A Rapid Analysis of Greenhouse Gas Emission Mitigation Opportunities for Ethiopia: A Framework for Synthesis and Prioritization

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EXECUTIVE SUMMARY

In a rapidly changing environment and society, it is critical that novel and swift strategies are devised to help direct and prioritize potential greenhouse gas (GHG) mitigation activities across the world. Ethiopia provides a unique opportunity to develop a framework to rapidly assess greenhouse gas emission and mitigation opportunities, and prioritize actions. Here, we outline a novel framework to conduct a rapid analyses at the country level using Ethiopia as our focus. Our process involves multiple key components that include 1) a comprehensive literature review and synthesis, 2) a targeted country-wide survey of stakeholders, 3) a method for rapid analysis to identify relevant mitigation opportunities and associated potential, and 4) a country profile highlighting geographic, political, economic and social trends, and a decision support table that combines some key elements in providing a guide to prioritize where and what type of mitigation actions would be the most successful. With a strong and growing economy, Ethiopia is a diverse country, both environmentally and culturally. The country has set ambitious goals to become a middle-income country by 2025 while also committing to green initiates that emphasize energy efficiency and emission reductions as outlined in their Climate Resilient Green Economy strategy. Ethiopia consists of eight distinct agro-ecological zones that support a number of different land management practices and mitigation opportunities. The agriculture, forestry and other land use sectors currently represents about 85% of the net GHG emissions in Ethiopia and some of the most beneficial mitigation options include the sequestration potential by improving crop and livestock production practices, and protecting and re-establishing forests through reforestation and afforestation practices. Ethiopia has had a significant number of studies and reports examining current emissions from land management practices and suggestions for mitigation opportunities. Building off this information, we designed an online survey to focus more on the socio-economic factors that impact land use practices and adoption of mitigation strategies. The survey was designed to complement the Carbon Benefit Project (CBP) tool that is used to rigorously evaluate different scenarios to estimate their emission reduction that complies with the Intergovernmental Panel on Climate Change standards. The results of the survey improve our understanding of the driving forces, and their degree of significance, that effect land management activities, such as war and conflict, population pressure, poverty, affluence, etc. This socio-economic assessment was then complimented by a rapid assessment of mitigation options and associated GHG mitigation potential for select regions using the CBP tools. We illustrate the next step of conducting a detailed assessment of multiple scenarios within a region of Ethiopia using the CBP tool with a case study. These components were combined in a decision support table that included the number of existing mitigation projects, multiple socio-economic criteria and mitigation potential of relevant actions that together can be used to guide and prioritize mitigation actions for a specific region of Ethiopia. How these are combined can vary depending on the interests and resources of the user. With our approach, we focus first on the ‘real world’ situation based on the unique economic, cultural and political context for a potential emission mitigation activity, which is then augmented with estimated GHG emission mitigation values from potential projects. This framework provides a strategy to rapidly asses the current emissions and mitigation potential at regional scales while considering the socio-economic factors for successful actions that can be reproduced in other countries.

TABLE OF CONTENTS

LIST OF ACRONYMS

AFOLU	Agriculture, Forestry and Other Land Uses
ALU	Agriculture and Land Use
BAU	Business as Usual
CBP	Carbon Benefits Project
CSA	Climate Smart Agriculture
CRGE	Climate Resilient Green Economy
CSU	Colorado State University
DPSIR	Drivers, Pressures, State, Impact and Response
FAS	Foreign Agricultural Service
FECCC	Forests, Environment and Climate Change Commission
FRL	Forest Reference Level
FY	Fiscal Year
GEF	Global Environment Facility
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GTP	Growth and Transformation Plan
HDI	Human Development Index
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate
IRB	Institutional Review Board
LULUCF	Land Use Land Use Change and Forestry
MRV	Monitoring Verification and Reporting
NREL	Natural Resource Ecology Laboratory
OCBD	Office of Capacity Building and Development
PFM	Participatory Forest Management
REDD+	Reducing Emission from Deforestation and Forest Degradation plus
SNNPR	Southern Nations, Nationalities, and People's Region
UNCCD	United Nations Convention to Combat Desertification
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WOCAT	World Overview of Conservation Approaches and Technologies

LIST OF TABLES AND FIGURES

TABLES

FIGURES

INTRODUCTION

The Federal Democratic Republic of Ethiopia is one of the world's oldest continuous civilizations and has gained international recognition as the cradle of humanity. Ethiopia is also Africa's oldest independent country. The landscape and topography are incredibly diverse from high Afro-alpine vegetation to desert and semi-desert scrublands to four large river systems that provide water to millions of people across East Africa. Multiple studies have shown that Ethiopia's natural resources, economy, and population are highly vulnerable to climate change (Evangelista et al. 2013; Milne et al. 2016). With over 80% of Ethiopia's population residing in rural areas and dependent on natural resources for their livelihoods, climate change is considered a major challenge for development.

As the country pursues its goal of becoming a middle-income country by 2025, Ethiopia's government has made clear its commitment to green growth and to a low-carbon economy that meets its development goals, while balancing its greenhouse gas (GHG) emissions trajectory. Ethiopia's Climate Resilient Green Economy (CRGE) strategy is well-respected nationally and internationally as a leading example of how to build economic resilience in the face of climate change adaptation. CRGE aims to balance economic growth in concert with energy efficiency and emissions reductions (FDRE 2011). In general, Ethiopia is a low GHG emitter. However, under its current growth trajectory, the energy and industrial sectors are projected to grow considerably and have a much larger impact on the environment. The CRGE, if implemented fully, will ensure Ethiopia pursues a low-emissions trajectory (Evangelista et al. 2018).

The agricultural sector accounts for ~ 60% of Ethiopia's total GHG emissions with a further ~18% coming from land use change and forestry. This makes agriculture, forestry and other land use (AFOLU) a crucial sector for mitigation activities. Data for 2016 show agricultural emissions continue to be dominated by livestock with 52% of emissions coming from enteric fermentation and 37% coming from manure left on pastures. Livestock management presents a mitigation opportunity, something which is recognized by the Ethiopian Government; however, opportunities in reducing enteric emissions (e.g., improving livestock breeds, feed types, and using feed supplements) would require both a significantly higher level of productivity and income stream within the agricultural sector, and significant investment from the government and/or private industry in livestock breeding programs and extension resources (FAO 2017).

Management of grazing lands is perhaps the best opportunity for carbon sequestration in soils. Although gains would be low in terms of tonnes per ha, better managed grazing lands could also lead to a reduction of the overall herd size and reduced enteric emissions per head. Further analysis of the potential role of exclosures, a practice used widely in Ethiopia, and avoidance of overgrazing is needed. In terms of land use change, emissions come mainly from loss and degradation of native forests driven by agricultural expansion and the need for fuel. As in other places in Africa, quantification of rates of forest loss has been difficult. An analysis of the drivers and pressures leading to smallholder agricultural expansion and the need for alternative fuelwood sources would lead to a better understanding of mitigation in the land use and land use change sector. In summary, mitigation options for Ethiopia in the land use sector should focus on reducing land use conversion and restoring degraded forests and rangelands. In the agricultural sector the greatest potential lies in increasing soil carbon and woody carbon stocks in agricultural systems. Supporting Ethiopia in its sustainable landscapes approaches in the AFOLU sector can help the USDA and USAID achieve many of their agricultural, food security, economic, resilience, democracy and self-reliance goals.

PROJECT GOAL AND OBJECTIVES

The goal of this project is to develop and demonstrate a replicable framework for a countrywide, jurisdiction-specific analysis and prioritization of GHG emissions and mitigation activities in the AFOLU sector for Ethiopia. During the study, we identified and tested methods that can provide a rapid assessment of the opportunities and risks for short- and long-term GHG mitigation investments both at the national and regional (administrative region) scale. The purpose of the framework is to help guide decision-making, policy formulation and future investment. The objectives of the project were to:

1. Review and compile the best available existing information on emission and mitigations activities.
2. Strategically and systematically gather socio-economic information from professional and institutional stakeholders.
3. Analyze GHG emissions and potential mitigation activities for the country and administrative regions using readily available, standardized and science-based methods.
4. Explore and summarize political, economic and social trends that may affect GHG mitigation activities.
5. Synthesize the information and results in a final report that clearly documents and describes the analytical framework.

This approach aims to balance emission and mitigation analyses with in-country stakeholder expertise. The approach uses science-based methods to provide comprehensive, replicable and actionable products.

PROJECT FRAMEWORK

We proposed to link the objectives stated above as shown in our final framework workflow to develop the products stated in the proposed work (Figure 1). Our approach was dramatically different from previous efforts in that we aimed to give more weight to the socio-economic factors that drive current practices and that might affect mitigation activities (See PROJECT SYNTHESIS AND DISCUSSION section below), however we still include emission benefits across large scales for select mitigation activities. We did not take an inventory only approach, but rather built a framework whereby regions and mitigation activities could be prioritized and selected based on the social-economic, political, and land uses, information gathered using multiple means. This direction was selected both because of the short timeframe and large-scale nature of the study and because we wanted to explore non-traditional approaches to solving this problem. Here, we will present each of the core objectives and associated results that supported the decision table and final framework discussed in later sections for this rapid analysis of GHG emission mitigation opportunities for Ethiopia

Literature Review: Greenhouse Gas Emissions and Mitigation Activities in Ethiopia

We began our analyses by compiling, reviewing, and synthesizing existing publications, reports and assessments that have been developed for Ethiopia (or the larger region) related to AFOLU emissions and mitigation opportunities. Ethiopia and the East African region have received a considerable amount of research focus and support from the international community aimed at the assessment of GHG emissions from the AFOLU sector and potential mitigation activities. However, activities have been relatively disparate and were developed for different purposes.

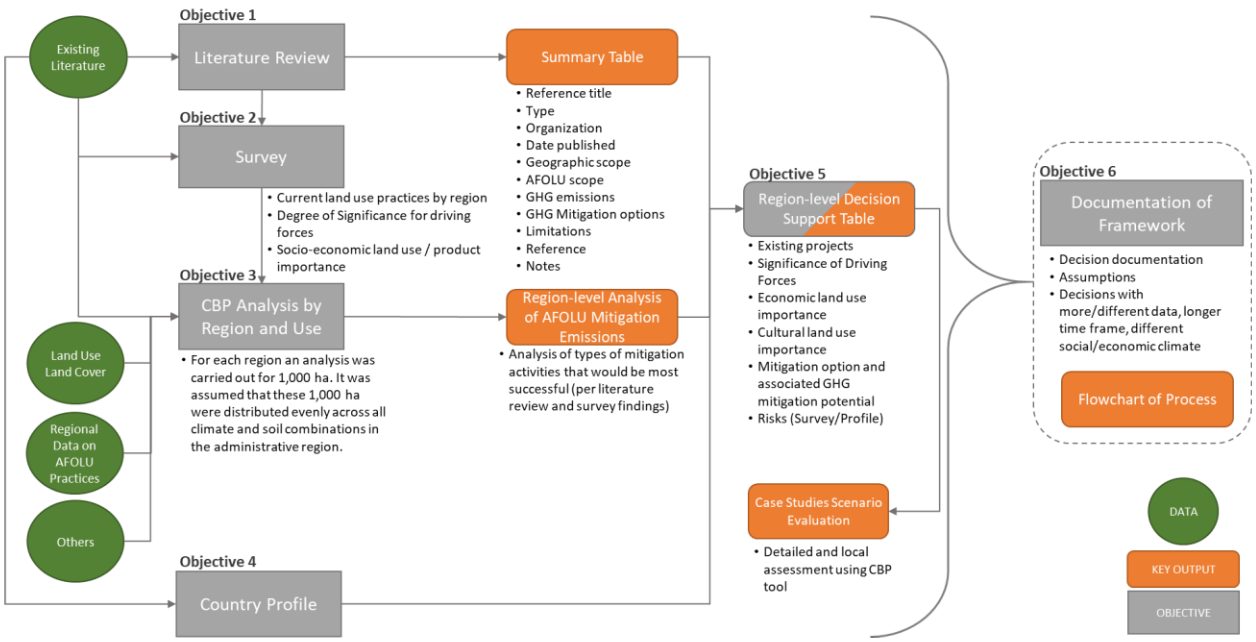

Figure 1. Framework and workflow of the project showing the data accessed, the objectives and the associated products resulting from objectives.

The primary objective of the literature review was to identify, synthesize and report on the current understanding of GHG emissions and mitigation activities in Ethiopia. From the review, we developed tables summarizing the literature on GHG emission and mitigation in Ethiopia (Table 1, Appendix II). The information compiled consists of the following:

- *Reference title:* The reference title
- *Type:* A categorical description of the reference type. Examples include Scientific Publication, Report, Assessment, White paper, etc.
- *Organization*: If applicable, the organization that compiled the reference
- *Date published*: The date that the reference was published
- *Geographic scope*: The spatial extent that the reference addresses
- *AFOLU scope*: The emission fields that the reference addresses
- *GHG emissions*: Any reported figures on emissions or deforestation rates
- *GHG mitigation options*: List any mitigation options presented in the document
- *Limitations*: List any limitations that are associated with this reference
- *Reference*: Standard citation for reference

- *Notes*: Provide any other details that may be important to list regarding the reference

The table was then modified to present these findings for publication that included a summary table below (Table 1) and a more detailed form as Appendix II.

Ultimately, 25 references were included in the synthesis. These comprised of nine journal articles, eight formal reports from government and non-government organizations, two book chapters and six other reference types (Table 1). These items were published between the years 2007 and 2019 with 30% having been published in the last three years. From these sources, we compiled a summary synthesis of emissions and mitigation activities in the region. These descriptions are provide below.

Table 1. List of references used in the GHG emission and mitigation synthesis. This presents a subset of the complete attributes captured for each reference. Appendix II complements this table.

Reference	Reference Title	Type	Organization or Journal	Year Published	Geographic Scope	AFOLU Scope
Weldegebriel and Gustavsso 2017	Climate Change Adaptation and Mitigation Strategies Vis-À-Vis the Agriculture and Water Sectors in Ethiopia - Case Review/Study of the EPCC Project	Review scientific article	Environment Pollution and Climate Change	2017	Ethiopia	Agriculture, Water
EPCC 2015	Ethiopian Panel on Climate Change First Assessment Report, Agriculture and Food Security (Working Group II)	Assessment report	Ethiopian Academy of Sciences	2015	Ethiopia	Agriculture, Forestry
FDRE 2011	Ethiopia's Climate-Resilient Green Economy	Document	Federal Democratic Republic of Ethiopia	2011	Ethiopia	Agriculture, Forestry
Gonzalo et al. 2017	REDD+ and Carbon Markets: the Ethiopian Process	Book chapter	Published by springer	2017	Global with few sections specific to Ethiopia	Forestry
Crumpler et al. 2017	Regional Analysis of the Nationally Determined Contributions of Eastern Africa: Gaps and opportunities in the agriculture sectors	Working paper	Food and Agricultural Organization of the Unite Nations.	2017	East Africa (18 countries)	AFOLU
Kim et al. 2018	Calling for Collaboration to Cope with Climate Change in Ethiopia: Focus on Forestry	Scientific article	Journal of Climate Change Research	2018	Ethiopia	Forestry
Kuramochi et al. 2016	Greenhouse gas mitigation scenarios for major emitting countries: Analysis of current climate policies and mitigation pledges	Report	PBL/New Climate Institute/IIASA	2016	25 countries including Ethiopia	Agriculture, Forestry
Smith et al. 2014	Agriculture, Forestry and other land use (AFOLU)	Book chapter	Contributions of working group III to the fifth assessment report of the IPCC	2014	Global	AFOLU
Bekele et al. 2015	The context of REDD+ in Ethiopia: Drivers, agents and institutions	Occasional paper	CIFOR (Center for international forestry research)	2015	Ethiopia	Forestry

Reference	Reference Title	Type	Organization or Journal	Year Published	Geographic Scope	AFOLU Scope
Dibaba et al. 2019	Carbon stock of the various carbon pools in Gerba-Dima moist Afromontane forest, South-western Ethiopia	Scientific article	Carbon Balance and Management	2019	Gerba-Dima l (Illu Aba-Bora zone)	Forestry
Branca et al. 2012	The Carbon Footprint of the Agricultural Growth Project (AGP) in Ethiopia An application of the EX-Ante Carbon-balance Tool (EX-ACT)	Document	Food and Agriculture Organization of the United Nations, FAO	2012	Project Ethiopia	Agriculture, Grassland
FDRE 2015	Ethiopia's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). Submitted to: United Nations Framework Convention on Climate Change (UNFCCC)	Report	The Federal Democratic Republic Of Ethiopia	2015	Ethiopia	AFOLU
USAID 2015	Greenhouse gas emissions from Ethiopia	Fact sheet	USAID	2015	Ethiopia	
Vuorinen 2016	Study of causes of deforestation and forest degradation in Ethiopia and the identification and prioritization of strategic options to address those	Report	Oy Arbonaut Ltd, FM-International OY FINNMAP and Baseline Surveying Engineering Consultant	2016	Ethiopia (except Oromia region)	Forestry
FDRE 2018	National REDD+ Strategy (2016 - 2030)	Document	Federal Democratic Republic of Ethiopia: Ministry of Environment, Forest and Climate Change	2018	Ethiopia	Forestry
FDRE 2017	National REDD+ Consultation and Participation Plan	Ethiopia's REDD+ document	Ministry of Environment, Forest and Climate Change	2016	Ethiopia	Forestry
Yosef et al. 2019	Carbon stock potentials of woodlands in north western lowlands of Ethiopia	Scientific article	Journal of Sustainable Forestry	2019	Northwestern Lowlands of Ethiopia	Forestry
Negash and Starr 2015	Biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment, Ethiopia	Scientific article	Plant Soil	2015	South-eastern Rift Valley escarpment (Gedio zone)	Agroforestr y
Mohammed and Bekele 2014	Changes in Carbon Stocks and Sequestration Potential under Native Forest and Adjacent Land use Systems at Gera, South-Western Ethiopia	Scientific article	Global Journal of Science Frontier Research: Agriculture and Veterinary	2014	Southwestern Ethiopia (Gera Forest, Jimma zone)	Forestry, Agroforestr y, Crop land
Bikila et al. 2016	Carbon sequestration potentials of semi-arid rangelands under traditional management practices in Borana, Southern Ethiopia	Scientific article	Agriculture, Ecosystems and Environment	2016	southern Ethiopia (Yabello district of Borana zone)	Rangeland

Reference	Reference Title	Type	Organization or Journal	Year Published	Geographic Scope	AFOLU Scope
Beenhouwer et al. 2016	Biodiversity and carbon storage co-benefits of coffee agroforestry across a gradient of increasing management intensity in the SW Ethiopian highlands	Scientific article	Agriculture, Ecosystems and Environment	2016	southwestern Ethiopia (Jimma zone)	Forestry, Agroforestry
Kendie et al. 2019	Biomass and soil carbon stocks in different forest types, Northwestern Ethiopia	Scientific article	International Journal of River Basin Management	2019	Northwestern Ethiopia (Gondar zuria district)	Forestry
UNFCC 2016	Report on the technical assessment of the proposed forest reference emission level of Ethiopia submitted in 2016	Report	United Nations Framework Convention on Climate Change	2016	Ethiopia	Forestry
FDRE 2007	Climate Change Technology Needs Assessment Report of Ethiopia	Report	Ministry of Water Resources National Meteorological Agency	2007	Ethiopia	All sectors including AFOLU
FAO 2017	Supporting low emissions development in the Ethiopian dairy cattle sector – reducing enteric methane for food security and livelihoods	Report	Food and Agriculture Organization	2017	Ethiopia	Livestock

Emissions synthesis

Globally, the AFOLU sector is responsible for about 10-12 Gt CO_2e yr^{-1} of human induced GHG emissions. The main sources are deforestation, livestock production and agricultural emissions associated with soil and nutrient management (Smith et al. 2014).

Regional Emissions (East Africa)

In East Africa, the AFOLU sector represents 67% of net GHG emissions as of 2017. The agriculture sector constitutes a source of annual net emissions of 0.36 Gt CO_2e while the Land Use Land Use Change and Forestry (LULUCF) sector represents a net sink of -0.11 Gt CO_2e, for a combined total of 0.25 Gt CO_2e yr^{-1} net GHG emissions in the AFOLU sector for 17 East Africa countries (FAO 2017). Regionally, 25% of the GHG emissions comes from forest degradation, 19% from grassland biomass burning, 14% each from deforestation and enteric fermentation holding, 12% from croplands at the regional level (FAO 2017). The remaining emission (16%) come from burning crop biomass, managed soils, rice cultivation and manure management. The aggregated country data of East Africa suggests that forest degradation is the highest source of LULUCF emissions (48%), while deforestation and cropland account for 27 and 23%, respectively. However, at national levels, sources and sinks vary due to differences in forest cover type and energy consumption trends from fuel wood use. For example, deforestation constitutes all the sectorial emissions in Ethiopia and Mozambique while forest degradation is responsible for almost 90% of emissions in Malawi. On the aggregate level, 17 economy-wide net emissions in East Africa reported are expected to increase by 80% between 2015 and 2030 (FAO 2017).

National Emissions (Ethiopia)

In 2011, the Ethiopian government initiated the CRGE initiative to reach middle-income status by 2025, while developing a green economy and mitigating the negative effects of climate change

(FDRE 2011). The plan is the first national effort that specified the sources of GHG emissions and proposed mitigation directions for the country. According to the CRGE document, the GHG emissions in 2010 was about 150 metric tons of carbon dioxide equivalent ($MTCO_2e$), representing less than 0.3% of total global emissions. Under then current practices and the country's Growth and Transportation Plan (GTP), GHG emissions were projected to reach to an estimated 400 $MTCO_2e$ by 2030 (FDRE 2011). More than 85% of the GHG emissions in Ethiopia is from the AFOLU sector, while the remaining emissions are from the transportation, construction, industry and power sectors. In a second report by the Ethiopian government, national GHG emissions was estimated at 146 $MTCO_2e$ in 2013, 79% of which was reported from the AFOLU sector (FDRE 2015). Revised projected emissions for 2030 in the second national communication was estimated at 367 $MTCO_2e$. Kuramochi et al. (2016), projected Ethiopia's GHG emissions to be 310 $MTCO_2e$ by 2030 assuming the second phase of GTP will not be reached in the projected year. It is important to note that in most of the documents and scientific literature reviewed (Appendix II) where the GHG emissions of Ethiopia were stated, the CRGE report form 2011 was the primary reference.

