentralisation, and community forest management.

Tanzania is one of developing countries that is a signatory to the Kyoto Protocol and is seeking to contribute to global climate change efforts through REDD+. Stakeholders in Tanzania have engaged in REDD+ initiatives through national programme development, awareness raising, advocacy and pilot project implementation. The country initially piloted 10 REDD+ projects with support from the Norwegian Government and implemented by NGOs.

1.2 Rationale

Kilosa is one of the districts in Tanzania where REDD+ payment scheme was piloted with facilitation from the Tanzania Forest Conservation Group (TFCG) in partnership with MJUMITA, a Kiswahili acronym for the Community Forest Conservation Network of Tanzania. TFCG and MJUMITA implemented a project known as “Making REDD+ work for Communities and Forest Conservation in Tanzania”. The project aimed to reduce greenhouse gas emissions from deforestation and forest degradation in the district in ways that provide direct and equitable incentives to communities to conserve and manage forests sustainably. The project supports the development of Community Carbon Enterprises (CCE) co-operative hosted within the existing Network of Tanzanian communities (MJUMITA) that are engaged in Participatory Forest Management (PFM). The co-operative is envisaged to aggregate Voluntary Emission Reductions (VER) from its members and market them according to internationally recognised standards (Lyimo, 2011). These interventions are aimed to ensure that communities benefit from forest conservation through internationally recognised arrangements.

The piloting process was associated with issues of governance, institutional structures, transaction costs and incentives, among others, all of which required an in-depth study to provide lessons that can feed into National REDD+ Strategy development process. This study endeavoured to investigate these aspects in detail.
1.3 Study objectives

The overall objective of the study was to examine the emerging governance structures, associated transaction costs and incentive schemes in the implementation of REDD+ piloting in the context of Participatory Forest Management (PFM) in Kilosa district. Specifically, the study aimed to assess emerging institutions at district and village levels, examine transaction costs associated with REDD+ project implementation, evaluate introduced incentive schemes and project economic efficiency.

2.0 Methodology

2.1. The study area

Kilosa district is located about 100km from Morogoro and about 300km inland from Dar es Salaam, towards the west. The district lies between 6°S and 8°S, and 36°30'E and 38°E and it has an area of 14,245 km² (Benjaminsen et al., 2009). According to the Tanzania Population and Housing Census of 2012, Kilosa district has a population of 438,175 of which 218,378 are males and 219,797 are females.

Land in Kilosa can basically be divided into five categories: agricultural (37.5%), natural pasture (33.5%), Mikumi National Park (22.5%), forest reserves (5.5%) and urban areas, water and swamps (1%) (KDC, 2010). More than 80 percent of the communities in Kilosa depend on agriculture for their livelihoods. It is estimated that 25 percent of the food crop produced is consumed at the household level. Livestock keeping is an important economic activity in the district involving about 172,000 indigenous cattle, 1,000 improved cattle stock, 87,000 goats and 23,000 sheep (KDC, 2010).

The district is characterised by a dry tropical climate of the semi-arid type. The vegetation type of the district is dominated by Miombo woodland in the hilly areas where grasslands occur in the alluvial plains. However, much of the Miombo vegetation is under pressure due to wood fuel extraction, shifting cultivation and pasture for grazing (Kajembe et al., 2013). The study involved six villages. Figure 15.1 shows the location of the villages studied in the district:
2.2 Sampling procedure, data collection and analysis

Sampling at the study site was done in two stages. The first stage involved sampling of the study villages. During this stage the sampling frame was a list of villages participating in the REDD+ project in the study site. In all, there was 16 villages participating in the REDD+ project and, therefore, they constituted the sampling frame. From the 16 villages, a sample of six villages (Kisongwe, Chabina, Lunenzi, Nyali, Munisagara and Mfuluni) was purposively selected for the study representing about 38 percent of all the villages piloted in REDD+. The selection was based on accessibility and extent of involvement in REDD+
payment activities. The second stage involved sampling of the households in the selected villages. The sampling frame at this stage was the updated list of the households in the selected villages. The respondents were drawn using random sampling procedure, specifically the random number table technique.

Fisher et al. (2002) and Bartlett et al. (2001) argue that sample size is one of the most important determinants of survey estimates, and that depends on precision (amount of sampling error that can be tolerated by the researcher) and confidence level (level of certainty that the true value of the variable being studied is captured within standard error or sampling error). The authors argue further that the greater the precision of estimate and confidence in the results, the larger the sample size needed. The authors furthermore posit that another equally important factor in determining the sample size is the amount of resources (time, money and personnel) available for the study. Generally the number of respondents for the study depends on the type of research whether descriptive, correlational, or experimental. For descriptive research, the sample should be 10 percent of the population. But if the population is small, then 20 percent of the population may be required. For correlational research at least 30 subjects are required to establish the relationship. For experimental research, the number of 30 subjects per group is often cited as the minimum (Gay and Diehl, 1992). According to Bailey (1994), for socio-economic studies a sample of at least 30 households is adequate for the study. This is consistent with Anon (2012) who suggests that a sample size of 30 is enough for a socio-economic study. In light of the above, 30 households were sampled from each village, hence a total sample of 180 households.

