Federal Democratic Republic of Ethiopia
Ministry of Environment, Forest and Climate Change

NATIONAL POTENTIAL AND PRIORITY MAPS FOR TREE-BASED LANDSCAPE RESTORATION IN ETHIOPIA

VERSION 0.0 | TECHNICAL REPORT

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ABBREVIATIONS

AFR100	African Forest Landscape Restoration Initiative
CBD	Convention on Biological Diversity
CCI	Clinton Climate Initiative
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
EEFRI	Ethiopian Environment and Forest Research Institute
EMA	Ethiopian Mapping Authority
FAO	Food and Agriculture Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
FEWSNET	Famine Early Warning Systems Network
GCP	Ground Control Point
GDP	Gross domestic product
GGGI	Global Green Growth Institute
GIZ	Gesellschaft für Internationale Zusammenarbeit (German agency for international cooperation)
GTP	Growth and Transformation Plan
ICPAC	IGAD Climate Prediction and Applications Centre
ICRAF	World Agro-Forestry Center
IGAD	Intergovernmental Authority on Development
INBAR	International Network for Bamboo and Rattan
IPC	Integrated Food Security Phase Classification
KBA	Key Biodiversity Area
MoANR	Ministry of Agriculture and Natural Resources
MEFCC	Ministry of Environment, Forest and Climate Change
MoWIE	Ministry of Water, Irrigation and Electricity
NDRMC	National Disaster Risk Management Commission
NFPA	National Forest Priority Area
OFWE	Oromia Forest and Wildlife Enterprise
PA	Protected Area
PSNP	Productive Safety Net Program
SNNP	Southern Nations, Nationalities, and Peoples' Regional State
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WCMC	World Conservation Monitoring Centre
WLRC	Water and Land Resource Center

FOREWORD

Our country has an ambitious, but achievable vision: By 2025, we want to substantially improve our people's standards of living by reaching middle-income status and simultaneously better manage our natural capital by transitioning to a green economy.

Much work has been done toward realizing these seemingly divergent goals, but much work and many challenges remain. Our country will have to harness our many human, economic, cultural, and natural assets in order to ensure success. Among our great natural assets are the diversity and productivity of our trees.

Our trees support our farmers by decreasing erosion and enriching the soil, and providing fodder, fruits, incense, and woodfuel. Our trees and forests recharge our groundwater and offer protection against flooding and landslides. Our woodlots and commercial plantations support innumerable jobs. Our forests slow down climate change and support biodiversity.

The importance of trees in achieving our economic and environmental goals cannot be overstated. Eighty-five percent of our country suffers from moderate to very serious land degradation. In the highlands, up to 3 percent of agricultural GDP is lost to soil erosion and nutrient loss. More than 4 million cubic meters of our growing economy's demand for industrial roundwood is unmet. Our unwavering commitment to increasing the number of trees in our landscapes and addressing these issues was reiterated when Ethiopia pledged to restore 22 million hectares of deforested and degraded lands by 2030.

My Ministry and the World Resources Institute worked closely with various sectors, inside and outside government, to map potential for tree-based landscape restoration. Together, we have identified landscapes with acute social and environmental problems where tree-based landscape restoration should be coordinated and integrated across sectors to ensure that it translates into commensurable improvements on the ground.

Now, for the first time, governmental and nongovernmental institutions have access to information about where they could increase the number of trees in our landscapes and where cross-sectoral coordination would have the greatest impact.

The maps we have produced, though important, are only a first step on the way toward greater restoration impacts. With support from data providers, we will refine these maps so that we can differentiate among potential for restocking degraded natural forest, agro-silvo-pastoralism, and buffer plantation around protected areas and water bodies. My Ministry is also committed to engage all interested stakeholders in defining an implementation strategy for tree-based landscape restoration, ensuring that the human, institutional, and financial resources are in place for a restoration movement to blossom.

Together, we can build more productive, resilient, and verdant landscapes in Ethiopia.

Gemedo Dalle (PhD)
Minister, Ministry of Environment,
Forest and Climate Change

EXECUTIVE SUMMARY

Ethiopia has devised a multipronged approach to becoming a middle-income country while mitigating and adapting to a changing climate. Increasing the number of trees in agricultural, pastoral, and forest landscapes features prominently in this approach. In its development blueprint, the Climate Resilient Green Economy Strategy, Ethiopia aims by 2030 to sustainably manage 4 million hectares of forest, afforest 2 million hectares, and reforest 1 million hectares. Ethiopia is also committed to contributing to the African Forest Landscape Restoration Initiative, the Bonn Challenge, and the New York Declaration on Forests by restoring 15 million hectares of degraded and deforested land within the same time frame.

Version 0.0 of the National Tree-Based Landscape Restoration Potential and Priority Maps presented in this report constitutes a first step in planning Ethiopia's large-scale, coordinated restoration efforts. The maps aim to guide decision-makers as to where more trees could benefit Ethiopian landscapes, which tree-based landscape restoration options could be implemented in these landscapes, and where to prioritize cross-sectoral implementation. The maps are the product of a cross-sectoral effort of national and regional experts led by the Ministry of Environment, Forest and Climate Change (MEFCC).

The potential maps show that there are many opportunities to increase the number of trees in Ethiopian landscapes: based on the criteria and data used in this work, a total of 82 million hectares was deemed as having potential for tree-based landscape restoration (Map A).

Ethiopia will need to overcome obstacles to reach its economic, social, and environmental goals and commitments. These barriers include forest degradation and deforestation, loss of soil fertility, overgrazing, soil erosion and sedimentation of water bodies, flooding and landslides, as well as climate change impacts, all of which can be addressed to various extents by an increase in trees.

National and regional experts mapped eight tree-based landscape restoration options seen as critical to overcoming these barriers:

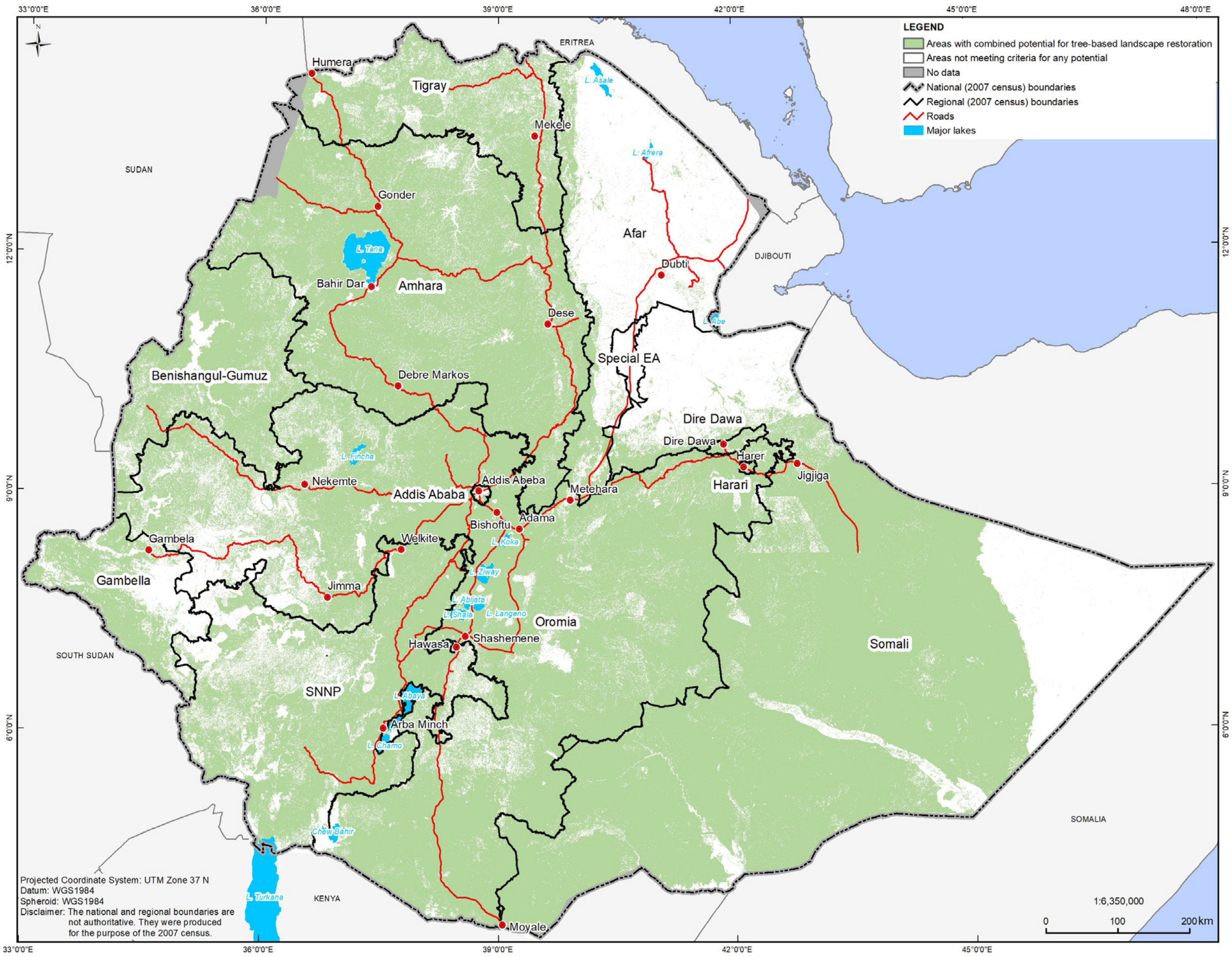
1. Restoration of secondary forests
2. Restocking of degraded natural forests
3. Agri-silviculture and agro-silvo-pastoralism
4. Silvo-pastoralism
5. Woodlots and home gardens
6. Commercial plantations for products other than industrial roundwood[1]
7. Buffer plantations around protected areas and national forest priority areas
8. Tree-based buffer zones along rivers, lakes, and reservoirs

The national tree-based landscape restoration potential maps,[2] presented in the technical report and accessible on Ethiopia's Tree-Based Landscape Restoration Atlas, will help stakeholders in the agricultural, forest, water, energy, and livestock sectors identify where trees can contribute to their objectives under the current Growth and Transformation Plan.

To facilitate coordination among sectors, the priority map for cross-sectoral implementation of tree-based landscape restoration helps identify areas facing a complex set of challenges. Meeting these challenges will require a cross-

1. This option complements the potential for industrial roundwood plantations mapped previously (World Bank Group 2016).
2. Appendix B highlights the limitations of version 0.0 of the national tree-based landscape restoration potential maps to depict potential on the ground for the individual restoration options in four woredas. The MEFCC is committed to improving and updating the maps over time. In future iterations of these maps, both potential for individual options and combined potential will reliably depict tree-based landscape restoration potential on the ground and will be made available in the technical report and on Ethiopia's Tree-Based Landscape Restoration Atlas.

Map A | Combined Potential for Tree-Based Landscape Restoration



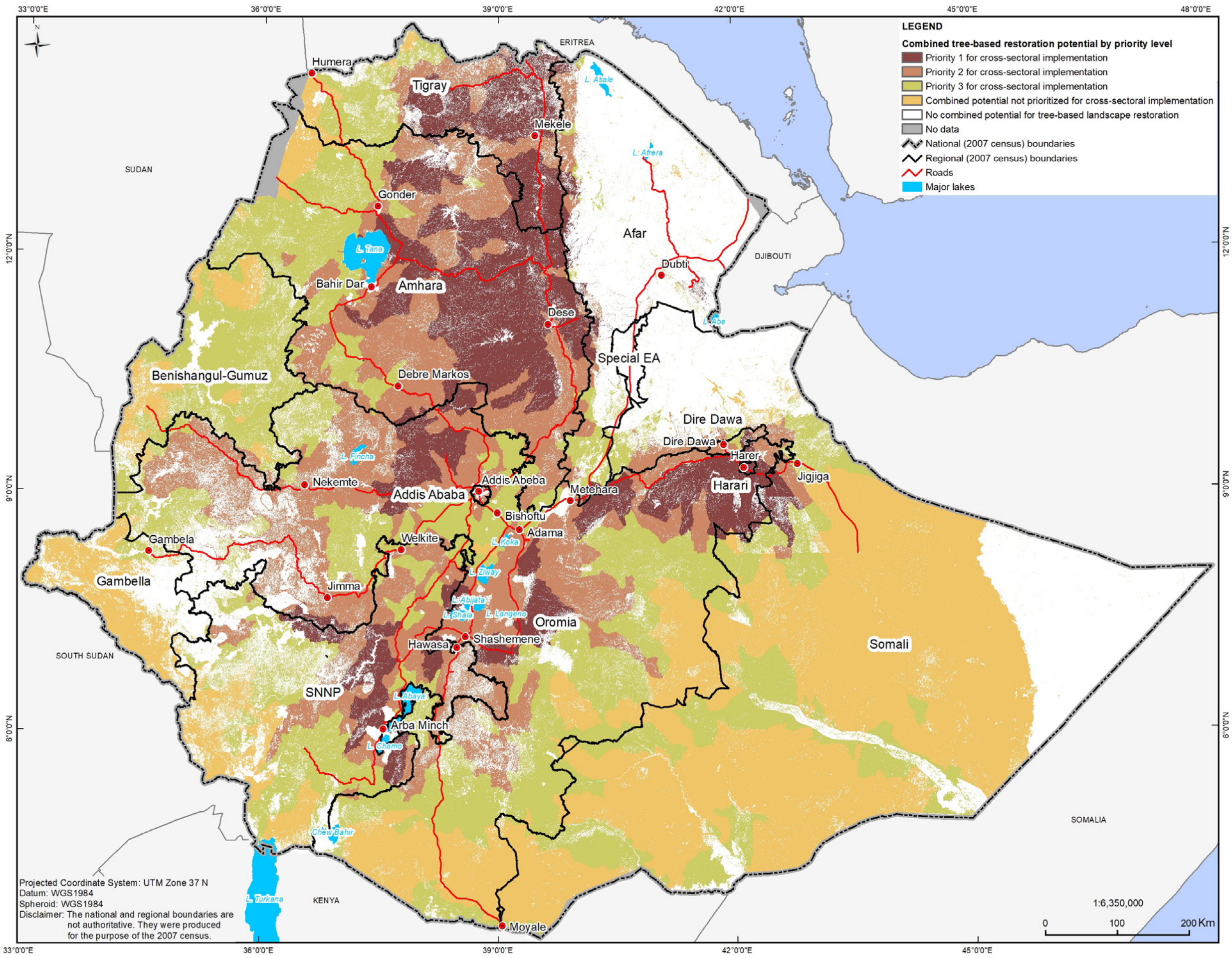
Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a.

sectoral approach to tree-based landscape restoration. Based on the prioritization criteria chosen by the experts, a total of 54 million hectares was prioritized for cross-sectoral implementation. Based on the urgency of cross-sectoral intervention, these landscapes can be further broken down into priority 1 (11 million ha), priority 2 (18 million ha), and priority 3 (25 million ha) (Map B).

The national maps were produced under the continual guidance of national and regional experts and are based on the best readily available national datasets. Nonetheless, they need to be strengthened with additional regional and local input before being used for implementation.

Given the diversity of livelihood strategies and landscapes across Ethiopia, the success of tree-based landscape restoration will depend on collaboration among many stakeholders. The MEFCC, which is committed to a collaborative approach to tree-based landscape restoration,

Map B | Combined Potential for Tree-Based Landscape Restoration According to Priority Level for Cross-Sectoral Implementation



Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a. Tree-based landscape restoration cross-sectoral priority landscapes: MEFCC 2018c.

plans to engage governmental institutions at all levels, nongovernmental entities, the public and private sectors, communities, and individual farmers, as well as development and financial partners, to develop and implement a tree-based landscape restoration implementation strategy.

The goal of this strategy is to create optimum conditions for individual and organized farmers, communities, companies, and governmental and nongovernmental institutions to achieve their long-term goals through tree-based landscape restoration.

INTRODUCTION

Ethiopia has set a high bar for itself and the world: In its development blueprint, the Climate Resilient Green Economy (CRGE) Strategy, it aims to achieve middle-income status by 2025 while transitioning to a climate-resilient green economy.

Protecting existing forest and tree-based landscape restoration are central to these goals as trees contribute not only directly to economic development and raising living standards, but also to climate change mitigation and adaptation.

The CRGE Strategy is organized around four pillars: agriculture; forestry; power; and transport, industrial sectors, and buildings. Tree-based landscape restoration contributes to the goals of the forestry pillar of "protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks" (FDRE 2010). The forest sector plans to increase forest cover through afforestation (2 million ha) and reforestation (1 million ha) and to improve forest management (2 million ha of high forests and 2 million ha of woodlands), which would both increase ecosystem services and the sector's economic contribution to the national Gross Domestic Product (GDP). The forest sector also supports the conservation and propagation of trees outside forests for their contributions to livelihoods, ecosystem services, and lessening the pressure on remaining forests.

Tree-based landscape restoration can also support the three other pillars identified to build a green economy (FDRE 2010):

- The agriculture pillar aims to improve "crop and livestock practices for higher food security and farmer income while reducing emissions." Agro-forestry—or trees in agricultural production systems—can help boost crop and livestock productivity by reducing soil erosion, improving soil fertility and soil moisture, and providing fodder for livestock feed. Fruit trees can also support income diversification.
- The power pillar aims to expand "renewable power generation for domestic and regional markets." Trees can help regulate water flow timing and quantity[3] and reduce sedimentation of water bodies, all of which influence hydropower generation. In addition, some tree species are major sources of biodiesel feedstock and promising sources of renewable energy (MME 2007).
- The transport, industrial sectors, and buildings pillar aims to "leapfrog to modern and energy-efficient technology in transport, industrial sectors and buildings." To meet the demands of its growing industrial economy, Ethiopia will need professionally managed plantations to sustainably increase its supply of forest products for construction, furniture, utility poles, pulp and paper, and so on (MEFCC 2017).

Particularly between 2016 and 2020, increasing the number of trees in Ethiopian landscapes can contribute to achieving objectives set in the second Growth and Transformation Plan (GTP II) including, but not limited to, increasing forest coverage and the ecological benefits of forests; enhancing crop productivity; improving biodiversity; developing the paper and paper products, rubber, and meat and dairy industries; increasing national capacity for the generation and production of electric power; rehabilitating and conserving water bodies; expanding urban greening and beautification; and reducing carbon emissions (FDRE 2016).

Increasing the number of trees in Ethiopia will also contribute to Ethiopia's international commitments. These include Ethiopia's commitments to the Sustainable Development Goals' objectives of ending poverty, promoting prosperity and well-being for all, protecting the environment, and addressing climate change; the Convention on Biological Diversity's pledge of restoring at least 15 percent of degraded ecosystems (CBD 2010); the United Nations Convention to Combat Desertification's ambition of achieving zero net land degradation (UNCCD 2012); the objective set forth by the United Nations Framework Convention on Climate Change (UNFCCC) of limiting net greenhouse gas emissions (FDRE 2015a); and the African (AFR100[4]) and global (Bonn Challenge[5] and New York Declaration on Forests[6]) restoration targets.

3. Whether trees can improve water availability through groundwater recharge, and the extent to which they do, depends on various factors such as rainfall intensity; soil type; tree spatial distribution; tree size, age, and species; and management practices (for example, pruning) (Ilstedt et al. 2016).
4. AFR100 is a country-led effort to bring 100 million hectares of land in Africa into restoration by 2030.
5. The Bonn Challenge is a global commitment to restore 150 million hectares of land around the world by 2020.
6. The New York Declaration on Forests calls for the restoration of more than 350 million hectares of forests and croplands by 2030.

While trees have played a significant role in many of Ethiopia's successful restoration initiatives, tree-based landscape restoration needs to be scaled up if Ethiopia is going to meet its ambitious goals.

No single governmental or nongovernmental institution can singlehandedly scale up tree-based landscape restoration in agricultural, pastoral, and forest landscapes as needed to regain ecological functionality and enhance standards of living across Ethiopia. Scaling up the restoration of degraded and deforested land will require that many state and nonstate actors act in concert.

In support of the restoration efforts in Ethiopia, the MEFCC, in collaboration with national and regional experts from various sectors, has been developing version 0.0 of the national tree-based landscape restoration potential maps to support national planning and coordination.

This report presents version 0.0 of the national potential maps and how they were developed. It also presents the accuracy assessment of these maps in four woredas, which highlight the limitations of the individual potential maps (in contrast to the combined potential map). The MEFCC is committed to improving and updating the potential maps over time. Future iterations of these maps will reliably depict potential for individual options on the ground.

National tree-based landscape restoration potential maps can help various state and nonstate actors identify where

- existing forests can be restocked to restore their role in biodiversity conservation, carbon sequestration and sustainable income generation;
- new natural forests can be established to generate economic benefits, prevent landslides and flooding, and increase carbon sequestration and biodiversity habitat;
- agro-forestry can be scaled up to reduce erosion and increase livelihood diversification, fodder production and/or soil fertility;
- trees can stabilize riverbanks and control sedimentation; and
- commercial plantations can be promoted to meet the domestic and international demand for industrial wood products and other tree products.

For example, the MEFCC and interested parties can use the potential map for restocking degraded natural forests, differentiated by land use-land cover, to identify where to improve forest management in 2 million ha of high forests and 2 million ha of woodlands in order to increase carbon sequestration through restocking. Similarly, the Ministry of Agriculture and Natural Resources and the Ministry of Livestock and Fisheries can use the potential maps for agri-silviculture and agro-silvo-pastoralism, silvo-pastoralism, and woodlots and home gardens to screen where to promote agro-forestry, which would contribute to the CRGE objective of "improving crop and livestock practices for higher food security and farmer income while reducing emissions."