Mitigation synthesis

In addition to reviewing the status of GHG emissions reporting in Ethiopia, we also compiled the reported mitigation efforts. Mitigating GHG emissions while ensuring food security and supporting an agriculture economy will be the greatest challenges for countries in East Africa. While agriculture is the driving force for most GHG emissions, it also drives the economy and is responsible for 70% of employment in the region (FAO 2017). However, all 18 countries in East Africa have ambitious goals towards reducing net GHG emissions and increasing resilience under future climate change (FAO 2017). Full implementation of sectoral mitigation targets scaled to the regional level in the agriculture sector would limit emissions to approximately one-third below the projected baseline equivalent to accumulated net reduction of 0.94 Gt CO_2e by 2030. While similarly, implementation of the mitigation targets at regional level in the LULUCF sector would enhance removals by roughly 275% compared with the baseline-equivalent to accumulated net reduction of 5.6 Gt CO_2e by 2030 (FAO 2017).

In Ethiopia, with the full implementation prioritized mitigation initiatives in the CRGE strategy, a net reduction of 255 $MTCO_2e$ by 2030 is expected (FDRE 2011). Several agriculture and forestry-based initiatives were indicated in the literature that described mitigation activities in Ethiopia. A reduction of net LULUCF emissions is expected in the range of 90 $MTCO_2e$ from agriculture and 130 $MTCO_2e$ from forestry by 2030 as compared to projected BAU levels (FDRE 2011). According to the analysis of the nationally determined contributions of different countries, Ethiopia is among the countries which require additional measures to achieve its 2030 targets (Kuramochi et al. 2016). Our review of the literature showed the carbon sequestration potential in LULUCF. In northwestern Ethiopia, total carbon (biomass plus soil) in woodlands ranged from 55.3 to 71.0 Mg ha^{-1} (Yosef et al. 2019) while total carbon in other forests types ranged 131.6 to 195.3 Mg ha^{-1} (Kendie et al. 2019). Agroforestry systems sequestered a total carbon ranging from 173 to 375 Mg ha^{-1} and 150.7 to 387 Mg ha^{-1} in southern and southwestern Ethiopia, respectively (Mohammed and Bekele 2014; Negash and Starr 2015; Beenhouwer et al. 2016). Native forest in southwestern Ethiopia had a total carbon ranging 230-508.9 Mg ha^{-1} (Mohammed and Bekele, 2014; Beenhouwer et al. 2016; Dibaba et al. 2019). Forest restoration in Humbo, southern Ethiopia as a part of a carbon project resulted in the storage of 226 Mg/ha of total carbon (Chinasho et al. 2015). In addition, in southern Ethiopia, rangelands under different management have a stock of total carbon in the range 141.5 to 300.4 Mg ha^{-1} (Bikila et al. 2016). The national mitigation potential of afforestation and reforestation in addition to rehabilitating degraded forest was estimated at 2 billion tons of CO_2e and 3.7 billion tons of CO_2e, respectively in biomass alone (Vuorinen 2016). Estimated potential emission reduction from avoided biomass fuel use by improved stoves and installing biogas digesters were 77 and 115 $MTCO_2e$, respectively (Vuorinen 2016).

There are examples of mitigation efforts currently underway in Ethiopia (Bekele et al. 2015; FDRE 2017) (Table 2). Oromia and the Southern Nations, Nationalities, and People's Region (SNNPR) regions have multiple projects while there is limited ongoing projects in other regions across Ethiopia that are not country-wide projects. Another mitigation activity is the Efficient Stoves Program of Activities by The Paradigm Project, Colorado and World Vision Ethiopia. While it is early to fully understand the effects of this intervention, it will likely reduce the amount of fuelwood needed and therefore reduce emission from deforestation. The emissions that are produced from the stove would then be accounted as a part of the energy sector.

Table 2. Summary of the large-scale GHG mitigation projects underway in Ethiopia as identified in the literature review.

Project Name	Founder	Location	Estimated C Emission Reduction	Notes	Years
Bale Mountains Eco-region REDD+ Project	Norway through the World Bank	Bale Mountains, Oromia Region	18 million MtCO2	The largest REDD+ pilot project in the country to date. The program was initiated by Farm Africa and SoS Sahel to organize PFM in the Bale eco-region and help local communities sustainably manage forests. The project covers about half a million ha and is intended to run for 20 years.	2013-2033
The Humbo Ethiopia Assisted Natural Regeneration Project	World Vision Ethiopia	Wolaita zone, SNNPR	880,295 MtCO2	Afforestation and reforestation activities including regenerating native forests, reducing soil erosion and establishing income stream for local communities among others. Focus on community involvement.	2007-2036
The Abote Community-Managed Reforestation Project	World Vision Ethiopia	Oromia, Ethiopia	2.67 million MtCO2	Afforestation, reforestation and revegetation activity implemented on existing communal forestlands and croplands. Uses the Climate Community and Biodiversity Standards.	2008-2038

Sustainable Land Management Program 2013-18	Inter. Develop. Assoc. and the Global Environ. Facility	Nation-wide		Although not a carbon project, rehabilitation work in 45 critical watersheds in 6 regions have been undertaken.	2013-2018
The Sodo Community Managed Agroforestry & Forestry Project	World Vision Ethiopia and World Vision Australia	Sodo Zuria, SNNPR	189,027 MtCO2	Certified Emission Reduction purchase agreement (1 ton CO2 = $9 USD)	2006-2041

Survey of Ethiopia GHG Land Uses and Driving Factors

To better understand the social, political, and economic factors that may facilitate or prohibit the adoption of GHG mitigation activities at the regional level, our team designed a survey to capture on-the-ground perspectives that can be difficult to capture in international reports and publications. The survey was distributed to a targeted sample of federal and regional government officials, professionals and practitioners distributed throughout the AFOLU sectors in Ethiopia. Through our government partnerships and existing networks, we were able to collect national-, regional- and local-scale information. The surveys were emailed to respondents in collaboration with the Forests, Environment and Climate Change Commission (FECCC). Respondents were asked to forward the survey to other relevant individuals, organizations and stakeholders using a strategy referred to as snowball sampling (Goodman 1961).

Survey Design and Administration

We had a number of objectives, audiences and mechanisms to consider as we constructed the survey. Through our existing knowledge of cultural and professional norms in Ethiopia, and from our stakeholder meetings in Ethiopia in May 2019, we determined that the survey needed to be designed to provide multiple media options for respondents (Bernard and Gravlee 2014). For example, relying on an internet link to the survey would not suffice for all individuals and we needed to provide both a pdf version and a soft copy (Microsoft Word document) of the survey to facilitate recipients' response. The primary and preferred response was through a link to an online version of the survey using Qualtrics XM® (2019) software, a web-based survey tool used to conduct survey research, evaluations and other data collection activities (Reips 2005). In addition, we understood that to improve response rate, the request to complete a survey would need to come from known individuals and, preferably, individuals that were well-established in careers related to this project. Therefore, we relied on our extensive network of top professionals in government, non-government and academic institutions to help administer the survey. We encouraged all recipients to pass along the survey to colleagues that may also have valuable expertise to contribute. A combination of open-ended and closed-ended survey questions were used to capture both qualitative and quantitative data. To limit bias, leading, double-barreled, and double-bind questions were avoided (Reja et al. 2003). The survey comprised of 32 questions (Appendix III) that were reviewed by the Institutional Review Board (IRB) at Colorado State University and determined to be exempt. We had to consider what information was of highest priority to limit the length of the survey to maximize survey responses and completion. While we would have liked to capture information for multiple aspects of the project, we focused on gaining information related to the degree of significance to multiple socio-economic drivers (driving forces, Table 3 and 4) and self-reported land uses and current practices that would influence the adoption of mitigation strategies and that could be integrated into GHG mitigation analyses (i.e., Carbon Benefits Project tools). Respondents were asked about the importance of land use in the context of economic and cultural considerations. Questions also collected information on the political geographic regions that the respondents worked in. All responses were coded and analyzed using Qualtrics and Microsoft® Excel® 365 ProPlus (2019) software packages.

Table 3. List and description of the driving forces evaluated by survey respondents that is also used within the Carbon Benefits Project tool.

Driving Force	Description
Population Pressure	High: may trigger or enhance degradation, e.g., by increasing pressure on resources of ecosystem services. Low: may lead to degradation through lack of labour to manage resources.
Affluence	Change in consumption pattern and individual demand of the population or in the individual demand for natural resources (e.g., for agricultural goods, water, land resources, etc.).
Land Tenure	Poorly defined tenure security or access rights may lead to land degradation, as land-users are reluctant to invest in management when returns are not guaranteed.
Land Availability	Fragmentation of land into uneconomical units. Potential loss of cropland by conservation technologies involving construction (e.g., hedges, trash lines, trenches, terraces) could lead to an overall decrease in yield even with benefits of the conservation technology.
Poverty	Limits land-user investment and choice. Poor people often make short-term investment decision, ruling out some practices that require too much land, labour or capital investment. However, poor farmers are almost wholly dependent on their land and might invest more than the rich.
Labour Availability	Shortage of rural labour (e.g., through migration, prevalence of diseases, out migration) can lead to abandonment of traditional resources conservation practices such as terrace maintenance. May also alleviate pressure on land resources.
Inputs and Infrastructure	Inaccessibility to roads, markets, distribution of water points etc., or high prices for key agricultural inputs such as fertilizers. Quality of infrastructure will affect access to input and product markets.
Education, Access to Knowledge and Support Services	Education land users are less likely to be poor and more likely to adopt new technologies. Land users with education often have higher returns from their land. Education can also provide off-farm labour opportunities.
War and Conflict	Leading to reduced options for using the land and reluctance to invest.
Formal Institutions	Formal laws, policies controlling access and use of land resources. Government induced intervention.
Informal Institutions	Local rules and regulations, social and cultural arrangements and obligations affecting access to resources.

Table 4. Degree of significance and their description of how they impact to the driving forces.

Degree of Significance	Description
+++	The Driving Force is a predominant and crucial factor in increasing the adoption of the land management practices.
++	The Driving Force is an important in increasing the adoption of the land management practices.
+	The Driving Force is a factor in increasing the adoption of the land management practices.
+/-	The Driving Force has mixed effects on the adoption of the land management practice, increasing and decreasing adoption with no clear net effect on adoption.

-	The Driving Force is a constraint to the adoption of the land management practice.
--	The Driving Force is an important constraint to the adoption of the land management practice.
---	The Driving Force is predominant and crucial constraint to the adoption of the land management practice.

Survey Results

The survey was open for a total of three weeks and we sent two reminder emails to recipients. Due to the nature of the snowball sampling, we were unable to know the total number of individuals the survey was distributed to, but we estimate that it was between 400-600 individuals. At the end of the three weeks, we recorded 75 survey responses with 45 of those having been 100% completed (Figure 2). The response rate (estimated at 10-15%, which is relatively high for this type of survey) ensured that multiple perspectives were captured. This provided an adequate sample to draw on for analysis. While all regions were represented in the responses, often they were grouped with other regions (i.e., the recipient indicated that they were knowledgeable about multiple regions). As such, some regions could not be represented on their own. We choose to use survey responses that were > 31% completed as this captured the majority of the information needed to conduct additional analyses.

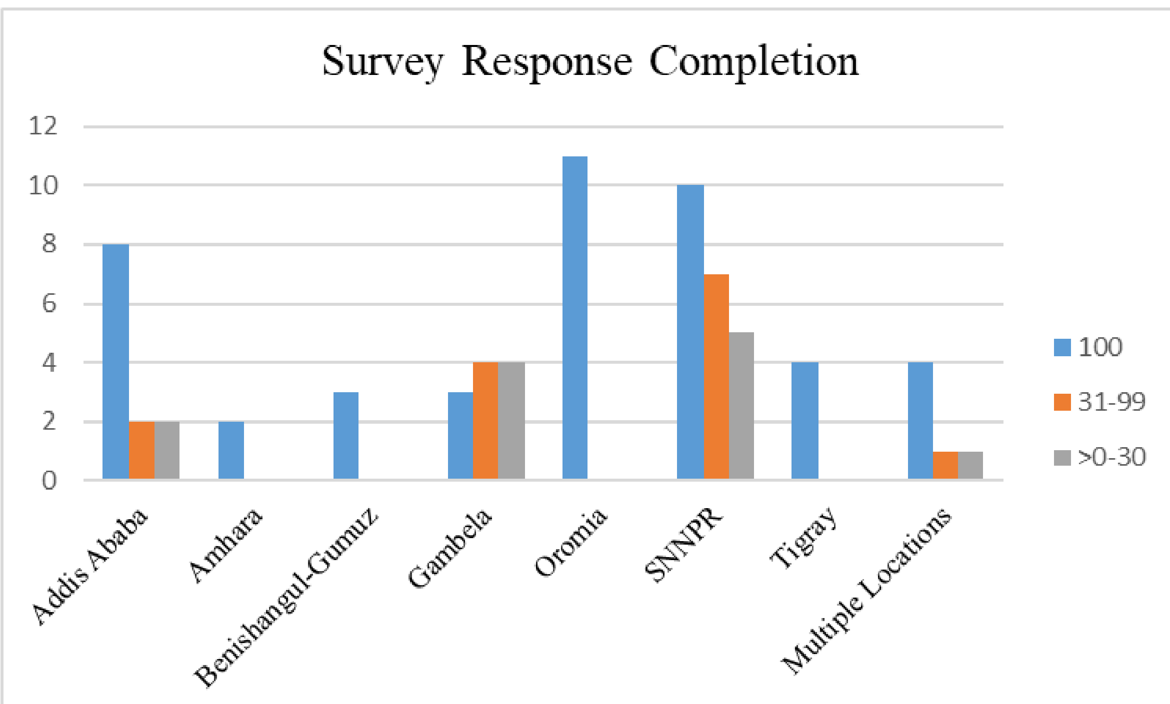

Figure 2. The number of responses by survey completion percentage for each political region in Ethiopia and for those respondents that indicated they work in multiple regions.

We asked recipients to evaluate the degree of significance of 11 critical driving pressures to the adoption of mitigation practices (Tables 3 and 4). The results of these questions are presented in Figure 3. Some of the main trends found was that war and conflict was a constraint to the adoption of land management practices on the western side of Ethiopia and that affluence and population pressure has the potential increase the adoption of land management practices in the southwestern regions.

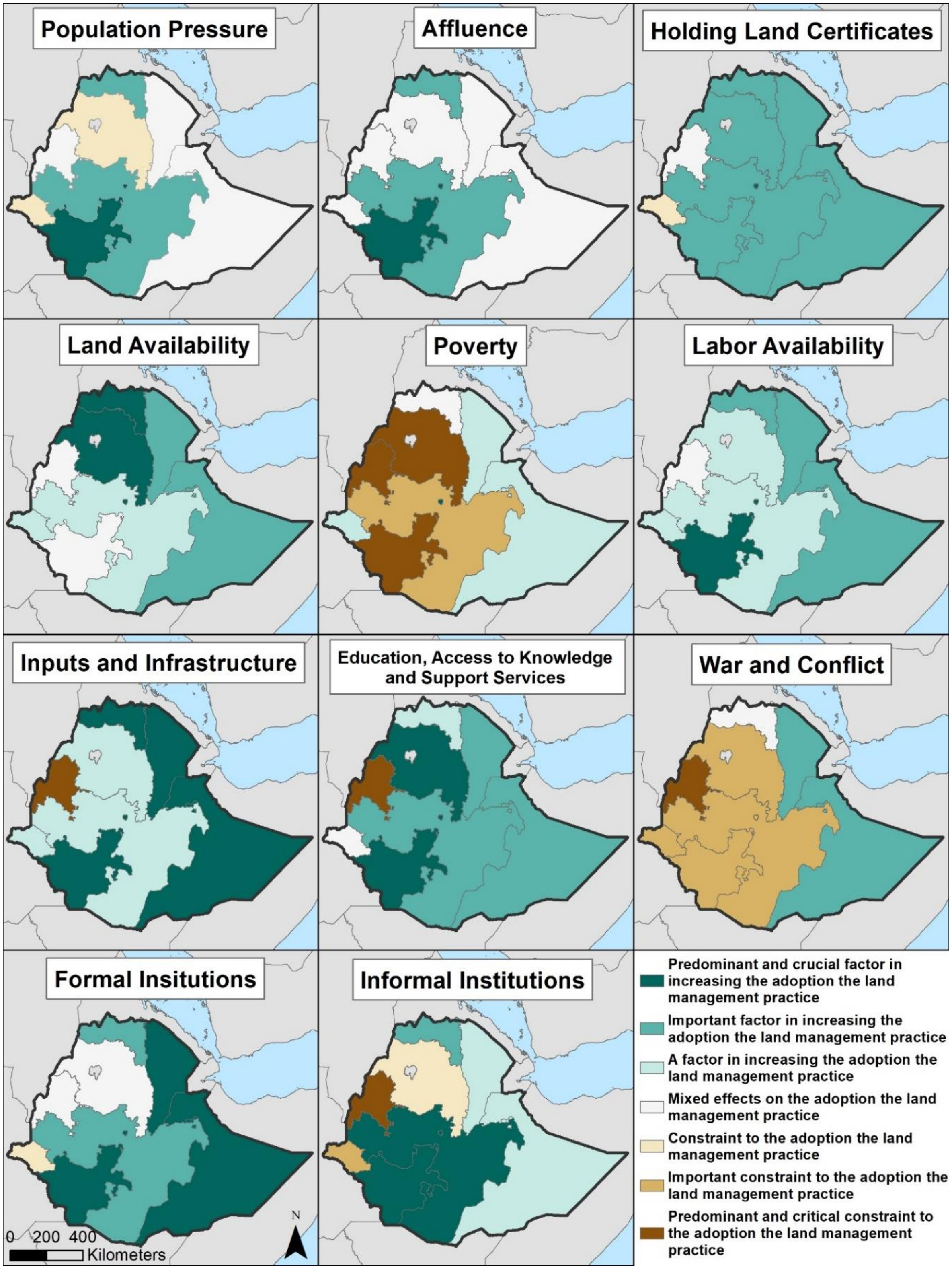

Figure 3. Degree of significance for 11 driving factors at the regional level for Ethiopia that may impact the adoption of land management practices as indicated from the survey responses.

Survey respondents indicated that, in terms of economic importance, forestry and forest products were extremely important to regions on the western side of Ethiopia whereas agroforestry was extremely important in the Tigray region in the north and the SNNPR region in the south. Urban development was extremely important for Addis Ababa but only slightly important for the surrounding Oromia region which reflects some of the current tension and conflict in the country (Figure 4).

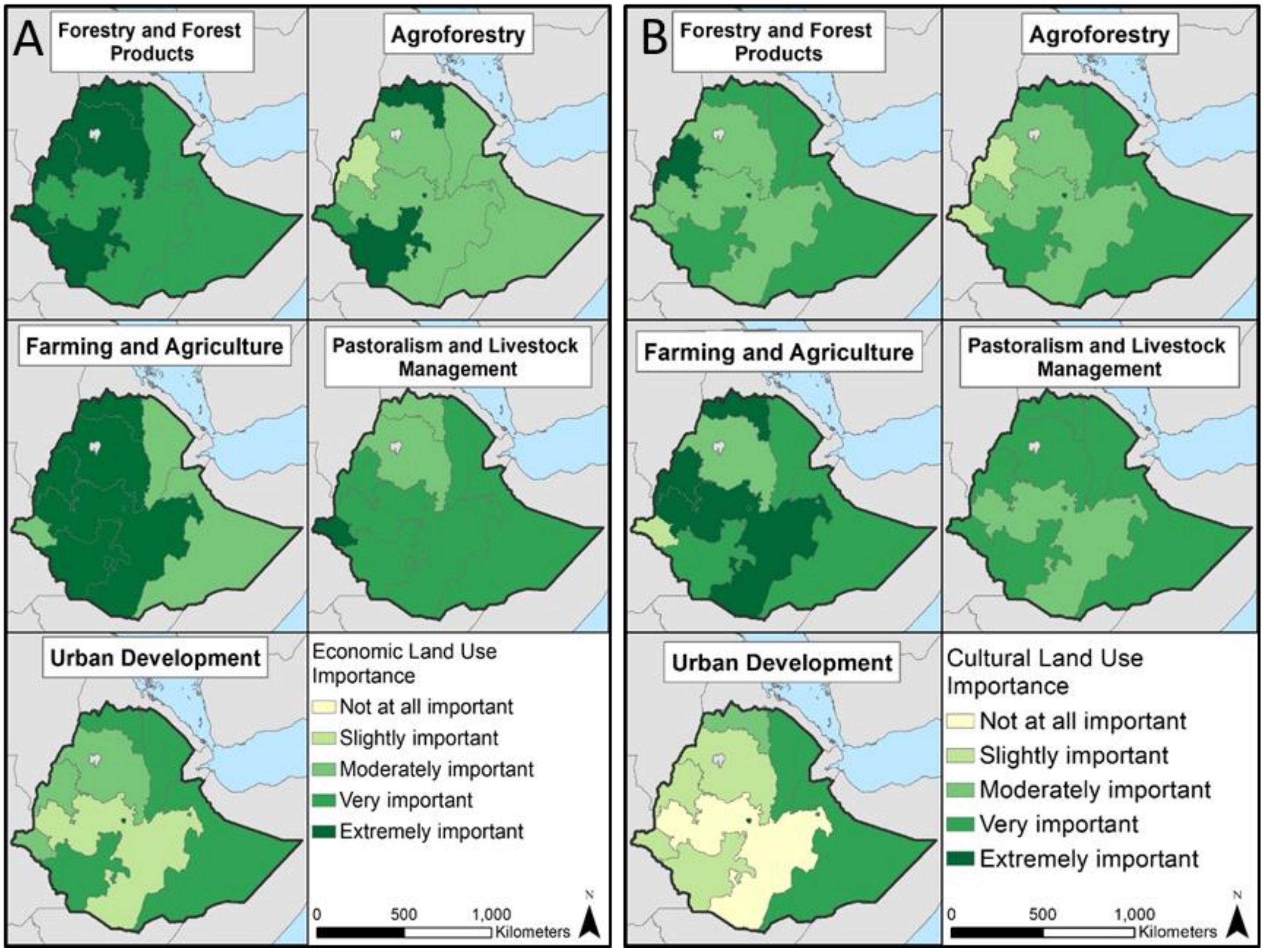

Figure 4. The level of importance of major land use practices in each region, in A) economic terms and B) cultural terms as reported from the survey respondents.