Most of the qualitative data were collected through focused group discussions and key informant interviews. The key informants during the research included project staff, district technical staff, village leaders and representatives from village environmental committees. To supplement the collected primary data, secondary data were collected through documentary search focusing on available literature on REDD+ piloting in Kilosa. The study also collected data on the types of incentives that are associated with REDD+ piloting in the study area. The purpose of the data was to get an impression on the kind of incentive schemes that can be designed to facilitate the implementation of REDD+ at the village and district levels.

Thematic analysis was performed guided by topics identified in the questionnaire that was used for data collection, reoccuring topics in discussions with key informants and direct field observations. Themes were further aggregated into categories including institutions, transaction costs, incentives, awareness and perceptions. Findings from quantitative data were used to build up analysis of the material collected and presented in percentages and frequencies.
Total transaction cost per year was calculated as the sum of costs to the REDD+ project and costs incurred by villagers in the respective year. The unit transaction cost was then calculated by dividing transaction cost per year by the forest area under the REDD+ project.

3.0  Major findings

3.1  Households characteristics in study villages

The study strived to capture, among other things, the characteristics of respondents in the study site. The findings on the same are presented in Table 15.1. It is apparent that most of the respondents (58.9%) are of middle income category. About 84 percent of respondents are married. Generally, the respondents in study area have formal education (72.1% have primary school education). As for the occupation of respondents 81.2 percent were farmers.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Kisongwe</th>
<th>Chabima</th>
<th>Lunenzi</th>
<th>Nyali</th>
<th>Munisagara</th>
<th>Mfulumi</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wealth Categories</strong></td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
</tr>
<tr>
<td>Low income</td>
<td>3.3% (6)</td>
<td>5.6% (10)</td>
<td>5.6% (10)</td>
<td>4.4% (8)</td>
<td>7.8% (14)</td>
<td>6.7% (12)</td>
<td>33.3% (60)</td>
</tr>
<tr>
<td>Middle income</td>
<td>10.0% (18)</td>
<td>8.9% (16)</td>
<td>11.2% (20)</td>
<td>12.2% (22)</td>
<td>6.7% (12)</td>
<td>8.9% (16)</td>
<td>58.9% (104)</td>
</tr>
<tr>
<td>High income</td>
<td>6.6% (6)</td>
<td>2.1% (4)</td>
<td>0% (0)</td>
<td>0% (0)</td>
<td>2.2% (4)</td>
<td>1.1% (2)</td>
<td>7.8% (16)</td>
</tr>
<tr>
<td><strong>Marital status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>14.4% (26)</td>
<td>12.2% (24)</td>
<td>15.6% (28)</td>
<td>11.1% (20)</td>
<td>14.4% (26)</td>
<td>6.7% (28)</td>
<td>84.4% (152)</td>
</tr>
<tr>
<td>Single</td>
<td>0.0% (0)</td>
<td>3.3% (6)</td>
<td>0.0% (0)</td>
<td>1.1% (2)</td>
<td>0.0% (0)</td>
<td>8.9% (2)</td>
<td>5.5% (10)</td>
</tr>
<tr>
<td>Widowed/separated</td>
<td>2.2% (4)</td>
<td>0.0% (0)</td>
<td>2.2% (2)</td>
<td>4.4% (8)</td>
<td>2.2% (4)</td>
<td>1.1% (0)</td>
<td>10.0% (18)</td>
</tr>
<tr>
<td><strong>Formal education level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2.2% (4)</td>
<td>5.6% (10)</td>
<td>3.3% (6)</td>
<td>5.6% (10)</td>
<td>2.2% (4)</td>
<td>2.2% (4)</td>
<td>21.2% (38)</td>
</tr>
<tr>
<td>Primary school</td>
<td>14.4% (26)</td>
<td>8.9% (16)</td>
<td>13.3% (24)</td>
<td>11.1% (20)</td>
<td>11.1% (20)</td>
<td>13.3% (24)</td>
<td>72.1% (130)</td>
</tr>
<tr>
<td>Secondary school</td>
<td>0.0% (0)</td>
<td>2.2% (4)</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>3.3% (6)</td>
<td>0.0% (0)</td>
<td>5.5% (10)</td>
</tr>
<tr>
<td>Collage/University</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>1.1% (2)</td>
<td>1.1% (2)</td>
</tr>
<tr>
<td><strong>Occupation of respondents</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop farmer</td>
<td>14.4% (26)</td>
<td>16.6% (30)</td>
<td>15.7% (28)</td>
<td>15.7% (28)</td>
<td>2.2% (24)</td>
<td>16.7% (30)</td>
<td>81.2% (166)</td>
</tr>
<tr>
<td>Livestock keeper</td>
<td>1.1% (2)</td>
<td>0% (0)</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>11.1% (2)</td>
<td>.0% (0)</td>
<td>12.2% (4)</td>
</tr>
<tr>
<td>Business persons</td>
<td>1.1%(2)</td>
<td>0%(0)</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>3.3% (4)</td>
<td>.0% (0)</td>
<td>4.4%(6)</td>
</tr>
<tr>
<td>Waged people</td>
<td>0.0% (0)</td>
<td>0% (0)</td>
<td>1.1% (2)</td>
<td>1.1% (2)</td>
<td>0.0% (0)</td>
<td>.0% (0)</td>
<td>2.2%(4)</td>
</tr>
</tbody>
</table>