In addition to the national potential maps, this report also presents version 0.0 of maps meant to inform the prioritization of landscapes for cross-sectoral implementation of tree-based landscape restoration for greater impact on the ground. For example, a coordinated implementation of tree-based landscape restoration interventions would see, in a same landscape, the Ministry of Agriculture and Natural Resources supporting implementation of agro-forestry in agricultural land; the Ministry of Livestock and Fisheries supporting implementation of silvo-pastoral systems; the Ministry of Environment, Forest and Climate Change supporting rehabilitation of degraded forestland and establishment of commercial plantations; and the Ministry of Water, Irrigation and Electricity supporting establishment of tree-based buffer zones along lakes, reservoirs, and rivers. Together, these interventions would boost the contribution of forest and tree products to people's income, increase food and wood security, improve habitat for wildlife, control erosion, and maximize hydropower production while sequestering carbon.

Current and future versions of the maps, available on Ethiopia's Tree-Based Landscape Restoration Atlas, can help provide a common vision regarding tree-based landscape restoration for the actors involved in achieving Ethiopia's domestic and international economic, social, and environmental commitments.

The responsibility for delivering on the ambitious Climate Resilient Green Economy lies with many actors, governmental and nongovernmental. The MEFCC hopes that this version and future iterations of the national maps, together with the 10-year National Forest Sector Development Program, will help provide a common vision regarding tree-based landscape restoration for all actors.

DEFINITIONS AND METHOD

Definitions

In the context of this work, national tree-based landscape restoration potential maps are defined as meeting the following criteria:

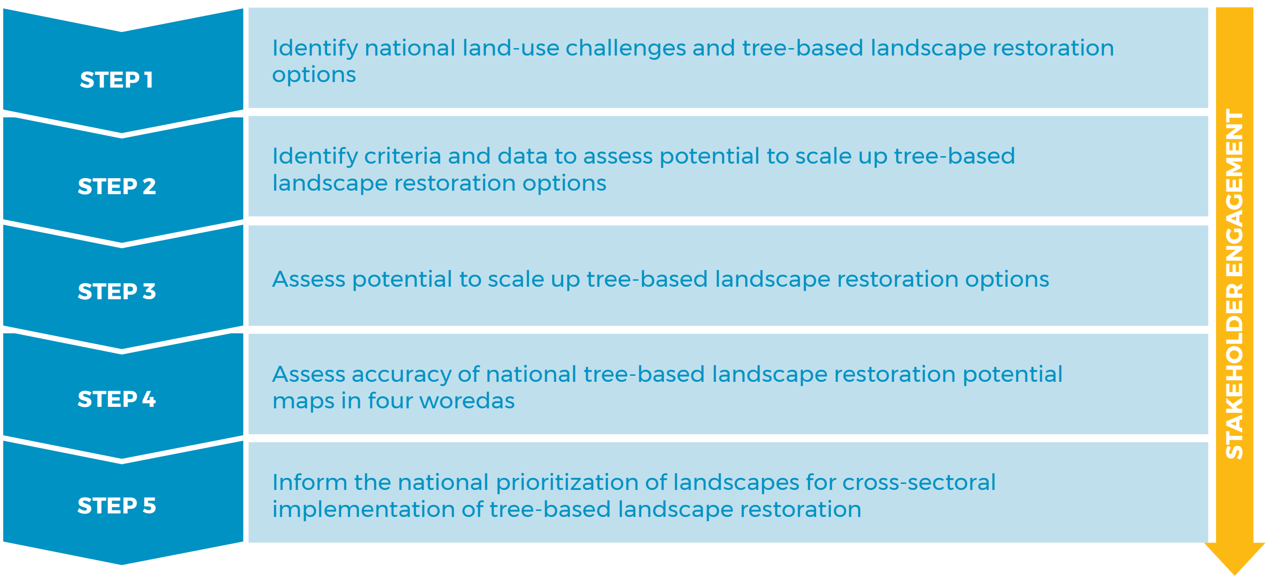
- **National:** Supporting national-level decision-making. While these maps are produced to support decision-making processes at the national level, they can be used at the regional level. Regions are encouraged to refine the maps based on their regional circumstances and priorities.
- **Tree-based:** Adding more trees in landscapes, which may or may not result in a forest.[7]
- **Landscape:** Constituting a social-ecological system that comprises a mosaic of natural and/or human-modified ecosystems and is delineated based on the restoration objectives (adapted from Buck and Bailey 2014).
- **Restoration:** Contributing to a long-term natural or human-mediated process of regaining a vegetation cover, and thereby ecological functions, and enhancing human well-being in degraded landscapes. This process may or may not bring the original vegetation back.
- **Potential:** Indicating where restoration potential criteria are met and therefore where a tree-based landscape restoration option could be implemented.

Method

Overall Process

The process of producing the national tree-based landscape restoration potential and priority maps followed six steps (Figure 1), which were adapted from the mapping module of the Restoration Opportunities Assessment Methodology (IUCN and WRI 2014).

Figure 1 | Steps to Produce the National Tree-Based Landscape Restoration Potential and Priority Maps



Source: Authors.

7. A forest is "a community of plants, either naturally grown or developed by planting and mainly consisting of trees and other plants having woody character" (FDRE 2007). Technically, forests in Ethiopia are of a minimum mapping unit of 0.5 hectares, minimum tree height of 2 m and minimum canopy cover of 20 percent (MEF 2015).

Box 1 shows how the principles behind tree-based landscape restoration align with and complement those of the Community-Based Participatory Watershed Management.

While the steps are presented in a linear fashion, they were revisited in response to additional stakeholder input, new knowledge and/or new data.

Box 1 | How Tree-Based Landscape Restoration Complements Participatory Watershed Management

The integrated approach promoted by tree-based landscape restoration aligns with the principles of the Community-Based Participatory Watershed Management principles, which are widely used in Ethiopia and for which detailed guidance is available (Lakew et al. 2005), in that tree-based landscape restoration

- focuses on landscapes in identifying restoration options, optimizing the use of a specific piece of land in the context of the landscape to which it belongs;
- requires involving all stakeholders to identify restoration goals, choose implementation methods, and assess trade-offs in terms of costs and benefits;
- aims to restore multiple benefits, striving to increase both ecological integrity and human well-being within landscapes;
- leverages a suite of implementation strategies that have proven successful and tailors them to local conditions; and
- promotes adaptive management that emphasizes iterative learning and midcourse adjustments and helps ensure that restoration goals are achieved (adapted from IUCN and WRI 2014).

While following these five principles, the tree-based landscape restoration approach complements Participatory Watershed Management in cases where the following conditions prevail:

- Landscapes do not follow watershed boundaries. For example, Ethiopia' Nationally Determined Contributions identify the creation of biodiversity movement corridors as a way to adapt to climate change (FDRE 2015a). The creation of such corridors will have to follow the habitat range of the target species, and some might cross multiple watersheds.
- The focus of the Participatory Watershed Development interventions has been on physical measures (for example, terracing) and/or tree-based biological measures circumscribed to area exclosure of hillsides. Building on these measures, tree-based landscape restoration can bring more trees in and outside forestland through agro-forestry, home gardens, woodlots, tree-based buffer zones along water bodies, or commercial plantations.

In situations where a participatory watershed management plan is already initiated, the tree-based landscape restoration approach can be used to ensure that the following statements are true:

1. The watershed boundaries make sense in terms of achieving all economic, social, and environmental goals of the tree-based landscape restoration intervention.
2. Trees, either being mixed with crop and livestock land uses or as commercial and conservation forests, have been duly considered to achieve these goals.

Stakeholder Engagement

Stakeholder engagement was fundamental to the process of developing the national tree-based landscape restoration potential and priority maps. A series of consultation workshops took place (see Appendix A for the list of participants), each providing invaluable expert input and access to data:

- A consultation workshop, held in September 2014 in Addis Ababa with national and regional experts, worked on the following topics:
  - National land-use challenges
  - National tree-based landscape restoration options to address these land-use challenges
  - Preliminary criteria to be used for mapping potential for these restoration options
- Consultation workshops were held in June 2015 in Tigray; Amhara; Oromia; and Southern Nations, Nationalities, and Peoples' National Regional States.[8] Regional experts reviewed the draft maps and the data and criteria that informed them.
- A consultation workshop was held in October 2015 in Addis Ababa with national and regional experts to review the national maps revised based on regional inputs and identify criteria to inform the national prioritization of landscapes for cross-sectoral implementation. Along with the consultation workshop, a training session on the development of tree-based landscape restoration potential maps was organized for regional staff from Tigray; Amhara; Oromia; Gambella; Benishangul-Gumuz; and Southern Nations, Nationalities, and Peoples' National Regional States.
- Consultation workshops were held with the CRGE implementing sectors and with MEFCC experts in March 2016 in Addis Ababa to review the proposed priority landscapes for cross-sectoral implementation.
- A consultation workshop was held with Ethiopian Environment and Forest Research Institute researchers in April 2016 in Addis Ababa to discuss the draft potential and priority maps.

In addition to these consultation workshops, one-on-one meetings were organized with data providers and sectoral experts as need arose.

Input Data

The national potential and priority maps for tree-based landscape restoration are based on the best available national datasets as of May 15, 2016. When national datasets did not exist or were not available, global or regional datasets were used (provided they were deemed of sufficient quality and with relevant spatial and temporal scales). The datasets used during the spatial analyses are listed in the GIS Data section of the References. In addition to the sources of errors identified as part of the accuracy assessment in four woredas (Step 4 and Appendix B), general observations on the input data are presented in Appendix C.


PHOTO: MARIUSZ KLUZNIAK

8. Because of time and resource constraints, the team could not visit all the regions. The regions for the regional consultation workshops were identified based on their comparative tree-based landscape restoration potential. However, most of the regions could take part to the second consultation workshop in Addis Ababa, including the training session on the development of regional tree-based landscape restoration potential maps.

RESULTS

Step 1: Identify National Land-Use Challenges and Tree-Based Landscape Restoration Options

Step 1.1 Identify National Land-Use Challenges

Land-use challenges are problems arising from the way land is used and/or managed. Based on how socioeconomic factors (for example, increase in population, land tenure, shifting cultivation, lack of land-use planning and policy) affect the way land is used and/or managed, the experts at the first consultation workshop identified the following land-use challenges as barriers to achieving Ethiopia's national economic, social or environmental goals:[9]

- Habitat fragmentation/loss of biodiversity
- Forest degradation
- Loss of soil fertility
- Overgrazing/free grazing
- Deforestation
- Soil erosion
- Siltation/sedimentation of water bodies
- Water scarcity (in water bodies and soils)[10]
- Flooding
- Landslides
- Climate change impacts
- Air pollution (in urban areas)

The drivers behind these land-use challenges (for example, poverty, population density, weak enforcement of laws, climate change) were discussed during the identification of the land-use challenges. These drivers need to be addressed in order to increase tree cover and ensure its long-term maintenance. The Restoration Diagnostic (Hanson et al. 2015) can be used to systematically identify, understand, and strategically address these drivers.

Step 1.2 Identify National Tree-Based Landscape Restoration Options

Trees supply ecosystem services that can directly and indirectly help address land-use challenges (Figure 2). By increasing the number of trees and forest cover in Ethiopian landscapes, progress can be made toward restoring lost or degraded ecosystem services.

Options to incorporate more trees in landscapes are manifold. The optimal choice depends on the main ecosystem services intended to be restored. At the first consultation workshop, experts identified the following national tree-based landscape restoration options:

1. **Potential for restoring secondary forests:** Establishing forests, including natural high forests, woodlands, and bamboo forests, on land that had recent tree cover (reforestation) or on land that has been deforested for much longer (afforestation) (adapted from IPCC 2014). In Ethiopia, common practices to restore secondary forests include area exclosure and assisted natural regeneration.

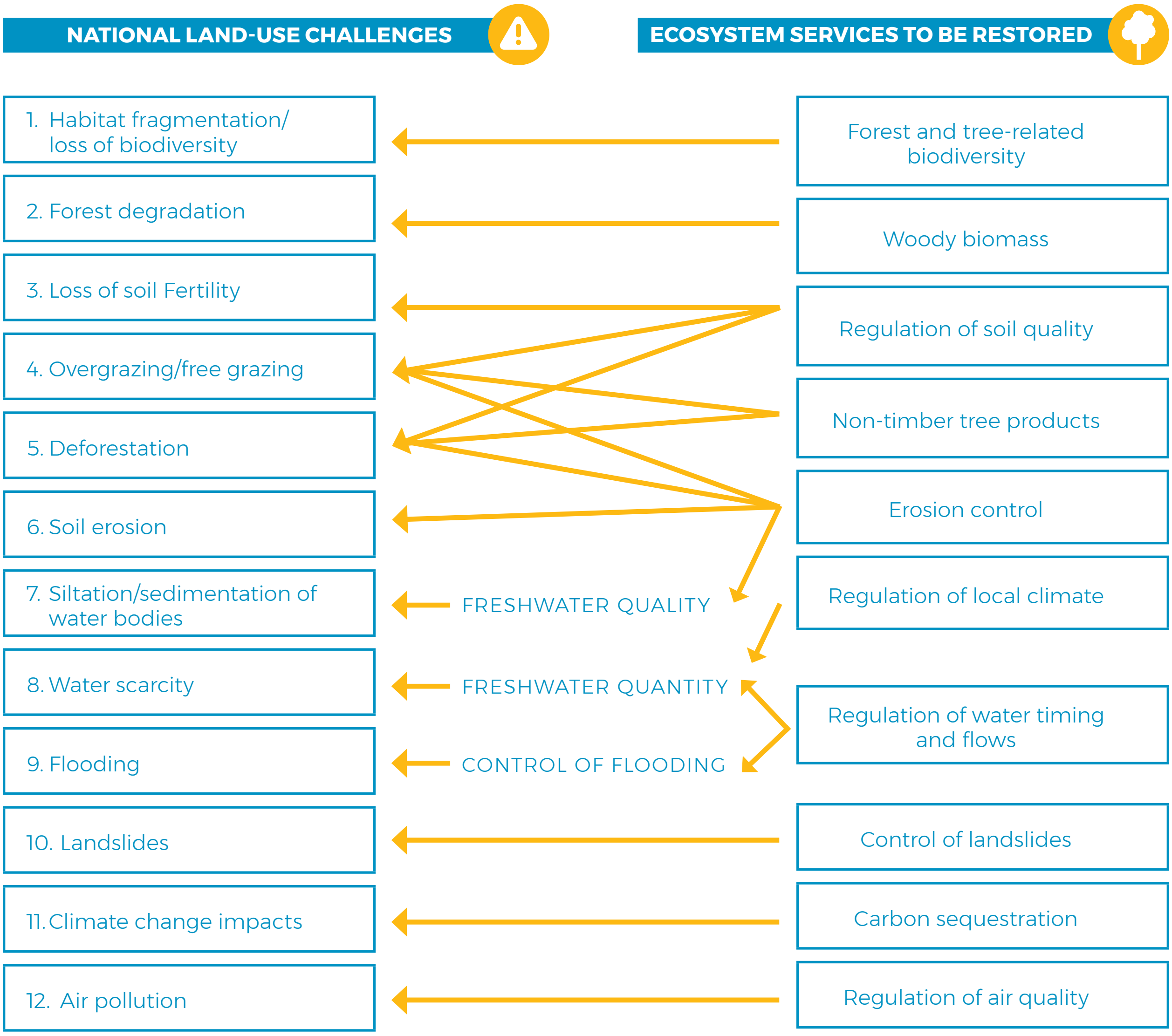
2. **Potential for restocking degraded natural forests:** Increasing stock of existing degraded natural forests, including degraded high forests, woodlands, and bamboo forests. Common practices to restock degraded forests are enrichment planting and assisted natural regeneration.

3. **Potential for agro-forestry:** Increasing the number of trees on existing crop, pastoral, and agro-pastoral land with sparse tree cover.

4. **Potential for woodlots and home gardens:** Expanding small-scale production of wood (for example, woodfuel, timber for construction) and non-wood products (for example, fruits, forage) for domestic and commercial uses on both communal and private land.

9. Land-use challenges specific to regions should be addressed at the regional level following a process similar to the national process.
10. Whether trees can improve water availability through groundwater recharge, and the extent to which they do, depends on various factors such as rainfall intensity; soil type; tree spatial distribution; tree size, age, and species; and management practices (for example, pruning) (Ilstedt et al. 2016).

Figure 2 | Trees, Ecosystem Services, and National Land-Use Challenges



Source: Authors.

5. **Potential for commercial plantations:** Expanding income-generating commercial plantations for the production of wood and tree products. This includes commercial plantations on communal/public, state-owned and private land.

6. **Potential for tree-based buffer zones along rivers, lakes, and reservoirs:** Expansion of secondary forests, including natural high forests, woodlands, and bamboo forests, to protect rivers, lakes, and reservoirs.

7. **Potential for tree-based urban green infrastructure:** Increasing the number of trees in urban areas and industrial parks (for example, urban parkland, roadside tree planting, buffer zones around urban water bodies, protective forests).

8. **Potential for roadside trees (outside of urban areas):** Increasing the number of trees along roads outside of urban areas, providing this is safe for traffic and does not block scenic views.

Two other options originally identified by the experts were deemed to fold in the first eight ones:

9. **Potential for tree-based corridors among religious forests:** Increasing the number of trees and forest habitat among religious forests. This potential fits into the previous tree-based landscape restoration options based on the land use-land cover where the trees and/or forests are established/restored.

10. **Potential for tree-based corridors among biodiversity hotspots:** Increasing the extent of forest habitat in areas important to forest fauna and flora. This potential fits under options 1 and 2 based on whether or not forests already exist in the corridors among the biodiversity hotspots.

Table 1 | National Tree-Based Landscape Restoration Options and Land-Use Challenges

National land-use challenges	Tree-Based Landscape Restoration Options							
	Restoring Secondary Forests	Restocking Degraded Natural Forests	Agro-forestry	Woodlots and Home Gardens	Commercial Plantations	Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs	Tree-Based Urban Green Infrastructure	Roadside Trees
Habitat fragmentation/ loss of biodiversity	✖	✖	×		×	✖	×	×
Forest degradation	×	✖	✖	✖	✖	×	×	
Loss of soil fertility			✖	✖				
Overgrazing/free grazing	×	×	✖	×		×	×	
Deforestation	✖	×	✖	×	×	×	×	
Soil erosion	✖	✖	✖	✖	✖	✖	×	✖
Siltation/ sedimentation of water bodies	✖	✖	✖	✖	✖	✖	×	✖
Water scarcity[a]	✖	✖	✖	✖	✖	✖	✖	✖
Flooding	✖	✖	✖	✖	✖	✖	✖	×
Landslides	✖	✖	×	✖	✖	✖	✖	✖
Climate change impacts	✖	✖	✖	✖	✖	✖	✖	✖
Air pollution	✖ if close to urban area	✖ if close to urban area		✖ if close to urban area	✖ if close to urban area	✖ if close to urban area	✖	

LEGEND:

✖ This restoration option is important to address this land-use challenge.

× This restoration option is secondarily important to address this land-use challenge.

Note: [a] Whether trees can improve water availability through groundwater recharge, and the extent to which they do, depends on various factors such as rainfall intensity; soil type; tree spatial distribution; tree size, age, and species; and management practices (for example, pruning) (Ilstedt et al. 2016).
Source: Authors.

These landscape restoration options can potentially address multiple land-use challenges as trees supply multiple ecosystem services. However, some restoration options might be more helpful than others in addressing specific land-use challenges (Table 1). For example, restoring secondary forests is more relevant than commercial plantations to addressing habitat fragmentation and loss of biodiversity.

Where a restoration option is implemented within a landscape will also influence the extent to which it addresses a specific land-use challenge. For example, restoring secondary forests on steep slope would contribute more to controlling soil erosion than restoring secondary forests on flat land. Similarly, restoring secondary forests would contribute more to biodiversity conservation and enhancement if located within a degraded wildlife corridor.

Step 1.3 Identify Tree-Based Landscape Restoration Options for Which to Map Potential

Altogether, the tree-based landscape restoration options would help Ethiopia deliver on its CRGE forestry targets of 3 million hectares of afforestation/reforestation and 4 million hectares of forest management, as well as its pledge to restore 15 million hectares of degraded land and forests by 2030 as part of its contribution to the AFR100, the Bonn Challenge, and the New York Declaration on Forests.

The following landscape restoration options were mapped for potential because of their relevance to the Climate Resilient Green Economy Strategy, both in terms of mitigating and adapting to climate change and improving people's lives:

1. **Potential for restoring secondary forests:** In its contribution to the CRGE, the forest sector committed to afforesting and reforesting 3 million hectares (FDRE 2010), part of which would be through restoring secondary forests.

2. **Potential for restocking degraded natural forests:** Along with the 3 million hectares of reforestation and afforestation, the forest sector committed to improving forest management on 2 million hectares of high forests and 2 million hectares of woodlands (FDRE 2010).

3. **Potential for agro-forestry:** In its contribution to the CRGE, the agriculture and livestock sectors have committed to increasing the productivity of up to 40 million head of livestock and the yield and value of crops in agricultural land (FDRE 2010). Since silvo-pastoralism is taking place under very different conditions than agri-silviculture and agro-silvo-pastoralism, both the potential for agri-silviculture and agro-silvo-pastoralism, and the potential for silvo-pastoralism were mapped.

4. **Potential for woodlots and home gardens:** The Ethiopia Forest Sector Review estimates that the role of small-scale woodlots for woodfuel supply has significantly increased and will keep doing so as alternative sources of woodfuel such as forests and woodlands have become increasingly degraded (MEFCC 2017). Home gardens[11] can be an important livelihood strategy for farmers (Linger 2014; Kebebew et al. 2011).