In terms of cultural importance, survey respondents indicated that farming and agriculture is very important in the Oromia, Gambela and Tigray regions (Figure 4). Culturally, urban development was not at all important in the Oromia region while it was very important to the Somali and Afar regions in the east.

Survey Discussion

The survey allowed us to gather important perspectives to the overall project and provided a wealth of information to help construct the decision support table (presented below). Overall, the survey was lengthy, and the intent was to have one survey for personnel at all levels of government and stakeholder groups working within those tiers making land use decisions. We found that 40% of returned surveys were not completed, which could be attributed to respondents not fully understanding what the questions were asking. Reevaluating these questions to ensure clarity and to simplify would likely improve completion rate. Further, many questions could be omitted depending on answers to earlier questions. For example, if a respondent indicated that she/he was only an expert in agricultural practices then questions related to other land uses could have been automatically hidden from the respondent significantly reducing the number of questions that respondent encountered in the online format.

In the survey, questions 8 through 18 asked the degrees of significance for each driving force, which included the social and economic barriers for their region. This was helpful to identify these forces and their significance; however, we did not ask for people to rank or compare the driving forces to one another. It was not clear what the prevailing driving force was for each region or the country as a whole. Similarly, for questions 19 through 21, we asked about the importance of each land use category (i.e., forestry, agroforestry, agriculture, urban development, livestock management and others). The questions provided insight on how each land use was valued but did not compare the importance among them all. We recommend that future surveys should ask for a ranking of level of importance for the driving forces as well as the economic cultural land use practices and products so that potential regions can be more effectively prioritized to help guide mitigation activities.

GHG Mitigation Analysis

The literature review and survey responses helped to identify regions in Ethiopia suitable for GHG mitigation activities and projects, and the types of mitigation activity that would be most successful. The next level of analysis was to use scenario comparisons to evaluate the potential emissions impact of alternative mitigation options at the region level.

The Carbon Benefits Project GHG analysis tools (www.carbonbenefitsproject.org) were used to estimate the net greenhouse gas mitigation potential of a selection of land management strategies. The CBP modeling tools were developed by Colorado State University under a Global Environment Facility (GEF) co-financed project. The tools estimate the impacts of land use and management practices on carbon stock changes and GHG emissions. They cover all of the land use and source categories described by the Intergovernmental Panel on Climate Change (IPCC 2006).

The tools can be used to make complex landscape-scale assessments which involve a wide range of land management activities, such as afforestation, reforestation, land rehabilitation, changes in crop production practices, changes in livestock numbers and manure management, and others. The CBP tools generate GHG accounting reports which compare one scenario (generally a business as usual scenario) with an alternative (generally a mitigation scenario). Two types of report are produced, a summary report with GHG balance displayed in United Nations Framework Convention on Climate Change (UNFCCC) and IPCC AFOLU format, accompanied by measures of uncertainty. The tools, therefore, use the same methods as those required for national GHG inventories and output can be fed into national inventory tools, such as Agriculture and Land Use (ALU) National Greenhouse Gas Inventory Software (also developed at Colorado State University).

In the CBP tools, users select either the Simple or Detailed Assessment depending on data availability and time available to complete the analysis. The CBP Simple Assessment uses IPCC default stock change and emission factors, providing a quick analysis. The Detailed Assessment give the user the flexibility to describe land management, particularly cropping systems in more detail and, importantly, allows users to input project specific stock change and emission factors thereby reducing the uncertainty associated with a GHG analysis. The CBP tools have been used to conduct GHG assessments consistent with IPCC protocols in 136 countries, including Ethiopia. The tools are freely available (www. carbonbenefitsproject.org) providing users' access to IPCC standardized and scientifically-based methods. The CBP tools have also now been linked to the World Overview of Conservation Approaches and Technologies (WOCAT, https://www.wocat.net), the database of sustainable land management practices approved by the United Nations Convention to Combat Desertification (UNCCD). World Overview of Conservation Approaches and Technologies (WOCAT) contains details of over ~2,000 sustainable land management practices. This means that all new sustainable land management practices in WOCAT can be accompanied by a GHG mitigation assessment.

The CBP tools also include a simple cost benefits analysis and a qualitative socio-economic analysis (Drivers, Pressures, State, Impact and Response, DPSIR). These tools aim to capture human-biophysical interactions relating to a project's greenhouse gas balance. The Cost Benefit Analysis is a quantitative tool to determine the economic impact of land management practices on land users, including the initial investment and ongoing labor and inputs associated with a land use activity. The Driver, Impact, Response, Analysis (DPSIR) is a qualitative tool which allows users to explore and summarize the main drivers of, or barriers to, different land management practices being.

Rapid Regional Analysis of Average GHG Mitigation Potential for Common Land Based Mitigation Strategies in Ethiopia

Here, we present the method for estimating average mitigation potential of five possible climate friendly land management options, as determined through the literature review and survey responses. The Carbon Benefits Project Simple Assessment tool was used to estimate the potential GHG mitigation of five possible land based mitigation strategies in six regions of Ethiopia. This gave an estimate in t CO2 e per hectare per year of average mitigation potential for that particular intervention in a given region. The CBP system uses default soils and climate information. Therefore, the mitigation potential was an average of what is possible for a 1,000 ha spread evenly across all soil/climate combinations in the region being considered.

Step 1. Creation of regional polygons in the CBP tool

The CBP allows users to draw polygons on a map to delimitate their project area. This then creates the area for an analysis and automatically calculates the area of the polygon. Polygons were created for six regions in Ethiopia (Amhara, Benishangul-Gumuz, Gambela, Oromia, SNNPR and Tigray). For annual cropland, agroforestry, grassland, and perennial cropland land uses, the polygons may be drawn to represent the entire region. For forest land uses, polygons should be drawn that represent the intersection between the political region and the IPCC climate regions, so that climate-specific forest types may be assigned to the polygons.

Step 2. Data input for five potentially climate friendly land management options

The literature review and survey results were used to devise five simple land management options:

1) Degraded grassland is restored to nominal condition.
2) Conventionally-managed annual cropland with intensive tillage is converted to agroforestry.
3) Native forest is conserved through avoided deforestation.
4) Former forestland, now degraded grassland is replanted to an afforested landscape
5) Annual cropland is converted to perennial cropland.

Each of these land management options are described in more detail below. The descriptive data for the five scenarios were then put into the CBP system Simple Assessment. The model was run and a summary report was produced giving GHG mitigation potential and emissions by source and sub-source category for each of the land management options for each of the five regions. In addition, a detailed report was also produced for the mitigation option only, which gave mitigation potential disaggregated by land use type, climate, soil, etc. These Excel reports are available for further analysis.

Average mitigation potential for each land management option for six regions is given in Table 5.

<u>1) Degraded grassland restored to nominal condition</u>
For each region, an analysis was carried out for 1,000 ha of severely degraded rangeland being restored to native grassland (nominal condition). It was assumed that these 1,000 ha were distributed evenly across all climate and soil combinations in the administrative region. Average mitigation potential is given in Table 5. Data input for grassland restoration was as follows:

Initial conditions and baseline scenario:
Grassland type: Rangeland
Grassland condition: Severely degraded
Improvements: None
Burning: Never burned

Mitigation scenario
Grassland type: Rangeland
Grassland condition: Nominally degraded, native grassland
Improvements: None
Burning: Never burned

<u>2) Conventionally-managed annual cropland with intensive tillage converted to agroforestry</u>
For each region, an analysis of 1,000 ha going from annual cropland to a generalised agroforestry system - enset with a mix of small grains maize/sorghum/millet and legumes grown in the understory with reduced tillage. Annual crops chosen were as shown in Table 6.

Data input for annual cropland converted to agroforestry was as follows:

Initial conditions and baseline scenario
Annual crop: As per Table 6, (where two systems are listed 500 ha was assumed in each), 50 kg/ha of urea fertilizer, intensive tillage, residues grazed, no cropping system improvements.

Mitigation scenario
Tree crop; enset, 100 trees per ha (total of 100,000 trees) < 5 years, 50 kg urea
Annual crop; Small grain maize/sorghum/millet intercropped with legume, reduced tillage, 50 kg Urea, residue grazed

<u>3) Native forest conserved through avoided deforestation</u>
For each region, 1,000 ha of forested area was projected to be cleared without burning, at a rate of 100 ha per year for 10 years.

Initial land use
We selected native forest types to correspond to the climate regions that dominated the region. For example, if 40% of the land area in each of the regions analysed fell within the sub-humid category, then 40% of the forest area was assigned to the corresponding forest type. Deforestation was modelled over 10 years, at 10% of the total project targeted reforestation area per year.

Baseline scenario
Moderately degraded rangeland, with no improvements, no fertilizer, and never burned.

Project scenario
We selected native forest types corresponding to those in the Initial Land Use, with the same total area for each total area as in the Initial Land Use, but with no deforestation.

<u>4) Former forestland, now degraded grassland, replanted to an afforested landscape</u>
For each region, 1,000 ha of deforested area that had become degraded grassland was projected to be reforested, at a rate of 100 ha per year for 10 years.

Initial land use
Moderately degraded rangeland, with no improvements, no fertilizer, and never burned.

Baseline Scenario
Severely degraded rangeland, with no improvements, no fertilizer, and never burned.

Project scenario
We selected plantation forest types to correspond to the climate regions that dominated the region. Interviews and previous experience indicated that afforestation and reforestation plantings are dominated approximately evenly by eucalyptus and cypress species. In 2006, IPCC guidelines, the plantation forest types where data were available for East Africa are dry, moist, or rain forest plantations of eucalyptus, or “other” (corresponding to cypress).

Semiarid areas corresponded to the IPCC dry forest category, sub-humid corresponded to moist forest categories, and humid corresponded to rain forest categories. If 40% of the land area in each of the regions analysed fell within the sub-humid category, then 40% of the projected forest reforestation/afforestation area was assigned to the corresponding forest type. Reforestation and afforestation activities were modelled over 10 years, at 10% of the total project targeted reforestation area per year.

5) Annual cropland converted to perennial cropland

For each region, an analysis of 1,000 ha going from annual cropland to perennial cropland was analyzed. Annual crops chosen were as shown in Table 6. The perennial crop option chosen was banana/plantain. In a full analysis, this should be replaced with the dominant perennial crop for the region or preferred option based on a socio-economic analysis.

It was assumed that the 1,000 ha were distributed evenly across all climate and soil combinations in the administrative region. Average mitigation potential is given in Table 5.

Data input for annual cropland converted to perennial cropland was as follows:

Initial conditions and baseline scenario
Annual crop: As per Table 6, (where two systems are listed 500 ha was assumed in each), 50 kg/ha of urea fertilizer, intensive tillage, residues grazed, no cropping system improvements.

Mitigation scenario
Perennial crop: Plantain/banana < 5 years old 50 kg/ha of urea fertilizer, no tillage. Are established per year = 1,000 ha divided by 10 years (100).

Table 5. Average climate change mitigation potential of five possible land management strategies when applied to six regions in Ethiopia.

	GHG mitigation potential in t CO2e ha^{-1} yr^{-1}					
Mitigation Option	**Amhara**	**Benishangul -Gumuz**	**Gambela**	**Oromia**	**Tigray**	**SNNPR**
1) Degraded grassland restored to nominal condition	2.81	2.23	1.98	2.8	1.89	2.60
2) Conventionally-managed annual cropland with intensive tillage converted to agroforestry (enset and small grain)	5.26	5.36	5.35	5.3	5.35	5.33
3) Native forest conserved through avoided deforestation	38.2	50	50.1	40.7	48.5	2.2
4) Former forestland, now degraded grassland, replanted to an afforested landscape	9.8	11.6	9.5	12.2	11.8	116

5) Annual cropland converted to perennial cropland (banana/plantain)	17.53	18.48	18.99	18	15.04	17.45

Table 6. Annual cropland selection per region.

	Amhara	Benishangul-Gumuz	Gambela	Oromia	Tigray	SNNPR
Annual crop	Wheat Maize Sorghum	Sorghum Maize Millet	Sorghum Millet Maize	Wheat Maize	Wheat Maize Sorghum	Maize Sorghum

Step 3. Prioritizing regional and nation mitigation strategies

Output from the CBP model runs in steps 1 and 2 to determine potential mitigation were used alongside the results from the survey to make recommendations for potential mitigation strategies for each region and nationally.

Local Case Study: Wolaita Zone

Once a region and potential mitigation actions have been identified, the next step in the framework is to run a detailed CBP analysis within the region to compare different scenarios. The exact location and scenarios that should be evaluated depends on multiple factors (discussed below). Most importantly, knowledgeable and willing partners and stakeholders should be involved so that they can provide the detailed information to parameterize the CBP tool and implement the project on the ground. Below we present a case study example of how a detailed CBP analysis would be constructed and executed.

Project Area

The Wolaita administrative zone is located within the Southern Nation Nationality People Region (SNNPR), Ethiopia. Its capital, Soddo, is situated 329 km south of Addis Ababa, the capital of Ethiopia, and 156 km from Hawassa, the capital town of SNNPR. Christianity is the dominant religion with Protestants (50%) and Ethiopian Orthodox (40%), while the remaining are Muslim (CSA 2007). Elevation in the Wolaita zone ranges from 500 to 3,000 meters above sea level and most of the land (60%) is located in mid-elevation areas. The population in Wolaita was estimated at 1.9 Million in 2014 and the zone has an area of 4,208 km^2 (CSA 2014). The population is almost entirely rural and not experiencing urbanization at the same rate as other parts of the country. In 2013, the government estimated that 57.4% held less than 0.5 ha of land, with the average land holding in Wolaita at 0.58 ha with only 1.7% holding more than two ha (CSA 2014). The main challenges of the area are the growing population, the fragmentation of smallholder plots, and the vulnerability to unpredictable rainfall (Rahmato 2007). According to Rahmato (2007), the agriculture in Wolaita “has exhausted its potential and is becoming increasingly unviable for the great majority”. Management shifts within the agricultural sector in such areas can have impact on mitigating GHGs while increasing the productivity. Based on the availability of published information, we selected three of the 14 districts in the Wolaita zone for this case study: Damot Gale, Soddo Zuria and Damot Sore. All three selected districts are located in the mid-highlands with elevation ranges between 1,500 and 2,800 (Laekemariam et al. 2016).

Project Period

The project duration considered is 14 years spanning from 2016 to 2030. The project implementation period was in the same period of CRGE strategy of Ethiopia, which is from 2015 to 2030 (FDRE 2011).

Livestock

The livestock population of the initial, baseline and project scenario are shown in Table 7. The initial cattle population estimate was drawn from Cochrane (2017). The baseline scenario (business as usual) population was projected by extrapolating population data from the current trends for different livestock categories from three national data sets (FAO 2008; Leta and Mesele 2014; Zeleke 2017). The livestock population under the project scenario was drawn from the suggestions of livestock numbers needed to attain the CRGE strategy of Ethiopia from 2015 to 2030 (Shapiro et al. 2017).

Table 7. Livestock Population for the three districts in Wolaita zone, southern Ethiopia under the initial land use and the baseline and project scenarios.

Project area	**Livestock category**	Population		
		Initial	*Baseline*	*Project*
Damot Sore	Poultry	58,956	40,562	538,740
	Sheep	12,133	14,657	18,079
	Mules and Asses	2,796	4,828	6,721
	Horses	17	22	41
	Goats	8,609	15,436	12,827
	Non-Dairy Working Cattle	20,056	32,664	25,514
	Dairy Cattle	30,656	50,981	39,822
	Total	**133,223**	**159,150**	**641,744**
Sodo Zuria	Poultry	94,310	64,885	861,800
	Sheep	19,409	23,446	28,920
	Mules and Asses	4,472	7,724	10,752
	Horses	27	35	65
	Goats	13,771	24,692	20,519
	Non-Dairy Working Cattle	32,083	52,251	40,814
	Dairy Cattle	49,039	81,552	63,702
	Total	**213,111**	**254,585**	**1,026,572**
Damot Gale	Poultry	73,589	50,629	672,453
	Sheep	15,145	18,295	22,566
	Mules and Asses	3,490	6,027	8,389
	Horses	21	27	51
	Goats	10,746	19,267	16,011
	Non-Dairy Working Cattle	25,032	40,771	31,847
	Dairy Cattle	38,265	63,634	49,706
	Total	**166,288**	**198,650**	**801,023**

Land Use

The initial land use is extracted from the digital Land Use Land Cover map created from 2016 the Sentinel-2 Global Land Cover Data for Ethiopia (ESA Climate Change Initiative - Land Cover project 2017). The baseline scenario was derived by taking the rate of land use change from the study at the watershed level in Wolaita (Babiso et al. 2016). Projections were made considering the best land use scenario possible. Table 8 shows the initial, baseline and project scenarios of the land use change in the project area.

Table 8. Land use area of the three districts in Wolaita zone, southern Ethiopia under the Initial land use, Baseline and Project scenarios

Project area	**Land use category**	Area (ha)		
		Initial	*Baseline*	*Project*
Damot Gale	Forest	349	350	361
	Grassland	1,780	965	1,768
	Settlement	184	197	196
	Annual crop	21,074	22,605	21,062
	Perennial crop	3,147	2,417	3,147
	Total	**26,534**	**26,534**	**26,534**
Sodo Zuria	Forest	1,082	1,084	1,094
	Grassland	3,728	2,021	3,676
	Settlement	785	840	836
	Annual crop	35,536	38,120	35,525
	Perennial crop	5,308	4,374	5,308
	Total	**46,439**	**46,439**	**46,439**
Damot Sore	Forest	480	481	494
	Grassland	1,052	571	1,049
	Settlement	55	58	59
	Annual crop	13,990	15,005	13,975
	Perennial crop	2,181	1,643	2,181
	Total	**17,758**	**17,758**	**17,758**

Management

The initial agricultural land management of the sites was studied by Laekemariam et al. (2016). From their study, we used data from 'Initial Land Use' for our analyses. For the baseline scenario, we assumed that the same land management practices would continue without changing for the next 14 years. In the project scenario, the best management practices were formulated to what can be practically applied in the project area. The managements used in different land uses in this study are indicated in Table 9.

Table 9. The land uses and managements in the three scenarios.

Land Use Category	Management and land use differences		
	Initial	*Baseline*	*Project*
Forest	Tropical mountain system Eucalyptus plantations	Rate of deforestation and tree planting are very close to each other. Tropical mountain system declined, and Eucalyptus plantation increased.	Maintain the tropical forest and increase Eucalyptus plantation by afforesting degraded agricultural land. Eucalyptus is a source of fuelwood, construction material, a soil conservation tree and a source of income.
Grassland	**Management:** Continuous pasture Moderately degraded	Area of grassland declined **Management:** Continuous pasture **Status:** Severely degraded	Land area maintained as in the initial **Management:** 50% silvopasture with Acacia 50% improved grass verities **Status**: Nominally degraded
Settlement	Tree cover: 5%	Tree cover: 3 %	Tree cover: 10% Mostly fruit trees but Eucalyptus was used in the tool
Annual crop	The agriculture land use was partitioned into annual and perennial using the data of land allocation to different crops in the zone (Cocharane et al. 2017). **Management:** (Laekemariam 2016): Crop residue removed Little fertilization Crop rotation Tillage - animal traction	Area under annual cropping expanded with decline in grazing land and perennial cropland The initial management continued	The initial land size is nearly maintained **Management:** 1. 40% crop residue retained in the field and fertilized with blanket recommendation (100 kg/ha DAP and 100kg/ha urea) 2. 40% limed with organic amendment 3. 10% increased legume in crop rotation
Perennial crop	enset and coffee Management: manure applied	The area under perennial crops declined because of annual cropping the same land management continued.	Initial land size is nearly maintained. Similar management with integrating 5% of the area with fruit trees.
Livestock	Manure management: 33% pasture/range/padlock: 67% compost piles	The same manure management as in initial. Following the natural growth in the existing practice.	The same manure management as in initial. More growth is set to poultry, sheep and goat, which have lower enteric methane emission. Cattle populations decreased.