Table 15.1: Respondents’ characteristics in the study villages
3.2 Emerging hybrid institutions

The study found that REDD+ initiatives in Kilosa operated within the existing institutional structures both at the district and village levels where planning makes use of the existing district planning team. However, hybrid governance institutions with representatives from the NGO sector and district staff to facilitate REDD+ initiatives has emerged. A hybrid institution is an institution which exists between or across the boundaries of sectors, government departments, geographic units, or combines the governance regimes of “traditional dichotomies” such as the state and the market or private. This ‘hybrid institution’, demonstrates “a concern with new arrangements for policy-making rather than a new look at old institutions”. The emerging hybrid institutions were characterised by participatory and interdisciplinary features that are likely to influence deliverance of REDD+ outputs. The hybrid institutions included the Project Advisory Committee (PAC), Village Land Use Management Team (VLUM) and REDD+ committees.

The Project Advisory Committee (PAC) has been established to serve as an advisory body on all REDD+ matters implemented by the Project. PAC has emerged as a hybrid institution and a stakeholders’ platform with representatives drawn from the facilitating NGOs, government staff, and district staff. This was found to be in line with recommendations by Kessy (1998) on the need to have stakeholders’ reconciliation platforms in conservation initiatives. In terms of membership, the PAC has representatives from the District Natural Resources Office, the Regional Natural Resource Office and representatives from all collaborating institutions such as the Tanzania Natural Resources Forum (TNRF), CARE International, World Wide Fund for Nature (WWF), Valuing the Arch project, the Clinton Foundation – Clinton Climate Initiative, Climate Change Impact Adaptation and Mitigation (CCIAM programme-SUA), the Institute of Resource Assessment (IRA), University of Dar es Salaam (UDSM), Mpingo Conservation and Development Initiative (MCDI), the Vice President’s Office-Environment Division, the Tanzania Forest Service (TFS) (Agency, and Technical advisors, directors and project managers – for both TFCG and MJUVITA. PAC meets every six months to discuss the project’s progress report, work plans and budget, lessons and advise on the challenges of project implementation and interrelations with its partners, collaborators, beneficiaries and implementers for the interest of its effectiveness and efficiency. TFCG serves as a facilitator of PAC for the smooth undertaking of PFM/REDD+ activities in the District.

Additionally, at the district level land use planning is undertaken by Participatory Land Use Management (PLUM) Teams consisting of foresters, land officers, water specialists, agriculture and livestock keeping experts and community development officers to undertake village level land use planning processes. At the village level, the establishment of the Village Land Use Management Team (VLUM) attests to the emergence of yet another hybrid institution for
the management of REDD+ initiatives. The composition of VLUM ensures that each sub-village has at least two representatives and that all stakeholders at the village level including private investors (for example hunting companies/plantations where applicable) are considered in constituting the VLUM. This is in accordance with the Participatory Land Use Planning Guidelines (1998). Decision-making is actually falls in the hands of villagers themselves with the technical team from the district providing technical guidance. Finally, the plan has to be approved by both village and district leadership level councils. It was noted that, although PLUM and VLUM were instituted by the 1998 guidelines, their functioning became more conspicuous under the REDD+ programme when resources were deliberately availed for Land Use Planning purposes.

The Natural Resources Committees established in most of the villages deal with the management of forests and report to the village council. The Village Natural Resources Committee is normally made up of 12 members drawn from all the sub-villages. Although the VNRC deals with the management of forests, VLUM deals with the rest of the resources including livestock, crops, human settlements, water resources and oversees the functioning of VNRC. Both VLUM and VNRC report to the Village Council.

The institutional framework encountered is associated with a number of operational challenges. The study found that sometimes there is a power struggle between and among institutions. For instance, VNRCs are not adequately answerable to the Village Council, especially on financial related decisions. It was noted that in the selling of confiscated products some VNRCs do proceed without due consultations and approval of Village Councils. The power struggle emanates from the fact that VNRCs are often endowed with more resources than village governments, the outcome of which are misunderstandings between the two bodies based on operational mandates. The study further established that, although REDD+ committees have been formed in all the villages with responsibility to oversee the planning and implementation of REDD+ payment scheme at the village level, in some villages, the formally established VNRCs seem to have been replaced in their roles by the REDD+ committees, leaving the former dormant, yet in others both committees operate alongside with notable overlaps in their mandate. The REDD+ Committees formed were reported to receive more benefits from the Project than the VNRCs, village chairs and Village Executive Officers in the villages. The benefits received include training, study tours and regular meetings and seminars. In consequence, the REDD+ Committees accumulated more knowledge than the local government authorities in the villages.