5. **Potential for industrial roundwood[12] plantations:** The Ethiopia Forest Sector Review, which focused on commercial forestry and industrialization, estimated that 310,000 ha of professionally managed plantations would be necessary just to meet the domestic demand for industrial wood products (MEFCC 2017). This potential was mapped as part of the Commercial Plantation Forestry Investment Plan Study conducted by the International Finance Corporation and the World Bank for the Federal Democratic Republic of Ethiopia. The study mapped the potential for expanding plantations for *Cupressus lusitanica, Eucalyptus spp.*, *Pinus spp.* and *Grevillea robusta* (World Bank Group 2016).

11. Home gardens are "intimate, multistory combinations of various trees and crops, sometimes in association with domestic animals, around homesteads" (Kumar and Nair 2004).
12. The Ethiopia Forest Sector Review follows FAO's *Forest Products Yearbook* in understanding "industrial roundwood" as all industrial wood in the rough (saw logs and veneer logs, pulpwood, and other industrial roundwood) and, in the case of trade, chips and particles and wood residues (MEFCC 2017).

6. **Potential for commercial plantations for products other than industrial roundwood:** In addition to the potential for the four industrial roundwood species selected under the previous option, there is substantial commercial potential for other tree species. For example, the contribution of non-timber forest products[13] to the Ethiopian national economy and the livelihood of rural households has potential to grow with increasing domestic and international markets (MEFCC 2017), as demonstrated by the objectives of GTP II to boost the rubber industry (FDRE 2016).

7. **Potential for buffer plantations around protected areas and national forest priority areas:** A plantation 1 km wide would be established around protected areas and national forest priority areas to support the livelihood of local communities, decreasing the pressure on protected areas and national forest priority areas as prescribed in the Forest Development, Conservation and Utilization Policy and Strategy (FDRE 2007) and Proclamation (FDRE 2018).

8. **Potential for tree-based buffer zones along rivers, lakes, and reservoirs:** In its contribution to the CRGE, the energy sector committed to fast-tracking hydropower and promoting integrated watershed management system to prevent sedimentation of hydropower dams (FDRE 2010).

The potential for tree-based urban green infrastructure and roadside trees will be addressed based on interest from relevant governmental agencies and restoration actors.

Step 2: Identify Criteria and Data to Assess Potential to Scale Up Tree-Based Landscape Restoration Options

This section presents the criteria and data[14] considered in assessing the potential for scaling up each of the tree-based landscape restoration options and the rationale for considering them.

The criteria were identified by the stakeholders during the various consultation workshops. The criteria to assess the potential for scaling up commercial bamboo plantations were discussed with bamboo experts.

The following categories were not included in any of the tree-based landscape restoration potential maps:

- Dense forests, because they need to be conserved through sustainable forest management rather than through increasing their tree cover. *Data source: EMA 2015.*
- Wetlands, because they provide important ecosystem services that should be conserved. *Data source: EMA 2015.*
- Natural grasslands that ecologically do not have trees, because they provide important ecosystem services that should be conserved. *Data source: No readily available national data.*
- Bare soil, rock outcrop, lava flow, salt pan, and water bodies (that is, lakes and current and planned reservoirs), because they are not conducive to tree-based landscape restoration. *Data source for bare soil, rock outcrop, lava flow, salt pan, and water bodies: EMA 2015. Data source for lakes and reservoirs: MoWIE 2015.*
- Settlements, urban expansion areas, and industrial parks, because potential for tree-based urban green infrastructure is not part of this mapping exercise. *Data source for settlement: EMA 2015. Data source for urban expansion areas: No readily available national data. Data source for industrial parks: IPDC 2016.*

13. The Ethiopia Forest Sector Review considers non-timber forest products to include forest coffee; honey; beeswax; spices; wild food; traditional pharmaceutical products; gum and incense; bamboo; fodder; woodfuel (firewood and charcoal); and farm implements and climbers (MEFCC 2017).
14. The cutoff line for data compilation was May 15, 2016. "No readily available national data" indicates either that no national spatial data exist or that national spatial data exist but were not made available by the deadline.

Table 2 presents the criteria used to identify areas with potential for restoration of secondary forest.

Table 2 | Potential Assessment Criteria for Restoring Secondary Forests

Assessment Criteria	Value	Justification and Data Sources
Potential Natural Vegetation	Include following classes:[a] ■ Acacia-Commiphora woodlands and bushlands ■ Acacia wooded grasslands of the Rift Valley ■ Wooded grasslands of the western Gambela region ■ Combretum-Terminalia woodlands and wooded grasslands ■ Dry evergreen Afromontane forest and grassland complex ■ Moist evergreen Afromontane forest ■ Transitional rainforest	These are the areas where forests could grow, based on national and regional vegetation and land-use maps, field expertise from national botanical experts, and suitability modeling. *Data source: Van Breugel et al. 2015.*
Current Land Use-Land Cover	Exclude moderate forests, sparse forests, and woodlands	This land is already forested even if these moderate forests, sparse forests, and woodlands have potential for being restocked (see the "potential for restocking degraded natural forests" option). *Data source: EMA 2015.*
	Exclude perennial and annual croplands and closed and open grasslands with slopes ≤ 60%	Below slopes of 60%, rural lands can be used for farming and grazing (FDRE 2005). *Data sources: EMA 2015 and SRTM n.d.*
Future Land Use-Land Cover	Exclude large-scale agricultural investments	These areas are not conducive to restoring secondary forests. *Data source: No readily available national data.*
Altitude	Exclude areas with altitude > 3,500 m	There is less potential for trees above the tree line. *Data source: SRTM n.d.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 250 mm	There is little potential for trees below 250 mm average annual rainfall. *Data source: Hijmans et al. 2005.*

Note: [a] Riverine forests are not included as a separate class because of the 1 km spatial resolution of the potential natural vegetation data.
Source: Authors.

Table 3 presents the criteria used to identify areas with potential for restocking degraded natural forests. There are many different definitions of degraded forest (Simula 2009). In the absence of a comprehensive forest degradation assessment in Ethiopia, *degraded forest* was defined in the context of this work as "forest whose biomass stock could be increased."

Table 3 | Potential Assessment Criteria for Restocking Degraded Natural Forests

Assessment Criteria	Value	Justification and Data Sources
Stock Estimate	Include moderate forests, sparse forests, and woodlands[a]	These are the areas of existing forest whose stock could be enhanced. *Data source: EMA 2015.*
Current Land Use-Land Cover	Exclude plantations	This restoration option focuses on natural forest. *Data source: MEFCC 2016.*
Future Land Use-Land Cover	Exclude large-scale agricultural investments	These areas are not conducive to restocking degraded natural forests. *Data source: No readily available national data.*

Note: [a] In the absence of data on woodland stock, experts recommended including all woodlands, taking note that most of them are understocked.
Source: Authors.

Table 4 presents the criteria used to identify areas that have potential for agri-silviculture and agro-silvo-pastoralism.

Table 4 | Potential Assessment Criteria for Agri-Silviculture and Agro-Silvo-Pastoralism

Assessment Criteria	Value	Justification and Data Sources
Current Land Use-Land Cover	Include annual and perennial croplands	Agri-silviculture and agro-silvo-pastoralism can take place on croplands. (In areas with less than 250 mm rainfall, it is assumed cropland is made possible thanks to irrigation, which can also be used for trees; this is why cropland is not limited to where average annual rainfall is more than 250 mm). *Data source: EMA 2015.*
	Include closed and open grasslands in cropping livelihood areas where average annual rainfall > 250 mm	Agri-silviculture and agro-silvo-pastoralism can take place on grasslands where cropping is the main source of livelihood as long as there is more than 250 mm average annual rainfall. *Data sources: EMA 2015; MoARD and USAID 2009; and Hijmans et al. 2005.*
	Exclude mechanized farming	From field visits and discussion in regions, these agricultural practices were not deemed compatible with higher tree cover across the plot. *Data source for large-scale sugar cane plantations: ESC 2016.* *Data source for mechanized farming and rice fields: No readily available national data.*
	Exclude large-scale sugar cane plantations	
	Exclude rice fields	
Tree Cover	Exclude areas with tree cover > 30%	Agro-forestry systems with > 30% tree cover are considered already well-stocked (while ICRAF proposes that "agro-forestry" be defined by tree cover > 10% on farms, it also recognizes the potential to improve the existing agro-forestry system with 10–30% tree cover [Zomer et al. 2014]). *Data source: Hansen et al. 2014.*

Table 4 | Potential Assessment Criteria for Agri-Silviculture and Agro-Silvo-Pastoralism (continued)

Assessment Criteria	Value	Justification and Data Sources
Areas Legally or Socially Protected	Exclude all protected areas	No agriculture should be promoted in these areas. *Data source for PAs: EWCA 2015.* *Data sources for NFPAs: IUCN and UNEP-WCMC 2016; Tigray BoARD 2016; Amhara BoA 2016; and OFWE 2016.*
	Exclude all national forest priority areas	
	Exclude religious forests	Some religious forests might be too small to be classified as forests but should be preserved nonetheless. *Data source: No readily available national data.*
Slope	Exclude areas with slopes > 60%	Rural lands whose slope is more than 60% shall not be used for farming and free grazing; they shall be used for development of trees, perennial plants, and forage production (FDRE 2005). *Data source: Derived from SRTM n.d.*

Source: Authors.

Table 5 presents the criteria used to identify areas that have potential for silvo-pastoralism.

Table 5 | Potential Assessment Criteria for Silvo-Pastoralism

Assessment Criteria	Value	Justification and Data Sources
Livelihood Zone	Include following classes: ■ agro-pastoralist ■ pastoralist	These are the areas where pastoralism livelihoods are important to well-being. *Data source: MoARD and USAID 2009.*
Current Land Use-Land Cover	Exclude moderate forests, sparse forests, and woodlands	Existing forests need to be protected. *Data source: EMA 2015.*
	Exclude annual and perennial croplands	Increasing the number of trees on croplands is already included in the "potential for agri-silviculture and agro-silvo-pastoralism" option. *Data source: EMA 2015.*
Tree Cover	Exclude areas with tree cover > 20%	Pastoral lands with 20% or more tree cover are considered already well-stocked silvo-pastoral systems. (ICRAF proposes "agro-forestry" to be defined by tree cover greater than 10% on farms [Zomer et al. 2014], but experts proposed also promoting the improvement of existing silvo-pastoral systems with 10–20% tree cover.) *Data source: Hansen et al. 2014.*
Invasive Species	Include areas with invasive tree species	While invasive species might show a canopy cover of more than 20% the species are not desirable. These areas need to have the invasive species eradicated before increasing their tree cover with desirable species. *Data source: No readily available national data.*
Areas Legally or Socially Protected	Exclude all protected areas	No agriculture should be promoted in these areas. *Data source for PAs: EWCA 2015.* *Data sources for NFPAs: IUCN and UNEP-WCMC 2016; Tigray BoARD 2016; Amhara BoA 2016; and OFWE 2016.*
	Exclude all national forest priority areas	
	Exclude religious forests	Some religious forests might be too small to be classified as forest but should be preserved nonetheless. *Data source: No readily available national data.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 250 mm	There is little potential for trees to grow below 250 mm average annual rainfall. *Data source: Hijmans et al. 2005.*

Source: Authors.

Table 6 presents the criteria used to identify areas that have potential for woodlots and home gardens.

Table 6 | Potential Assessment Criteria for Woodlots and Home Gardens

Assessment Criteria	Value	Justification and Data Sources
Distance to Homesteads	Include areas ≤ 10 km distance from homesteads	Farmers are allocating portion of their land for woodlots and/or home gardens in proximity to their homesteads. *Data source: No readily available national data.*
Current Land Use-Land Cover	Include annual and perennial croplands	Woodlots and home gardens can take place on croplands. (In areas with less than 250 mm rainfall, it is assumed that cropland is made possible thanks to irrigation, which can also be used for trees; this is why cropland is not limited to where average annual rainfall is more than 250 mm.) *Data source: EMA 2015.*
	Include closed and open grasslands in cropping livelihood areas where average annual rainfall > 250 mm	Woodlots and home gardens can take place on grasslands where cropping is the main source of livelihood as long as there is more than 250 mm average annual rainfall. *Data sources: EMA 2015; MoARD and USAID 2009; and Hijmans et al. 2005.*
	Exclude mechanized farming	From field visits and discussion in regions, these agricultural practices are not compatible with woodlots and home gardens. *Data source for large-scale sugar cane plantations: ESC 2016.* *Data source for mechanized farming and rice fields: No readily available national data.*
	Exclude large-scale sugar cane plantations	
	Exclude rice fields	
Tree Cover	Exclude areas with tree cover > 30%	Agro-forestry systems with 30% or more tree cover are considered already well-stocked. (While ICRAF proposes that "agro-forestry" be defined by tree cover greater than 10% on farms, it also recognizes the potential to improve existing agro-forestry system with 10–30% tree cover [Zomer et al. 2014].) *Data source: Hansen et al. 2014.*
Areas Legally or Socially Protected	Exclude all protected areas	No woodlots or home gardens should be promoted in these areas. *Data source for PAs: EWCA 2015.* *Data sources for NFPAs: IUCN and UNEP-WCMC 2016; Tigray BoARD 2016; Amhara BoA 2016; and OFWE 2016.*
	Exclude all national forest priority areas	
	Exclude religious forests	Some religious forests might be too small to be classified as forest but should be preserved nonetheless. *Data source: No readily available national data.*
Plot Size	Exclude areas with plot size > 1 ha	The national average plot size being 1 hectare (Teshome 2014), it was considered that woodlots and home gardens on bigger plots could be considered as serving more commercial purposes. *Data source: No readily available national data.*

Source: Authors.

Table 7 presents the criteria identified as part of the Commercial Plantation Forestry Investment Plan Study (World Bank Group 2016). This restoration option focuses on areas with potential for expanding *Cupressus lusitanica, Eucalyptus spp., Pinus spp.* and *Grevillea robusta* plantations.

Table 7 | Potential Assessment Criteria for Industrial Roundwood Plantations

Assessment Criteria	Value	Justification and Data Sources
EITHER LOWLANDS WITH ENOUGH RAINFALL		
Altitude	Exclude areas with altitude ≤ 800 m and > 1,500 m	While the altitude bracket allowing a yield of 15 m^3/ha/year for Grevillea and 25 m^3/ha/year for eucalyptus is between 800 and 2,400 m, securing land for commercial forest plantation development in the highlands is difficult. Potential was therefore circumscribed to the lowlands. *Data source: SRTM n.d.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 800 mm	This is the minimum average annual rainfall allowing a yield of 15 m^3/ha/year for Grevillea and 25 m^3/ha/year for eucalyptus. *Data source: Hijmans et al. 2005.*
Current Land Use-Land Cover	Exclude ■ *Afro alpine:* erica/hypericum and grass-land/moorland ■ *Bare land:* exposed rock/sand/soil ■ *Cultivated land:* irrigated ■ *Forests*: bamboo (dense), semi-evergreen (dense, close), montane broadleaf (dense, closed), montane coniferous (dense, closed), montane mixed (dense, closed), riparian (dense) ■ Woodland (dense and open) ■ Unknown ■ Urban ■ *Wetland:* open water and seasonal and perennial swamp/marsh	These land use-land covers either are already forested (forests with at least a close canopy), provide important ecosystem services (i.e., wetlands, afro alpine), are not conducive to plantations (i.e., bare land), or would have opportunity costs that are too high (i.e., irrigated crops, urban). *Data source: WBISPP 2004c.*
Slope	Exclude areas with slopes > 15 degrees	The slope threshold of 15 degrees is an industry benchmark. *Data source: Derived from SRTM n.d.*
OR DEGRADED NATURAL FOREST		
Distance to Existing Natural Forest	Include areas ≤ 1 km from dense or close natural forests	It was assumed that areas close to the remaining forests are more likely to be heavily degraded forests (which are partly managed by the regional forest enterprises and therefore could be allocated for commercial plantation forestry). *Data source: WBISPP 2004c.*
Altitude	Exclude areas with altitude ≤ 800 m and > 2,400 m	This is the altitude bracket allowing a yield of 15 m^3/ha/year for Grevillea and 25 m^3/ha/year for eucalyptus. *Data source: SRTM n.d.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 800 mm	This is the minimum average annual rainfall allowing a yield of 15 m^3/ha/year for Grevillea and 25 m^3/ha/year for eucalyptus. *Data source: Hijmans et al. 2005.*

Table 7 | Potential Assessment Criteria for Industrial Roundwood Plantations (continued)

Assessment Criteria	Value	Justification and Data Sources
Current Land Use-Land Cover	Exclude ■ *Afro alpine*: erica/hypericum and grass-land/moorland ■ *Bare land:* exposed rock/sand/soil ■ *Cultivated land:* irrigated ■ *Forests:* bamboo (dense), semi-evergreen (dense, close), montane broadleaf (dense, closed), montane coniferous (dense, closed), montane mixed (dense, closed), riparian (dense) ■ Woodland (dense and open) ■ Unknown ■ Urban ■ *Wetlands:* open water and seasonal and perennial swamp/marsh	These land use-land covers are either already forested (forests with at least a close canopy), provide important ecosystem services (i.e., wetlands, afro alpine), or are not conducive to plantations (i.e., bare land), or the opportunity costs would be too high (i.e., irrigated crops, urban). *Data source: WBISPP 2004c.*
Slope	Exclude areas with slopes > 15 degrees	The slope threshold of 15 degrees is an industry benchmark. *Data source: Derived from SRTM n.d.*

Source: World Bank Group 2016.

Table 8 presents the criteria used to identify areas that have potential for commercial plantations for products other than industrial roundwood.

Table 8 | Potential Assessment Criteria for Commercial Plantations for Products Other Than Industrial Roundwood

Assessment Criteria	Value	Justification and Data Sources
Current Land Use- Land Cover	Include closed and open shrublands	Shrublands could be used for commercial plantations. For ecological reasons and/or as a result of degradation, additional inputs might be needed (e.g., fertilizers). *Data source: EMA 2015.*
Land Designation	Include non-forested forestland	These are areas meant to be forest, including commercial plantations. *Data source: No readily available national data.*
Market Accessibility	Exclude areas > 20 km from roads	Markets need to be easily accessed to transport and sell wood products. *Data source: ERA 2007.*
Areas Legally or Socially Protected	Exclude all protected areas	No productive activities should be promoted in these protected areas. *Data source for PAs: EWCA 2015.* *Data sources for NFPAs: IUCN and UNEP-WCMC 2016; Tigray BoARD 2016; Amhara BoA 2016; and OFWE 2016.*
	Exclude all national forest priority areas	
	Exclude religious forests	Some religious forests might be too small to be classified as forest but should be preserved nonetheless. *Data source: No readily available national data.*
Biodiversity Conservation	Exclude key biodiversity areas	Shrublands might be important for biodiversity conservation. *Data source: BirdLife International and CI 2016.*
Population Density	Exclude areas with population density > 200 people/km^2	The opportunity for commercial plantations is higher in areas with low population density. *Data source: CSA 2007b.*
Plot Size	Exclude areas with plot size ≤ 1 ha	To be economically feasible, plantations need to benefit from economies of scale. *Data source: No readily available national data.*

Table 8 | Potential Assessment Criteria for Commercial Plantations for Products Other Than Industrial Roundwood (continued)

Assessment Criteria	Value	Justification and Data Sources
Slope	Exclude areas with slopes > 60%	Given the risks of landslides during skidding and harvesting, these lands should be used for conservation forests (see the “potential for restoring secondary forests” option). *Data source: Derived from SRTM n.d.*
Altitude	Exclude areas with altitude > 3,500 m	There is less potential for trees to grow above the tree line. *Data source: SRTM n.d.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 250 mm	Unlike tree species planted for industrial roundwood, tree species for other products can be productive with average annual rainfall as low as 250 mm (e.g., *Acacia senegal*). In some cases, supplementary irrigation might be recommended. *Data source: Hijmans et al. 2005.*

Source: Authors.

The Bamboo Sector Strategy Framework (FDRE 2009) demonstrates Ethiopia’s commitment to developing its bamboo sector. Table 9 presents the criteria used to map the potential for commercial bamboo plantations.

Table 9 | Potential Assessment Criteria for Commercial Bamboo Plantations

Assessment Criteria	Value	Justifications and Data Sources
Potential for Commercial Plantations for Products Other Than Industrial Roundwood	Include areas with potential for commercial plantations for products other than industrial roundwood	These are the areas identified as having potential for commercial plantations for products other than industrial roundwood. *Data source: MEFCC (unpublished).*
Average Annual Temperature	Exclude areas with average annual temperature ≤ 17°C or > 35°C	These are the ecological conditions under which lowland bamboo (*Oxytenanthera abyssinica*) can grow. *Data source for climate data: Hijmans et al. 2005.* *Data source for altitude: SRTM n.d.* *Data source for soil data: FAO 1984.*
Average Rainfall During Wettest Quarter	Exclude areas with average rainfall during the wettest quarter ≤ 500 mm or > 1,000 mm	
Altitude	Exclude areas with altitude ≤ 500 m or > 1,800 m	
Soil type	Exclude: ■ Arenosols ■ Fluvisols ■ Gleysols ■ Histosols ■ Leptosols ■ Regosols ■ Solonchaks ■ Vertisols ■ Xerosols ■ Yermosols	
Average Annual Temperature	Exclude areas with average annual temperature ≤ 10°C or > 21°C	These are the ecological conditions under which highland bamboo (*Arundinaria alpina*) can grow. *Data source for climate data: Hijmans et al. 2005.* *Data source for altitude: SRTM n.d.* *Data source for soil data: FAO 1984.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 900 mm or > 2,400 mm	
Altitude	Exclude areas with altitude ≤ 2,200 m or > 3,500 m	
Soil Type	Exclude: ■ Fluvisols ■ Gleysols ■ Histosols ■ Leptosols ■ Regosols ■ Solonchaks ■ Vertisols ■ Xerosols ■ Yermosols	

Source: Authors.