*****With reduced rate of deforestation and crop residue this projection considers the implementation of improved stoves to some parts although not considered in the tool**.**

Emissions and Mitigations

The total carbon and greenhouse gas balance for the report period for baseline scenario (over 14 years) was 6,176,511 t CO_2e while the total carbon and greenhouse gas balance for report period for project scenario was 4,451,458 t CO_2e (Table 10). No mitigation benefit from manure management is presented on this analysis because no improved manure management was considered. Two types of mitigation benefit are represented in the analysis:

- Avoided Emissions: Avoided deforestation offers the largest magnitude benefit of any of the practices considered, ranging from 23.2-50.1 Mg CO_2e ha^{-1} yr^{-1}. The principal benefit is in eliminating the loss of native forests, typically cleared to be used for firewood, charcoal, and building materials. Tigray had the lowest values (23.1) due to the large proportion of forest land in dry tropical forest type. Gambela had the largest value (50.1) due to higher proportions of forests with higher rainfall and higher productivity. This type of mitigation benefit is valuable primarily as an offset or avoided emission. A small portion of this benefit (typically < 5%) is from preserving soil organic carbon stocks, as deforestation typically leads to losses in soil organic carbon.
- Reduced Emissions and Carbon Sequestration:
    - The highest carbon benefit predicted in this class is in converting annual cropland to perennial woody cropland (15-19 Mg CO_2e ha^{-1} yr^{-1}). Perennial woody crops tend to be fast growing, are fertilized, and are frequently irrigated in drier regions, leading to high carbon uptake rates that exceed the soil nitrous oxide emissions associated with fertilizer use. The predicted rates were comparable across regions, with SNNP having the lowest potential benefit (15) and Gambela having the highest (19).
    - The second highest carbon benefit in this class was from reforestation / afforestation activities (9.5-12.2 Mg CO_2e ha^{-1} yr^{-1}. The Oromia region had the highest potential carbon sequestration benefit (12.2), partially due to the higher productivity climate, but also due to the capacity in the region's soils to sequester carbon. Although not specifically accounted for in the model, reduced use was assumed to be driven by the establishment of fuel efficient stoves in rural households in the area. The tool predicted carbon losses in forest and grassland conversions.
    - The CBP system predicted agroforestry conversion to have the third highest benefit in this class (5.3-5.4 Mg CO_2e ha^{-1} yr^{-1}). This benefit is approximately evenly split between soil carbon stock increases and biomass carbon stock increases.
    - The lowest benefit (1.98-2.81 Mg CO_2e ha^{-1} yr^{-1}) was predicted in restoring degraded grassland to nominal condition. The lowest potential mitigation benefit was in Tigray (1.89), and the highest was in Amhara (2.81), due to soil type differences in these regions.

Following the result from proposed project, one can choose one or more of the components of the projects for implementing C sequestration projects by considering other relevant issues. This example demonstrates how CBP tool can be used for planning C projects in a given area and for monitoring afterwards if implemented.

Table 10. Summary report following UNFCCC common reporting guidelines

GHG Source and Sink Categories	Baseline Scenario (2016 - 2030) emissions and removals (tCO_2 e)			Project Scenario (2016 - 2030) emissions and removals			Carbon Benefits		
	CO_2	*CH_4*	*N_2O*	*CO_2*	*CH_4*	*N_2O*	*t CO_2e*	*tCO_2e /ha*	*tCO_2e /ha/yr*
	tonnes CO_2 equivalent (t CO_2e)			tonnes CO_2 equivalent (t CO_2e)					
Agriculture									
A. Enteric Methane		3,337,964			2,928,983		-408,981	-4.5	-0.32
B. Manure Management		18,531	445,995		24,372	511,787	71,633	0.79	0.06
C. Agricultural Soils			1,736,859			1,663,681	-73,178	-0.81	-0.06
Land Use Change and Forestry									
A. Forest and other Woody Biomass	290,882			-392,875			-683,757	-7.5	-0.54
B. Forest and Grassland Conversion	89,068			77,510			-11,559	-0.13	-0.01
C. CO_2 Emissions and Removals from Soil	257,212			-361,999			-619,210	-6.8	-0.49
Total	**637,162**	**3,356,495**	**2,182,854**	**-677,364**	**2,953,355**	**2,175,468**	**-1,725,052**	**-19**	**-1.4**

***Notes**: Global Warming Potential (GWP) are 100-year time horizon based on estimates from the IPCC Second Assessment Report. Signs for uptake are (-) and for emissions (+). A. Forest and other Woody Biomass includes biomass growth and losses from timber harvest and fuelwood gathering. B. Forest and Grassland Conversion includes emissions from deforestation and shifting cultivation. C. The change in mineral soil carbon is shown under the 'Project Emissions CO_2' column as Baseline minus Project.

Geographic, Political, Economic and Social Trends that may Affect GHG Mitigation Activities in Ethiopia

To better understand how the political, social, natural and economic environments in Ethiopia relate to GHG emission and mitigation actions, we compiled the most recent information to help detect potential opportunities and risks for short- and long-term GHG mitigation investments at national and regional scales. Information was gathered from government agencies and international non-government organizations to build a country profile of Ethiopia. Data from these agencies and organizations are available for most countries around the world, and will allow the integration of information into a replicable framework. The sources we selected also have information at finer scales providing an opportunity to create a more detailed country profile than what we provide here.

Geographic and Physical Profile

Ethiopia is located in East Africa (8 00 N, 38 00 E) covering an area of 1,104,300 km^2 (CIA 2019). It is a landlocked country that borders Djibouti, Eritrea, Kenya, Somalia, Sudan and South Sudan (Figure 5). Its geography is defined by some of the most extensive mountain ranges on the African continent and one of lowest and hottest places on Earth. Elevations in Ethiopia range from 125 m below sea level (bsl) in the Danakil Desert to the peak of Mt. Ras Deshen at 4,550 m above sea level (asl). Most of the central part of Ethiopia encompasses multiple mountain ranges and high plateaus fringed with arid plains and lowland savannas along the country’s borders. The highlands are divided by the Great Rift Valley which runs through the center of Ethiopia from northeast to southwest. The Northern Highlands are characterized by drier climates and steep rock-faced

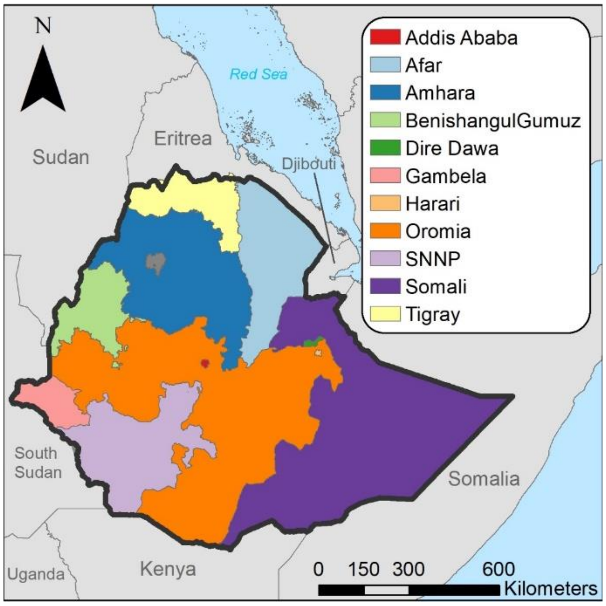

Figure 5. Regions of Ethiopia and the surrounding countries

mountains, while the Southern Highlands are more mesic from orographic rains stemming from the Indian Ocean.

Ethiopia's contrasting topography supports extensive water resources that are unevenly distributed across the country. There are 12 major river basins that contribute to four major watersheds to East Africa. These are the Nile River Basin (i.e., Blue Nile, Baro-Akobo, Setit-Tekeze/Atbara and Mereb), the Rift Valley (i.e., Awash, Denalki, Omo-Gibe and Central Lakes), and the Shebelli-Jubi Basin (i.e., Wabi-Shebelle and Genale-Dawa), and the North-East Coast (i.e., Ogaden and Gulf of Aden basins; FAO 2016). Most of the rivers in Ethiopia have seasonal flow with few perennial rivers at elevations below 1,500 m asl. The country also has 11 large freshwater lakes, most found in the Rift Valley. These lakes are rich in biodiversity and provide vital resources that support local livelihoods, agriculture and economies. Most of the Rift Valley lakes are endorheic (having no surface outlets), so they tend to have high salinity. There are an estimated 1.14 and 1.8 million ha of wetlands in Ethiopia (IUCN 2010). Groundwater potential is unknown and remains largely undeveloped, though it is still the primary water source for people living in rural areas and several of the largest cities, including Addis Ababa and Dire Dawa (EPA and UNEP 2008; FAO 2016). There are seven transboundary aquifers, the largest being the Sudd Basin which has an estimated area of 331,661 km^2 and shared with Kenya and Somalia (FAO 2016).

Ethiopia's landscape is characterized by a wide range of ecosystems that include arid deserts, lowland scrublands, grass savannas, dry woodlands, montane forests and Afro-alpine. Land use is coarsely estimated to be 36.3% agriculture (arable land 15.2%, permanent crops 1.1%, permanent pasture 20%), 12.2% forest, and 51.5% "other" (CIA 2019). The World Bank (2019) and Food and Agriculture Organization (GFRA 2015) estimates the country's forests and other woodlands to occupy 125,000 km^2 and 40,600 km^2, respectively. Annual deforestation rates for forests are estimated to be 1.25% and other woodlands reported to be 1.8% (GFRA 2015). There are approximately 9,700 km^2 of small-scale and industrial forest plantations, largely found in the Oromia (1,333 km^2), Amhara (6,840 km^2), SNNPR (913 km^2), and Tigray (634 km^2) administrative regions (GFRA 2015).

The different types of ecosystems and habitat types found throughout the country are rich in biodiversity and harbor a high number of endemic plant and wildlife species. There are 120 species in Ethiopia that are on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Of these, 14 are listed as *critically endangered*, 36 as *endangered*, and 70 as *vulnerable* (IUCN 2019). There are 104 areas in Ethiopia that have some level of protection. These cover an area approximately 200,074 km^2 or 17.62% of the country's land area, and include 15 national parks, eight wildlife reserves, four sanctuaries, 18 controlled hunting areas, and 58 national forest priority areas (UNEP-WCMC 2019). Additionally, the United Nations Educational, Scientific and Cultural Organization (UNESCO) has designated two sites in Ethiopia, Kafa and Yahu, as Biosphere Reserves, and the Simien Mountains as an IUCN World Heritage Site (UNEP-WCMC 2019).

Climate

Ethiopia's climate is described as tropical monsoon, though there are extensive variations in rainfall and temperature across the country. The country's climate can generally be classified into 8 agro-ecological zones (Figure 6). The average annual precipitation for the country is 848 mm but may reach 2,000 mm in some areas in the southwest to less than 100 mm in the northeast (FAO 2016). The FAO (2016) distinguishes four general rainfall zones:

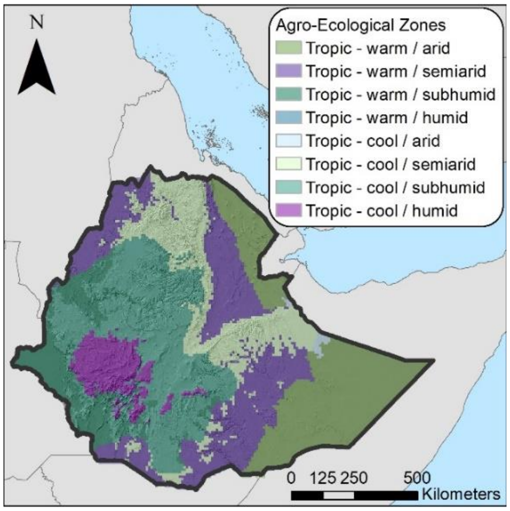

Figure 6. Agro-ecological zones of Ethiopia as defined by the International Food Policy Research Institute (Sebastian and Kate 2009) which includes three dimensions: major climate zone, moisture zones and highland/lowland.

- The lowlands, including the east, northeast, and southeastern part of Ethiopia (< 400 mm of annual rainfall) and the Afar region in the northeast (< 100 mm of annual rainfall).
- The eastern mountain highlands which have a single rainy season from February/March to October/November.
- Eastern Ethiopia which has two rainy seasons (the Belg and the Meher), peaking in April and September.
- South/Southeastern lowlands which has two rainy seasons, February-April and June-September, interspersed with two distinct dry periods (annual rainfall as high as 2,000 mm).

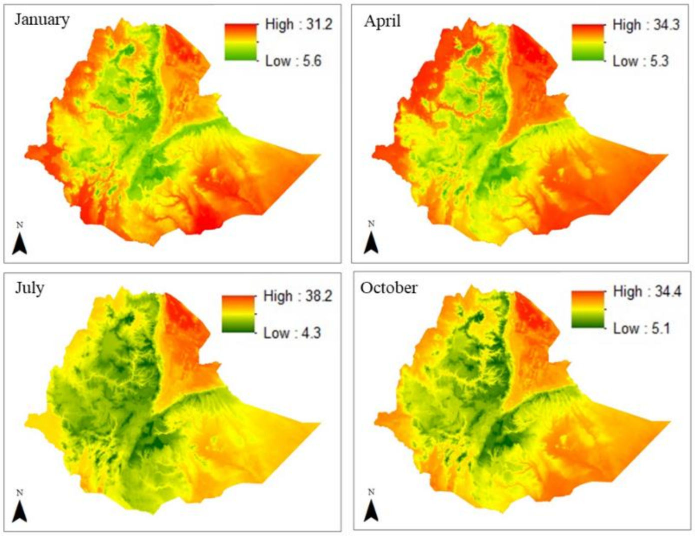

Figure 7. Average temperature for Ethiopia at different seasons of the year (WorldClim, Fick et al. 2017).

The mean annual temperature ranges < 7 to 12ºC in the cooler mountains to > 25ºC in the hot lowlands. Mean annual potential evapotranspiration varies between 1,700 to 2,600 mm in arid and semi-arid areas and 1,600 to 2,100 mm in dry sub-humid areas (FAO 2016). The WorldClim-Global Climate Data has data for the past, current and future climates with a spatial resolution of 1 km^2. Quarterly temperatures and precipitation for Ethiopia are shown in Figures 7 and 8 (WorldClim2 2018) and regional measurements in Table 11. Because of Ethiopia's diverse climate, there have been multiple efforts to define major agro-ecological zones (Figure 6) – areas that can support certain crop and land cover types (e.g., NMSA 1996; Amede et al. 2015).

Rainfall patterns can be very unpredictable in Ethiopia, and droughts and dry spells are not uncommon in many regions of the country. In the past fifty years, major droughts occurred in 1973/74, 1983/84, 1987/88, 1990/91, 1993/94 and 2015/16 causing famines and, in some cases, civil and political unrest. The recent drought in 2015-16 is considered to be the worst drought for over 30 years and continues to effect some areas of the country. In 2017 alone, a report by the United Nations estimated, 8.5 million people required food assistance, 10.5 million people needed access to safe drinking water, 2.25 million households needed livestock support, and 376,000 children were expected to suffer from acute malnutrition (UN-OCHA 2017).

Despite the reoccurrence of droughts, there is generally some seasonal predictability that rural communities in Ethiopia have relied on for generations. How climate change will further impact food and water security, traditional livelihoods, human health and economic stability? By nearly all accounts, Ethiopia is considered highly vulnerable to climate change (e.g., Conway and Schipper 2011; Evangelista et al. 2013, Simane et al. 2016). A summary of historical climate data for Ethiopia indicate that rainfall is becoming increasingly erratic, droughts and heavy rain events are more frequent, average temperatures are rising, and extreme weather events will become more frequent (USAID 2015). The CRGE (2011) reported that the mean annual temperature in Ethiopia has already increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade (Conway and Schipper 2011). Further warming of 0.7°C to 2.3°C is projected in the 2020s and between 1.4°C and 2.9°C by the 2050s (World Bank 2008). There is a number of agencies and institutions that provide global climate change projections (e.g., IPCC 2014) and early warning systems (e.g., FEWS NET 2019). The WorldClim-Global Climate Data provides future climate maps from projections from the Intergovernmental Panel on Climate Change (IPPC) fifth assessment. These data represent global climate models for four representative greenhouse gas concentration pathways (RCP). The implementation and effectiveness of climate change mitigation strategies, require an understanding of Ethiopia's government.

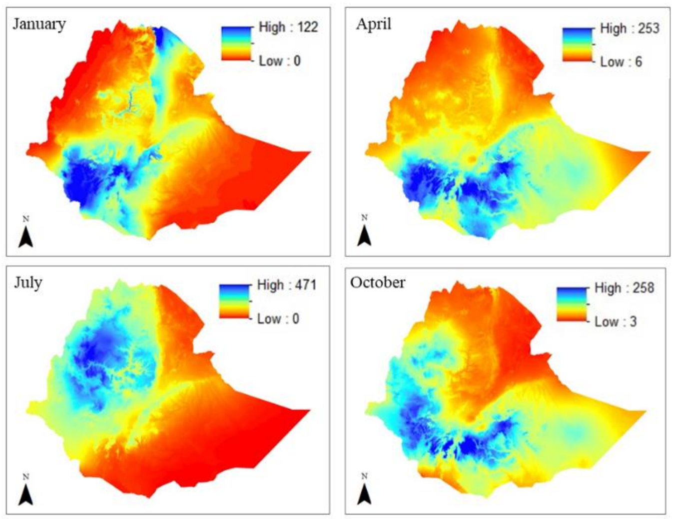

Figure 8. Average precipitation for Ethiopia at different seasons of the year (WorldClim, Fick et al. 2017).

Governance and Administrative Composition

Ethiopia is formally known as the Federal Democratic Republic of Ethiopia, and its government type is referred to as federal parliamentary republic. There are three branches of Ethiopia's national government; executive, legislative and judicial (CIA 2019). The executive branch includes the Prime Minister (head of government), President (chief of state), and the Council of Ministers (cabinet). The legislative branch, known as the Federal Parliament Assembly, consists of two tiers; the House of the Council of Peoples Representatives and the House of Federation. The House of

People's Representatives has 547 members and serve five-year terms. The House of Federation has 110 members, one for each (Ethiopian) nationality and an additional member for each one million of its population. The judicial branch is overseen by the Federal Supreme Court, which consists of 11 judges and has authority over federal high courts, state courts, sharia courts and traditional courts (CIA 2019). The country is divided into nine ethnically based regional states and two chartered cities, Addis Ababa and Dire Dawa (Figure 5). Brief descriptions of each of the regions are proved in Table 11. Each region has its own president, parliament and various regional bureaus that oversee legislative and administrative affairs. Regions are further broken down into smaller administrative units called zones, which divided into *woredas* (districts) and then *kebeles* (formally known as peasant associations).

Historically, Ethiopia has had a one of the most complex land tenure system in the world. Except for the Ethiopian Orthodox Church, lands have always been under the authority of the ruling monarchies or, in recent times, property of the state. Article 40 of the 1995 constitution, "Land is a common property of the nations, nationalities and people of Ethiopia and shall not be subject to sale or to other means of exchange." The constitution goes on to state that "Ethiopian peasants have the right to obtain land without payment and the protection against eviction from their possession." Despite the constitutional language that attempts to reinforce land ownership by the state while securing property rights to rural people, there remains strong debate among politicians, stakeholder organizations, and the farmers occupy the land (Nega et al. 2003). Ethiopia's current government and ruling party advocate that private land ownership should remain with the state arguing that change will ultimately benefit those who can afford to buy land, resulting in the eviction and landlessness of people. The opposition political parties, backed by scholars, economic advisors and international organizations, disagree, and argue that the current system does not secure farmer's rights or equitable access to the land over time, or provide incentives for long-term improvements to the land. Furthermore, the current system fails to promote agricultural intensification, environmental conservation, accumulation of capital or credit, and the development of rural areas (Hoban 2000; Nega et al. 2003).

Table 11. General descriptions of administrative regions and chartered cities in Ethiopia, including land area (CSA 2019), population (WPR 2019), elevation, precipitation and temperature (Fick and Hijmans 2017), and land cover type (Servir ESA 2018).

Regional State/City	Land Area (km)	2007 Population Census and 2015 Projections	Elevation Range (m asl)	Minimum, Maximum, and Annual Mean Temperature (°C)	Annual Mean minimum and Maximum Precipitation (mm)	Land Cover
Addis Ababa	527	2,739,551 (2007) 3,273,000 (2015)	2,050 to 3,105	5.4 to 25.8; 16.2	880 to 1,250	Tree cover (2.3%), Shrubs (1.8%), Grassland (9.1%), Cropland (50.3%), Vegetation aquatic or regularly flooded (0.9%), Bare areas (0.3%), Built up areas (35.2%)
Afar	72,053	1,390,2732 (2007) 1,753,000 (2015)	- 214 to 2,992	4.2 to 43.8; 28.4	102 to 900	Tree cover (2.6%), Shrubs (7.8%), Grassland (31.1%), Cropland (6.7%), Vegetation aquatic or regularly flooded (0.5%), Bare areas (50.1%), Built up areas (<1%)

Amhara	154,709	17,221,976 (2007) 20,401,000 (2015)	504 to 4,529	-1.8 to 38.1; 20	593 to 1,997	Tree cover (11.9%), Shrubs (7.5%), Grassland (20.1%), Cropland (57.9%), Vegetation aquatic or regularly flooded (0.1%), Bare areas (0.1%), Built up areas (0.1%), Open Water (2.1%)
Benishangul-Gumuz	50,699	784,345 (2007) 1,005,000 (2015)	483 to 2,734	6.9 to 37.4; 24	807 to 1,938	Tree cover (71.3%), Shrubs (6.8%), Grassland (15.6%), Cropland (6.1%), Vegetation aquatic or regularly flooded (<1%), Bare areas (<1%), Built up areas (<1%), Open Water (0.1%)
Dire Dawa	1,559	341,834 (2007) 440,000 (2015)	1001 to 2,364	6.8 to 36.9; 22.8	463 to 829	Tree cover (0.9%), Shrubs (6.9%), Grassland (71.8%), Cropland (18%), Vegetation aquatic or regularly flooded (<1%), Sparse vegetation (<1%), Bare areas (0.8%), Built up areas (1.7%)
Gambela	29,783	307,096 (2007) 409,000 (2015)	388 to 2,277	8.8 to 37.2; 26.4	831 to 1,796	Tree cover (51.1%), Shrubs (13.8%), Grassland (28.9%), Cropland (1.8%), Vegetation aquatic or regularly flooded (0.1%), Bare areas (<1%), Built up areas (<1%), Open Water (0.2%)
Harari	334	183,415 (2007) 232,000 (2015)	1,284 to 2,192	7.1 to 31.0; 19.6	596 to 794	Tree cover (1.8%), Shrubs (26.5%), Grassland (21.6%), Cropland (48.1%), Vegetation aquatic or regularly flooded (<1%), Sparse vegetation (<1%), Bare areas (0.1%), Built up areas (1.9%)
Oromia	284,538	26,993,933 (2007) 33,692,000 (2015)	297 to 4,387	-2.3 to 37.3; 19.8	294 to 2,002	Tree cover (20.7%), Shrubs (20%), Grassland (21.6%), Cropland (36.5%), Vegetation aquatic or regularly flooded (0.1%), Sparse vegetation (0.1%), Bare areas (0.2%), Built up areas (0.1%), Open Water (0.7%)
Somali	279,252	4,445,219 (2007) 5,453,000 (2015)	157 to 2,649	5.9 to 40.3; 25.9	153 to 956	Tree cover (1.9%), Shrubs (37.6%), Grassland (48.2%), Cropland (5.5%), Vegetation aquatic or regularly flooded (<1%), Sparse vegetation (3.3%), Bare areas (3.5%), Built up areas (<1%), Open Water (<1%)
Southern Nations, Nationalities and Peoples	105,476	14,929,548 (2007) 18,276,000 (2015)	325 to 3,558	1.8 to 37.8; 21.6	340 to 1,968	Tree cover (37.5%), Shrubs (12.3%), Grassland (18.6%), Cropland (30%), Vegetation aquatic or regularly flooded

Region (SNNPR)						(0.2%),Sparse vegetation (0.2%), Bare areas (0.2%), Built up areas (0.1%), Open Water (1%)
Tigray	84,722	4,316,988 (2007) 5,056,000 (2015)	156 to 3,948	1.9 to 40; 22.5	338 to 1,024	Tree cover (15.8%), Shrubs (18.6%), Grassland (18.8%), Cropland (46.1%), Vegetation aquatic or regularly flooded (0.1%), Sparse vegetation (<1%), Bare areas (0.3%), Built up areas (0.2%), Open Water (0.1%)

Economy

Ethiopia has the fastest growing economy in Africa (Table 12; IMF 2018). Its gross domestic product (GDP) was calculated at $ 203.6 billion USD in 2017/18 with a growth rate of 7.7% (growth has averaged 9.9% a year since 2007/08; World Bank 2019). The primary sectors contributing to GDP in 2017 were agriculture (34.8%), industry (21.6%) and services (44.6%; CIA 2019). Despite its rapidly growing economy, Ethiopia also remains one of the poorest with a per capita income of $570.3 USD. However, the population living below the national poverty line decreased from 30% in 2011 to 24% in 2016 (World Bank 2019) which are in line with country's goal to reach lower-middle-income status by 2025 (FDRE 2011).