Sometimes, the District TFS staff overrides the functions of the VNRC. For example, the District Forest Manager (DFM) is not supposed to confiscate forest products in a village forest under the CBFM without consultations with
the VNRC. This applies when the CBFM bye-laws have been approved by the District Council. Operationally, the DFM has by-passed VNRCs under such situations. In the worst case scenarios, approval of CBFM bye-laws in some villages is perceived to be intentionally delayed to relinquish the powers of the village level institutions. In addition, the study observed that, although the VNRC members are elected by the Village Assembly and are supposed to report to the Village Council they do not have regular compensation. As a result, some committee members reportedly have lost morale. In other parts of the country, VNRC members are exempted from other communal works (Kessy, 1998; Kajembe and Kessy, 2000; Mombo, 2001) unlike in Kilosa.

3.3 Legitimacy and effectiveness of REDD+ committees

Investigations were conducted in relation to the legitimacy and functioning of the REDD+ committees at the village level. The parameters used to assess the legitimacy of these committees include determining whether household members were satisfied with the election process that resulted into the formation of the committees. Figure 15.2 presents a summary of the findings. According to the findings in Figure 2 more than 70 percent of the respondents indicated that the committees were legitimately in place. The main reasons given by those who reported being dissatisfied with the REDD+ committees included limited office tenure, lack of consensus in village meeting, favouritism during the election process and lack of awareness.

![Figure 15.2: Responses on satisfaction with the election of REDD+ committees](image)

To determine the functioning of the REDD+ committees, the respondents were asked to either agree or disagree with some statements. One of the statements required respondents to confirm that ‘REDD+ committees are effective’. Responses are summarised in Table 2. According to the findings presented in Table 15.2, only about 52 percent indicated that the committees are effective out of which only 17 percent of the total respondents strongly agreed that the
committees are functioning well. The findings also reveal that about 27 percent of the respondents could not assess the functioning of the committees, a feature which is associated with low awareness on the role of the committees.

<table>
<thead>
<tr>
<th>Responses</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>strongly agree</td>
<td>17.1</td>
</tr>
<tr>
<td>agree</td>
<td>35.4</td>
</tr>
<tr>
<td>undecided</td>
<td>26.8</td>
</tr>
<tr>
<td>disagree</td>
<td>7.3</td>
</tr>
<tr>
<td>strongly disagree</td>
<td>13.4</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Table 15.2: Responses on the effectiveness of REDD+ committees*

Source: Survey data (2012/2013).

### 3.4 Transaction costs of REDD+ implementation

Transaction costs identified fell under two main categories: costs to the project and costs borne by the villagers (Mrutu *et al*., 2016). In the context of this study start-up costs were also regarded as transaction costs. Therefore, the costs to the project included baseline setting up costs and start-up costs, monitoring and verification costs, and REDD+ readiness costs. Costs to the villagers included operation costs, preparation costs and costs associated with attending meetings. The study endeavoured to quantify these costs as specified in their respective categories. The quantification of the cost of participating in various REDD+ activities in monetary terms are shown in Table 15.3 (Exchange rate was 1 USD: TZS 1600 [BoT, 2013]):

<table>
<thead>
<tr>
<th>Cost centres</th>
<th>Dodoma</th>
<th>Isanga</th>
<th>Chabima</th>
<th>Nyali</th>
<th>Kisongwe</th>
<th>Average costs (TZS/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest management for REDD+</td>
<td>504 532</td>
<td>565 894</td>
<td>559 076</td>
<td>347 718</td>
<td>497 714</td>
<td></td>
</tr>
<tr>
<td>VLUP &amp; CBFM process</td>
<td>334 082</td>
<td>265 902</td>
<td>122 724</td>
<td>109 088</td>
<td>211 358</td>
<td></td>
</tr>
<tr>
<td>REDD+ meetings</td>
<td>68 180</td>
<td>61 362</td>
<td>54 544</td>
<td>61 362</td>
<td>61 362</td>
<td></td>
</tr>
</tbody>
</table>

*Table 15.3: Transaction costs borne by villages for participating in project activities*

Source: Field survey (2012/13)
Table 15.3 shows that the average annual forest management costs for REDD+ are relatively high (TZS 497 714) due to time spent in routine activities such as carbon measurements and forest patrols compared to TZS 211 358 and 61 362 of annual average VLUP and CBFM process costs and REDD+ meeting costs, respectively. Moreover, there were differences between costs incurred between villages. For example, Chabima and Nyali villages had incurred higher costs of TZS 565 894 and 559 076, respectively, in forest management for REDD+ than Dodoma Isanga and Kisongwe, which incurred TZS 504 532 and 347 718, respectively.

3.5 Estimation of total transaction costs incurred by the project

The total transaction costs for a REDD+ project includes transaction costs incurred by the project and transaction costs incurred by the villagers (see Table 15.4).