Table 10 presents the criteria used to identify areas that have potential for buffer plantations around protected areas and national forest priority areas. These criteria do not include minimum plot size or access to markets because these are relevant to commercial viability, and buffer plantations can support both subsistence and commercial activities.

In the case of buffer plantations around protected areas, the plantation should benefit local communities and provide some continuity to the protected area in terms of biodiversity and ecological functions.

Table 10 | Potential Assessment Criteria for Buffer Plantations around Protected Areas and National Forest Priority Areas

Assessment Criteria	Value	Justification and Data Sources
Distance to Protected Areas and National Forest Priority Areas	Include 1 km buffer zone around all protected areas Include 1 km buffer zone around all national forest priority areas	To alleviate pressure on protected areas and national forest priority areas, a 1 km buffer of plantations to benefit local communities is proposed to be established. *Data source for PAs: EWCA 2015.* *Data sources for NFPAs: IUCN and UNEP-WCMC 2016; Tigray BoARD 2016; Amhara BoA 2016; and OFWE 2016.*
Current Land Use-Land Cover	Exclude moderate forests, sparse forests, and woodlands	Existing forests need to be protected. *Data source: EMA 2015.*
Land Designation	Exclude wildlife migratory corridors	It is not desirable to promote anything but conservation forests within migratory corridors so as not to interfere with wildlife movement. *Data source: No readily available national data.*
Areas Socially Protected	Exclude religious forests	Some religious forests might be too small to be classified as forest but should be preserved nonetheless. *Data source: No readily available national data.*
Altitude	Exclude areas with altitude > 3,500 m	There is less potential for trees to grow above the tree line. *Data source: SRTM n.d.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 250 mm	There is little potential for trees to grow below 250 mm average annual rainfall. *Data source: Hijmans et al. 2005.*

Source: Authors.

Table 11 presents the criteria used to identify areas that have potential for tree-based buffer zones along rivers, lakes, and reservoirs.

Table 11 | Potential Assessment Criteria for Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs

Assessment Criteria	Value	Justifications and Data Sources
Distance to Water Bodies	Include 60 m buffer from lakes and reservoirs	The buffers in Ethiopia's National Framework for Protection and Management of Water Body Buffers (MWE 2013) were specified as: ■ Flood attenuation: 50 m ■ Perennial/Class 1 streams (rivers, streams, lakes, ponds or other water bodies): 15 m (more if slope > 15%) ■ Intermittent/Class 2 streams (small rivers or streams) and wetlands: 9 m (more if slope > 15%)
	Include 30 m buffer from perennial rivers	Based on the 30-m resolution of the land use-land cover, the buffer distances were adjusted to 60 m around lakes and reservoirs, and to 30 m along perennial rivers. The buffer zone along intermittent streams was not mapped because of the resolution of the land use-land cover. *Data source for perennial rivers: Friis et al. 2010.* *Data source for lakes and reservoirs: MoWIE 2015.*
Current Land Use-Land Cover	Exclude moderate forests, sparse forests, and woodlands	This land is already forested. Some of these forests might need restocking though (see the "potential for restocking degraded natural forests" option). *Data source: EMA 2015.*
	Exclude closed shrublands	This natural vegetation is already protecting water bodies from sedimentation. *Data source: EMA 2015.*
Altitude	Exclude areas with altitude > 3,500 m	There is less potential for trees to grow above the tree line. *Data source: SRTM n.d.*
Average Annual Rainfall	Exclude areas with average annual rainfall ≤ 250 mm	There is little potential for trees to grow below 250 mm average annual rainfall. *Data source: Hijmans et al. 2005.*

Source: Authors.

Step 3: Assess Potential to Scale Up Tree-Based Landscape Restoration Options

Tree-based landscape restoration potential maps fall into two categories:

1. Extent maps, which show where a specific restoration option can be implemented at the national level.

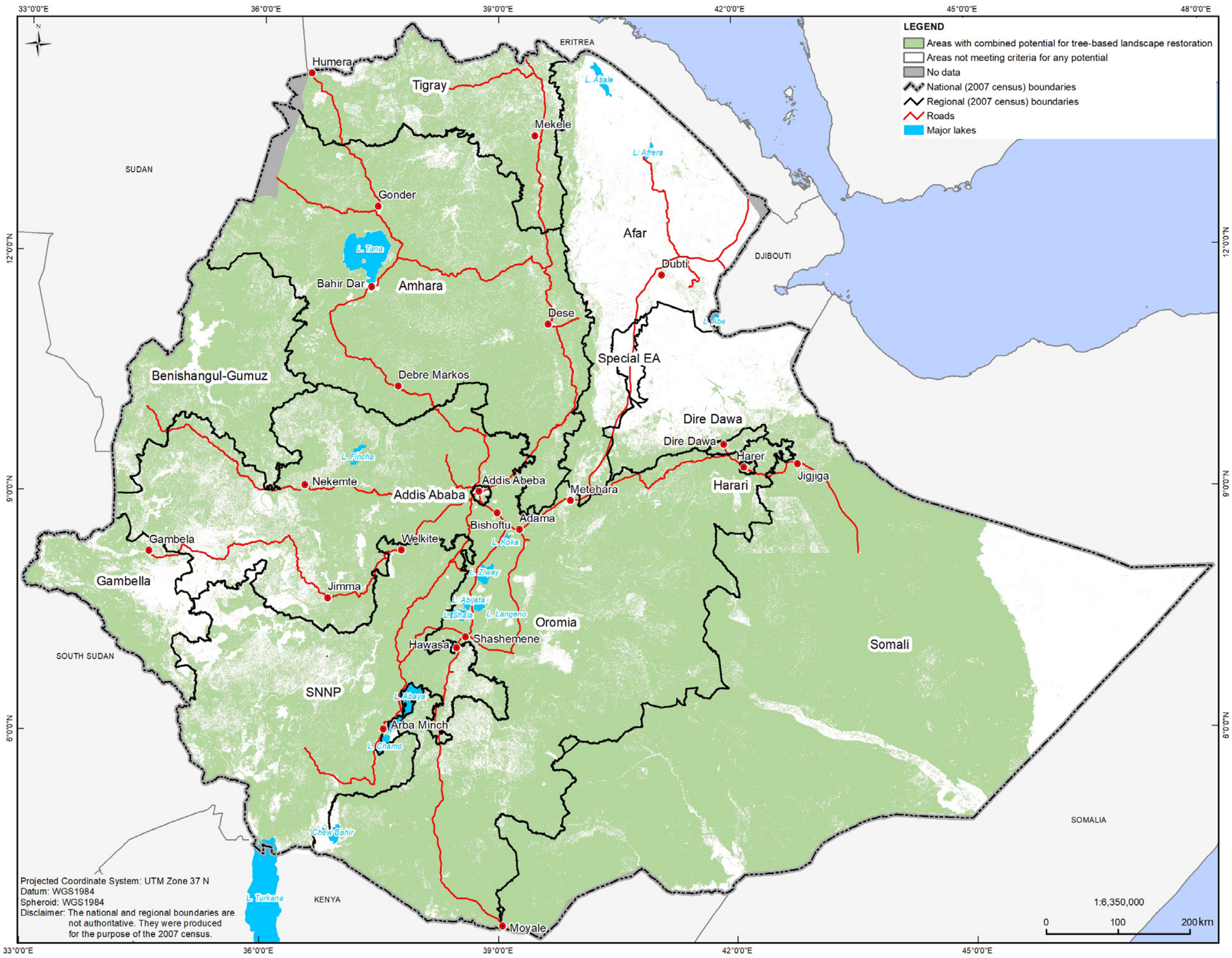
2. Contextual maps, which show biophysical and/or socioeconomic factors that could influence how a given restoration option is implemented. For example, increasing the number of trees on croplands through agri-silviculture or agro-silvo-pastoralism on land with a slope above 30 percent should be accompanied by bench terraces as required by the Federal Rural Land Administration and Use Proclamation (FDRE 2005).

This section presents the extent and contextual maps for the combined potential for tree-based landscape restoration. As the accuracy assessment conducted in four woredas indicates limitations in their reliability (Appendix B), the potential maps for the individual options will be published in a future version.

The combined maps can also be found on Ethiopia's Tree-Based Landscape Restoration Atlas, where users can zoom in and out the maps as well as toggle layers on and off. On the interactive atlas, users can conduct spatial analyses at the zone and woreda levels and download the combined tree-based landscape restoration potential data. Once the sources of their limitations addressed, the potential maps for the individual restoration options will be made available on the online atlas in the same fashion.

Maps 1a to 1e and Table 12 depict the combined potential for tree-based landscape restoration, which is the spatial overlay of all the individual restoration options. Some of the individual options might overlap (for example, agri-silviculture and agro-silvo-pastoralism on slopes greater than 60%, and restoring secondary forests). In overlapping areas, local stakeholders will need to select which of these options to implement so as to provide local, regional, and global benefits.

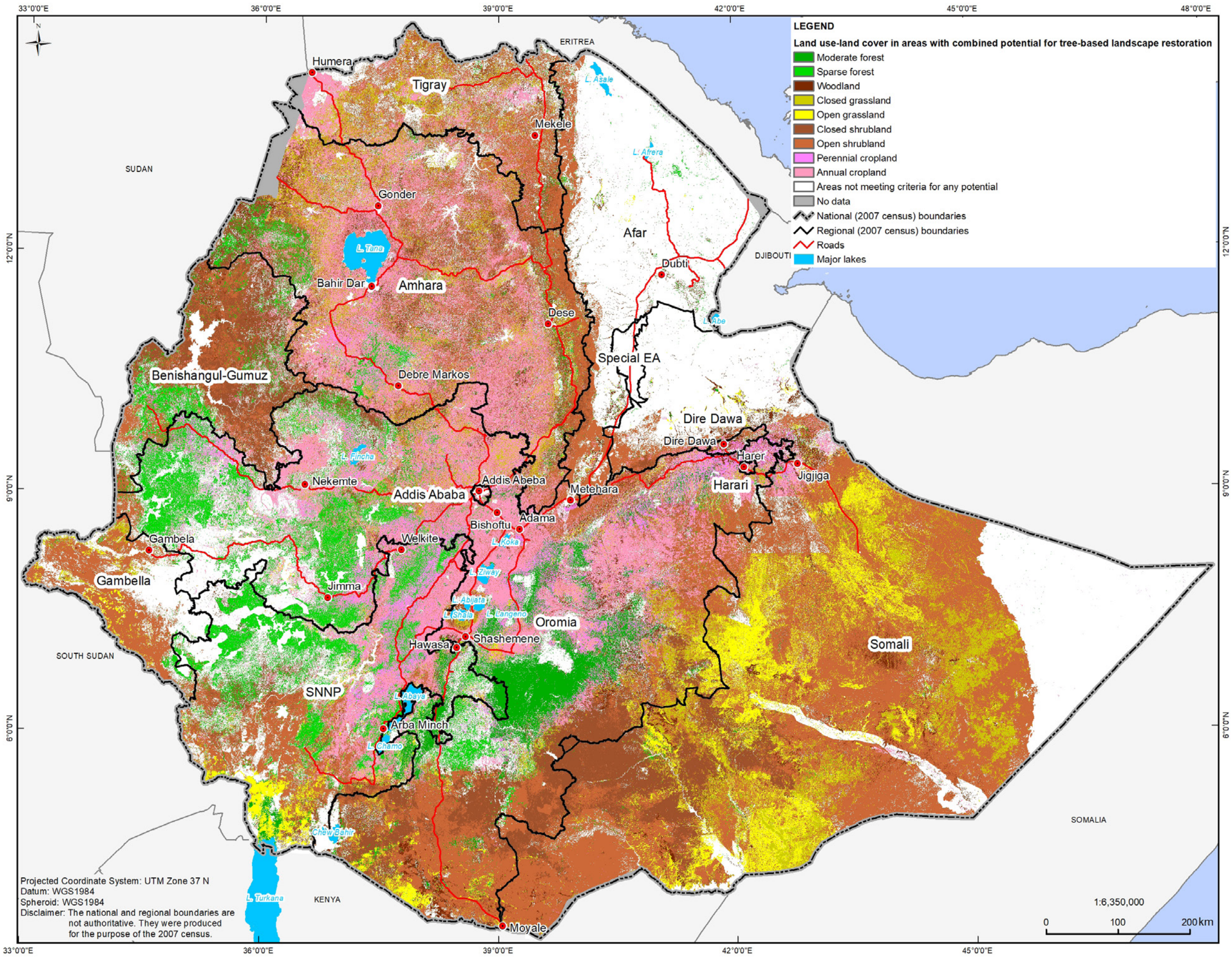
Map 1a | Extent of Combined Potential for Tree-Based Landscape Restoration



CAPTION: Map 1a shows where there is combined potential for tree-based landscape restoration in Ethiopia. The map indicates where there could be additional trees, without specifying which specific tree-based landscape restoration option could be implemented. Some areas might have potential to scale up multiple restoration options. Once the reliability of the potential maps for the individual options is improved, the combined potential map will specify where and which individual options overlap.

Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a.

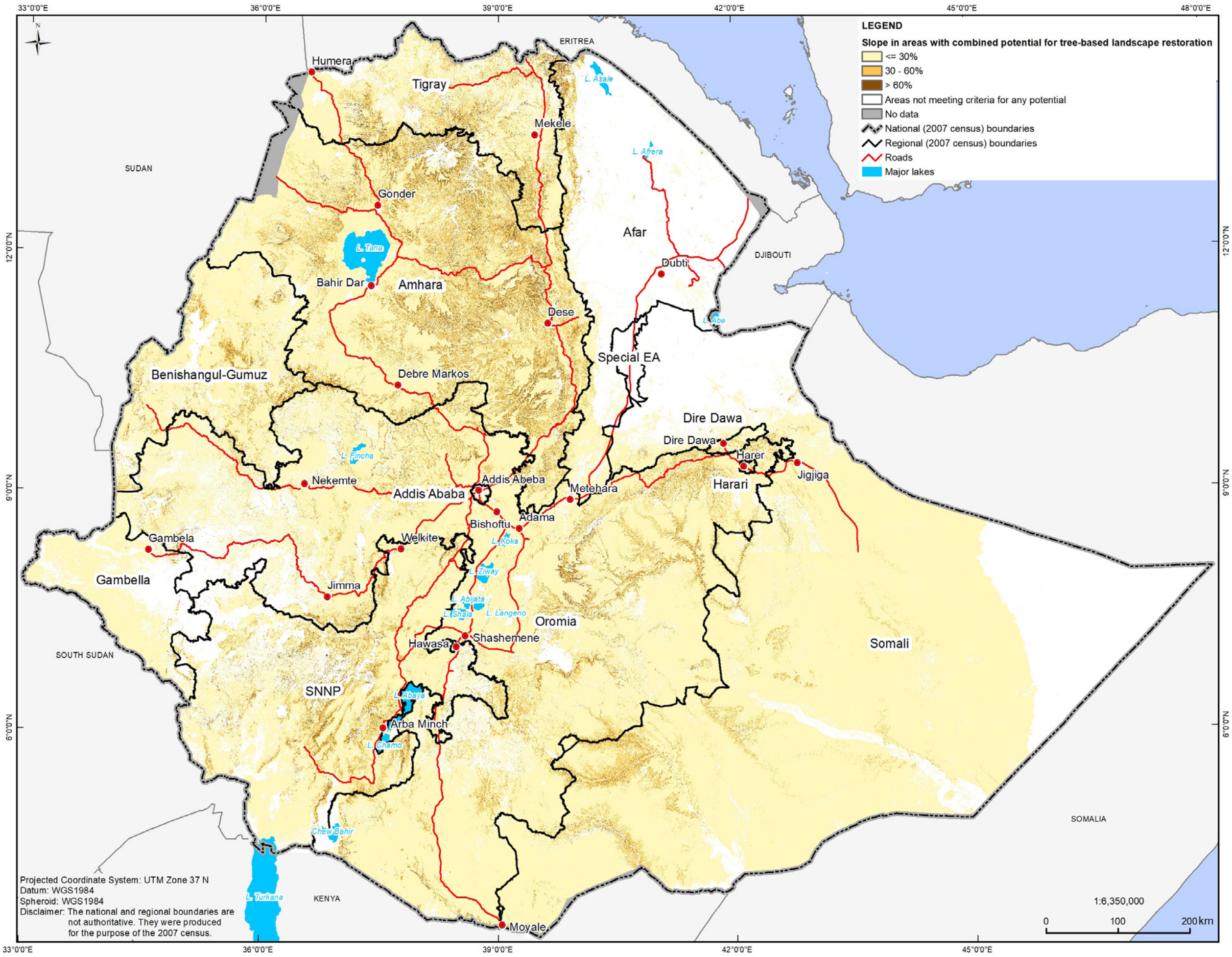
Map 1b | Land Use-Land Cover in Areas with Combined Potential for Tree-Based Landscape Restoration



CAPTION: Map 1b shows the land use-land cover in areas with combined potential for tree-based landscape restoration. According to the land use-land cover, different restoration options should be considered, some of which might overlap. For example, in croplands (in shades of pink), there might be potential for agri-silviculture and agro-silvo-pastoralism, as well as for restoring secondary forests (when the cropland is on slopes over 60%) and for tree-based buffer zones along rivers, lakes, and reservoirs (when the cropland is within a water body buffer zone).

Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a. Land use-land cover: EMA 2015.

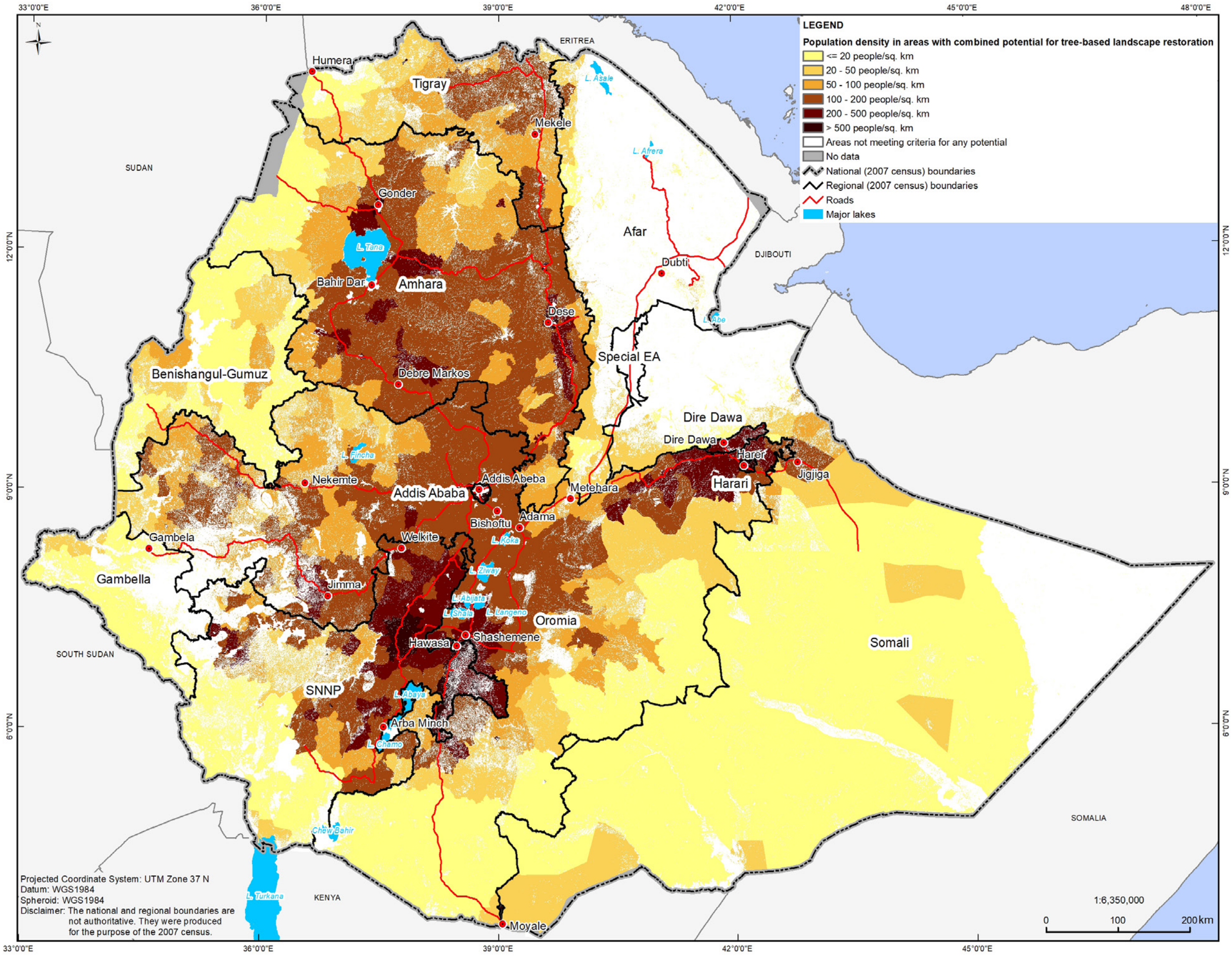
Map 1c | Slope in Areas with Combined Potential for Tree-Based Landscape Restoration



CAPTION: Map 1c shows the slope in areas with combined potential for tree-based landscape restoration. Most areas are on slopes below 30% (in salmon). Some areas are on slopes between 30 and 60% (in orange), and few are on slopes over 60% (in brown). Slope steepness will dictate the type of soil and water conservation measures to be implemented as per the Federal Rural Land Administration and Use Proclamation (FDRE 2005). Slope can also be a consideration in terms of the type of ecosystem services to which trees can contribute. For example, trees and forest in areas with steep slopes would contribute most to preventing soil erosion and landslides.

Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a. Slope: Derived from SRTM n.d.