Table 12. Key budget indicators for Ethiopia from 2013 to 2017. Gross Domestic Product (GDP) reported in Ethiopian birr (ETB) (CABRI 2019).

	2013	2014	2015	2016	2017
GDP (constant 2010/11 ETB) (billions)	1,102	1,216	1,342	1,449	1,596
GDP (current ETB) (billions)	867	1,061	1,298	1,541	1,807
GDP growth (%)	9.9	10.3	10.4	8	10.15
GDP per capita (constant 2010/11 ETB)	12,674	13,760	14,951	15,893	17,230
GDP per capita (current ETB)	9,970	12,008	14,460	16,900	19,499
Inflation (CPI) (%)	8.07	7.4	9.57	6.63	10.69
General government revenue (% of GDP)	15.83	14.9	15.38	15.88	14.96
General government expenditure (% of GDP)	17.76	17.48	17.33	18.23	18.25
Budget balance (% of GDP)	-1.93	-2.58	-1.95	-2.34	-3.29
Primary balance (% of GDP)	-1.59	-2.23	-1.54	-1.87	-2.83
General government debt (% of GDP)	47.5	47.85	54.52	56.06	58.99

In 2017, Ethiopia exported $2.2 billion USD of goods while imports totaled $8 billion USD. Agriculture is the foundation of Ethiopia's economy providing 70-80% of jobs (IFAD 2016; CIA 2019). The top exports in 2017 were coffee ($712 million USD), oil seed ($348 million), gold ($242 million USD), cut flowers ($207 million USD) and dried legumes ($116 million USD;

OEC 2019). The top imports are air/spacecraft ($660 million USD), gas turbines ($351 million USD), medicine/health products ($322 million USD), and telephones ($235 million USD; Data Africa 2019). China is Ethiopia's largest trading partner, buying $343 million USD worth of goods and selling $2.65 billion USD back to Ethiopia (Data Africa 2019).

People and Society

Ethiopia has an estimated population of 113,000,000 people with a density of 101 people per km^2 and growth rate of 2.61% (WPR 2019). It is the second most populous country in Africa and ranked 12th in the world (CIA 2019a). The median age is 17.9 years with 60% of the population under the age of 25. Ethiopia's people come from diverse ethnic backgrounds with the dominant being Oromo (34.4%), Amhara (27%), Somali (6.2%), Tigray (6.1%), Sidma (4%), Gurage (2.5%), Welaita (2.3%), Hadiya (1.7%), Afar (1.7%), Gamo (1.5%), Gedeo (1.3%), Silte (1.3%), Kefficho (1.2%) and other (8.8%) (CIA 2019). Amharic is the official national language; however, there are over 80 languages spoken – some being the official working language of their native administrative region (i.e., Oromo, Somali, Tigrigna and Afar; CIA 2019). Adult literacy is 49.1% (WPR 2019), an increase from 39% between 2005 and 2012 (UNDP 2016). In 2010, approximately 80% of the children were enrolled in primary education, 82% of boys and 78% of girls (FAO 2016). Ethiopia has a long history with Christianity, Islam and Judaism. Today, Ethiopian Orthodox is the dominant religion (43.5%), followed by Muslim (33.9%), Protestant (18.5%), traditional (2.7%), Catholic (0.7%) and other (0.6%; CIA 2019).

According to the World Food Programme (WFP 2019), 89 million people (87% of Ethiopia's population) are poor and suffer from food insecurity, insufficient access to education and health services, and inadequate employment opportunities. Only 57% of the population has access to clean drinking water (FAO 2016). About a third of Ethiopia's people continue to live below the poverty line, most living in rural areas. In particular, pastoral communities from lowland areas of the country fall behind on nearly all social indicators (UNDP 2019). Although, Ethiopia continues to improve with most poverty indicators, the pace has slowed since 2011. In a 2019 study by Ethiopia's Central Statistical Agency (CSA) and the United Nations Children's Fund (UNICEF), poverty among children was studied across nine dimensions; development/stunting, nutrition, health, water, sanitation, housing, education, health related knowledge, and information and participation (CSA and UNICEF 2019). The study found that 36 million children (88%) in Ethiopia under 18 years of age lack basic services in at least three of the nine dimensions examined. The results also showed large geographic inequalities with 94% of children in rural areas being multi-dimensionally deprived compared to 42% in urban areas. The vast majority of children living in poverty were from three regions; Oromo (16.7 million), SNNPR (8.8 million) and Amhara (8.5 million; CSA and UNICEF 2019).

Considering that at 44% of the population was below the poverty line in 2000, Ethiopia has made remarkable progress toward its goal of becoming a middle-income country by 2025 (FDRE 2002). Similar trends in household health, education and living standards have also been seen from 2000 to 2011. For example, life expectancy increased from 52 to 63 years of age, households with electricity rose from 12% to 23%, and the children under five years of age fell from 58% to 44% (World Bank 2014). The reduction in poverty and improved living standards are tied to agricultural and economic growth during the same time period. However, growth in these sectors have had little impact on other societal indicators. The Human Development Index (HDI) is a summary measure for assessing long-term progress in human development which considers a long and healthy life, access to knowledge and education, and a person's standard of living. In 2017, the HDI value for Ethiopia was 0.46 for 2017, giving the country a ranking of 173 out of 189 countries and territories (UNDP 2019). Ethiopia also lags in gender inequality. The Gender Inequality Index (GII), a component of the HDI that considers gender-based inequalities on reproductive health, empowerment and economic activity, gave Ethiopia a value of 0.50 in 2017 ranking the country at 121 out of 160 countries (UNDP 2019). Women and girls are highly disadvantaged in all social sectors including literacy, health, food and nutrition security, livelihoods, basic human rights and access to land, credit and productive assets. For every 100,000 live births, 353 women die from pregnancy-related causes and the adolescent birth rate is 62.5 births per 1,000 women of ages 15-19 (UNDP 2019).

Agriculture

Approximately 80% of Ethiopia's population live in rural areas and are largely dependent on subsistence farming and livestock production for their livelihoods (IFAD 2016; FAO 2018; CIA 2019). The agricultural sector contributes 35-37% to the country's GDP and constitutes about 84% of exports (FAO 2018). Ethiopia's agriculture is largely rain-fed and supports an assortment of crops and agricultural systems that are adapted to the country's varied climate and topography. The FAO (2016) reports five main agricultural productions systems in Ethiopia. These are:

- The highland mixed farming system (1,500 m asl) is practiced in most regions of the south and southwest with prolonged humid periods.
- The lowland mixed agricultural production system (below 1,500 m) is practiced in low-lying plains, valleys and mountain foothills, which include the northern parts of the Awash and the Rift Valley.
- The pastoral complex supports the livelihood of only 10% of the total population living in the Afar and Somali regions and the Borena zone.
- Shifting cultivation is practiced in the southern and western part of the country.
- Commercial agriculture is a farming system that has only emerged very recently, but likely to increase as irrigation systems become available and with international investments.
- These households are only loosely tied to the markets, and have limited access to financing and modern agricultural technologies. Furthermore, they are highly vulnerable to drought, environmental degradation and other hazards that comprise the country's food security (IFAD 2016). The biggest threats to rural livelihoods are 1) climate variability and change; 2) land degradation and desertification; and 3) water scarcity and stress (IFAD 2016).

Cereals, such as teff, maize, wheat, barley and sorghum are the main crops grown for subsistence, though other crops such as roots and tubers, pulses, seed oil, vegetables and fruits are common at smaller scales. Approximately 74% (12 million rural households) of the country's farmers are considered smallholders, with about a third farming on less than 0.5 ha (FAO 2018; 2019). Smallholder farming households is estimated to account for 95% of the country's agricultural production and 85% of employment (FAO 2019). Agricultural products are also Ethiopia's primary exports. In 2017, coffee accounted for $713 million USD (32%), oil seed $349 million USD (16%), cut flowers $207 million USD (9.4%), dried legumes $116 million USD (5.3%), and soybeans $20.6 million USD (0.94%) of all exports (OEC 2019). Industrial crops, such as sugarcane, cotton and fruits have increased in recent years and adding to the list of agricultural exports.

Despite the government’s attempts to increase Ethiopia’s agriculture production, there has been little progress in the use of fertilizers. Although Ethiopia is known for having rich soils, their productivity is being compromised by severe topsoil erosion, depleted organic matter from the use of biomass and dung as fuel, diminishing macro and mico-nutrients, and high acidity and salinity in many regions (Spielman et al. 2012). The use of fertilizers has been slowly, but steadily, rising from 100,000 tons in 1993 to 300,000 tons in 2000 to 625,000 tons in 2009, primarily for teff, wheat and maize (Spielman et al. 2012).

Despite the country’s rich water resources, the area of irrigated lands (< 3%) remain small and undeveloped. Estimates of irrigated lands and water managed areas vary widely. For example, in 2004, approximately 510,000 ha were reported have some water management for agriculture, where 175,300 ha estimated to have full-control irrigation. Further research found that about 30% of these lands were not in operation (IWMI 2010). In 2015, an estimated 1,958,000 ha were under some type of irrigation system. Full-control irrigation was estimated to be 658,340 ha, state irrigation was estimated to be 200,000 ha, and small temporary water management schemes were estimated to be 1,100,000 ha (NPC 2015; FAO 2016). Although, irrigation systems fall short of the country’s potential, Ethiopia is rapidly expanding its capacity through the constructing of new dams, foreign investments, and development of commercial crops (e.g., cotton, sugarcane, maize). The biggest constraints to modernizing Ethiopia’s agricultural sector are centered on the need for improved irrigation practices. These include farmer’s resistance for adopting new technologies, lack of inputs and financing, poor agricultural extension and water management services, insufficient infrastructure and electricity, and uncertainty in the country’s land tenure system (FAO 2015).

Ethiopia has one of the largest livestock populations in Africa, contributing 17% to Ethiopia’s GDP and 39% of the agricultural GDP. Livestock supports, to varying degrees, livelihoods of more than 11.3 million rural households. In a 2017 report by the Ethiopia Ministry of Livestock and Fisheries and the International Livestock Research Institute (ILRI), Ethiopia’s livestock population consisted of 55.2 million cattle, 29 million sheep, 29 million goats, 4.5 million camels and nearly 50 million chickens. In addition to 1,128 metric tonnes of meat annually, livestock produces 174 million eggs, 5.2 billion liters of milk, 68 million MT of organic fertilizer, and 617 million days of animal traction (Shapiro et al. 2017). Ethiopia’s livestock production system can be broadly defined into two classes: a grazing system, where more than 90% of dry matter fed to animals comes from rangelands, pastures and annual forages, and a mixed system, where at least 10% of feed comes from crop residues. (Shapiro et al. 2017).

Ethiopia’s demand for livestock products (e.g., meat, milk) is currently being met from domestic production; however, projected human population growth in the next few decades are likely to result in significant deficits. In the case of milk production, investments in better genetics, feed and veterinarian services can improve both traditional and commercial dairy farming, and capable of a 20% surplus in the next 30 years. Similar investments in poultry production also has the potential to generate a surplus of meat by 8% over the same time period. For other livestock, the biggest constraint will be from limited feed, as stocking rates will exceed available grazing and fodder across the country (Shapiro et al. 2017). Higher densities of livestock will also increase the vulnerability to zoonotic diseases. Currently, only 44% of cattle, 20% of sheep and goats, 2% of chickens and 1.8% of camels are vaccinated (FAO 2017b). The Ethiopian government is taking major steps towards a sustainable livestock sector while developing a green economy, which appear to be moving in opposite directions. In the 2015-2020 Livestock Master Plan, the Ministry of Livestock and Fisheries aims to increase beef production by nearly 2 million tonnes and milk production by 8 billion liters (Shapiro et al. 2015), while the CRGE strategy calls for a reduction in cattle by a least 45 million head by 2030 (FDRE 2011).

Security

Considered one of the most stable countries in East Africa, Ethiopia has often struggled to find a balance between building a nation and maintaining ethnic identities. In the last few years, civil unrest has been a frequent occurrence in some parts of the country, and new changes in the current administration and proposed reforms are starting to spark new protests in other areas. Acts of terrorism is considerably low for East Africa with the main threat coming from al-Shabaab in retaliation for Ethiopia's participation in the African Union Mission in Somalia (CIA 2019). In 2013, a terrorist attack failed when two Somali suicide bombers accidently blew themselves up during Ethiopia's World Cup qualifying match in Addis Ababa. In September 2019, the Ethiopian government arrested an unspecified number of Islamist militant members of al-Shabaab who were planning to carry out attacks at hotels, religious festivals, and public places in Addis Ababa. Given recent political reforms and increasing ethnic violence, al-Shabaab may be plotting future terrorist attacks on Ethiopia.

Civil unrest, mostly in the form of protests, are not uncommon since Ethiopia became a democratic republic in 1995. Early protests were largely driven by political opposition groups that were underrepresented in the new government, inequality among different ethnic groups, and the expansion of Addis Ababa into Oromia. From 2016 to 2018, Ethiopia was, by some accounts, close to civil war and ultimately led to the resignation of Prime Minister Hailemariam Desalegn. With the appointment of Abiy Ahmed as the new Prime Minister in April 2018, the first Oromo to hold office, tensions relaxed as he advanced a number of political reforms, including releasing political prisoners and allowing opposition leaders to return from exile. However, many of his policies led to unintentional unrest with multiple ethnic groups across the country. For example, there's been a resurgence of the Oromo Liberation Front, an armed insurgent group seeking greater autonomy since the 1970s. More recently, in the Southern Nations, Nationalities, and Peoples' Region, the Sidama zone is bidding to become a separate regional state by the end of 2019, a move that has prompted at least 10 other ethnic groups from the region to do the same. Violence has also been escalating in other regions throughout Ethiopia. On June 22, 2019, Ambachew Mekonnen, the president of the Amhara region, and his top advisor were assassinated. That same day, the Chief of Staff of the Ethiopian National Defense Forces, General Seare Mekonnen, and retired Major General Gezai Abera were also killed in the related coup.

According to the US State Department (2019), Ethiopia has a travel advisory level of 2 (exercise increased caution) due to civil unrest and communications disruptions. Regionally, the US State Department has issued a travel advisory level of 3 (reconsider travel) to 1) the Somali region due to the potential for terrorism, 2) the SNNPR due to civil unrest, 3) East Hararge and Guji zone of Oromia due to armed conflict and civil unrest, and 4) Benishangul Gumuz and western part of Oromia due to armed conflict and civil unrest. The US State Department has also issued a travel advisory level of 4 (do not travel) to 1) the border area with Somalia due to the potential for terrorism, kidnapping and landmines, and 2) the border area with Kenya, Sudan, South Sudan, and Eritrea due to crime, armed conflict and civil unrest (US State Dept. 2019).

DECISION SUPPORT

The wide ranging information gathered from the framework described above provides insights into current emissions and mitigation practices in Ethiopia, while presenting some of the socio-economic drivers that may influence ongoing and future mitigation activities. For ease of access, some of this information was distilled into a decision support table (Table 13) that can be used when planning where to implement GHG mitigation activities and which activities are most likely to be successful. Table 13 partitions the country into geopolitical regions to serve as a decision level unit with a multitude of different criteria to consider.

The decision table (Table 13) was constructed by combining information gathered during the literature review, from responses to the survey, and from the regional CBP analysis of mitigation potential (constrained to six regions due to the time available) that may affect GHG mitigation activities in Ethiopia. From the literature review, we listed the number of ongoing projects (Table 1) in each region so that existing activities could be taken into account when choosing new activity locations. Survey responses for the degree of significance of the 11 driving forces of land management choices (Table 3 and 4) were summarized and converted to values from -3 to 3, where -3 represents a driving force that is a predominant and critical *constraint* to the adoption of a land management practice, a value of 3 represents a driving force that is a predominate and crucial factor in *increasing* the adoption of a land management practice. A value of zero is a driving force that has mixed effects on the adoption of a land management practice (Appendix IV). To obtain a single degree of significance value across survey responses, we took the most frequent response for each region. When multiple degree of significance values were equal in frequency for a region, we took the average to obtain a single value (Figure 4). Similarly, the economic and cultural land use importance rankings for each category were also converted to numerical values from zero (not at all important) to four (extremely important) (Appendix V Figure 3). The most frequent value was used to obtain a single value for each region and when multiple values were equal in frequency, they were averaged to obtain a single value. Mitigation potential is based on an average for the region across all soil climate combinations. If this option is chosen, a more detailed CPB analysis should be carried out. Estimated mitigation potential in t CO_2 e per ha per year (based on an average for a given region across all soil climate combinations) for five mitigation options, were also included in the decision table by running the CBP tool at a coarse resolution for six example regions (in a full application of this framework, the CBP tool would be run in all regions where the survey indicated GHG mitigation and avoided emissions are practical). Finally, all factors were rescaled to be between 0 and 1 to bring them to the same scale.

Results from this example modeling exercise show that two GHG mitigation activity classes had the greatest mitigation potential: a) activities involving tree planting (reforestation/afforestation and converting annual cropland to perennial cropland; and b) avoided land use conversion (avoided deforestation). Avoided deforestation showed the greatest potential (23.2–50.2 t CO_2e ha^{-1} yr^{-1}), followed by planting perennial crops (15.04 – 18.99 t CO_2e ha^{-1} yr^{-1}) and reforestation/afforestation (9.5-12.2 t CO_2e ha^{-1} yr^{-1}). The avoided deforestation model scenario involved conversion from forestland to degraded grassland, and so both losses in biomass and soil carbon apply. The afforestation/reforestation scenario involves conversion from degraded grassland to forestland, and so increases in soil carbon and biomass carbon apply.

It is important to note that the benefits of reforestation/afforestation would likely extend well beyond the 20-year projection period, as forest trees tend to be longer-lived and accumulate biomass longer than perennial cropland. This is reflected in the IPCC models for forestland and perennial cropland biomass accumulation.

The predicted benefits of agroforestry are relatively uniform across the different cropping regions. This is an artifact of the IPCC model framework. Whereas biomass stocks and accumulation rates for forest and perennial cropland are stratified by climate region, the same parameters for agroforestry are stratified by geographic region and do not take into account climate variability.

Restoring degraded grassland has the smallest potential mitigation benefit on a per hectare basis, however the magnitude of the practice may have the largest potential benefit as the total area in degraded grassland very likely exceeds that of potential areas where afforestation/reforestation may occur.

Table 13. Proposed decision support table to evaluate the regions of Ethiopia for potential climate change mitigation actions.