<table>
<thead>
<tr>
<th>Main category</th>
<th>Sub-category</th>
<th>Total value (TZS/year)</th>
<th>Total transaction cost (TZS ha(^{-1}) yr(^{-1}) [%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>To project</td>
<td>Monitoring and Verification</td>
<td>166 421 389</td>
<td>1 411.0 (52.20)</td>
</tr>
<tr>
<td></td>
<td>Start-up costs</td>
<td>123 672 000</td>
<td>1 049.0 (38.80)</td>
</tr>
<tr>
<td></td>
<td>REDD+ readiness costs</td>
<td>28 000 000</td>
<td>237.0 (8.70)</td>
</tr>
<tr>
<td></td>
<td>Baseline setting</td>
<td>50 000</td>
<td>0.4 (0.01)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sub-total 318 143 389</td>
</tr>
<tr>
<td>To villagers</td>
<td>Forest Management for REDD+</td>
<td>497 714</td>
<td>4.2 (0.20)</td>
</tr>
<tr>
<td></td>
<td>VLUP &amp; CBFM process</td>
<td>211 358</td>
<td>1.8 (0.07)</td>
</tr>
<tr>
<td></td>
<td>REDD+ meetings</td>
<td>61 362</td>
<td>0.5 (0.02)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sub-total 770 434</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Grand total 318 913 823</td>
</tr>
</tbody>
</table>

Table 15.4: Total transaction costs for implementing a REDD+ project

Source: Field survey (2012/13)
The total transaction costs for this project as Table 15.4 illustrates is estimated at TZS 2,704 (equivalent to USD 1.7 Rates year 2013). The study found that the highest contributors to the transaction costs were monitoring and verification (52.2%) and start-up costs (38.8%). The high transaction costs for monitoring and verification observed are likely to have been influenced by carbon pools covered, activities adopted for reducing deforestation and/or forest degradation and monitoring methods employed. The results are quite similar to Antinory and Sathaye’s (2007) findings that, monitoring and verification costs rank as the largest component (34%) of the weighted transaction costs. Thompson et al. (2013) estimated the average transaction cost of the six Peruvian REDD+ projects (6,672,440ha) at USD 0.73 ha\(^{-1}\) yr\(^{-1}\) which is equivalent to TZS 1,146 ha\(^{-1}\) yr\(^{-1}\) and concluded that, REDD+ transaction costs tend to increase with the reduction of the project area and carbon benefits due to economies of scale. The transaction costs are discussed further in the subsequent sections.

### 3.6 Incentives associated with REDD+

Table 15.5 provides a summary of the incentives reported by respondents during the study. It was revealed that both direct and indirect types of incentives were realised in the study area. Some of the incentives reported benefitted individual households whereas others were realised at the level of the community. However, both types of incentives have contributed to the positive attitude that community members have towards the REDD+ initiatives in Kilosa.

<table>
<thead>
<tr>
<th>Reported type of incentives/benefit</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of village government office</td>
<td>25.0</td>
</tr>
<tr>
<td>Provision of agricultural extension service</td>
<td>8.3</td>
</tr>
<tr>
<td>Provision of grants (e.g. bicycles, phones)</td>
<td>8.3</td>
</tr>
<tr>
<td>Introduction of field school (“shamba darasa”)</td>
<td>33.3</td>
</tr>
<tr>
<td>Introduction of conservation agriculture (CA)</td>
<td>16.7</td>
</tr>
<tr>
<td>Increased water</td>
<td>8.3</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Table 15.5: Incentives reported by respondents in the study area
Source: Field data (2012/2013)*

#### 3.6.1 Tangible incentives

One of the tangible benefits reported by beneficiaries of REDD+ project is the construction of village government offices with support from the project. Within the constructed Village Government Offices a space is set aside to serve as Village Land Registry Office. This is a requirement of the land use plan as per guidelines for registration. To facilitate the construction of village government offices the project provided a total support of US$ 10,000 per village, with the villagers contributing in kind through availing their labour and locally-available materials.
In addition, the project provided grants such as bicycles, phones and working gears (boots, raincoats, overalls) to VNRCs and registered MJUMITA selected leaders at the village level. Other benefits included stationery, nursery equipment, office equipment, T-shirts and laptops. Cash income from REDD+ amounting to TZS 20,000/= per household was another direct benefit realised at the household level. The REDD+ committee was responsible for overseeing the distribution of funds. For a village to qualify for cash payment the village must have completed its land use plan, undertaken carbon measurements and established a fund management leadership.

3.6.2 Development and environmental benefits

REDD+ interventions were associated with a number of development and environmental benefits that were realised in the targeted areas. In the targeted villages, extension education for conservation agriculture was provided as a development incentive. Agricultural officers were employed and supported to facilitate the process of establishing demonstration plots on Conservation Agriculture for farmers to adopt. Additionally, thirty farmers were selected from the six villages in Kilosa to participate in a study tour at Mgeta in Mvomelo district for purposes of improving their agricultural practices and productivity. Another group of 30 farmers were supported to attend the Nane Nane (August 8) exhibitions in Morogoro Municipality. In addition, 170 farmers from the six villages were trained in scaring wild animals from their farms. Other development support provided by the project to the district included the development of Kilosa agriculture strategy to guide agricultural activities in the district, introduction of improved charcoal-stoves and beekeeping in five villages and the introduction of farmers’ field schools for the improvement of conservation agriculture.