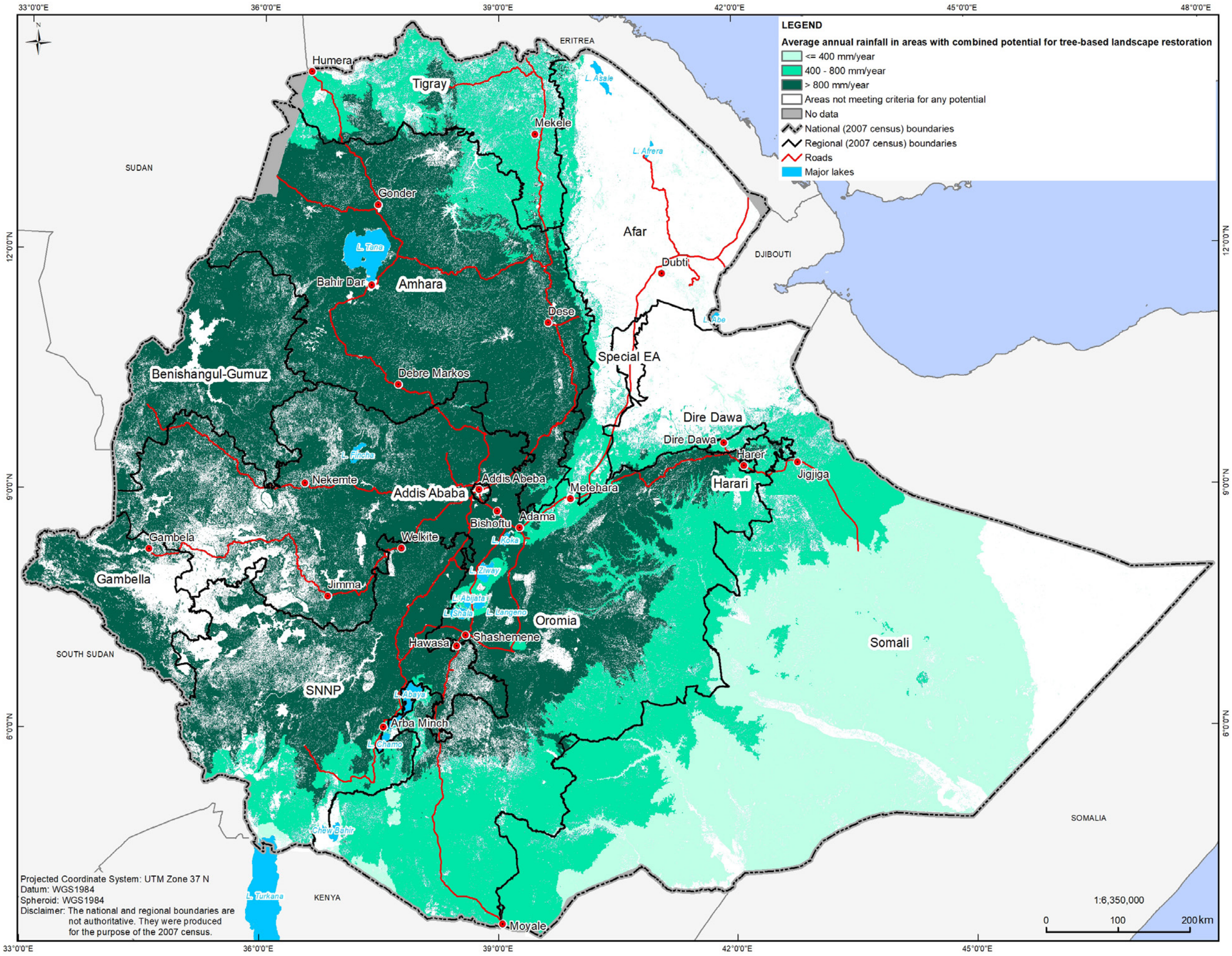
Map 1d | Population Density in Areas with Combined Potential for Tree-Based Landscape Restoration



CAPTION: Map 1d shows the population density in areas with combined potential for tree-based landscape restoration. Some areas are in low population density areas (in yellow), and others are in high population density areas (in brown and dark brown). Population density can inform restoration implementation strategies in terms of opportunities (e.g., high population density can drive demand for tree products) and challenges (e.g., in areas with high population density, pressure on restored trees and forests needs to be managed).

Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a. Population density: CSA 2007b.

Map 1e | Average Annual Rainfall in Areas with Combined Potential for Tree-Based Landscape Restoration



CAPTION: Map 1e shows average annual rainfall in areas with combined potential for tree-based landscape restoration. Areas can receive between 250 and 400 mm (in light green), 400 and 800 mm (in green), or more than 800 mm of rainfall a year (in dark green). The amount of rainfall in any particular area influences the choice of tree species to be planted and indicates if supplementary irrigation would be required.

Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a. Average annual rainfall: Hijmans et al. 2005.

Table 12 | Combined Tree-Based Landscape Restoration Potential: Regional Area Statistics[a]

	Land Area (ha) of Nation/Region	Combined Tree-Based Landscape Restoration Potential (ha)	Percentage of Nation/ Region with Potential for Tree-Based Landscape Restoration
Addis Ababa	52,700	22,000	43%
Afar	8,551,000	1,387,000	16%
Amhara	15,478,000	13,594,000	88%
Benishangul-Gumuz	5,070,000	4,193,000	83%
Dire Dawa	155,000	122,000	79%
Gambella	2,975,000	1,762,000	59%
Harari	33,000	30,000	91%
Oromia	29,785,000	24,560,000	82%
SNNP	10,542,000	7,705,000	73%
Somali	34,840,000	25,077,000	72%
Special Enumeration Areas	350,000	48,000	14%
Tigray	5,142,000	3,830,000	74%
National	**112,979,300**	**82,335,000**	**73%**

Note: [a] The regional boundaries used to calculate the area statistics are the regional boundaries defined for the 2007 census.
Source: Authors.

Step 4: Assess Accuracy of National Tree-Based Landscape Restoration Potential Maps in Four Woredas

The potential maps for tree-based landscape restoration are based on the best readily available national datasets. As such, their accuracy is a function of, and limited by, the accuracy of each input dataset. The accuracy assessment conducted in the four woredas aimed at gauging the reliability of the maps, and understanding and communicating any potential limitations of version 0.0 from a planning and policy point of view. While this accuracy assessment, limited to four woredas, is not necessarily representative of the accuracy of the maps across the country, it sheds light on the limitations of the current version of the potential maps and highlights sources of errors that should be addressed for version 1.0.

This section presents the accuracy of the combined potential for tree-based landscape restoration map in four woredas. The accuracy assessment results for the individual restoration option maps can be found in Appendix B.

When identifying sources of errors in the input data, it is important to acknowledge that, in some instances, what is identified as error might in fact originate in any of the following circumstances:

- There might be a discrepancy between the field at the time data were collected for the accuracy assessment (April to August 2017) and the field as depicted by the input data. (While data were compiled until May 15, 2016, some datasets portray the field at much earlier times, for example, the land use-land cover data are based on the interpretation of 2013 satellite images.)
- There might be some subjectivity in staff's interpretation in the field for some criteria (for example, differentiating between sparse forests and shrubland).
- Some of the criteria rely on information from local communities (for example, whether there is a national forest priority area or not), which might be ill-informed.

Accuracy Assessment Process

To assess the reliability of the maps to describe the potential for tree-based landscape restoration in the field, data were collected for 351 ground control points (GCPs) in four woredas: Sodo Gurage (SNNP), Meket (Amhara), Ambalage (Tigray), and Chole (Oromia). After cleaning the field data, restoration potential in the field was assessed for 337 GCPs for each of the eight mapped options and their combination.

To assess tree-based landscape restoration potential in the field, data must be collected for all the criteria used to map restoration potential. In the case of potential for agri-silviculture and agro-silvo-pastoralism, for example, data must be collected in the field regarding current land use-land cover, slope, tree cover, and presence of protected areas and national forest priority areas.

The "National Tree-Based Landscape Restoration Potential Assessment Criteria (version 0.0)" mobile app was developed with Open Data Kit (ODK) to support data collection for all the assessment criteria. The mobile app implements a skipping logic—that is, if one criterion for one potential is not met, the data collector is not asked any more questions regarding that specific restoration option; instead, he skips to the next restoration option. As a result, sources of errors related to the first (few) criteria might be overrepresented.

Table 13 presents a theoretical error matrix of one restoration potential option map based on field data (adapted from FAO 2016). The proportion of GCPs classified correctly, called "overall accuracy", is calculated as $\frac{A+D}{A+B+C+D}$. Because the focus is on whether the potential identified in the map represents the actual potential in the field, both the errors of commission and omission regarding potential are important. The error of commission regarding potential, calculated as $\frac{B}{A+B}$, is the percent of GCPs mapped as having potential that do not have potential in the field. The error of omission regarding potential, calculated as $\frac{C}{A+C}$, is the percent of GCPs with potential in the field that are mapped as not having potential.

Table 13 | Theoretical Error Matrix of Mapped Tree-Based Landscape Restoration Potential Based on Field Data

		Field	
		POTENTIAL IN THE FIELD (i.e., all criteria for the restoration potential option are met in the field)	**NO POTENTIAL IN THE FIELD** (i.e., at least one criterion for the restoration potential option is not met in the field)
Map	**POTENTIAL ON THE MAP** (i.e., all criteria for the restoration potential option are met in the input data)	Number of GCPs rightfully having potential on the map (A)	Number of GCPs wrongfully having potential on the map (B)
	NO POTENTIAL ON THE MAP (i.e., at least one criterion for the restoration potential option is not met in the input data)	Number of GCPs wrongfully not having potential on the map (C)	Number of GCPs rightfully not having potential on the map (D)

Source: Authors.

Accuracy Assessment Results for the Combined Potential for Tree-Based Landscape Restoration Map

The overall accuracy of the map in depicting the combined potential for tree-based landscape restoration in the four woredas is 80 percent. Unlike the commission and omission errors of the individual restoration options (Appendix B), the errors of commission and omission regarding combined tree-based landscape restoration potential are low, at 15 and 7 percent respectively (Table 14). This somewhat counterintuitive result is due to the fact that the errors in the land use-land cover input data lead to significantly less errors when specific restoration potential options are undifferentiated. For example, although the map mistakenly shows potential for agri-silviculture and agro-silvo-pastoralism when field data indicate potential for commercial plantations for products other than industrial roundwood, the map still rightly indicates that there is combined potential for tree-based restoration.

Of the 312 GCPs mapped as having combined potential for tree-based landscape restoration, 46 did not meet all the criteria for any option in the field and therefore should not have been included in the map as having potential.

Their commission comes from the following errors in the input data:[15]

- 39 GCPs (24 in dense forests, 1 in a natural grassland, 10 in settlements, and 4 in bare soil) were mistakenly classified in the land use-land cover data as degraded natural forests (12), grasslands (2), shrublands (15) and croplands (10);
- 6 GCPs in an urban expansion area were not identified as such for lack of input data; and
- 1 GCP with mechanized farming was not identified as such for lack of input data.

Of the 286 GCPs that had combined potential for tree-based landscape restoration in the field, 20 were not mapped as such. Their omission stems from the following errors in the input data:[16]

- 11 GCPs were mistakenly identified as being in a national forest priority area;
- 7 GCPs (2 in croplands, 2 in degraded natural forests, and 3 in shrublands) were mistakenly classified in the land use-land cover data as dense forests (5) and bare soil (2);
- 6 GCPs were mistakenly identified as being in a protected area; and/or
- 2 GCPs were mistakenly identified as having more than 30 percent tree cover.

15. As a result of the skipping logic embedded in the mobile app, other sources of errors in the input data might not have been identified as their related criteria were skipped. See Appendix C for general observations on input data.
16. The total number of GCPs with errors in the input data can be more than the number of GCPs omitted because one GCP might be characterized by multiple errors.

Table 14 | Error Matrix of the Map for Combined Potential for Tree-Based Landscape Restoration Based on Field Data

		Field			
		Combined Potential for Tree-Based Landscape Restoration (i.e., Potential for at Least One Option) in the Field	No Combined Potential for Tree-Based Landscape Restoration (i.e., No Potential for Any Option) in the Field	**Total**	**Commission Error**
Map	Combined Potential for Tree-Based Landscape Restoration (i.e., Potential for at Least One Option) on the Map	**266**	**46**	**312**	15%
Map	No Combined Potential for Tree-Based Landscape Restoration (i.e., No Potential for Any Option) on the Map	**20**	**5**	**25**	80%
	Total	**286**	**51**	**337**	Overall Accuracy: 80%
	Omission Error	7%	90%		

Source: Authors.

Insights from the Accuracy Assessment in Four Woredas

While the national maps for the individual eight restoration options have high commission and omission errors in the four woredas (Appendix B), the map of combined potential for tree-based landscape restoration, which indicates the potential for trees irrespective of the option, has acceptable commission and omission errors.

The accuracy assessment of the national potential maps in the four woredas might not be representative of their accuracy in the whole country, but it is likely indicative of their limitations beyond the four woredas.

Based on the sources of errors identified, the accuracy of the individual potential option maps in the four woredas would highly benefit from the following actions:

- Improving land use-land cover input data in the four woredas, and possibly beyond, as many errors in mapping the individual restoration options originates from errors in the land use-land cover classes (it should be noted that the land use-land cover is often one of the first criteria and therefore overrepresented compared to other sources of error);
- Updating datasets in the four woredas and possibly beyond (for example, protected areas and national forest priority areas boundaries, rivers);
- Producing and/or publishing missing data (for example, urban expansion areas, mechanized farming);
- Reducing the staff's subjectivity in field interpretation; and
- Revising the "National Tree-Based Landscape Restoration Potential Assessment Criteria (version 0.0)" mobile app to capture all sources of errors.

In addition, general observations on input data (Appendix C) can also help identify other ways to improve future iterations of the national tree-based landscape restoration potential maps.

Step 5: Inform the National Prioritization of Landscapes for Cross-Sectoral Implementation of Tree-Based Landscape Restoration

There are myriad opportunities for Ethiopia to achieve greater human well-being and ecological resilience through tree-based landscape restoration (Map 1a). While individual sectors can contribute independently to Ethiopia's national and international restoration objectives according to their respective GTP objectives, certain landscapes need a cross-sectoral approach to implementation to ensure significant on-the-ground results. For example, managing siltation of hydropower reservoirs will require joint efforts on the agricultural, forest, and pastoral lands of a watershed.

This section presents version 0.0 of maps meant to inform the national prioritization of landscapes for cross-sectoral implementation of tree-based landscape restoration. Restoration potential areas that are not prioritized for cross-sectoral implementation must be given due attention by the relevant sectors. For example, the MEFCC should work on management and restocking of forest and woodlands outside landscapes prioritized for cross-sectoral implementation. Similarly, the Ministry of Livestock and Fisheries should make use of trees to support pastoral livelihoods in lowlands that have potential for tree-based landscape restoration but do not meet the prioritization thresholds for cross-sectoral implementation.

Step 5.1 Identify National Landscape Prioritization Criteria and Data

National and regional experts identified the following criteria and data[17] to prioritize cross-sectoral implementation of tree-based landscape restoration, in line with the criteria proposed by the Community-Based Participatory Watershed Development guidelines (Lakew et al. 2005):

- **Land degradation and soil erosion risk:** Tree-based landscape restoration needs to help address and prevent land degradation, which has an estimated annual cost of approximately $4.3 billion (Gebreselassie et al. 2015). In addition to the implications of soil erosion for agricultural productivity, siltation is significantly affecting the storage capacity of hydroelectric dams (ICOLD 2009). *Data source for land degradation: EMA and ICPAC 2015. Data source for soil erosion risk: WBISPP 2004a.*

- **Food insecurity:** Tree-based landscape restoration needs to contribute to fighting food insecurity.[18] Over 30 percent of the population is unable to afford the minimum caloric intake for a healthy and active life (CSA and WFP 2014), with significant costs to individuals, families, and society as a whole. The total social and economic cost of child undernutrition in 2009 was estimated at $4.7 billion (AUC et al. 2014). *Data source for PSNP beneficiaries: based on MoANR 2015. Data source for Acute Food Insecurity Phase classification: FEWSNET 2016.*

- **Biodiversity:** Tree-based landscape restoration is a vital component of maintaining and enhancing biodiversity and ensuring the supply of key ecosystem services that contribute to local communities' well-being and the health of the national economy. The annual value of watershed services provided by protected areas alone was estimated to be at least US$432 million (EWCA 2009). *Data source for PAs: EWCA 2015. Data sources for NFPAs: IUCN and UNEP-WCMC 2016; Tigray BoARD 2016; Amhara BoA 2016; and OFWE 2016. Data source for KBAs: BirdLife International and CI 2016. Data source for biodiversity outside of PAs, NFPAs and KBAs: Costingnature 2016.*

- **Water availability:** As an integral component of sustainable agriculture and land management, tree-based landscape restoration can help rehabilitate and conserve water bodies, a priority of GTP II (FDRE 2016). *Data source for water availability: No readily available national data. Proxy used: area of water bodies with data source for rivers: Friis et al. 2010, and for lakes and reservoirs: MoWIE 2015.*

17. The cutoff line for data compilation was May 15, 2016. "No readily available national data" indicates either that no national spatial data exist or that national spatial data exist but were not made available by the deadline.
18. Many landscapes with food insecurity suffer from water scarcity. Trees should only be considered in the fight against food insecurity when they do not negatively affect water availability, which depends on various factors such as rainfall intensity; soil type; tree spatial distribution; tree size, age, and species; and management practices (for example, pruning) (Ilstedt et al. 2016).

- **Risk of forest degradation and deforestation:** Tree-based landscape restoration needs to help reduce forest degradation and deforestation. Not only are forests crucial to a green economy, but deforestation costs an estimated $660 per hectare per year, amounting to a loss of $19 million per year, as a result of the loss in raw material (for example, timber and woodfuel), food supply, carbon, and erosion control (EWCA n.d.). *Data source for risk of deforestation: No readily available national data. Data source for risk of forest degradation: No readily available national data. Proxy used: population density in forested areas with data source for forest: EMA 2015 and for population density: CSA 2007b.*
- **Woodfuel deficit:** The demand for woodfuel is by far the largest driver of deforestation and forest degradation (MEFCC 2017), imperiling the large contribution of forests to Ethiopia's domestic greenhouse gas emissions abatement (FDRE 2010). *Data source: WBISPP 2004b.*
- **Hazard-prone areas:** Tree-based landscape restoration needs to help mitigate and prevent natural hazards, the incidence of which could worsen and cost Ethiopia up to 10 percent of its GDP by 2050 (FDRE 2015b). *Data source: No readily available national data.*
- **Grazing pressure:** Ethiopia has the largest livestock population in Africa, contributing 9 percent to its GDP (FDRE 2015b). Forage trees can play an important role in supporting a livestock population that is expected to double by 2030 (FDRE 2010). *Data source: No readily available national data.*

Step 5.2 Rank Landscapes According to National Prioritization Criteria

While landscapes are to be delineated on a case-by-case basis according to the restoration objectives, this national mapping exercise used watersheds[19] to follow the principles prescribed by the Community-Based Participatory Watershed Development guidelines (Lakew et al. 2005).

The national prioritization exercise was undertaken on 1,691 watersheds averaging an area of 66,500 hectares. While relevant for national-level prioritization, these watersheds will have to be split into subwatersheds for implementation purposes. The Community-Based Participatory Watershed Development guidelines recommend 200- to 500-hectare microwatersheds as planning units for implementation (Lakew et al. 2005).

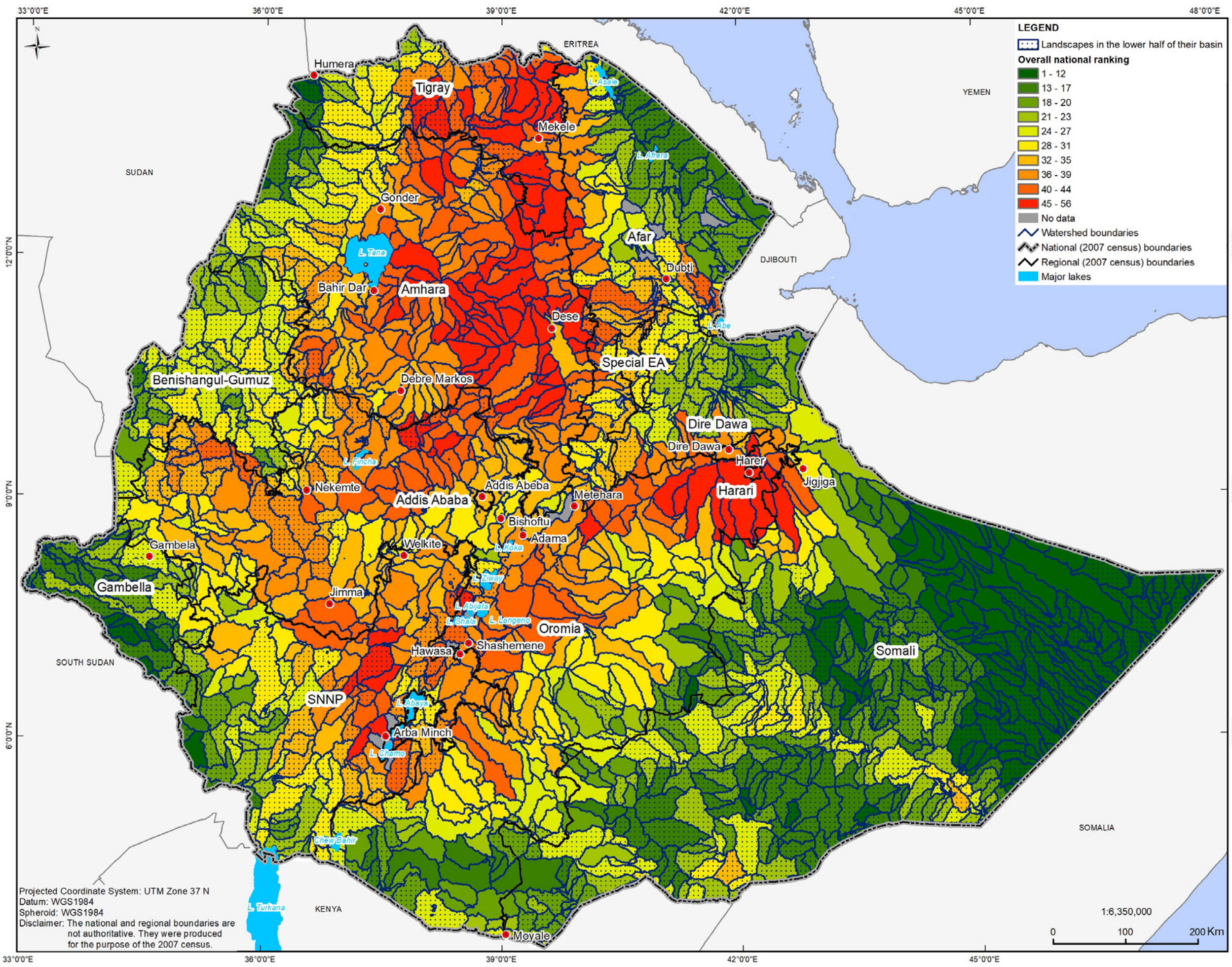
The process to rank the landscapes included the following steps:

1. **Selection of values of interest:** Values that do not indicate a problem that needs to be addressed were discarded (for example, nondegraded lands, areas with no food insecurity).
2. **Aggregation of values of interest at landscape level:** Data available at the administrative boundary or pixel level were aggregated to provide a value at landscape level.
3. **Reclassification of landscape values in deciles:** Original landscape values across criteria had diverse ranges of values (for example, landscape values for biodiversity range between 0 and 1, while landscape values for woodfuel deficit range between 0 and 10,000). To allow criteria to be compared and added up, the landscape values for each criterion had to be reclassified in deciles. In a decile classification, each of the 10 classes contains approximately 10 percent of the values. For example, a landscape with a value of 10 for both biodiversity and food insecurity ranks in the top 10 percent for each criterion.
4. **Calculation of overall national ranking:** Landscape decile rankings for individual criteria were summed up to provide an overall national ranking.