Region		Significance of Driving Forces to Land Management Practices											Economic Land Use Importance					Cultural Land Use Importance						*Mitigation Option and associated GHG mitigation potential in t CO_2e ha^{-1} yr^{-1}				
	Existing projects	Population Pressure	Affluence	Holding Land Certificates	Land Availability	Poverty	Labor Availability	Inputs and Infrastructure	Education, Access to Knowledge and Support Services	War and Conflict	Formal Institutions	Informal Institutions	Forestry and Forest Products	Agroforestry	Farming and Agriculture	Pastoralism and Livestock Management	Urban Development	Forestry and Forest Products	Agroforestry	Farming and Agriculture	Pastoralism and Livestock Management	Urban Development	*TOTAL	Degraded Grassland restored to nominal condition	Conventionally-managed annual cropland with intensive tillage converted to agroforestry	Native forest conserved through avoided deforestation	Former forestland, now degraded grassland, replanted to an afforested landscape	Annual cropland converted to perennial cropland
Addis Ababa	0.3	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	-0.3	1.0	0.8	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	0.8	1.0						
Afar	0.3																											
Amhara	0.3	-0.2	0.0	0.7	0.8	-1.0	0.2	0.2	0.8	-0.3	0.0	-0.2	1.0	0.6	1.0	0.5	0.5	0.5	0.6	0.6	0.8	0.5		2.81	5.26	38.2	9.8	17.53
Benishangul-Gumuz	0.3	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	-1.0	-0.7	0.0	-1.0	1.0	0.3	1.0	0.8	0.5	1.0	0.3	1.0	0.8	0.5		2.23	5.36	50	11.6	18.48
Dire Dawa	0.3																											
Gambela	0.3	-0.1	0.0	-0.2	0.2	0.2	0.3	0.1	0.0	-0.5	-0.2	-0.3	1.0	0.9	0.6	1.0	0.6	0.5	0.4	0.4	0.8	0.5		1.98	5.35	50.1	9.5	18.99
Harari	0.3																											
Oromia	1.0	0.0	1.0	1.0	1.0	-1.0	1.0	1.0	1.0	-1.0	0.7	1.0	1.0	1.0	1.0	0.5	0.8	0.6	0.5	1.0	0.5	0.1		2.8	5.3	40.7	12.2	18
Somali	0.3																											
SNNPR	1.0	1.0	1.0	0.5	0.0	-1.0	1.0	1.0	1.0	-0.4	1.0	0.8	1.0	1.0	1.0	0.8	0.8	0.9	0.8	0.9	0.8	0.5		2.6	5.35	48.5	11.8	15.04
Tigray	0.3	0.5	0.6	0.7	0.8	0.0	0.7	0.8	0.3	0.0	0.7	0.7	1.0	1.0	1.0	0.5	0.8	0.8	0.8	1.0	0.8	0.6		1.89	5.35	23.2	11.6	17.45
Multiple Locations	0.3	0.0	0.0	0.7	0.4	0.2	0.4	1.0	0.4	0.4	1.0	0.3	0.8	0.5	0.5	0.8	0.8	0.8	0.8	0.9	0.8	0.8						

*Mitigation potential is based on an average for the region across all soil climate combinations. If this option is chosen a more detailed CBP analysis should be carried out.
¥Total column intentionally left blank. How criteria are combined can and should be tailored to the specific needs of the user.

N.B. The criteria to evaluate regions include: the number of existing GHG mitigation projects active in each region; the significance of driving forces to the adoption of land management practices as reported from the survey respondents (11 total); the economic and cultural land use/ products importance, also reported from the survey responses; the mitigation potential for five of the most relevant mitigation options and; a risk value as determined through a country profile of the political and security risks each region may pose. All original values were scaled between 0-1 except for the degree of significance (as reported by the survey respondents) of driving forces which spans from -1 to 1 to capture the fact that driving forces can be a constraint or a positive influence on the adoption of a land management practice. Regions without data did not have enough response from the survey. The total is not calculated but demonstrates that how all or a portion of the criteria could be combined to provide a prioritized risk index to select regions for mitigation actions. Cells are conditionally colored to visualize the degree of each value. For the degree of significance values of the driving forces, high positive values ('the Driving Force is a predominant and crucial factor in increasing the adoption of the land management practices') are colored green while low negative values ('the Driving Force is predominant and crucial constraint to the adoption of the land management practice') are colored red. For the importance of land use practices and products (both economically and culturally), yellow represents a low value ('not at all important') while dark green indicates a high value ('extremely important').

The decision support table was designed to allow flexibility in selecting which factors to consider in a choice on where and what type of mitigation action to implement. Criteria can be included or omitted depending on the user's preference. Further, criteria can be weighted to different degrees to emphasize one criteria over others or can be modified to have a negative (convert factor to negative values) or positive effect. Finally, the way in which criteria are combined (summed, multiplied or some combination of the two) can also be tailored to fit a potential mitigation action. The driving forces and land practice/products values reported should also be sure to direct what mitigation activity would be most applicable and successful.

An example of how the table could be used to help choose potential mitigation options to consider in a more in-depth analysis can be seen if the decision support table is applied to the land management mitigation options chosen for the Wolita zone case study (presented above). This zone is in the SNNPR region of Ethiopia. Using Table 13, the most economically and culturally important land uses identified in the survey for SNNPR are forestry, agroforestry and agriculture, with livestock production also being important culturally. Avoided deforestation, reforestation and conversion of annual cropland to perennial cropland have high mitigation potential on a t per ha per year basis. Therefore avoided deforestation, reforestation and promotion of perennial cropland could be good candidates for more in-depth CBP analysis of mitigation potential. When going to the zonal level it can be seen that this is the case for perennial cropland. The zone is experiencing a decline in perennial cropland due to conversion to annual cropland. Maintaining the current area of perennial cropland rather than allowing further decline could therefore be good mitigation activity to investigate further. The framework could ultimately be used in a nested way, with a regional decision support table being used to choose regions and a zonal table being used in the same way within a given region.

The survey responses on driving forces, and the relative risks and rewards that result from conditions within a region, can have a significant impact on the types of mitigation activities one might choose. Following are some factors to consider in choosing regional mitigation activities:

- Population Pressure: Population pressure can lead to pressure for land and for land use intensification. For example, increasing population may combine with land availability to incent deforestation to make land available for crop production and livestock grazing.
- Affluence: The relative affluence of communities and regions is frequently an indicator for the stability of land use systems and the rate of land use change. Greater affluence can lead to more stable land use due to fewer incentives to convert forest or grassland to cropland to improve incomes. Income disparity, however, can create conditions where demand for agricultural and forest products from an affluent class drives land use change.
- War and Conflict: People's attentions are elsewhere during conflict. The uncertainty introduced by war and conflict typically upend social and cultural priorities, and prevent the sorts of organized, coordinated activities required for greenhouse gas mitigation. Conflict within a region can prevent formal and informal institutions from engaging and supporting individuals and groups.
- Formal Institutions: The presence of organizations like federal, state, and local departments of agriculture and forestry can have an important impact on the likelihood of success in any given mitigation activity. Extension and research expertise can be leveraged not only for surveys, but for guiding and implementing mitigation activities.

- Informal Institutions: The presences of organizations like growers cooperatives, watershed planning groups, community groups, and regional economic collaborations can have an important impact on projects. Leveraging the expertise of such groups, and engaging with them in both surveys and implementing mitigation activities can lead to a higher likelihood of success.

PROJECT SYNTHESIS AND DISCUSSION

A Reproducible Framework for Rapid Assessment

Our project demonstrates a process by which information can be rapidly combined from multiple sources to develop a decision support tool to decide on possible types of land based climate change mitigation activities and where they can be implemented. The factors we considered included; the presence of existing projects, driving pressures behind land use and management choices, cultural and economic factors related to land use practices and a summary of political, environmental and security and circumstances. In this way, we have developed a framework designed to consider both technical mitigation potential and (importantly) constraints set by the social, economic, political and cultural landscape in which land based activities are implemented.

As discussed in Griscom et al. (2017), social and political barriers can have dramatic impacts on effective implementation. Many of the Natural Climate Solutions options presented in their study are not convenient for a nation that is striving to grow its economy and move from a developing country to one with middle-income status - at least in the short term. Other priorities such as net carbon emissions are often given higher preference than climate conscious solutions. While Ethiopia is very progressive with their green initiatives, they are also aggressive with strengthening their economy, infrastructure and food security. Climate solutions are a part of that equation, but Ethiopia also prioritizes national development as demonstrated by multiple hydroelectric dam construction projects, large-scale agro-business, massive manufacturing projects, and even their own space program. However, Ethiopia has demonstrated that large-scale mitigation activities are important to its economy and environment, and recently made national news by planting over 350 million trees in a single day. Ethiopia has a history of substantial reforestation and afforestation projects but have been less successful at conserving their existing natural forests (FAO 2018).

We approached this project with the assumption that there is too much focus on GHG emission mitigation values (i.e., net carbon emissions of a mitigation practice) in existing projects without considering the likelihood of adoption and long-term success. With our approach, we focus first on the ‘real world’ situation based on the unique economic, cultural and political context for a potential emission mitigation activity and evaluate these at geopolitical area (Ethiopia regions). Then, from this foundation, we can use this information to identify where in the country to focus GHG mitigation activities and which activities would be most successful and makes for a rapid targeted analysis.

The study by Griscom et al. (2017) mainly draws on emissions estimates taken from the literature. These will unavoidably involve a range of different methods and approaches. The approach that we advocate here using the CBP tool for regional and then more targeted GHG mitigation analysis uses the IPCC method as this is the method behind the CBP tools (both Tier 1 and Tier 2). This makes output immediately compatible with national emissions reporting. Something that has advantages if estimates are to be used to help countries achieve Nationally Determined

Contributions, etc. Like Griscom et al. (2017), we used the IPCC method to estimate the uncertainty of the GHG mitigation potential of the land management strategies considered in both the regional and case study analysis. The IPCC error propagation method is built into the CBP tools.

Challenges

The project faced a number of challenges which was expected given the large-scale and short timeline. A major challenge encountered during the project period was several weeks without internet communication and longer periods for regions outside of Addis Ababa. This disrupted the online survey and communication with in-country collaborators. While the team adapted to this disruption, it ultimately delayed the survey distribution and potentially limited the responses. However, it provides a good example of how an approach such as this can be implemented during intermittent internet connectivity.

One of the administrative challenges we faced was getting approval from the Institutional Review Board (IRB) to conduct the surveys. To save time, we structured the questions so that we were only collecting information that is generally publically available and we took care not to collect data in a manner that would allow subjects to be identified from their answers. Additional information about each respondent could help gain further insights into how to effectively use the information obtained from recipients. If a longer timeframe is available for implementation of this framework in another country, IRB approval for an amended survey could be sought bearing in mind it could take several months to secure.

Suggestions for Implementation

We would strongly recommend identifying key individuals that have a professional network in the country in the AFOLU sector, including expertise in forestry, agronomy, rangeland management, and GIS/spatial analysis. The execution of this project relied heavily on our existing knowledge, experiences, reputation and professional networks in Ethiopia. Without these in place, components of this project, specifically the survey, would not have been as successful. This not only provides a level of credibility and endorsement, but also provides a source for the most current and applicable information on land use practices, propensity for mitigation adoption, cultural and economic considerations and potential partners to help implement any actions in the future.

A timeline for implementing a project like this within a given country should be long enough to allow adequate time to query a group of experts within the country about potential classes of greenhouse gas mitigation practices, and specific details within those practices where survey respondents can help to improve the modeling exercise.

Additional time should be made for the following after the surveys are completed, to help guide the modeling exercise:

- Identify regionally where mitigation activities may be applied. For example, identifying communities and/or regions where afforestation/reforestation is most likely to occur and where tree survivorship is most likely will lend strong credence to the work.
- Research and describe regionally-specific management practices that may be applied within each land use category. For example, understanding the appropriate agroforestry

tree/shrub species and planting density and associated cropping systems on a regional basis will improve the model results.

- Consider survey responses regarding socio-economic issues, conflict, and civil unrest and how such factors can contribute to the potential for GHG leakage and mitigation permanence.

While we see the value of conducting a rapid assessment, this approach obviously has consequences on the quality and quantity of information that can be gather to help direct mitigation activities. Having additional time to conduct the rapid assessment would allow us to clarify and improve multiple components of this work. With additional time, we could have conducted a test implementation of the survey to identify what questions needed to be clarified (for example, to ensure recipients were interpreting the driving force degree of significance appropriately), what additional questions could be asked to provide more information (ranking of driving pressures and the economic and cultural land use practices/products), and get comments on the confusion in the interpretation of the. In addition, a more thorough analysis of the emission benefits would have been possible. We limited the CBP analysis at the regional level to six regions due to time constraints to obtain the data needed and conduct the analysis.

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APPENDICES

Appendix I: Data Availability for Conducting Tier II assessment of Enteric Fermentation in Ethiopia: Question posed from Caitlin and our response

Question: I received a question about data availability for conducting Tier II assessment of enteric fermentation in Ethiopia. The BioCarbon fund is doing a reference level assessment for the Initiative for Sustainably Forested Landscapes (ISFL) program and there is an ongoing discussion about whether Ethiopia can go beyond Tier I calculations in Oromia or if more data needs to be collected first. If you can include a reference to this question with any info/insights in the final report that would be great.

Work in this area is ongoing. For enteric methane emissions if only using the Tier 1 factors calculations in Ethiopia could be improved by using regional factors developed for Africa by ILRI (Herrero et al. 2008; Herrero et al. 2013). Work has also been carried out on the impact of feed availability and other factors on direct CH_4 emissions in smallholder systems in neighboring Kenya which could be applied to many Ethiopia conditions (Goopy et al. 2018; Merbold et al. 2018). A recent study by the Norwegian University of Life Sciences was specific to Ethiopia and considered the CH4 mitigation potential of using different feedstocks. However this relied to some extent on Tier 1 assumptions (Berhanu et al. 2019).

A current study which should provide Tier II factors for Ethiopia in the near future is being carried out by the Climate Change Agriculture and Food Security (CCAFS) research program of the CGIAR. An initial workshop was held in May 2019 in Addis Ababa

https://ccafs.cgiar.org/news/tracking-ethiopia’s-livestock-emissions-identify-low-carbon-development-pathways#.XZ8Nh3dFzNP

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Appendix II: Literature Review Summary. Compliments Table 1 in the main text.

Reference Title	AFOLU Scope	Key Findings: GHG Emissions	Key Findings: Mitigation options	Limitations	Notes
Ethiopian Panel on Climate Change First Assessment Report, Agriculture and Food Security (Working Group II)	Agriculture, Forestry	Emissions from conversions of other land uses to croplands is estimated to be 130, 088, 256 tones CO_2 e per year. Rate of deforestation was estimated at 141,000 ha per year.	Improved agronomic practices that increase soil carbon storage; improved crop varieties; judicious use and optimum external inputs; tillage and residue mast; integrated farming system including crop, livestock and tree; soil conservation (e.g. traditional Konso Soil Conservations) and land rehabilitation; irrigation in arid environment; conservation agriculture; afforestation and fuel saving stoves to save manure; biogas installations; the use of compost in cultivated lands; Agroforestry	Mitigation potential of other options such as grassland is not known	
Ethiopia's Climate-Resilient Green Economy	Agriculture, Forestry	In 2010, GHG emission =150 Mt CO_2e from all sectors, of these 50% (65 Mt CO_2e) represents emission from agriculture and 38% (55 Mt CO_2e) from Forestry (50% of this share of forestry is due to agricultural conversion). From fertilizer use (crop residue, fertilizer and manure use) = 12 Mt CO_2e per year in 2010 (projections are also given). Following the current pathway for economic development, the emission increases from 150Mt CO_2e to 400 Mt CO_2e in 2030. Sectorial emissions in 2030 will be 110, 65 and 35 Mt CO_2e from agriculture, industry and forestry, respectively.	Some examples of **CRGE prioritized agricultural initiatives**: Intensify agriculture through usage of improved inputs and better residue management; Create new agricultural land in degraded areas; the use of carbon-and nitrogen-efficient crop cultivars to the promotion of organic fertilizers. **CRGE prioritized forestry initiatives**: Reduce demand for fuelwood via the dissemination and usage of fuel-efficient stoves, LPG, electricity and biogas; Increase afforestation, reforestation, and forest management to increase carbon sequestration in forests and woodlands; Promoting area closure via rehabilitation of degraded lands.	Exante assessment i.e. it did not follow specific project-level protocols of setting baseline emission scenarios such as that for carbon finance schemes. Managing rangeland was mentioned, but emissions and possible mitigations of GHGs were not considered.	Ethiopia intends to reach middle-income status before 2025. Conventional growth will more than double this emission level. Four pillar identified for Ethiopian green economy are: agriculture, forest, renewable energy source (hydroelectric, wind), and energy efficient technology (industry, transport, construction). Higher projected mitigation potential was given to forestry and agriculture. One of the objectives of CRGE is ensuring abatement and avoidance of future emissions. Agriculture is the mainstay of Ethiopian economy. Expansion of agriculture against forestry was projected BAU (9 million ha of land will be deforested by 2030 for agriculture not including forest degradation for grazing and fuelwood). CRGE attempts to project emission by 2030 and indicates mitigation options to reduce projected increase in emission by 2030. Estimated USD 150 billion expenditure over the next 20 years to implement the CRGE initiative. Green economy initiatives are divided into three: initiatives planned and funded by the government; initiatives planned by the government but require support for implementation; Market-based initiatives-carbon credits in exchange for GHG abatement.

Regional Analysis of the Nationally Determined Contributions of Eastern Africa: Gaps and opportunities in the agriculture sectors	AFOLU	AFOLU sector takes 67% of the net emission in the region. A total of 0.25 Gt of CO2e emission per year from the sector. Amongst sources in AFOLU, forest degradation (25%), grassland biomass burning (19%), with deforestation and enteric fermentation holding equal share (14%), followed by croplands (12%) at the regional level. Others from burning crop biomass, managed soils, rice cultivation and manure management. Overall, the LULUCF sector constitutes a net sink at the regional level, constituted mainly by forest management (65%) and afforestation (31%). However, aggregated country data suggests that forest degradation is the highest source of LULUCF emissions (48%), while deforestation and cropland account for around one-third of the total (27 and 23%, respectively). However, at national level sources and sinks are different due to forest cover type and energy consumption trends. E.g. Deforestation constitutes all the sectorial emission in Ethiopia; forest management contributes to all removals in Zimbabwe and afforestation accounts for all removals in Malawi.	All 18 countries of the East African region identify mitigation Policy and measures (P&Ms) in the LULUCF sector. P&Ms identified by countries in the LULUCF sector are aggregated into six areas: 1) reducing deforestation/ forest conservation; 2) sustainable forest management (SFM)/reducing degradation; 3) afforestation/ reforestation; 4) cropland; 5) grassland; and 6) wetlands. In addition, ten countries also refer specifically to Reducing Emissions from Deforestation and Forest Degradation (REDD+). One-third of the countries include climate smart agriculture as mitigation strategy, while over 50% promote REDD+ as a national mitigation framework. Agroforestry was indicated as mitigation option only for Burundi, Malawi, Djibouti, Comoros and Madagascar. No country included mitigation contribution of fire management aiming to reduce biomass burning crop residue and savannas. If the selected mitigation actions were to be implemented in full across the region, the agriculture sectors alone could reduce economy wide net emissions to below historical levels by 2030		Estimates indicate that agroforestry and sustainable soil management entail negative costs and high mitigation potential. Improved livestock management entails higher costs per unit of mitigation. Sustainable forest management, afforestation and reduced deforestation constitute high mitigation potential at a relatively low cost. At the regional level, the selected management practices in the agriculture sectors could reduce economy-wide net emissions to below historical levels by 2030 with an estimated mitigation potential of -4.6 Gt CO_2 e in 2030, – at a cumulated abatement cost of 13.2 billion EUR – representing approximately 140% of the current GHG target set forth in the Nationally Determined Contributions (NDC)s for all sectors.

Greenhouse gas mitigation scenarios for major emitting countries: Analysis of current climate policies and mitigation pledges	Agriculture, Forestry	Ethiopia's GHG emissions are projected to be 310 Mt CO_2e by 2030 (including LULUCF) under the current policies projection (based on their re-calculation). The current policy projection did not consider the second phase of the Growth and Transformation Plan (GTP II) (2016-2020) of the country due to uncertainty on how the Climate Resilience and Green Economy Strategy shall be fully implemented until 2025.	According to the analysis in the present document, Ethiopia was among the countries, which required additional measures to achieve its 2030 targets.	The accounting approaches and methodologie s are unclear	Analyzed the intended nationally determined contribution(INDCs) or nationally determined contributions (NDCs) on the basis of the current existing polices of 25 major emitting countries/regions up to 2030. Among the countries analyzed, Ethiopia is one of them.
Agriculture, Forestry and other land use (AFOLU)	AFOLU	AFOLU sector is responsible for about 10-12 Gt CO_2e /yr of anthropogenic GHG emissions mainly from deforestation and agricultural emissions from livestock, soil and nutrient management. Annual total non-CO_2 emissions from agriculture in 2010 are estimated to be 5.2-5.8 Gt CO_2 e/yr and composed 10-12% of global GHG emissions. Enteric fermentation and agricultural soils represent together about 70% of the total emission, followed by paddy rice cultivation (9 - 11%), biomass burning (6 -12%) and manure management (7-8 %). Between 2000 and 2010, total GHG FOLU emission were 3.2 Gt CO_2e/yr. including deforestation (3.8 Gt CO_2e/yr.), forest degradation and forest management (-1.8 Gt CO2 e/yr.), biomass fire including peatland fire (0.3 Gt CO_2 e/ yr.,	**Forestry:** reducing deforestation; afforestation/ reforestation; forest management; Forest restoration (protecting secondary forests and other degraded forests). **Land-based agriculture:** Cropland-plant management (improved crop variety, crop rotation, use of cover crop, perennial cropping system, improved N use efficiency...); croplands-nutrient management (fertilizer input to increase yields and residue inputs, N-fertilizer application rate, type, timing); croplands-tillage/residues management; croplands-water management; croplands-rice management; croplands-set-aside and LUC (Replanting to native grasses and trees); biochar application. **Grazing lands management**: Grazing lands-plant management (improved grass varieties, appropriate stocking, carrying capacity and improved grazing management); Grazing lands-animal management (carrying capacity and improved grazing management); Grazing lands-fire management (improved use fire for sustainable grassland management, fire prevention and prescribed burning). **Livestock**: livestock feeding (improved feed/fodder and dietary additives to reduce emission); livestock-breeding and other long-term management; manure management. **Agroforestry:** Agroforestry (including agropastoral and agro-silvopastoral systems); Others mixed biomass		Mitigation effectiveness**:** Non-permanence/ reversibility -The permanence of the AFOLU carbon stock relates to the longevity of the stock i.e. how long the increased carbon stock remains in the soil or vegetation. Reversals are the release of previously sequestered carbon. This may be caused by natural events that affect yield/growth. E.g., frost damage, pest infestation, or fire. The timing of mitigation benefits from actions (e.g. forest management) can vary as a result of both the nature of the activity itself, and the rates of adoption. Timing thus needs to be considered when judging the effectiveness of a mitigation action. Increased pressure on land systems may also emerge when afforestation claims land, or forest conservation restricts farmland expansion.

		and drained peatlands (0.9 Gt CO_2 e/yr.)	production system. **Others:** degraded soils restoration (land reclamation)		

The context of REDD+ in Ethiopia: Drivers, agents and institutions	Forestry	The WBISPP's (2005) carbon stock assessment resulted in an estimate of 2,683,127 tons of carbon in woody biomass stock across the country. However, it was suggested by some that this estimate likely underestimates carbon density by a factor of two and suggests further classifying forest types for a more accurate estimate. Estimates of GHG emissions from agricultural clearing of major forested regions is 1.2 Mt of C. Ethiopia has the potential to mitigate the release of 2.76 billion tons of carbon into the atmosphere if it protects and sustainably manages its forest resources.	Reducing deforestation through agricultural intensification. The impact of agriculture on forest cover change requires the economy to diversify and reduce the share of agriculture in overall employment. Enhancement of carbon stock through rehabilitation of degraded areas and afforestation activities could also be effective strategies in the short term. **Mitigation being carried out in Ethiopia, examples: Bale Mountains Eco-region REDD+ Project**: funded by Norway through the World Bank. The largest REDD+ pilot project in the country to date. The program was initiated by Farm Africa and SoS Sahel to organize PFM in the Bale eco-region and help local communities sustainably manage forests. The project covers about half a million ha and is intended to run for 20 years. It is estimated to reduce 18 million tCO_2 emissions. **The Humbo Ethiopia Assisted Natural Regeneration Project**: In 2005, World Vision Ethiopia initiated the afforestation/ reforestation project over 2700 ha of highly degraded lands in Wolaita zone, SNNPR. The project was identified and validated as an afforestation/ reforestation project under the CDM in 2009.The 30-year project will sequester an estimated 880,295 tCO2 (USD 4.5/t). **The Abote Community-Managed Reforestation Project and other 4 CDM projects** given in the document. **Sustainable Land Management Program 2008-13.** Although not a carbon project, rehabilitation work in 45 critical watersheds in 6 regions have been undertaken. **The Sodo Community Managed Agroforestry & Forestry Project is located in Sodo Zuria, SNNPR:** is certified in accordance with the Gold Standard. 189,027 tCO2 (35 years crediting period). Certified Emission Reduction purchase agreement (1 ton CO2 = $9 USD).		FAO's forest resource assessment (2010) and the Woody Biomass Inventory and Strategic Planning Project (WBISPP) (2004) are the two most commonly used and influential sources of information for describing Ethiopia's forest resources.