Investigations were further conducted to establish whether community members do associate some improvements observed in their livelihoods with the REDD+ undertakings in the area. To achieve this aim, the respondents were requested to either confirm or disagree with the statement that there are positive livelihoods improvements associated with REDD+. According to results presented in Table 15.6, about 70 percent of the respondents indicated that there are positive livelihoods outcomes that can be associated with the REDD+ interventions in the area. The remaining percentage is shared by those who disagreed (7.8%) and those who were non-committal (18.4%), implying that they are not aware of the positive outcomes.
<table>
<thead>
<tr>
<th>Opinion</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>strongly agree</td>
<td>21.7</td>
</tr>
<tr>
<td>Agree</td>
<td>48.3</td>
</tr>
<tr>
<td>No opinion</td>
<td>18.4</td>
</tr>
<tr>
<td>disagree</td>
<td>8.3</td>
</tr>
<tr>
<td>strongly disagree</td>
<td>3.3</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Table 15.6: Respondents’ opinion on REDD+ related positive livelihood outcomes*

The relationship between positive livelihood outcomes and incentives as perceived by respondents is summarised in Table 15.7. Results in Table 6 indicate that about 66.7 percent of the respondents agreed that there is an increase in positive livelihood outcomes associated with REDD+ incentives.

<table>
<thead>
<tr>
<th>Opinions</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly agree</td>
<td>17.8</td>
</tr>
<tr>
<td>Agree</td>
<td>48.9</td>
</tr>
<tr>
<td>No opinion</td>
<td>26.6</td>
</tr>
<tr>
<td>Disagree</td>
<td>6.7</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Table 15.7: Respondents’ opinion on incentive-related positive livelihood outcomes*

*Positive livelihood outcomes refer to the improvement of the socio-economic status of the respondents attributable to REDD+ project.*

3.7 **Economic efficiency of the REDD+ project**

It was necessary for the research to examine the relationship between costs and benefits associated with the project to determine economic viability of REDD+
projects using Kilosa as a case study. Among other things, the analysis aimed to establish whether the project had the ability to offset the transaction costs identified and remain economically viable. In this regard, tangible benefits discussed in section 3.5.1 were quantified to constitute the benefits side of the project cash-flow. It should be noted that the computed benefits did not include benefits associated with ecosystem services with the exception of carbon sequestration. The cash-flow was subjected to cost-benefit analysis and NPV computed at different interest rates to examine the robustness of the estimates. The findings from the cost-benefit analysis are summarised in Table 15.8.

Based on the results, even when the discount rate is as high as 31 percent, the scheme would still be economically viable with the ability to offset transaction cost incurred during the implementation of REDD+ activities. On the other hand, the magnitude of the NPV decreases by 90 percent with an increase in discount rate from 15 percent to 31 percent. Results further show that the project would be able to recoup the total costs incurred including transaction costs even at higher interest rates (31%) although NPV would be reduced at a relatively high level. Higher interest rates consider all risks associated with the project, implying that the investment is relatively secure and robust under the given assumptions. The IRR of the project is 49.34 percent which is the maximum interest that the scheme can pay to offset transaction cost. However, the IRR of the project is higher than the recommended World Bank’s rate of 15 percent for agricultural projects in developing countries.
<table>
<thead>
<tr>
<th>Year</th>
<th>n</th>
<th>Costs (TZS)</th>
<th>Benefits (TZS)</th>
<th>Net Benefit</th>
<th>15%</th>
<th>23%</th>
<th>31%</th>
<th>33.70%</th>
<th>49%</th>
<th>49.34%</th>
<th>49.35%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>0</td>
<td>133350434</td>
<td>29357768</td>
<td>-103992666</td>
<td>-103992666</td>
<td>-103992666</td>
<td>-103992666</td>
<td>-103992666</td>
<td>-103992666</td>
<td>-103992666</td>
<td>-103992666</td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td>77187118</td>
<td>112630568</td>
<td>35443450</td>
<td>30820391.3</td>
<td>28815813.01</td>
<td>27056068.7</td>
<td>26509685.86</td>
<td>23787550.34</td>
<td>23733393.6</td>
<td>23731804.49</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>74456271</td>
<td>128630568</td>
<td>54174297</td>
<td>40963551.61</td>
<td>35808247.08</td>
<td>31568263.5</td>
<td>30306129.16</td>
<td>24401737.31</td>
<td>24290753.7</td>
<td>24287500.94</td>
</tr>
<tr>
<td>2012</td>
<td>3</td>
<td>16960000</td>
<td>128630568</td>
<td>111670568</td>
<td>73425211.14</td>
<td>60009967.4</td>
<td>49673508.77</td>
<td>4672482.86</td>
<td>33758249.6</td>
<td>33528203.53</td>
<td>33521469.15</td>
</tr>
<tr>
<td>2013</td>
<td>4</td>
<td>16960000</td>
<td>128630568</td>
<td>111670568</td>
<td>63848099.69</td>
<td>48788591.38</td>
<td>37918708.98</td>
<td>34947257.19</td>
<td>22656543.35</td>
<td>22444907.37</td>
<td>22444907.37</td>
</tr>
<tr>
<td>Total (TZS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>105,064,497.75</td>
<td>69,429,952.86</td>
<td>42,223,883.96</td>
<td>34,494,889.07</td>
<td>611,414.60</td>
<td>4,592.19</td>
<td>-6,984.05</td>
</tr>
</tbody>
</table>