Map 2 presents the overall national ranking of individual landscapes. Maps 4a to 9b in Appendix D present the input data and national ranking for each criterion. The national ranking for individual criteria can be used on a sector-by-sector basis. For example, once the map is deemed accurate,[20] the EWCA and other stakeholders interested in maintaining and/or enhancing biodiversity can use Map 6b to identify landscapes where tree-based landscape restoration would contribute most to enhancing habitat and biodiversity.

19. Lakew et al. (2005) define a watershed as "any surface area from which runoff resulting from rainfall is collected and drained through a common confluence point."
20. Ground-truthing and validation are required to assess the accuracy of version 0.0 of the priority maps. Meanwhile, Appendix C presents general observations on input data used in the prioritization exercise.

Map 2 | Overall National Ranking



CAPTION: Map 2 shows how individual landscapes rank in terms of all individual criteria combined. Landscapes with a high overall national ranking (in red) can either have a high ranking for each criterion or a combination of very high rankings for some criteria and low rankings for others. Map 2 differentiates landscapes according to their position within their basin as the watershed principles recommend starting treatment in the upper watersheds (Lakew et al. 2005).

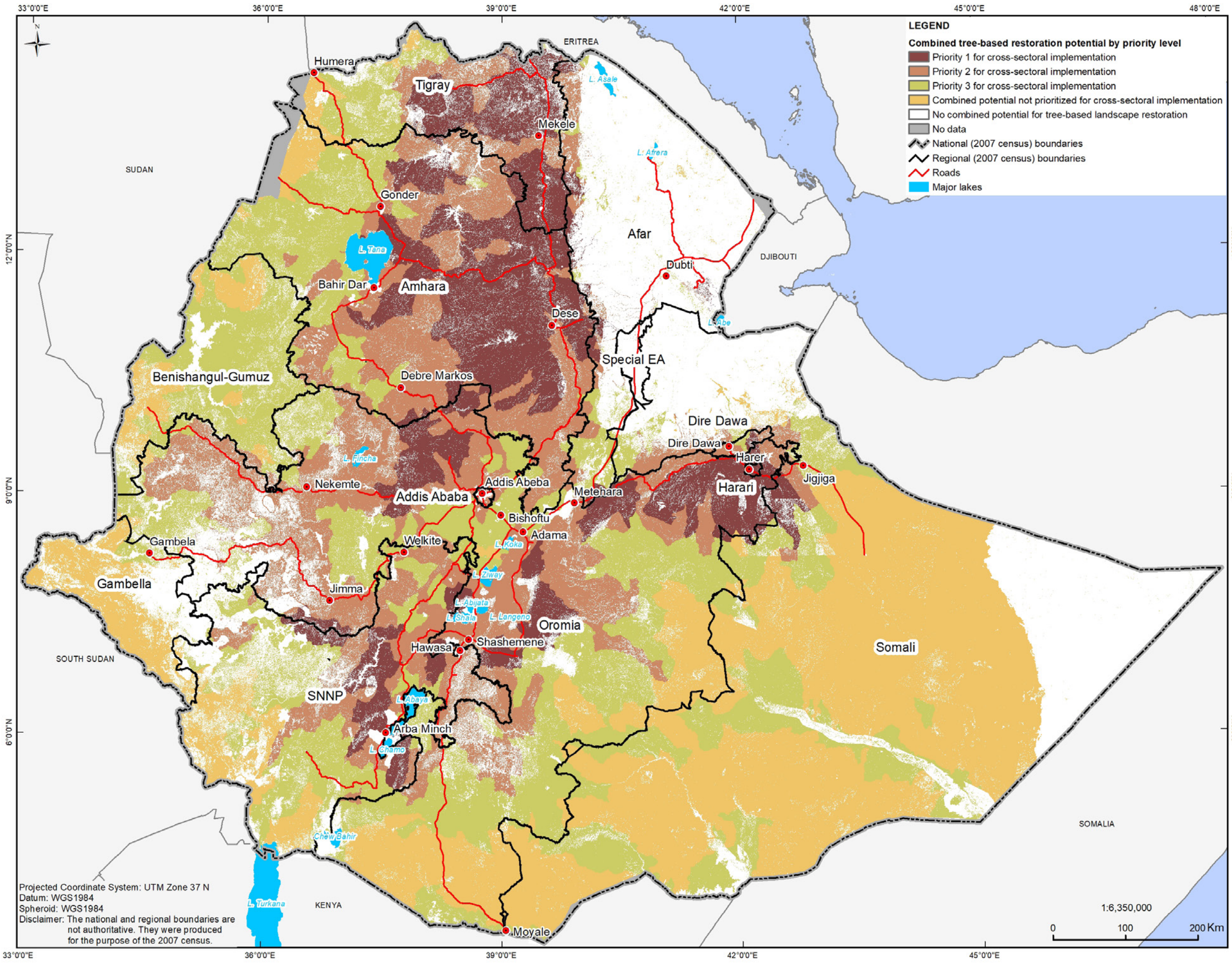
Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Overall national ranking: MEFCC 2018b.

Step 5.3 Identify Priority Landscapes

Landscapes were categorized according to the urgency of cross-sectoral intervention in the following priority areas, based on the histogram of the overall national ranking values and the guidance of experts:

- **Priority 1 landscapes:** Landscapes that require very urgent cross-sectoral intervention. These landscapes either rank higher than 5 on each individual criterion or their overall ranking is 42 or higher. They represent the top two classes of a 6-class standard deviation classification.
- **Priority 2 landscapes:** Landscapes that require urgent cross-sectoral intervention. These landscapes have an overall ranking of 34 or higher. They constitute the third top class of a 6-class standard deviation classification.
- **Priority 3 landscapes:** Landscapes that require moderately urgent cross-sectoral intervention. These landscapes' overall ranking is 23 or higher. They make up the fourth top class of a 6-class standard deviation classification.

Map 3a | Combined Potential for Tree-Based Landscape Restoration According to Priority Level for Cross-Sectoral Implementation



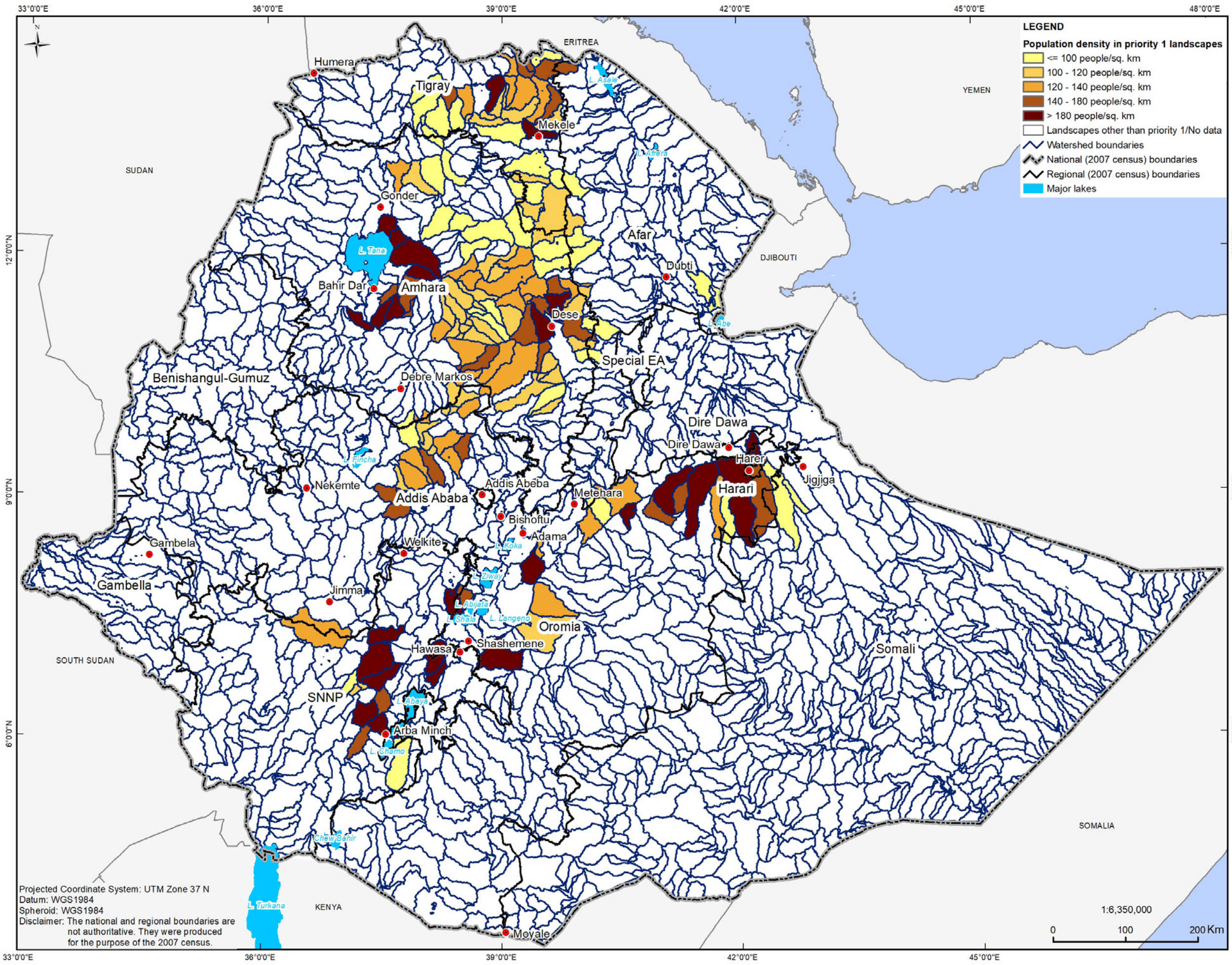
CAPTION: Map 3a shows the combined potential for tree-based landscape restoration in priority landscapes according to whether the potential falls in priority 1 landscapes (in dark red), priority 2 landscapes (in pink), or priority 3 landscapes (in tan).

Sources: International boundaries: UC Berkeley et al. 2015. Census boundaries, cities, and towns: CSA 2007a and c. Roads: ERA 2007. Major lakes: MoWIE 2015. Combined tree-based landscape restoration potential: MEFCC 2018a. Tree-based landscape restoration cross-sectoral priority landscapes: MEFCC 2018c.

Not all land in priority landscapes has potential for tree-based landscape restoration. A total of 54 million hectares with combined potential for tree-based landscape restoration meets the prioritization criteria for cross-sectoral implementation (Map 3a and Table 15). Areas with potential for tree-based landscape restoration that are not prioritized for cross-sectoral implementation (28 million ha) should nonetheless receive due attention from the individual relevant sectors.

To achieve the CRGE goal of middle-income status by 2025, it is important that tree-based landscape restoration benefit as many poor people as possible. In the absence of national poverty data, population density was used as a proxy. Map 3b shows population density in priority 1 landscapes to identify where tree-based landscape restoration would address the most urgent cross-sectoral needs and benefit the most people, regardless of their poverty level.

Map 3b | Population Density in Priority 1 Landscapes



CAPTION: Map 3b shows population density in priority 1 landscapes. Cross-sectoral implementation of tree-based landscape restoration could start in more populated priority 1 landscapes (in dark brown) to maximize the number of people benefiting from an increase in the number of trees in their landscapes.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Tree-based landscape restoration cross-sectoral priority landscapes: MEFCC 2018c. Population density: CSA 2007b.

Table 15 | Combined Tree-Based Landscape Restoration Potential by Priority Level for Cross-Sectoral Implementation: Regional Area Statistics[a]

	Land Area (ha) of Priority Landscapes	Combined Tree-Based Landscape Restoration Potential (ha)				Percentage of Priority Landscapes with Combined Potential for Tree-Based Landscape Restoration
		Priority 1 landscapes	Priority 2 landscapes	Priority 3 landscapes	Total	
Addis Ababa	52,700	-	22,000	-	**22,000**	43%
Afar	5,062,000	285,000	523,000	522,000	**1,330,000**	26%
Amhara	14,708,700	4,758,000	5,048,000	3,357,000	**13,164,000**	90%
Benishangul-Gumuz	3,828,200	-	90,000	3,065,000	**3,156,000**	82%
Dire Dawa	155,200	21,000	78,000	22,000	**122,000**	79%
Gambella	629,800	-	1,000	170,000	**171,000**	27%
Harari	33,100	30,000	-	-	**30,000**	91%
Oromia	25,465,100	3,254,000	8,244,000	9,036,000	**20,535,000**	81%
SNNP	8,443,200	992,000	2,425,000	2,819,000	**6,237,000**	74%
Somali	8,975,500	256,000	500,000	5,311,000	**6,068,000**	68%
Special Enumeration Areas	323,600	-	3,000	18,000	**21,000**	7%
Tigray	4,670,600	1,846,000	756,000	930,000	**3,533,000**	76%
National	**72,348,400**	**11,444,000**	**17,674,000**	**25,253,000**	**54,372,000**	**75%**

Notes: Numbers might not add up to totals because of rounding.
[a] The regional boundaries used to calculate the area statistics are the regional boundaries defined for the 2007 census.
Source: Authors.

CONCLUSIONS AND NEXT STEPS

National potential and cross-sectoral priority maps for tree-based landscape restoration can be useful in realizing the following objectives:

- Identifying and locating the different tree-based landscape restoration options available at the national level to help Ethiopia achieve its economic, social and environmental goals.
- Quantifying the potential of each restoration option and therefore assessing the human and financial resources that various sectors will need in order to support tree-based landscape restoration.
- Nuancing the restoration potential options according to factors influencing implementation strategies, such as slope, population density, land use-land cover, rainfall, and current tree cover.
- Strengthening cross-sectoral dialogues around coordination and collaboration among national, regional, and local restoration actors to help achieve Ethiopia's commitment to its green growth strategy and the Bonn Challenge and AFR100 of restoring a total of 15 million hectares by 2030.
- Targeting coordination and integration of human and financial resources in landscapes prioritized for cross-sectoral implementation to promote greater human well-being and ecological resilience.

The usefulness of the national maps in planning, coordinating, and implementing tree-based landscape restoration would be significantly heightened if the accuracy of version 0.0 of the national maps were assessed and sources of error identified countrywide; input data shortcomings, starting with those identified in the four woredas, were addressed; the maps were scaled down to regional and local levels; and an implementation strategy were developed.

1. *Assessing the accuracy of version 0.0 of the national potential and priority maps for tree-based landscape restoration and identifying sources of errors across the country*

   Version 0.0 of the national maps is based on the best readily available national datasets and criteria identified by national and regional experts. Nonetheless, as Step 4 and Appendix B describe for four woredas, these maps reflect the shortcomings of the input data.

   While the accuracy assessment identified some input data shortcomings, others may have been overlooked, given the limited geographical scope of the assessment.

   Recognizing that resources are unavailable to conduct a full-scale national accuracy assessment, the MEFCC proposes an incremental approach to assessing the maps' accuracy while moving toward implementation. The MEFCC plans to establish a process to assess the accuracy of the national maps and identify the sources of their limitations. The MEFCC also encourages restoration actors to use the "National Tree-Based Landscape Restoration Potential Assessment Criteria (version 0.0)" mobile app and report uncovered sources of errors to the ministry.

2. *Addressing input data shortcomings*

    As cross-sectoral decision-supporting tools, the national potential and priority maps for tree-based landscape restoration depend on the production and sharing of high-quality data by many institutions. It is critical that the mandated institutions act upon the data limitations and gaps identified in the accuracy assessment conducted in four woredas (Step 4 and Appendix B). The limitations documented in Appendix C provide additional areas of improvement for consideration (for example, using higher spatial/temporal resolution data, applying subnational classification algorithms).

    In addition to producing high-quality data, these institutions need to make their data readily available in a user-friendly format, including proper metadata and accuracy assessment, so that others can benefit from their investment in data production.

3. *Scaling down to regional and local levels*

    The national potential and priority maps for tree-based landscape restoration are meant to provide an overarching framework and inform national decision-making processes. To be more relevant to regional and local stakeholders and support implementation, they need to be supplemented by regional and local maps developed with regional and local knowledge, as well as by higher-resolution local data.

    Regions should produce their own potential and priority maps. This would ensure that the maps would address all region-specific land-use challenges through region-specific restoration options. While the national maps were developed based on nationally relevant assessment and prioritization criteria, regions might need to revise them to reflect their own regional contexts. Finally, regional data might be available and might better depict the situation in the regions than national datasets are able to do.

    At the local level, more detailed biophysical information needs to be considered, such as which specific tree species are ecologically, socially, and economically relevant to the landscape. Social information that could not be factored in at the national level (such as land rights and bylaws regarding uses of communal land) should be incorporated in local tree-based landscape restoration potential maps. Most important, local restoration potential maps need to reflect local communities' choices among different tree-based landscape restoration options. Local maps for tree-based landscape restoration can be developed as part of the GTP II rural land-use plans.

4. *Developing a tree-based landscape restoration implementation strategy*

    The national potential and priority maps for tree-based landscape restoration are an important, but not sufficient, first step toward maximizing trees' contribution to Ethiopia's goal of achieving middle-income status by 2025 while transitioning to a climate-resilient green economy. Scaling up tree-based landscape restoration across Ethiopian landscapes will require extensive coordination and collaboration among the many local, regional, national, and international actors involved in restoration, from the planning stage all the way to implementation, financing, and monitoring. To support such a significant cross-sectoral effort, the MEFCC, at the stakeholders' request, plans to invite key restoration stakeholders to develop a tree-based landscape restoration implementation strategy with the goal of achieving the CRGE targets and the commitment to the Bonn Challenge and AFR100 of restoring a total of 15 million hectares by 2030.

    The MEFCC envisions the tree-based landscape restoration implementation strategy, together with the national forest sector development program, as laying the groundwork for a nationwide restoration movement enabling individual and organized farmers, communities, companies, and governmental and nongovernmental institutions to achieve their long-term goals through tree-based landscape restoration.

The strategy will be a participatory, cross-sectoral undertaking that will engage governmental institutions at all levels, nongovernmental organizations, public and private sectors, communities, individual farmers, and development and financial partners. The strategy should, among other things, adhere to the following principles:

- The strategy should be informed by and promote the best knowledge available in Ethiopia and beyond regarding the creation and strengthening of a tree-based landscape restoration movement. The strategy should build on existing domestic large-scale restoration successes (for example, Participatory Watershed Management, the Sustainable Land Management Program, Participatory Forest Management, the Forest Sector Development Program) and foster additional research and innovation. It should ensure proper knowledge and data management.
- The strategy should ensure that individual and organized farmers, communities, governmental and nongovernmental institutions, as well as companies that invest in trees, will have the requisite policy, legal, institutional, and normative frameworks in place to guarantee the long-term benefits of their investments.
- The strategy should set up standards regarding environmental and social safeguards (for example, the participation and input of local communities and stakeholders) based on existing safeguards (for example, REDD+ safeguards).
- The strategy should address the need to increase citizens' awareness of the benefits provided by trees and forests.
- The strategy should put in place a system to ensure that best knowledge and practices reach restoration actors on the ground.
- The strategy should address the need to make adequate financing available to people interested in implementing tree-based landscape restoration or taking part in the value chain around tree and forest products. The strategy should put in place mechanisms to increase the finance readiness of individual and organized entrepreneurs so that they can access public and private finance.
- The strategy should articulate the various actors' roles and responsibilities, communication mechanisms, and cooperation modalities among them, including public-private partnerships, to ensure that optimal conditions are in place to promote and maintain a widespread restoration movement in Ethiopia.
- Building on existing monitoring systems, the strategy should explore development of a nationwide, multiscale, integrated tree-base landscape restoration monitoring and evaluation system tracking environmental, social, and economic costs and benefits.
- The strategy should ensure that there is strong institutional capacity regarding planning, implementing, financing, and monitoring tree-based landscape restoration at all levels.
- The strategy should leverage existing funding sources as well as channel additional resources to tree-based landscape restoration.