Ethiopia's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). Submitted to: United Nations Framework Convention on Climate Change (UNFCCC)	AFOLU	This document presents the national GHG inventory for Ethiopia. 146.2 Mt of CO_2e emitted in 2013, of which 79% (108.1 Mt CO_2e) of all emissions were from the AFOLU sector while energy, IPPU(industrial processes and product use) and the waste sector contributed 15, 1, and 5 %, respectively. In the same year, in the AFOLU sector, main emissions are from cropland, which totaled 75.6 Mt CO_2e while livestock account for 66.1 Mt of CO_2e emission (enteric fermentation plus manure management) and grassland 41.1 Mt CO_2e. The forest however was a sink of GHG and amounted to -91.5 Mt CO_2e. The estimated total emission in 2013 is marginal to the global GHG emissions, representing less than 0.3 % of 34.5 billion tons CO_2 in 2012. The projected trend of emissions for 2030 in this report is estimated at fairly close value of 367 Mt.	Mitigation options: introduction of lower-emitting techniques, such as conservation agriculture, watershed		The report gives summary emissions in AFOLU sector and others from 1994 to 2013 and projected emissions up to 2030. Followed IPCC 1996 tier 1 approach for the calculation.

Study of causes of deforestatio n and forest degradation in Ethiopia and the identificatio n and prioritization of strategic options to address those	Forestry	Livestock free-grazing and fodder use, fuel wood collection and charcoal production are the main sources for emissions followed by small holder farmland expansion, land fires and construction wood harvesting at the national level. There is large variation found in the driver importance order by forest types and regions. The large-scale investment agricultural schemes and extensive timber logging also play a significant role in some regions. The underlying causes of deforestation and degradation are population growth, unsecure land tenure, lack of sufficient off-farm work opportunities and poor forest law enforcement. Sustainable fuelwood and charcoal use can improve the health, livelihood and wealth situation of households.	Estimated abatement potential of Climate Smart Agriculture (CSA) is about 2,933 Mt CO_2e over 20 years. CSA contributes to the livelihoods and wellbeing of the rural society, as the farmers are able to achieve increased income generation through their agricultural and agroforestry operations. Estimated emission reduction potential for improved stoves, installing biogas digesters and establishing woodlot are 77, 115 and 429 Mt CO_2 e, respectively. The national mitigation potential of afforestation/ reforestation was estimated to 2 billion t of CO_2e in the biomass. The mitigation potential of rehabilitating the degraded forests is estimated about 3.7 billion t of CO_2e in the aboveground and belowground biomass. Estimated total emission reduction potential from protected forests and participatory forest management, in general, is about 3,621.9 MtCO_2e over 20 years. **Strategic options for mitigation** are grouped after two-phase screening as agricultural intensification through climate smart agriculture (**CSA**); Sustainable fuelwood and (commercial) charcoal use; and Protected forests and participatory forest management.		*The Oromia Forested Landscape Program is a sub-national REDD+ pilot project aiming to contribute to Ethiopia's climate neutrality goals following an integrated landscape approach and supported with sector-based investments. The BioCarbon Fund provided funding up to USD 50 million for the net emission reductions of a minimum 10 million tCO2 net GHG emissions reductions and carbon stock enhancements over a period of 10 years. The total national area of shrub lands and grasslands suitable for afforestation and reforestation activities account for up to 5.3 million ha. Most of the forest rehabilitation potential is discovered in Benishangul-Gumuz,Oromia, Amhara and Southern Nations, Nationalities, and People's Regions, which have also been affected by forest degradation over the past 10-15 years. Absence of the land use plans and the uncoordinated decision-making has resulted in natural resource depletion. Authors stated it is critical to consider family planning in the central sphere of the development.

National REDD+ Strategy (2016 - 2030)	Forestry	Ethiopia has been losing about 92,000 ha (0.54%) of forest annually between 2000 and 2013. It has historically lost most of its forest cover in the north and central areas. Recent deforestation occurs mainly in the remaining Moist Afromontane Forest in the southwest and southeast, and the Dry Forest areas in western lowlands. The rate of afforestation has been about 19,000 ha annually between 2000 and 2013. The forest gain mainly observed in the Dry Afromontane areas has likely been a result of area closure activities (forest restoration) in central and northern highlands and growing of eucalyptus woodlots by small holder farmers. As the result, the net deforestation rate equals 72,000 ha per year over the same period. Ethiopia has submitted its first FRL to the UNFCCC where the Forest Reference Emission Level for deforestation is: 17.9Mt CO2/year /year; the Forest Reference Level for afforestation is 4.8 MtCO2/year (removal).	A detailed list of targeted interventions identified to address direct drivers of deforestation and forest degradation are indicated in the document. Relative impact of direct drivers of deforestation and forest degradation in different regions are indicated in this material. Measures to address the underlying causes of deforestation and forest degradation are also indicated.		**Direct drivers** of deforestation are (1) small scale agricultural expansion, (2) large scale agricultural investment, (3) forest fire and (4) infrastructure development (e.g., roads). Forest degradation is caused by (1) increased wood extraction for firewood, charcoal and construction, (2) livestock overgrazing and (3) in Southwest Ethiopia, traditional coffee farming gradually degraded forests into coffee agroforestry while, particularly in South central Ethiopia, the expansion of the cash crop Khat (Catha edulis) gradually encroached into forested sites. **The indirect drivers** of deforestation and forest degradation are: Absence of land use planning; Inadequacy of forest laws, poor implementation associated with poor institutional capacity; institutional instability and low capacity of forestry institutions; Poor inter-sectoral coordination; unclear tenure/ forest user rights; population growth coupled with poverty. **Agents** of deforestation and degradation are thus, smallholder farmers, immigrants, investors, illegal loggers, charcoal producers, local communities, pastoralists, and farmers.
Report on the technical assessment of the proposed forest reference emission	Forestry	Proposed Forest Reference Emission Level (FREL; in t CO_2 e/year) =17,978,735. The FREL includes and gross emissions from deforestation (i.e. those associated with forest loss) and does not include forest degradation. **Duration:**	Proposed Forest Reference Level (FRL; in t CO_2 e/year) = -4,789 935. The FRL is the annual average of the CO_2 removals associated with adjusted estimates from the enhancement of forest carbon stocks, defined as the conversion of other land to forestland or any transition above the thresholds of the forest definition.		Areas for future technical improvements of Ethiopia's FREL/FRL have been identified in this report. At the same time, the Assessment Team (AT) acknowledges that these improvements are subject to national capabilities and policies, and notes the importance of adequate and predictable support. The AT also acknowledges that the assessment process was an opportunity for a rich,

level of Ethiopia submitted in 2016		FREL/FRL = annual average emissions/removals from carbon stocks between 2000 and 2013. **Pools in the estimate**: Aboveground biomass, belowground biomass and drywood biomass. The litter pool and soil organic carbon pool are not included owing to a lack of accurate data. For the reported pools, it is assumed that the carbon immediately after deforestation is zero.			open, facilitative and constructive technical exchange of information with Ethiopia.
Climate Change Adaptation and Mitigation Strategies Vis-À-Vis the Agriculture and Water Sectors in Ethiopia - Case Review/Study of the EPCC Project	Agriculture, Water		A general suggestion on mitigation in agriculture: reducing the expansion of agriculture through agricultural intensification.	Has few and very general content on GHG emissions and mitigation	Reviews the general scenario of climate change impact of increased temperature and decreased precipitation. Also, influence of climate change on suitable areas for different crops in Ethiopia.
REDD+ and Carbon Markets: the Ethiopian Process	Forestry		Ethiopia is designing a monitoring and measuring system for carbon emissions and removals. The MRV system will employ remote sensing and ground C inventory. The national forest inventory is currently underway. The forest reference emission level (FREL) was not developed except for Oromia. The preliminary work such as forest definition, scale, scope approach etc. are being carried out. Planned mitigation in the Forestry sector. REDD+ is in the process of implementation and not mitigation reporting.	Few pages specific to Ethiopia Ethiopian REDD+ process.	The Ethiopian REDD+ process is framed in the CRGE strategy. REDD+ strategy contributes to the achievement of projected targets through management of forests and agriculture. At COP 16, it is agreed that developing countries who undertake REDD+ must develop a national forest monitoring system to monitor and report REDD+ activities. MRV is coordinate by the REDD+ secretariat.

Calling for Collaboration to Cope with Climate Change in Ethiopia: Focus on Forestry	Forestry		Reforestation was emphasized as mitigation option. Reforestation approaches in Ethiopia are through 1. Area enclosure, 2. Plantation and 3. Improved stoves and renewable energy developments (indirect).	Only focused on one aspect of mitigation option	Highlights the importance of identifying climate change coping strategies through reforestation. Impact of deforestation on livelihood and food security of the local communities and environmental services are explained. Presents potential collaborations in reforestation by sectors: Government, research and education, and business and industry and lists Ethiopian collaboration partners by sector.
Carbon stock of the various carbon pools in Gerba-Dima moist Afromontane forest, South-western Ethiopia	Forestry		The mean above ground carbon stock in the study site was 243.85 ± 17.27 Mg /ha. The mean below ground carbon stock estimated was 45.97 ± 3.46 Mg/ha. Mean total carbon stock of litter was 0.026 ± 0.005 Mg /ha. Mean carbon stock of herb layer was 0.007 ± 0.0004 Mg /ha. The mean non-tree woody species (with DBH < 5 cm) carbon stock was 0.12 ± 0.01 Mg /ha. The mean standing dead wood carbon stock was 1.83 ± 0.55 Mg /ha. The mean lying dead wood C stock in the study area was 2.81 ± 0.35 Mg/ha. The mean soil carbon stock (0-30cm) was 162.62 ± 3.20 Mg /ha. The total carbon stock in the forest system (508.9 Mg/ha) may suggest the benefit of conserving such a forest for mitigating climate change besides preserving the biodiversity.	Allometric equations are not country specific	The mean carbon stock in all carbon pool of the study site was higher than the average value of tropical forests. The AGBC and BGBC in Gerba-Dima forest were higher than values reported by IPCC for tropical forests. The mean SOC of Gerba Dima forest was higher than mean SOC of Tropical & Subtropical Moist Broadleaf forests.

The Carbon Footprint of the Agricultural Growth Project (AGP) in Ethiopia An application of the EX-Ante Carbon-balance Tool (EX-ACT)	Agriculture, Grassland		This document presents and discusses the EX-Ante Carbon Balance Tool (EX-ACT) analysis performed on the Agricultural Growth Project (AGP) in Ethiopia. The project expected to sequester 8.3 $MtCO_2e$ while emitting 2.4 $MtCO_2e$ so that the net effect of project activities is to create a sink of 5.9 $MtCO_2e$, which corresponds to a mitigation potential of 1.1 tCO_2e/ha per year. Mitigation potential is linked to the changes in the management of annual cropland and grasslands (improved agronomic practices, soil and water conservation) and to the "avoided" expansion of annual cropland on grasslands. Most GHG emissions are determined by the increase in input use associated with the scaling up of the best practices on cropland. The analysis also showed that most of the project's mitigation potential is determined by the adoption of soil and water conservation measures.	Considers in the without project scenario that agriculture expands at the expense of grassland only.	Emissions considered in i**nstitutional strengthening and development**: 1.related to transportation considering the number of meeting and training sessions was considered. 2. Related to buildings and rehabilitation of buildings 3. The expected effect of the adoption of the best practices. The potential for expansion of sustainable land management practices on annual cropland around 2.5 million ha Adoption only by 50%. 4. Increase in planting material/seed/breed multiplication promoted by the project 5. Promotion of the adoption of best practices on grasslands 6. The increase in the use of chemicals which the implementation of best practices. **Market and agribusiness development** i. fuel for meetings, training and other activities 2. The GHG emissions related to the upgrade of livestock breeding facilities. **Small-scale Agricultural Water Development and Management**. In Small-scale Agricultural Water Development and Management. 1. Implementation of soil and water conservation practices was considered in the "grasslands" module. 2. The GHG emissions related to the training activities. **Small-scale Market Infrastructure Development and Managemen**t. 1. The GHG emissions related to road development. 2. the GHG emissions related to the training activities
Greenhouse gas emissions from Ethiopia			Ethiopia's emissions grew by 86% between 1993 and 2011. Ethiopia has the potential to mitigate an estimated 2.76 billion tons of carbon through protection and sustainable management of forest resources. Ethiopia pledges to cap its 2030 GHG emissions at 145 $MtCO_2e$, which equates to a 64% (255 $MtCO_2e$) reduction from projected business as usual emission levels in 2030. The reduction includes 90 $MtCO_2e$ from agriculture, 130 $MtCO_2e$ from forestry, and the rest from industry, transport, and buildings.		Ethiopia's agriculture sector is characterized by subsistence-oriented, low input/low output farming with over 90% of cultivated land dependent on rain. The majority of the sector consists of smallholder farmers with less than two hectares of land (even as low as 0.2 ha).

National REDD+ Consultation and Participation Plan	Forestry		**Country's experience in C mitigation projects**: I. The Bale Mountains Eco-Region REDD+ Project in Oromia Regional State was identified as the first national REDD+ pilot project at sub-national level. II. The Oromia Forested Landscape Programme recognized as a national REDD+ pilot project. This programme is believed to promote cross-sectoral initiatives in the area of participatory forest management (PFM), climate smart agriculture, livestock improvement and biomass energy to contribute to reducing poverty and address issues of deforestation and forest degradation within the framework of the national REDD+ strategy. III. Humbo and Soddo Afforestation/Reforestation CDM Projects in SNNPR. IV. NonoSele Participatory Forest Management REDD+ Project, and V. Yayu Coffee Forest REDD+ Project.		The national REDD+ programme is funded through the World Bank Forest Carbon Partnership Facility (FCPF) Readiness Fund as a participant country of the FCPF.
Carbon stock potentials of woodlands in north western lowlands of Ethiopia	Forestry		Boswellia Papyrifera Woodland at 3 sites Adi Goshu (Tigray), Lemlem Terara (Amhara) and Gemed (Benishangul), the mean carbon stocks of the aboveground was 16.71 -19.29, 26.59 - 27.91 and 25.87 Mg/ha, respectively. The mean belowground carbon stock was 4.18 - 4.82, 6.65 - 6.98 and 6.47 Mg/ha, respectively. The mean dead wood carbon stock was 0.48 to 2.89, 0.40 to 2.79 and 0.8 Mg/ha, respectively. The mean herb biomass carbon was 0.28 to 0.45, 0.26 to 0.42 and 1.19 Mg/ha, respectively. The mean soil organic carbon stock (0-30 cm soil depth) was 33.61 to 38.48, 34.25 to 58.19 and about 38 Mg/ha, respectively. The total carbon stock in the different carbon tools was 55.26- 65.93, 68.77-96.74 and 71.01, respectively.	Allometric equations are not country specific	The total carbon stock density in these sites was high and ranges from 55.26 to 96.74 Mg/ha, therefore it appears that they can offer a relatively low-cost approach to sequestering carbon. Range of values were shown because they have tapped for resins and untapped treatments for the first two sites.

Biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment, Ethiopia	Agroforestry		In three types of indigenous agroforestry systems: Enset, Enset-coffee and Fruit-Coffee. These systems were not significantly different from each other. Agroforestry systems mean aboveground biomass (trees, coffee, enset, herbs, and litter) C stock ranged from 16 to 93 Mg/ha among the smallholdings. The total belowground biomass (tree and coffee stumps and coarse roots, enset corms and attached proximal roots, and fine roots) C stock ranged from5 to 29 Mg/ha. In these systems total biomass C stocks ranged between 22 and 122 Mg/ha. The soil organic C stocks for the systems within 0–60 cm layer ranged between 109 and 253 Mg/ha. The total ecosystem C stocks (sum of total biomass C and SOC in 0–60 cm soil depth) ranged from 173 to 375 Mg/ha.	Below ground biomass C is based on global estimate	It was suggested that these agroforestry systems sequester considerably more C than forest ecosystems generally do in the tropics. It was indicated that smallholdings have the prospect of C trading and payments through the implementation of payment for environmental services and REDD+ programs for maintaining these agroforestry systems. In the conclusion, it was indicated that smallholding C stocks are more dependent on the practices of individual than on the agroforestry systems as such.
Changes in Carbon Stocks and Sequestration Potential under Native Forest and Adjacent Land use Systems at Gera, South-Western Ethiopia	Forestry, Agroforestry, Crop land		Biomass carbon (aboveground plus below-ground) in the native forest, coffee based agroforestry and cropland was 134.3, 58.3, and 0.04 Mg/ha, respectively. SOC in 0-30 cm soil depth in native forest, coffee based agroforestry and cropland was 95.5, 92.5, 65.2 Mg/ha, respectively. While the total C (Biomass C plus SOC in 0-30 cm soil depth) in native forest, coffee based agroforestry and cropland was 230.1, 150.7, 65.4 Mg/ha, respectively. The difference between the native forest as well as coffee based agroforestry and cropland may demonstrate the potential native forest and the agroforestry system for C sequestration.	Allometric equations are not country specific and below ground biomass C is based on global estimate	In this study, native forest had higher biomass C than coffee-based agroforestry, but the native forest and coffee-based agroforestry did not differ in soil organic C (SOC). The difference in total C between native forest and coffee based agroforestry was due to the difference in biomass C. The difference of both native forest and coffee based agroforestry from cropland was because of the difference in biomass and soil organic C.

Carbon sequestration potentials of semi-arid rangelands under traditional management practices in Borana, Southern Ethiopia	Rangeland		Rangeland types considered in this study area. a. communal grazing areas b. grazing enclosure (enclosed for 20 years for dry season grazing) and c. rangelands managed by prescribed fire. Total carbon stocks (aboveground, belowground and soil organic C) was higher in grazing enclosure (300.4 Mg C /ha) than in both rangelands managed by prescribed fire (184.9 Mg C /ha) and communally owned grazing areas (141.5 Mg C /ha). The SOC was 127.9, 237.4 and 172.7 Mg C/ha for communal, enclosure and prescribed burning grazing managements, respectively. Aboveground biomass C was 13.1, 61.5 and 10.5 Mg C/ha for communal, enclosure and prescribed burning grazing managements while root biomass was 0.53, 1.53 and 1.75 Mg C/ha for communal, enclosure and prescribed burning grazing management. The high mitigation potential of the rangelands was in soil. The soil carbon sequestration potentials of grazing enclosures could be greater or equal to that of forestlands.	Allometric equations are not country specific	The difference in biomass C was due to the difference in tree and shrub density in the rangeland management. Higher tree and shrub densities were found in grazing enclosures as compared with other rangeland management practices. Lowest tree carbon stocks in the prescribed fire managed rangeland. The rangeland's potential to the mitigation of global warming can enable pastoralists to benefit from carbon credit trading system and improve their livelihoods.