*Table 15.8: NPV at different discount rates*

Source: Field survey (2012/13)
4.0 Key Lessons and Implications

From the findings of the research, a number of lessons which have implications for both policy and practice were drawn. These can be summarised as follows:

• Implementation of REDD+ pilot schemes in Tanzania is associated with the emergence of governance structures in the form of hybrid institutions with the inclusion of key stakeholders. The emerging institutions have both participatory and interdisciplinary characteristics, which accords them requisite features to serve as stakeholders' reconciliation platforms during the process of implementing REDD+ initiatives. The implication of this lesson is that the government should recognise the emerging institutions and create an enabling policy environment for the institutions to be mainstreamed into the already existing structures without creating parallelism, which can degenerate into duplication of efforts.

• The project has demonstrated that effectiveness of incentive schemes increase if the schemes target individual households in addition to addressing community needs at the village level. During the implementation of the REDD+ scheme in Kilosa, the distribution of cash payments resulting from conservation efforts served as one of the tangible incentives for community participation and this was an effective incentive because it targeted to benefit individual households. The system took a step further to encourage individual households to contribute deliberately and willingly to community level projects. Common practice in a good number of conservation-related interventions incentives has often entailed targeting community level benefits without due consideration to individual household benefits. One such example of traditional practice can be the Tanzania National Parks Community Conservation Service projects. The implication of this lesson is that in designing conservation and development/livelihood interventions, designers including governments need to consider incentive systems that reach both individual household and community needs to have a double impact at the societal level.

• The study has shown that community perceptions on the REDD+ initiatives are largely positive (>70%). However, this positive perception is realised because the targeted communities have high expectations in terms of financial rewards from the REDD+ initiatives. This poses a challenge because the REDD+ initiatives studied were just pilots with funds provided from development partners to test how the system can work. The implication of this lesson is that for REDD+ projects to meet the expectations and aspirations of the community, forests have to be conserved, carbon traded and funds generated. It is imperative that implementers of REDD+ projects need to emphasise constantly to the target population that the realisation of tangible benefits from REDD+
is actually a conservation outcome from investments that communities put into conserving their forest resources and not otherwise.

- REDD+ projects as demonstrated by the Kilosa case study are associated with huge transaction costs mostly incurred as part of establishing the system itself. The implication here is that unless there is an institution to handle the transaction costs, undertaking REDD+ payment schemes is likely to collapse. In the current study, transaction costs were taken care of by development partners, implying that governments—both the central and at the local level—in the future need to be well positioned to handle such costs. It is encouraging however that such investment has proved to be economically viable with adequate returns to offset the transaction costs incurred, meaning that governments should not hesitate to invest in REDD+ projects because of their high potential in terms of return to investment if countries finally manage to sell their carbon.

REFERENCES


Summary and Conclusion
REDD+ prospects and way forward

Kassim Kulindwa, Dos Santos Silayo and Eliakim Zahabu

This book documents some of lessons addressing; climate change mitigation and adaptation strategies; forest carbon assessment strategies; community climate change adaptation and livelihoods strategies under REDD+ initiative; REDD+ governance processes in Tanzania; and economics of REDD+ implementation. These lessons were drawn as part of CCIAM programme that was designed to increase capacity through training and research where by 21 research project were implemented in different places of the country. These projects were designed to draw lessons from the piloting process that would help to shape future REDD+ in Tanzania.

In Section 1 strategies that can help the ecosystems and communities mitigate and adapt to the changing climate were developed. A strategy for sustaining carbon storage especially in the miombo ecosystems have been developed to include wildfire management. Wildfires are world-wide problems and uncontrolled or misused fire inflicts disaster on society and the environment. Several efforts have been done in Tanzania to reduce the occurrence of fire in Miombo but their success has been constrained with underfunding and/or lack of proper strategies. Therefore, fire management strategy for the Miombo woodland has
been developed as a tool for climate change mitigation while indicating a number of activities to be implemented and responsible actors. Strategies have also been developed to address climate change in the two main sectors of Agriculture and livestock keeping. Experience have shown that despite the number of coping strategies employed by agro-pastoralists in the study areas, the climate variability and change has evidenced to have serious impact on rangeland condition and livestock performance. Key lessons from the current studies is that, the climate change has adverse effects on human and livestock performance and inappropriate land use practices increased pressure on grazing land and forest reserves. The study indicates that information provided by different research perspectives about impacts and adaptation to climate change matter to recommendations for adaptation strategies in the agricultural sector in Tanzania.

Section 2 presented and discussed models that can be used to assess biomass and volume for different vegetation types in Tanzania. This is because the choice of a system to adapt to the climate change relies heavily on the accuracy of the method for quantifying biomass and volume as important primary variables for computing C stock and changes over time. The results from quantifying aboveground carbon stocks, soil carbon and carbon loss due to selective harvesting in five different vegetation types in Tanzania reveal that, tree above ground carbon, species composition, diversity and their relationships, and emissions from woodland selective harvesting were important parameters to consider when making decisions on biomass and volume for different vegetation types in Tanzania.