The MEFCC encourages all interested stakeholders to engage in this process and contribute to an Ethiopia that is more prosperous, green, and resilient to climate change.

APPENDIX A. LIST OF CONSULTATION WORKSHOP PARTICIPANTS

September 2014 Workshop (Addis Ababa)

No.	Name	Institution
1	H.E. Ato Kebede Yimam Dawd	MEFCC, State Minister of Forest Sector
2	Simon Berhanu	MEFCC, Forest Carbon Expert
3	Wubshet Getachew	MEFCC, Forest Carbon Expert
4	Robel Tesfaye	MEFCC, Forest Carbon Expert
5	Daniel Belay	MEFCC, Forestry expert
6	Tsegaye Debebe	Ministry of Water and Energy
7	Kalkidan Ayele	Ethiopian Mapping Agency
8	Degelo Sendabo	Addis Ababa University, GIS and RS expert
9	Ashenafi Burka	Wondo Genet College of Forestry and Natural Resources
10	Tadesse Woldemariam Gole	Environment and Coffee Forest Forum, Director
11	Tesfaye Hunde	INBAR Regional Coordinator for East Africa
12	Paul Siegel	World Bank
13	Melakneh Gelet	FAO Ethiopia
14	Feyera Abdi	SOS Sahel Ethiopia
15	Getachew Eshete	SOS Sahel Ethiopia
16	Mesfin Legese	SNV
17	Gedefa Negera	Oromia Forest and Wildlife Enterprise
18	Getachew Gebeyehu	Amhara Regional State Agricultural Office
19	Sewalem Selele	Amhara Regional State Agricultural Office
20	Mehari Goldemariam	Tigray Regional State Agricultural Office
21	Tesfay T. Maymanit	Tigray Regional State Agricultural Office
22	Salomon Mengesha	SNNP Regional State Agricultural Office
23	Debebe Woldermariam	SNNP Regional State Agricultural Office

June 2015 Workshops (Tigray; Amhara; Oromia; and Southern Nations, Nationalities, and Peoples' National Regional States)

TIGRAY

No.	Name	Institution
1	Berhane Merefu	Tigray Region
2	Mulugatu Gabresitasse	Tigray REDD
3	Tadesse Gebre	Tigray BoARD
4	Kiflom Meshesha	Tigray BoARD
5	Negash Haddis	EWRFS
6	Tesfay T/Haymanot	Tigray BoARD
7	Gidey Berhanu	GIZ SLM Tigray
8	Mehari Gabremedhin	SCMP
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10	Nkirote Koome	CCI

AMHARA

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1	Lakew Belay	Bureau of Agriculture
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3	Enelalkachew Kassa	Bureau of Agriculture NRM
4	Getachew Gebeyehnu	Amhara Biodiversity Centre
5	Tsegaye Sewinet	Bureau of Agriculture
6	Sintayehu Deresse	Amhara REDD+
7	Baylelegn Azene	Amhara Forest Enterprise
8	Addisu Metaligae	Amhara Forest Enterprise
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10	Getachew Enydayehu	Bureau of Agriculture
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3	Mengistu Tadesse	OFWE
4	Berhanu Jilcha	OFWE
5	Mekonnen Alemayenu	OFWE
6	Abenet Solomon	EMA
7	Elias Buzayene Gabremeskel	EMA
8	Misrak Alemu	OFWE
9	Diro Bulbula	OFWE
10	Yeshiwork Kifie	OBA
11	Aman Oulo	OFWE
12	Muhammed Kassim	Bureau of Agriculture
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7	Bogale Lencha	Bureau of Agriculture
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October 2015 Workshop (Addis Ababa)

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1	Tsehaye Mulugeta	Tigray, BoARD
2	Mehari Gabremedhin	Tigray, BoARD
3	Tsegaye Sewinet	Amhara, BoA
4	Muluneh Genanew	Amhara, BoA
5	Mesfin Admasu	Amhara, AFE
6	Misrak Alemu	Oromia, Bureau of Environmental Protection and Land Administration
7	Mekonen Alemayehu	Oromia, OFWE
8	Bekele Kefyalew	Oromia, BoANR
9	Solomon Mengesha	SNNP, BoA
10	Muluken Amare	SNNP, BoA
11	Abel Aseratu	BG, Bureau of Environmental Protection and Land Administration
12	Getachew Chaka	Gambella, BoA
13	Ruach Tut	Gambella, BoA
14	Tegenie Wodajeneh	EMA
15	Bemnet Ayalew	EMA
16	Hailemichael Ayele	MoANR
17	Beyene Sebeko Alye	MoANR, disaster risk management and food security
18	Eleni Beyene	MoANR
19	Lemessa Gudeta	EPA
20	Dr. Yigardu Mulate	Institute of Environment and Forest Research
21	Dr. Menassie Gashaw	MEFCC
22	Nigatu Girma	MEFCC
23	Getachew Eshete	SOS Sahel Eth
24	Feyera Abdi	SOS Sahel Eth
25	Mesfin Legese	SNV
26	Motuma Didita	Ethiopian Biodiversity Institute
27	Ashenafi Burka	Wondo Genet
28	Tesfaye Hunde	INBAR
29	Nkirote Koome	CCI
30	Techane Gonfa	Environment and Coffee Forest Forum
31	Rob Wild	IUCN—East and Southern Africa Office
32	Honelign Endalew	MoANR
33	Tsegaye Tadesse	Global Green Growth Initiative

March 2016 Workshop with CRGE Sectors (Addis Ababa)

No.	Name	Institution
1	Fantahun Haile	Ministry of Construction
2	Fikadu Gebeyehu	Ministry of Industry
3	Hana Basazinew	Ministry of Industry
4	Belaynesh Birru	Ministry of Water, Irrigation and Electricity
5	Getnet Fetene	Ministry of Water, Irrigation and Electricity
6	Berhanu Assefa	MoANR
7	Amir Oumer	MEFCC
8	Eyob Alemu	Ministry of Livestock and Fishery
9	Dr. Gessesse Dessie	USFS/USAID
10	Enatfenta Melaku	Ministry of Mining, Petroleum and Natural Gas
11	Ghirmawit Haile	MEFCC
12	Nkirote Koome	Clinton Climate Initiative

March 2016 Workshop with MEFCC Experts (Addis Ababa)

No.	Name	Institution
1	Mesfin Tsegaye	MEFCC
2	Adugna Abebe	MEFCC
3	Tiruneh Chaka	MEFCC
4	Mekonnen Alemu	MEFCC
5	Yelfign Assefa	MEFCC
6	Abebe Seifu	MEFCC
7	Heiru Sebrala	MEFCC
8	Meklit Asefa	MEFCC
9	Zerihun Lakew	MEFCC
10	Melakneh Gelet	FAO, ETH
11	Aberu Tena	MEFCC
12	Woinhareg Teklu	MEFCC

April 2016 Workshop with EEFRI Researchers (Addis Ababa)

No.	Name	Institution
1	Abera Tesfaye	EEFRI-CEEFRC
2	Tesfalem Belay	EEFRI-CEEFRC
3	Abdrie Seid	EEFRI-CEEFRC
4	Marta G/Yesus	EEFRI-CEEFRC
5	Getachew Kebede	EEFRI-Head office
6	Melaku Getachew	EEFRI-Head office
7	Mister Abebe	EEFRI-CEEFRC
8	Alemtsehaye Eyassu	EEFRI-CEEFRC
9	Tesfaye Humnessa	EEFRI-CEEFRC
10	Tinsae Bahru	EEFRI-CEEFRC
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12	Yewbdar Kebede	EEFRI-CEEFRC
13	Berhanu Sugebo	Jimma-CEEFR
14	Mindaye Teshome	EEFRI-CEEFRC
15	Tizazu H/mariam	EEFRI-CEEFRI
16	Nesibu Yulye	CEEFRI
17	Dagnew Yebeyen	CEEFRI
18	Dr. Abeje Eshete	CEEFRI
19	Eguale Taddese	CEEFRI

APPENDIX B. ACCURACY ASSESSMENT RESULTS FOR THE POTENTIAL MAPS FOR INDIVIDUAL TREE-BASED LANDSCAPE RESTORATION OPTIONS

This appendix presents the accuracy of the maps for the individual tree-based landscape restoration options in four woredas.[21]

Potential for Restoring Secondary Forests

While the overall accuracy of the map in depicting potential for restoring secondary forests in the four woredas is 66 percent, the errors of commission and omission regarding potential for this option are 74 and 52 percent, respectively (Table B1).

Of the 113 GCPs mapped as having potential for restoring secondary forests, 84 were not meeting all the criteria in the field and therefore should not have been included in the map as having potential. Their commission stems from the following errors in the input data:[22]

- 79 GCPs (21 in forests, 42 in croplands, 9 in grasslands, 4 in settlements, and 3 in bare soil) were mistakenly classified in the land use-land cover data as shrublands;
- 3 GCPs in forests were mistakenly classified in the land use-land cover data as croplands (croplands are included in this potential when they have more than 60 percent slope); and
- 2 GCPs in an urban expansion area were not identified as such for lack of input data.

Table B1 | Error Matrix of the Potential Map for Restoring Secondary Forests Based on Field Data

		Field			
		Potential for Restoring Secondary Forests in the Field	No Potential for Restoring Secondary Forests in the Field	**Total**	**Commission Error**
Map	Potential for Restoring Secondary Forests on the Map	29	84	**113**	74%
Map	No Potential for Restoring Secondary Forests on the Map	32	192	**224**	14%
	Total	**61**	**276**	**337**	Overall Accuracy: 66%
	Omission Error	52%	30%		

Source: Authors.

21. The accuracy assessment was limited to the restoration options mapped as part of this exercise. For the potential for industrial roundwood plantations, Ethiopia's Commercial Plantation Forest Industry Investment Plan (World Bank Group 2016) should be consulted.
22. As a result of the skipping logic embedded in the mobile app, other sources of errors in the input data might not have been identified as their related criteria were skipped. See Appendix C for general observations on input data.

Of the 61 GCPs that had potential for restoring secondary forests in the field, 32 were not mapped as such. Their omission comes from the following errors in the input data:[23]

- 32 GCPs in shrublands were mistakenly classified in the land use-land cover data as forests (13), croplands (15), and grasslands (4) (note that croplands and grasslands are excluded from this potential if they have less than 60 percent slope); and/or
- 4 GCPs were mistakenly identified as not having potential for forest vegetation in the potential natural vegetation input data.

Potential for Restocking Degraded Natural Forests

While the overall accuracy of the map in portraying potential for restocking degraded natural forests in the four woredas is 77 percent, the errors of commission and omission regarding potential for this option are 78 and 84 percent, respectively (Table B2).

Of the 40 GCPs mapped as having potential for restocking degraded natural forests, 31 did not meet all the criteria in the field and therefore should not have been included in the map as having potential. Their commission originates from the fact that all 31 GCPs (10 in dense forests, 3 in croplands, 6 in grasslands, 10 in shrublands, and 2 in settlements) were mistakenly classified in the land use-land cover data as degraded natural forests (that is, moderate or sparse forests and woodlands).[24]

Of the 55 GCPs that had potential for restocking degraded natural forests in the field, 46 were not mapped as such. Their omission comes from the fact that, despite being degraded natural forests (that is, moderate or sparse forests and woodlands), these GCPs were classified in the land use-land cover data as dense forest (1), grasslands (6), shrublands (13), croplands (25), and bare soil (1).

Table B2 | Error Matrix of the Potential Map for Restocking Degraded Natural Forests Based on Field Data

		Field			
		Potential for Restocking Degraded Natural Forests in the Field	No Potential for Restocking Degraded Natural Forests in the Field	**Total**	**Commission Error**
Map	Potential for Restocking Degraded Natural Forests on the Map	**9**	**31**	**40**	78%
Map	No Potential for Restocking Degraded Natural Forests on the Map	**46**	**251**	**297**	15%
	Total	**55**	**282**	**337**	Overall Accuracy: 77%
	Omission Error	84%	11%		

Source: Authors.

23. The total number of GCPs with errors in the input data can be more than the number of GCPs omitted because one GCP might be characterized by multiple errors.
24. As a result of the skipping logic embedded in the mobile app, other sources of errors in the input data might not have been identified as their related criteria were skipped. See Appendix C for general observations on input data.

Potential for Agri-Silviculture and Agro-Silvo-Pastoralism

The overall accuracy of the map in depicting potential for agri-silviculture and agro-silvo-pastoralism in the four woredas is 61 percent. The errors of commission and omission regarding potential for this option are 38 and 42 percent, respectively (Table B3).

Of the 159 GCPs mapped as having potential for agri-silviculture and agro-silvo-pastoralism, 61 did not meet all the criteria in the field and therefore should not have been included in the map as having potential. Their commission comes from the following errors in the input data:[25]

- 56 GCPs (31 in forests, 19 in shrublands, 1 in natural grassland, 4 in settlements, and 1 in bare soil) were mistakenly classified in the land use-land cover data as croplands (44) and grasslands (12);
- 4 GCPs in an urban expansion area were not identified as such for lack of input data; and
- 1 GCP with mechanized farming was not identified as such for lack of input data.

Of the 170 GCPs that had potential for agri-silviculture and agro-silvo-pastoralism in the field, 72 were not mapped as such. Their omission comes from the following errors in the input data:[26]

- 62 GCPs (47 in croplands and 15 in grasslands) were mistakenly classified in the land use-land cover data as forests (10), shrublands (51), and bare soil (1);
- 11 GCPs were mistakenly identified as being in a national forest priority area;
- 7 GCPs were mistakenly identified as being in a protected area; and/or
- 1 GCP was mistakenly identified as having more than 30 percent tree cover.

Table B3 | Error Matrix of the Potential Map for Agri-Silviculture and Agro-Silvo-Pastoralism Based on Field Data

		Field			
		Potential for Agri-Silviculture and Agro-Silvo-Pastoralism in the Field	No Potential for Agri-Silviculture and Agro-Silvo-Pastoralism in the Field	**Total**	**Commission Error**
Map	Potential for Agri-Silviculture and Agro-Silvo-Pastoralism on the Map	**98**	**61**	**159**	38%
Map	No Potential for Agri-Silviculture and Agro-Silvo-Pastoralism on the Map	**72**	**106**	**178**	40%
	Total	**170**	**167**	**337**	Overall Accuracy: 61%
	Omission Error	42%	37%		

Source: Authors.

25. As a result of the skipping logic embedded in the mobile app, other sources of errors in the input data might not have been identified as their related criteria were skipped. See Appendix C for general observations on input data.
26. The total number of GCPs with errors in the input data can be more than the number of GCPs omitted because one GCP might be characterized by multiple errors.

Potential for Silvo-Pastoralism

No field data were collected for this restoration option as none of the four woredas was in an agro-pastoralist or pastoralist livelihood zone.

Potential for Woodlots and Home Gardens

The overall accuracy of the map in depicting potential for woodlots and home gardens in the four woredas is 59 percent. The errors of commission and omission regarding potential for this option are 53 and 41 percent, respectively (Table B4).

Of the 161 GCPs mapped as having potential for woodlots and home gardens, 85 did not meet all the criteria in the field and therefore should not have been included in the map as having potential. Their commission comes from the following errors in the input data:[27]

- 58 GCPs (33 in forests, 19 in shrublands, 1 in natural grassland, 4 in settlements, and 1 in bare soil) were mistakenly classified in the land use-land cover data as croplands (46) and grasslands (12);
- 22 GCPs (3 in croplands and 19 in grasslands) with plot size greater than 1 hectare were not identified as such for lack of input data;
- 4 GCPs in an urban expansion area were not identified as such for lack of input data; and
- 1 GCP with mechanized farming was not identified as such for lack of input data.

Of the 129 GCPs that had potential for woodlots and home gardens in the field, 53 were not mapped as such. Their omission comes from the following errors in the input data:[28]

- 44 GCPs (41 in croplands and 3 in grasslands) were mistakenly classified in the land use-land cover data as forests (6), shrublands (37), and bare soil (1);
- 10 GCPs were mistakenly identified as being in a national forest priority area;
- 6 GCPs were mistakenly identified as being in a protected area; and/or
- 1 GCP was mistakenly identified as having more than 30 percent tree cover.

Table B4 | Error Matrix of the Potential Map for Woodlots and Home Gardens Based on Field Data

		Field			
		Potential for Woodlots and Home Gardens in the Field	No Potential for Woodlots and Home Gardens in the Field	**Total**	**Commission Error**
Map	Potential for Woodlots and Home Gardens on the Map	76	85	**161**	53%
Map	No Potential for Woodlots and Home Gardens on the Map	53	123	**176**	30%
	Total	**129**	**208**	**337**	Overall Accuracy: 59%
	Omission Error	41%	41%		

Source: Authors.

27. As a result of the skipping logic embedded in the mobile app, other sources of errors in the input data might not have been identified as their related criteria were skipped. See Appendix C for general observations on input data.
28. The total number of GCPs with errors in the input data can be more than the number of GCPs omitted because one GCP might be characterized by multiple errors.

Potential for Commercial Plantations for Products Other Than Industrial Roundwood

While the overall accuracy of the map in depicting potential for commercial plantations for products other than industrial roundwood in the four woredas is 74 percent, the errors of commission and omission regarding potential for this option are 74 and 59 percent, respectively (Table B5).

Of the 80 GCPs mapped as having potential for commercial plantations for products other than industrial roundwood, 59 did not meet all the criteria in the field and therefore should not have been included in the map as having potential. Their commission comes from the following errors in the input data:[29]

- 58 GCPs (13 in forests, 6 in grasslands, 33 in croplands, 3 in settlements, and 3 in bare soil) were mistakenly classified in the land use-land cover data as shrublands; and
- 1 GCP in an urban expansion area was not identified as such for lack of input data.

Of the 51 GCPs that had potential for commercial plantations for products other than industrial roundwood in the field, 30 were not mapped as such. Their omission stems from the following errors in the input data:[30]

- 26 GCPs in shrublands were mistakenly classified in the land use-land cover data as forests (8), grasslands (4), and croplands (14);
- 5 GCPs were mistakenly identified as being in a key biodiversity area; and/or
- 3 GCPs were mistakenly identified as being in a national forest priority area.

Table B5 | Error Matrix of the Potential Map for Commercial Plantations for Products Other Than Industrial Roundwood Based on Field Data

		Field			
		Potential for Commercial Plantations for Products Other Than Industrial Roundwood in the Field	No Potential for Commercial Plantations for Products Other Than Industrial Roundwood in the Field	**Total**	**Commission Error**
Map	Potential for Commercial Plantations for Products Other Than Industrial Roundwood on the Map	**21**	**59**	**80**	74%
Map	No Potential for Commercial Plantations for Products Other Than Industrial Roundwood on the Map	**30**	**227**	**257**	12%
	Total	**51**	**286**	**337**	Overall Accuracy: 74%
	Omission Error	59%	21%		

Source: Authors.

29. As a result of the skipping logic embedded in the mobile app, other sources of errors in the input data might not have been identified as their related criteria were skipped. See Appendix C for general observations on input data.
30. The total number of GCPs with errors in the input data can be more than the number of GCPs omitted because one GCP might be characterized by multiple errors.

Potential for Buffer Plantations around Protected Areas and National Forest Priority Areas

While the overall accuracy of the map in depicting potential for buffer plantations around protected areas and national forest priority areas in the field in the four woredas is 90 percent, the errors of commission and omission regarding potential for this option are 66 and 52 percent, respectively (Table B6).

Of the 32 GCPs mapped as having potential for buffer plantations around protected areas and national forest priority areas, 21 did not meet all the criteria in the field and therefore should not have been included in the map as having potential. Their commission comes from the following errors in the input data:[31]

- 20 GCPs were mistakenly identified as being within 1 km of a protected area or a national forest priority area; and
- 1 GCP in a forest was mistakenly classified in the land use-land cover data as cropland.

Of the 23 GCPs that had potential for commercial plantations for products other than industrial roundwood in the field, 12 were not mapped as such. Their omission stems from the following errors in the input data:[32]

- 10 GCPs were mistakenly identified as not being within 1 km of a national forest priority area;
- 7 GCPs were mistakenly identified as not being within 1 km of a protected area; and/or
- 3 GCPs (1 in a cropland and 2 in shrublands) were mistakenly classified in the land use-land cover data as forests.

Table B6 | Error Matrix of the Potential Map for Buffer Plantations around Protected Areas and National Forest Priority Areas Based on Field Data

		Field			
		Potential for Buffer Plantations around Protected Areas and National Forest Priority Areas in the Field	No Potential for Buffer Plantations around Protected Areas and National Forest Priority Areas in the Field	**Total**	**Commission Error**
Map	Potential for Buffer Plantations around Protected Areas and National Forest Priority Areas on the Map	**11**	**21**	**32**	66%
Map	No Potential for Buffer Plantations around Protected Areas and National Forest Priority Areas on the Map	**12**	**293**	**305**	4%
	Total	**23**	**314**	**337**	Overall Accuracy: 90%
	Omission Error	52%	7%		

Source: Authors.

31. As a result of the skipping logic embedded in the mobile app, other sources of errors in the input data might not have been identified as their related criteria were skipped. See Appendix C for general observations on input data.
32. The total number of GCPs with errors in the input data can be more than the number of GCPs omitted because one GCP might be characterized by multiple errors.