Biodiversity and carbon storage co-benefits of coffee agroforestry across a gradient of increasing management intensity in the SW Ethiopian highlands	Forestry, Agroforestry		Four coffee production management systems: natural forest, semi-forest, semi plantation and shade plantation were assessed for their carbon sequestration potential. The total carbon stocks in the natural forest system was 413 Mg /ha), while in the semi-forest system (387 Mg /ha), semi-plantation (258 Mg /ha) and plantation system (219 Mg/ ha). For the average biomass carbon stocks, overall differences were large between the management systems. Significantly higher biomass carbon was found in the natural forest and semi-forest system than the semi-plantation and plantation system. The highest SOC stock (0-30 cm depth) was found in plantations, being significantly higher than the natural forest, semi-forest and semi-plantation management systems. The study showed that decreasing carbon stocks across the management gradient co-occurred with decreasing woody plant richness (biodiversity). Overall, coffee agroforestry has great potential for carbon storage as long as the large, late-successional and high wood density trees are preserved.	Allometric equations are not country specific	Authors suggest that C payment mechanisms such as REDD+ are required to keep these extensive coffee agroforestry systems considering the coffee yield loss with associated management intensification and associated carbon and biodiversity losses.
Biomass and soil carbon stocks in different forest types, Northwestern Ethiopia	Forestry		Compared the total C in three types of forests namely: a natural forest, exclosure and Eucalyptus plantation. The total mean carbon stock for exclosure was 131.6 ± 45.5 t/ ha, for plantation 160.1 ± 35.8 t /ha and for natural forest 195.3 ± 58.3 t /ha. The estimated mean aboveground biomass carbon stock for Natural forest was 8.3 t /ha, for plantation forest 11.9 t /ha and for exclosure forest 5.9 t /ha. The soil carbon stock in natural forest was 181.6 t /ha), in plantation forest 142.5 t /ha and in exclosure forest 123.2 t /ha.	Allometric equations are not country specific	

Climate Change Technology Needs Assessment Report of Ethiopia	All sectors including AFOLU		Technologies suggested for climate change mitigation. ***Agriculture sector***: reducing livestock numbers, increasing the efficiency of animal production, genetic improvement; antimethanogenic feed additives, immunization (vaccination), manipulation of the rumen microbial ecosystem and manipulation of farm management. ***Land use and Forestry sector***: management of existing forests, forest cover expansion and usage of wood fuels as a substitute for fossil fuels.	Technology options are very general	Five sectors were identified as major sources contributing to GHG emissions in Ethiopia. Energy, Agriculture, Land use and Forestry, Industrial process, and waste sectors. Technology options for each sector were identified.

Appendix III. Distributed Survey

Ethiopia 2019 Nationwide Land Use Survey

Start of Block: Default Question Block

Q1 The following survey is being conducted by researchers at Colorado State University to help develop a framework to prioritize greenhouse gas mitigation projects in Ethiopia and identify areas that are eligible for support from the United States of America. Specifically, we want to learn more about the types of land use practices used by people in the region(s) you are familiar with, and the factors that drive people to use these practices. This survey is completely anonymous. Your identity will not be associated with your responses in any way.

Your response to this survey is highly valued and appreciated. We will provide a report summarizing the survey responses for all those who respond. This will provide a country-wide perspective of the socio-economic factors that drive greenhouse gas (GHG) emission and mitigation activities.

Please answer all of the questions below as far as possible. Please complete all the sections based on the land use related to your work and understanding. If you do not know an answer or are unsure, please leave the questions blank.

If you have any questions, or require clarification on a question, please contact Nicholas.Young@Colostate.edu
The survey is in three sections: Demographics, Drivers and Land use categories.

Q2 Please select the regional states where you currently work.

- ☐ Tigray
- ☐ Afar
- ☐ Amhara
- ☐ Oromia
- ☐ Somali
- ☐ Benishangul-Gumuz
- ☐ SNNP (State of Southern Nations, Nationalities and Peoples
- ☐ Harari
- ☐ Gambella
- ☐ Addis Ababa
- ☐ Diredawa

Q3 What is your gender?

- ○ Male
- ○ Female
- ○ Prefer not to say.

Q4 Please list the region, zone, Woreda, Kebele where you work.

____

____

____

____

____

Q5 Please select the level of government at which you do the majority of your work.

- ○ Federal or National
- ○ Regional State
- ○ Zone
- ○ Woreda
- ○ Kebele
- ○ Other (Please Specify) ____

Q6 Please select the land use types listed below that affect the work you do. If there are other major land use types that affect your work, please provide them as well.

- ☐ Cropland (annual and perennial crops)
- ☐ Grasslands (Pastoralism and Livestock Management)
- ☐ Forestry and Forest Products
- ☐ Agroforestry, i.e. agricultural operations that include tree cultivation.
- ☐ Settlements
- ☐ Wetlands
- ☐ Other ____

Q7 **SECTION 2, DRIVERS of land use and management: Questions for all Federal, Regional and Local participants.** The following section of the survey examines the *drivers* that lead to the uptake of different land use and management practices. These are the indirect drivers of system change. They may be biophysical, socio-economic or institutional in nature. They are the underlying explanations for the adoption of a particular management practice or perhaps the non-adoption of a practice that is being promoted in an area.

In the next questions, you will be presented with prompts relating to drivers that have already been identified as having a potential role in land management decision-making. Please answer with as much detail as you can by selecting the statement that applies best to the areas where you work.

Q8 **Population Pressure**

High population pressures may trigger or enhance degradation, e.g. by increasing pressure on resources or ecosystem services. Low population pressure, or declines, may also lead to degradation through lack of labour to manage resources.

- ☐ Population Pressure is a predominant and crucial factor in increasing the adoption of land management practices.
- ☐ Population Pressure is an important factor in increasing the adoption of land management practices.
- ☐ Population Pressure is a factor in increasing the adoption of land management practices.
- ☐ Population Pressure has mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption
- ☐ Population Pressure is a constraint to the adoption of land management practices.
- ☐ Population Pressure is an important constraint to the adoption of land management practices.
- ☐ Population Pressure is a predominant and critical constraint to the adoption of land management practices.

Q9 **Affluence Pressure**

Change in consumption patterns and individual demands of the population or in the individual demand for natural resources (e.g. for agricultural goods, water, land resources, etc.).

- ○ Affluence is a predominant and crucial factor in increasing the adoption of land management practices.
- ○ Affluence is an important factor in increasing the adoption of land management practices.
- ○ Affluence is a factor in increasing the adoption of land management practices.
- ○ Affluence has mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption
- ○ Affluence is a constraint to the adoption of land management practices.
- ○ Affluence is an important constraint to the adoption of land management practices.
- ○ Affluence is a predominant and critical constraint to the adoption of land management practices.

Q10 **Land Tenure Pressure** *Poorly defined tenure security / access rights may lead to land degradation, as land-users are reluctant to invest in management when returns are not guaranteed.*

○ Holding Land Certificates is a predominant and crucial factor in increasing the adoption of land management practices.

○ Holding Land Certificates is an important factor in increasing the adoption of land management practices.

○ Holding Land Certificates is a factor in increasing the adoption of land management practices.

○ Holding Land Certificates has mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption

○ Holding Land Certificates is a constraint to the adoption of land management practices.

○ Holding Land Certificates is an important constraint to the adoption of land management practices.

○ Holding Land Certificates is a predominant and critical constraint to the adoption of land management practices.

Q11 **Land Availability Pressure** *Fragmentation of land into uneconomical units. Potential loss of crop land by conservation technologies involving construction (e.g. hedges, trash lines,* *trenches, terraces) could lead to an overall decrease in yield even with benefits of the conservation technology*.

- ◯ Land availability is a predominant and crucial factor in increasing the adoption of land management practices.
- ◯ Land availability is an important factor in increasing the adoption of land management practices.
- ◯ Land availability is a factor in increasing the adoption of land management practices.
- ◯ Land availability has mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption
- ◯ Land availability is a constraint to the adoption of land management practices.
- ◯ Land availability is an important constraint to the adoption of land management practices.
- ◯ Land availability is a predominant and critical constraint to the adoption of land management practices.

Q12 **Poverty Pressure** *Limits land-user investment and choice. Poor people often make short term investment decisions, ruling out some sustainable land management practices that require too much land, labour or* *capital investment. However poor farmers are almost wholly dependent on their land and might invest more than the rich.*

- ○ Poverty is a predominant and crucial factor in increasing the adoption of land management practices.
- ○ Poverty is an important factor in increasing the adoption of land management practices.
- ○ Poverty is a factor in increasing the adoption of land management practices.
- ○ Poverty has mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption
- ○ Poverty is a constraint to the adoption of land management practices.
- ○ Poverty is an important constraint to the adoption of land management practices.
- ○ Poverty is a predominant and critical constraint to the adoption of land management practices.

Q13 **Labor Availability Pressure** *Shortage of rural labour (e.g. through migration, prevalence of diseases, out migration) can lead to abandonment of traditional resource conservation practices such as terrace maintenance. May also alleviate pressure on land resources*.

- ○ Labor availability is a predominant and crucial factor in increasing the adoption of land management practices.
- ○ Labor availability is an important factor in increasing the adoption of land management practices.
- ○ Labor availability is a factor in increasing the adoption of land management practices.
- ○ Labor availability has mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption
- ○ Labor availability is a constraint to the adoption of land management practices.
- ○ Labor availability is an important constraint to the adoption of land management practices.
- ○ Labor availability is a predominant and critical constraint to the adoption of land management practices.

Q14 **Inputs and Infrastructure Pressure** *Inaccessibility to roads, markets, distribution of water points etc., or high prices for key agricultural inputs such as fertilizers. Quality of infrastructure will affect access to input and product markets*.

- ◯ Inputs and infrastructure are a predominant and crucial factor in increasing the adoption of land management practices.
- ◯ Inputs and infrastructure are an important factor in increasing the adoption of land management practices.
- ◯ Inputs and infrastructure are a factor in increasing the adoption of land management practices.
- ◯ Inputs and infrastructure have mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption.
- ◯ Inputs and infrastructure are a constraint to the adoption of land management practices.
- ◯ Inputs and infrastructure are an important constraint to the adoption of land management practices.
- ◯ Inputs and infrastructure are a predominant and critical constraint to the adoption of land management practices.

Q15 **Education, Access to Knowledge and Support Services Pressure** *Educated land users are less likely to be poor and more likely to adopt new technologies. Land users with education* *often have higher returns from their land. Education can also provide off-farm labour opportunities.*

○ Education, access to knowledge and support services are predominant and crucial factors in increasing the adoption of land management practices.

○ Education, access to knowledge and support services are important factors in increasing the adoption of land management practices.

○ Education, access to knowledge and support services are a factor in increasing the adoption of land management practices.

○ Education, access to knowledge and support services have mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on
adoption

○ Education, access to knowledge and support services are a constraint to the adoption of land management practices.

○ Education, access to knowledge and support services are an important constraint to the adoption of land management practices.

○ Education, access to knowledge and support services are a predominant and critical constraint to the adoption of land management practices.

Q16 **War and Conflict Pressure** *War and conflict lead to reduced options for using the land and reluctance to invest.*

- ○ War and conflict are a predominant and crucial factor in increasing the adoption of land management practices.
- ○ War and conflict are an important factor in increasing the adoption of land management practices.
- ○ War and conflict are a factor in increasing the adoption of land management practices.
- ○ War and conflict have mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption
- ○ War and conflict are a constraint to the adoption of land management practices.
- ○ War and conflict are an important constraint to the adoption of land management practices.
- ○ War and conflict are a predominant and critical constraint to the adoption of land management practices.

Q17 **Formal Institutions Pressure** Formal laws, policies controlling access and use of land resources. Government induced interventions.

- ○ Formal institutions are a predominant and crucial factor in increasing the adoption of land management practices.
- ○ Formal institutions are an important factor in increasing the adoption of land management practices.
- ○ Formal institutions are a factor in increasing the adoption of land management practices.
- ○ Formal institutions have mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption.
- ○ Formal institutions are a constraint to the adoption of land management practices.
- ○ Formal institutions are an important constraint to the adoption of land management practices.
- ○ Formal institutions are a predominant and critical constraint to the adoption of land management practices.

Q18 **Informal Institutions Pressure** *Local rules and regulations, social and cultural arrangements and obligations affecting access to resources.*

- ◯ Informal institutions are a predominant and crucial factor in increasing the adoption of land management practices.
- ◯ Informal institutions are an important factor in increasing the adoption of land management practices.
- ◯ Informal institutions are a factor in increasing the adoption of land management practices.
- ◯ Informal institutions have mixed effects on the adoption of land management practices, increasing and decreasing adoption with no clear net effect on adoption
- ◯ Informal institutions are a constraint to the adoption of land management practices.
- ◯ Informal institutions are an important constraint to the adoption of land management practices.
- ◯ Informal institutions are a predominant and critical constraint to the adoption of land management practices.

Q19 What is the importance of each of the following land use practices in your region, in economic terms? If other land use practices are important in your area, use the "Other" option to write in a response.

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Forestry and Forest Products	○	○	○	○	○
Agroforestry, i.e. agricultural operations that include tree cultivation.	○	○	○	○	○
Farming and Agriculture	○	○	○	○	○
Pastoralism and Livestock Management	○	○	○	○	○
Urban Development	○	○	○	○	○
Other	○	○	○	○	○

Q20 What is the importance of each of the following land use practices in your region, in ***terms of land area used***? In the boxes below, approximate the percent of land used in your region for each purpose.

Forestry : ________

Agroforestry, i.e. agricultural operations that include tree cultivation. : ________

Agriculture : ________

Livestock : ________

Urban Development : ________

Other : ________

Total : ________

Q21 What is the importance of each of the following land use practices in your region, in terms of importance for local livelihoods and cultural practices?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Forestry	○	○	○	○	○
Agroforestry, i.e. agricultural operations that include tree cultivation.	○	○	○	○	○
Agriculture	○	○	○	○	○
Urban Development	○	○	○	○	○
Livestock Management	○	○	○	○	○
Other	○	○	○	○	○

Q22 Please explain your response to the previous question. Why are the various land uses chosen important to livelihoods and cultural life in your area?

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Q23 What locations within the area where you work do you see as having the most opportunities for new land management projects?

Q24 Listed below are several practices or process related to **agriculture and farming** with different implications for greenhouse gas emissions. **Please select the degree to which the practices listed take place as part of farming in your region.**

	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Crop residues are retained in fields following harvest.	○	○	○	○	○	○
Crop residues are removed from the field following harvest.	○	○	○	○	○	○
Crop residues are grazed by livestock following harvest.	○	○	○	○	○	○
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Crop residues are burned following harvest.	○	○	○	○	○	○
Irrigation is used.	○	○	○	○	○	○
Full tillage practices are used.	○	○	○	○	○	○
Soils are not tilled.	○	○	○	○	○	○
Reduced tillage is used.	○	○	○	○	○	○
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.

Crops are fertilized using synthetic Nitrogen fertilizer.	○	○	○	○	○	○
Cover crops are used in non-harvest seasons.	○	○	○	○	○	○
Improved crop varieties are implemented.	○	○	○	○	○	○
Fields are fallowed on a rotating basis.	○	○	○	○	○	○
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Crops are fertilized using organic fertilizers such as manure or compost.	○	○	○	○	○	○
Green manures and other cover crops are integrated into crop rotations.	○	○	○	○	○	○
Crushed lime or dolomitic lime is used to amend soil acidity.	○	○	○	○	○	○

	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Legumes (beans, lentils, and peanuts and similar species) are part of the crop rotation.	○	○	○	○	○	○
Soils are drained as part of field preparation.	○	○	○	○	○	○
Agroforesty is utilized, with trees integrated into cropping systems and land management by farmers.	○	○	○	○	○	○

Q25 Listed below are several practices or process related to **livestock management, grazing, and pastoralism** with different implications for greenhouse gas emissions. **Please select the degree to which the practices listed take place as part of livestock grazing in your region.**

	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Legumes are seeded on grasslands grazed by livestock.	○	○	○	○	○	○
Organic fertilizers, such as manure or compost, are added fields grazed by livestock.	○	○	○	○	○	○
Synthetic fertilizers are added to fields grazed by livestock.	○	○	○	○	○	○
Irrigation is used to grow livestock forage.	○	○	○	○	○	○
Irrigation features such as stock tanks, wells, or ponds are used to provide livestock with water.	○	○	○	○	○	○
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.

	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Grasslands are drained for livestock grazing purposes.	○	○	○	○	○	○
Grazing pastures are amended with lime to adjust soil acidity.	○	○	○	○	○	○
Silvopasture techniques are utilized, with the intentional planting of trees and forest plants in grazing areas.	○	○	○	○	○	○
Forests are burned to clear land for grazing areas.	○	○	○	○	○	○
Forests are cleared for grazing areas using labor and equipment	○	○	○	○	○	○
Improved cattle varieties are utilized.	○	○	○	○	○	○

	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Improved grass or other forage species are utilized and seeded.	○	○	○	○	○	○
Lands are degraded due to overgrazing.	○	○	○	○	○	○
Rangelands, grasslands, and pastures are actively restored by community members following degradation.	○	○	○	○	○	○
Manure from livestock is stored in lagoons.	○	○	○	○	○	○
Manure is burned as fuel or for disposal.	○	○	○	○	○	○

Manure is left in grazing pastures and grasslands.	○	○	○	○	○	○
	Never	Sometimes	About half the time	Most of the time	Always	I don't know.

Q26 Are livestock populations in the areas where you work increasing or decreasing?

- ○ Decreasing rapidly
- ○ Decreasing
- ○ Decreasing slowly
- ○ Increasing in some areas and decreasing in others
- ○ Increasing slowly
- ○ Increasing
- ○ Increasing rapidly

Q27 Listed below are several practices or process related to **forest management and**

forestry with different implications for greenhouse gas emissions. **Please select the degree to which the practices listed take place as part of forest management in your region.**

	Never	Sometimes	About half the time	Most of the time	Always	I don't know.
Trees are actively planted.	○	○	○	○	○	○
Timber is harvested.	○	○	○	○	○	○
Wood is gathered for household or commercial fuel use.	○	○	○	○	○	○
Forests are actively cleared through felling and the use of machinery.	○	○	○	○	○	○
Forests are actively cleared through the use of burning.	○	○	○	○	○	○
Trees are planted as part of other land uses, such as silvopasture or agroforestry.	○	○	○	○	○	○

Q28 Are there areas within your region where grasslands, shrublands, pastures, or other land types are being converted to forest lands? (In other words, is ***afforestation*** taking place in your region?)

- ○ Yes
- ○ No
- ○ Don't Know

Q29 Are there areas within your region where lands that once possessed forests are being restored, either through human or natural processes? (In other words, is ***reforestation*** taking place in your region?)

- ○ Yes
- ○ No
- ○ Don't Know

Q30 Are wetlands, such as swamps, lagoons, marshes or other similar areas being actively **drained** as part of land use in your region?

- ○ Yes
- ○ No
- ○ Don't Know

Q31 Are any wetlands, such as swamps, lagoons, marshes or other similar areas being actively **restored** by communities, governments, or other organizations?

- ○ Yes
- ○ No
- ○ Don't Know

Q32 Based on the questions above, can you think of any important land use practices in your region that might impact the soil, plant matter abundance, or water supplies of the lands in your region? If so, please list and describe them in the box below.

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End of Block: Default Question Block

Appendix IV. Survey response summary of the most common degree of significance (Table 3) for 11 driving forces of land management practices for each region in Ethiopia (Table 4). Regions without data did not have an adequate number of responses.

Region	Population Pressure	Affluence	Holding Land Certificates	Land Availability	Poverty	Labor Availability	Inputs and Infrastructure	Education, Access to Knowledge and Support Services	War and Conflict	Formal Institutions	Informal Institutions
Addis Ababa	+++	+++	+++	+++ ++	+++	+++	+++	+++	-	+++	++ +++
Afar											
Amhara	+ --	+ -	+ +++	+++ ++	---	-- +++	-- +++	++ +++	- -	++ --	++ ---
Benishangul-Gumuz	+++ ---	+++ ---	+++ ---	+++ ---	---	+++ ---	---	---	- ---	+++ ---	---
Dire Dawa											
Gambela	+/- ++ ---	- +	+ --	+ ++ -	+ ++ -	+/- ++	+ --- +++	+++ ---	-- ---	++ --- -	-- +/-
Harari											
Oromia	+++ ---	+++	+++	+++	---	+++	+++	+++	---	++	+++
Somali											
SNNPR	+++	+++	+/- +++	+/-	---	+++	+++	+++	+/- - ---	+++	+++ ++
Tigray	+/- +++	++ +/- +++	+++ +	++ +++	--- +++	+ +++	++ +++	+++ + -	- +++ -- +/-	++ + +++	+ ++ +++
Multiple Locations	+/-	+/-	+++ + ++	- ++ +++	+++ ++ ---	++ +/- +++	+++	++ +++ +/-	++ - +++	+++	+

Appendix V. Economic and cultural land use important ranting as reported by survey respondents for each region in Ethiopia. Regions without data did not have an adequate number of responses.

Region	Economic Land Use Importance					Cultural Land Use Importance				
	Forestry	*Agroforestry*	*Farming and Agriculture*	*Livestock Management*	*Urban Development*	*Forestry*	*Agroforestry*	*Farming and Agriculture*	*Livestock Management*	*Urban Development*
Addis Ababa	Very	Moderately Extremely	Extremely	Very	Extremely	Extremely	Extremely	Extremely	Very	Extremely
Afar										
Amhara	Moderately Very Extremely	Moderately Very	Moderately Extremely	Slightly Very	Moderately	Slightly Very	Moderately Very	Moderately Very	Moderately Extremely	Moderately
Benishangul -Gumuz	Extremely	Slightly	Extremely	Very	Moderately	Extremely	Slightly	Extremely	Very	Moderately
Dire Dawa										
Gambela	Moderately Very Extremely	Very Extremely	Moderately Very	Extremely	Moderately Very	Slightly Moderately Very	Slightly Moderately	Slightly Moderately	Moderately Extremely	Moderately
Harari										
Oromia	Very	Very	Extremely	Moderately	Very	Moderately Very	Moderately	Extremely	Moderately	Slightly Moderately Very
Somali										
SNNPR	Very	Very	Extremely	Very	Moderately Extremely	Very Extremely	Very	Very Extremely	Very	Moderately
Tigray	Very	Very	Extremely	Moderately	Very	Very	Very	Extremely	Very	Moderately Very
Multiple Locations	Very	Moderately	Moderately	Very	Very	Very	Very	Very Extremely	Very	Moderately Extremely