Discussion in Section 3 dwells on how communities adapt to the changing climate with the use of non-timber forest products. Existing balance between intensification and environmental sustainability under smallholder maize and rice cropping systems in Tanzania was also analyzed. This is due to the fact that maize and rice constitute 50% dietary energy of Tanzanian and smallholder farmers produce 90% of these crops. Productivity has found to be low due to low soil fertility, low use of agricultural inputs due to lack of capital, knowledge and extension services. The lessons drawn from this, points to future food demand arising from increasing population can either be met by increasing cultivated land or through intensification of agriculture. Pressure on land in Tanzania is increasing through population growth and expansion of protection areas. This raises a number of challenges in land use including conflicts and over utilization of resources. In consideration of REDD+ being implemented in Tanzania, there is need to think on how this can be done to have a balance between mitigation and other land use needs by communities.

Section 4 presents some experiences from local village level on the implementation of REDD+ in several areas of Tanzania. It has been shown that REDD+ has a potential to contribute to reducing poverty, combating global warming, and
conserving biodiversity. Amongst its challenges is the issue of governance. The issue of governance arises from the fact that one of the crucial actors in REDD+ implementation is local government authorities (LGAs). It has been argued that the LGAs are crucial for not only ensuring regulations are followed, but also in ensuring that REDD+ finances (money) are used to improve welfare of the adjacent communities and conserve forests. Despite Forest Stewardship Council (FSC) forest management certification standards being recognized to maintain and support the enhancement of forest ecosystem integrity, including forest structure and biodiversity conservation, little has been done to evaluate its influence on community forest management. This section presents evidence, from the assessment on the performance of a set of FSC-certified forests in REDD+ pilot project under village management through socio-ecological system conceptual framework. On the other hand some lessons on the governance structures for REDD+ – with the experience of Tanzania has been provided. The section also documents experiences from REDD+ pilot projects and discusses what findings from these imply for the national REDD+ strategy. Further, the findings show that establishing REDD+ will demand substantial developments in local land/forest governance structures including clarifying property rights and developing management plans.

Section 5 presents some lessons on REDD+ implementation from the economics point of view. The analysis has been done on the opportunity cost of reducing deforestation, transaction costs and incentives for managing REDD+ initiatives. Opportunity costs refer to the net benefits forgone because of not deforesting (preventing conversion of forestland to other land-uses, particularly to agriculture) or degrading forests (preventing non-sustainable wood harvest). Such costs may be calculated for individual landowners/users, for districts or nations. Opportunity costs can therefore be seen as payments required for compensating individuals for their forgone benefits. In this section costs and benefits of deforestation from the point of view of farming families in Morogoro region are discussed. Knowledge of the opportunity costs of reducing deforestation can help to evaluate the economic feasibility of the climate change mitigation mechanism known as REDD+. On the other hand the emerging governance structures have been examined, associated transaction costs and incentive schemes in the implementation of REDD+ piloting in the context of Participatory Forest Management (PFM) have also been assessed.

Specific lessons on emerging institutions at district and village levels have been provided. The implementation of REDD+ pilot schemes in Tanzania is associated with emerging of governance structures that take the form of hybrid institutions with inclusion of key stakeholders. The emerging institutions have both participatory and interdisciplinary characteristics giving them the needed features to serve as stakeholder’s reconciliation platforms during the process of implementing REDD+ initiatives. The implication of this lesson is
that the government should recognize the emerging institutions and create an enabling policy environment for the institutions to be mainstreamed in the already existing structures without creating parallelism. Similarly, effectiveness of incentive schemes increases if the schemes target individual households in addition to addressing community needs at village level.

These lessons are expected to help Tanzania to better prepare for the expected REDD+ implementation and other UNFCCC mechanisms. One of the important outcomes of the UNFCCC Conference of Parties Meeting (CoP21) in Paris is the formulation of Paris Agreement. The Paris Agreement establishes a binding obligation to all Parties to put forward Nationally Determined Contributions (NDCs) that formulate a country’s mitigation strategies and goals. It is widely acknowledged that such contributions include forest-related emission reductions and removals. The Agreement includes an explicit call to develop and developing countries to conserve and enhance forests and other biological carbon reservoirs. Recognition of REDD+ related activities in this agreement now guarantee that REDD+ will be implemented even beyond 2020.

The Paris Agreement therefore signifies the importance of Tanzania continuing with REDD+ activities. The most important pending issue in the REDD+ readiness process for the country was the establishment of NCMC for construction of the country Forest Reference Emission Level (FREL) for the monitoring of the implementation of REDD+ activities. Tanzania is looking forward to implement a result-based mechanism for REDD+, by establishing a robust and transparent forest carbon Measurement, Reporting and Verification (MRV) system to quantify its achievements in REDD+. MRV provides a system on how to account for the amount of forest carbon, including changes over time. This system establishes the FREL against which the REDD+ achievements will be gauged over time. Against this the country has established the National Carbon Monitoring Centre in early 2016 which will house the MRV system to develop the FREL. It is envisaged that NCMC may also be given broader mandate to monitor NDCs as well.