Potential for Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs

While the overall accuracy of the map in depicting the potential for tree-based buffer zones along rivers, lakes, and reservoirs in the field in the four woredas is 88 percent, the errors of commission and omission regarding potential for this option are 0 and 95 percent, respectively (Table B7). The commission error is not reliable because of the small sample size for mapped potential.

Of the 44 GCPs that had potential for tree-based buffer zones along rivers, lakes, and reservoirs in the field, 42 were not mapped as such. Their omission stems from the following errors in the input data:[33]

- 42 GCPs were mistakenly not identified as within 30 m of a perennial river;
- 9 GCPs (7 in croplands and 2 grasslands) were mistakenly classified in the land use-land cover data as forests (4), closed shrublands (4), and bare soil (1); and/or
- 1 GCP in open shrubland was mistakenly classified in the land use-land cover data as closed shrubland.

Table B7 | Error Matrix of the Potential Map for Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs Based on Field Data

		Field			
		Potential for Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs in the Field	No Potential for Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs in the Field	**Total**	**Commission Error**
Map	Potential for Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs on the Map	**2**	**0**	**2**	0%
Map	No Potential for Tree-Based Buffer Zones along Rivers, Lakes, and Reservoirs on the Map	**42**	**293**	**335**	13%
	Total	**44**	**293**	**337**	Overall Accuracy: 88%
	Omission Error	95%	0%		

Source: Authors.

33. The total number of GCPs with errors in the input data can be more than the number of GCPs omitted because one GCP might be characterized by multiple errors.

APPENDIX C. GENERAL OBSERVATIONS ON INPUT DATA

The potential and priority maps for tree-based landscape restoration are based on the best readily available national data. As such, their accuracy is a function of, and limited by, the accuracy of each input data.

While the accuracy assessment in four woredas helps identify some sources of error in depicting potential in the field (Step 4 and Appendix B), Tables C1 and C2 present general observations on key input data as they might affect the accuracy of the national maps outside the four woredas. It also includes observations about the input data used to identify priority landscapes.

Table C1 | Observations on Input Data

Theme	Observations on Input Data
Acute Food Insecurity Phase Classification from FEWSNET 2016	Acute food insecurity is a snapshot of the current severity of the situation, regardless of the causes, context, or duration. It does not represent chronic food insecurity, which is the prevalence of persistent food insecurity (IPC Global Partners 2012).
Climate Data (average annual rainfall, average annual temperature, average rainfall during wettest quarter) from Hijmans et al. 2005	■ Low spatial resolution (1-km resolution). ■ Average is calculated for values between 1950 and 2000 and likely to miss the effects of climate change.
Industrial Parks from IPDC 2016	This dataset is a work in progress; some industrial parks might be missing or their boundaries not up to date.
Key Biodiversity Areas from BirdLife International and CI 2016	KBA is an umbrella designation that includes globally important sites for different taxa and realms (e.g., Important Bird and Biodiversity Areas, Important Plant Areas, Important Sites for Freshwater Biodiversity, and Alliance for Zero Extinction sites). KBAs reflect "sites contributing significantly to the global persistence of biodiversity" (IUCN 2016), which might not represent locally important sites.
Lakes and Reservoirs from MoWIE 2015	This dataset is a work in progress; some lakes and reservoirs might be missing.
Land Degradation Index from EMA and ICPAC 2015	■ This index is based on low-resolution input data, which limits its own resolution. ■ The field visit report states that, "according to the field team findings, the preliminary model consolidation results matched very well with what was crosschecked on the ground cover." It should be noted, however, that the accuracy assessment was limited in its geographic scope.
Land Use-Land Cover from EMA 2015	■ The classification was conducted on 2013 images. ■ The 30-m resolution is too low to assess potential for tree-based buffer zones along rivers, lakes, and reservoirs. ■ One maximum likelihood classification algorithm was used across the country.

Table C1 | Observations on Input Data (continued)

Theme	Observations on Input Data
Large-Scale Sugar Cane Plantations (current and planned) from ESC 2016	This dataset is a work in progress; some plantations might be missing.
National Forest Priority Areas from IUCN and UNEP-WCMC 2016	This is a global dataset used for NFPAs outside of Oromia, Tigray, and Amhara. Some national forest priority areas might be missing or their boundaries not up to date.
National Forest Priority Areas from Tigray BoARD 2016	This dataset is a work in progress; some national forest priority areas might be missing.
National Forest Priority Areas from OFWE 2016	This dataset is a work in progress; some national forest priority areas might be missing.
National Forest Priority Areas from Amhara BoA 2016	This dataset is a work in progress; some national forest priority areas might be missing.
Number of Beneficiaries in Productive Safety Net Program Woredas, based on MoANR 2015	There were inconsistencies between the table providing the number of beneficiaries by PSNP woredas and the CSA census woredas, as some woredas have split.
Tree Cover from Hansen et al. 2014	■ This global dataset defines *tree cover* as "all vegetation taller than five meters in height," which is not aligned with Ethiopia's minimum tree height of 2 m. This leads to underestimating the percentage of tree cover in areas where trees are between 2 and 5 meters high. ■ The classification was conducted on 2010 images. ■ 30-m resolution is too low for the purpose of assessing percentage of tree cover outside forest.
Plantations from MEFCC 2016	This dataset is a work in progress.
Population Density from CSA 2007b	■ Census conducted back in 2007. ■ The census data are at the woreda level. More disaggregated data would better reflect population distribution within woredas.
Potential Natural Vegetation from Van Breugel et al. 2015	Low spatial resolution (1-km resolution).
Protected Areas from EWCA 2015	This dataset is a work in progress; some protected areas might be missing or their boundaries not up to date.
Rivers from Friis et al. 2010	This dataset was the only national dataset differentiating between perennial and intermittent rivers. However, some rivers are missing.
Roads from ERA 2007	Newly constructed main roads are missing.
Soil Type from FAO 1984	■ Low spatial resolution (1:1,000,000 scale). ■ Data were published in 1984.
Species Richness and Endemism from Costingnature 2016	■ This dataset reflects globally important species, which might not be aligned with locally important species. ■ This dataset only portrays species richness and endemism for fauna. Flora are not accounted for.
Risk of Soil Erosion from WBISPP 2004a	Data were published in 2004.
Woodfuel Balance from WBISPP 2004b	Data were published in 2004.

Source: Authors.

Table C2 | Implications of Missing Input Data

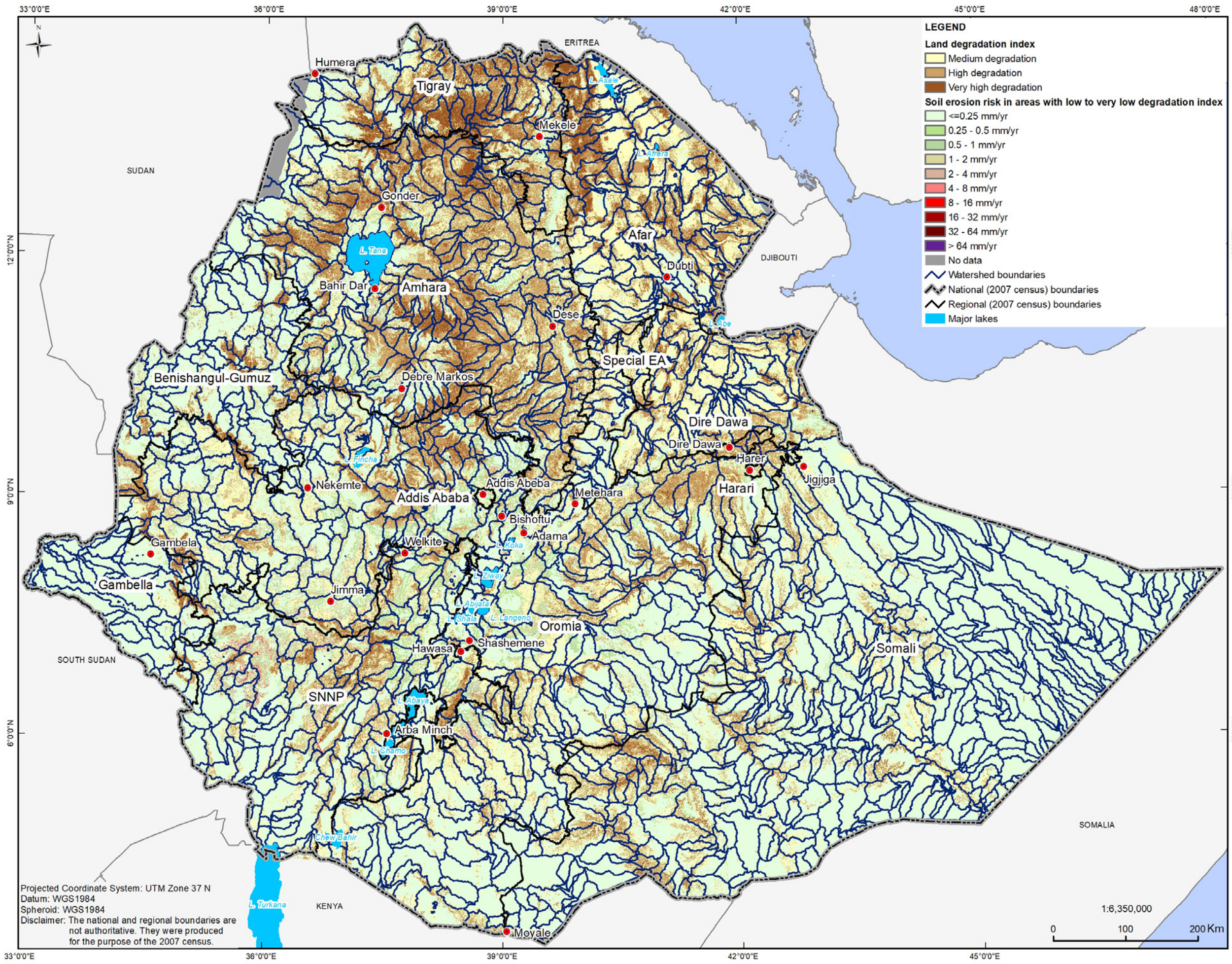
Theme	Implications of Missing Data
Areas with Invasive Tree Species	In the absence of data on areas invaded by tree species, these areas might be identified as having a sufficient tree cover (> 20%) and therefore be discarded from potential for silvo-pastoralism.
Forestland	The lack of data on forestland delineation could lead to underestimation of the potential for commercial plantations for products other than industrial roundwood, as some forestlands might be under agriculture but have the purpose of becoming forested.
Grazing Pressure	The lack of data on grazing pressure precludes the ranking of landscapes according to their contribution to supporting the current and future livestock population. This in turn can affect the overall national ranking and the selection of priority landscapes.
Hazard-Prone Areas	The lack of data on occurrence of natural hazards precludes the ranking of landscapes according to their contribution to preventing or mitigating these natural hazards. This, in turn, can affect the overall national ranking and the selection of priority landscapes.
Homesteads	The potential for woodlots and home gardens might be overestimated, as it considers the whole of croplands and grasslands to have potential instead of limiting it to an area within 10 kilometers of homesteads.
Large-Scale Agricultural Investments	Because large-scale agricultural investments are not excluded, the potential for restoring secondary forests and the potential for restocking degraded natural forests are overestimated.
Mechanized Farming	Because mechanized farming is not excluded, the potential for agri-silvi-culture and agro-silvo-pastoralism and the potential for woodlots and home gardens are overestimated.
Natural Grasslands That Ecologically Do Not Have Trees	The lack of data on where these natural grasslands are creates a risk of identifying potential for more trees in these grasslands.
Plot Size	The lack of data on plot size could lead to overestimation of the potential for woodlots and home gardens and for commercial plantations for products other than industrial roundwood. This occurs because of the inclusion of plots that are either too big (for woodlots and home gardens) or too small (for commercial plantations).
Poverty Density	The lack of poverty data prevents targeting of cross-sectoral implementation of tree-based landscape restoration to benefit the poor.
Religious Forests	Because religious forests are not excluded, there is a risk of identifying potential for agri-silvi-culture and agro-silvo-pastoralism, silvo-pastoralism, woodlots and home gardens, or commercial plantations for products other than industrial roundwood in smaller religious forests that might have been missed as forests in EMA 2015.
Rice Fields	Because rice fields are not excluded, the potential for agri-silvi-culture and agro-silvo-pastoralism and the potential for woodlots and home gardens are overestimated.
Risk of Deforestation	Because of the lack of data on the risk of deforestation, landscapes with forest areas in low-density areas (e.g., woodlands in the lowlands) are not identified as hotspots for restoration. This, in turn, can affect the overall national ranking and the selection of priority landscapes.
Urban Expansion Areas	Urban expansion areas are not excluded from any of the potential maps.
Wildlife Migratory Corridors	Missing data on wildlife corridors prevent them from being excluded from the potential for buffer plantations around NFPAs and PAs and therefore put them at risk of fragmentation.

Source: Authors.

APPENDIX D. NATIONAL RANKING BY INDIVIDUAL PRIORITIZATION CRITERIA

National Ranking According to Land Degradation and Soil Erosion Risk

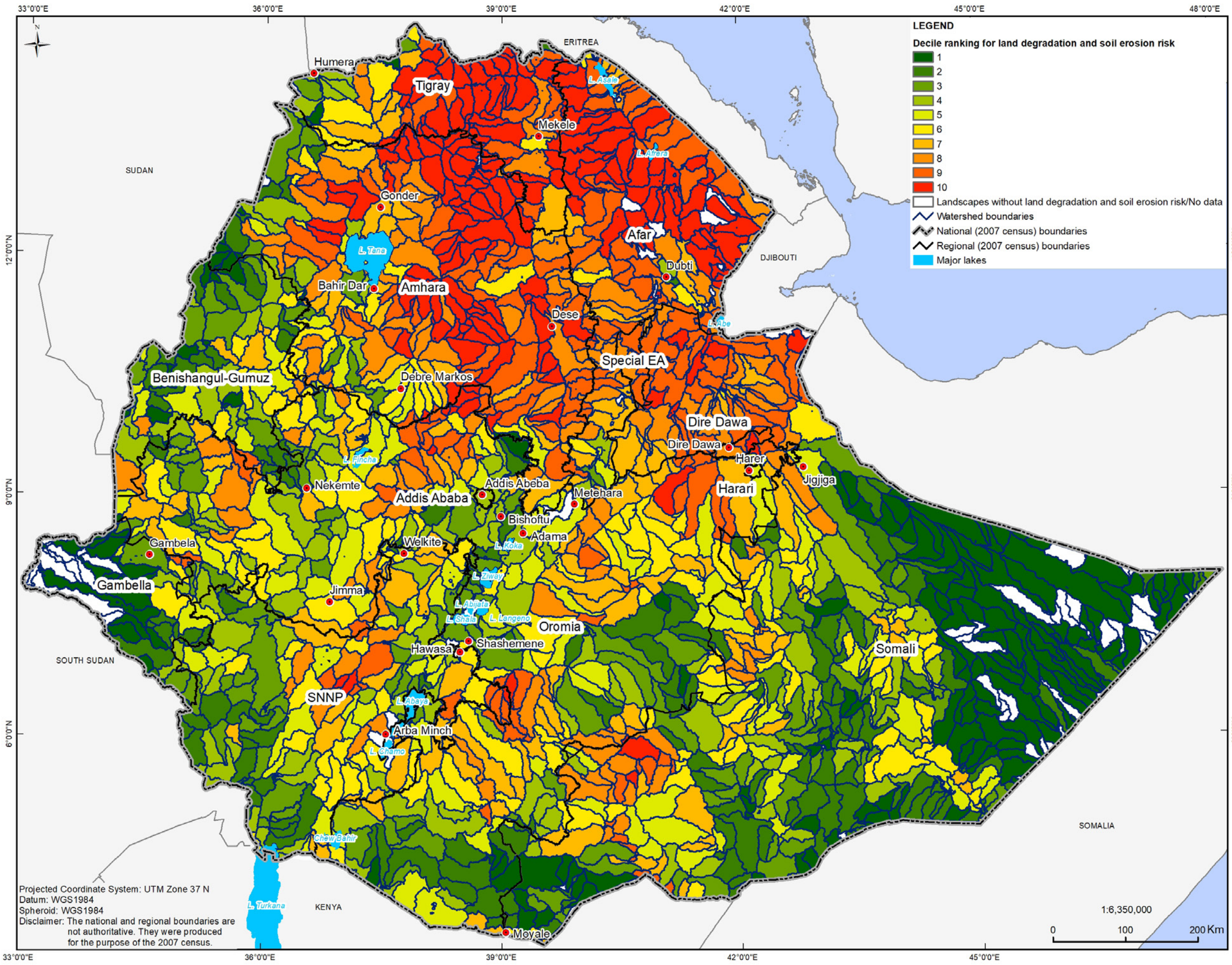
Map 4a | Land Degradation and Soil Erosion Risk



CAPTION: Map 4a shows the degradation index in areas where degradation can be observed and soil erosion risk in areas where degradation has not yet taken place. The degradation index is based on vegetation index, rainfall erosivity, soil erodibility, slope aspect, and human and livestock population density (Wangui 2013). The degradation index goes from medium (in beige) to high (in brown) and very high (in dark brown). Soil erosion risk is based on the combined effect of rainfall, soil factor, slope length, slope gradient, land cover factor, and land management factor (MoARD 2004). Soil erosion risk varies from very low (in light green) to very high (in purple). Erosion can occur and yet permit crop productivity to be sustained economically if it is at a rate below 1 mm of soil depth/year (Montgomery 2007). Consequently, only areas with soil erosion risk above 1 mm of soil depth/year (from tan to dark brown) were considered of interest in later steps of the prioritization process.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Land degradation index: EMA and ICPAC 2015. Soil erosion risk: WBISPP 2004a.

Map 4b | Land Degradation and Soil Erosion Risk National Ranking

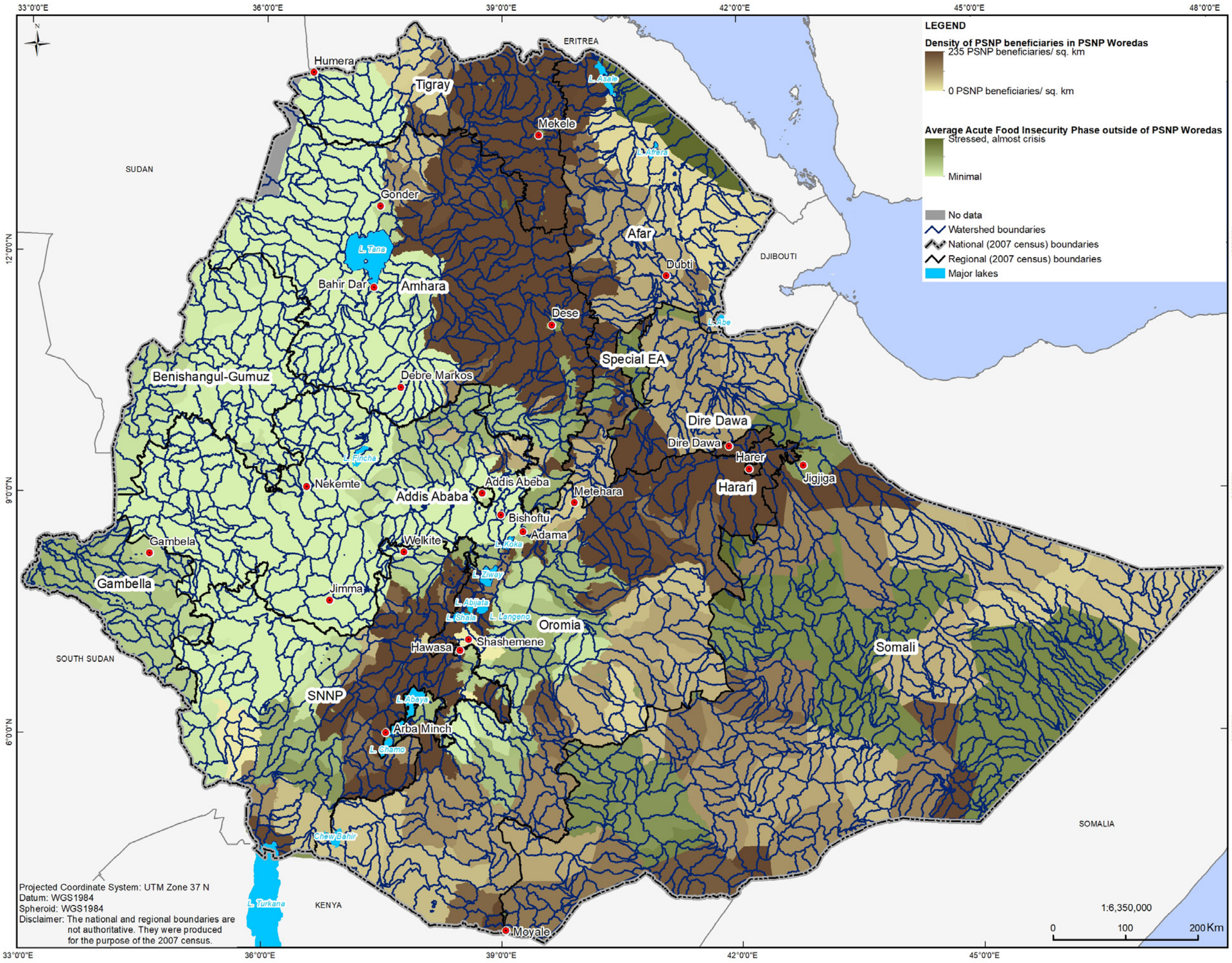


CAPTION: Map 4b shows the decile ranking of landscapes based on their average land degradation, where each class contains approximately 10 percent of the values. Landscapes in dark green are in the bottom 10 percent in terms of average land degradation, while landscapes in bright red are in the top 10 percent.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Land degradation and soil erosion risk national ranking: MEFCC 2018d.

National Ranking According to Food Insecurity

Map 5a | Food Insecurity

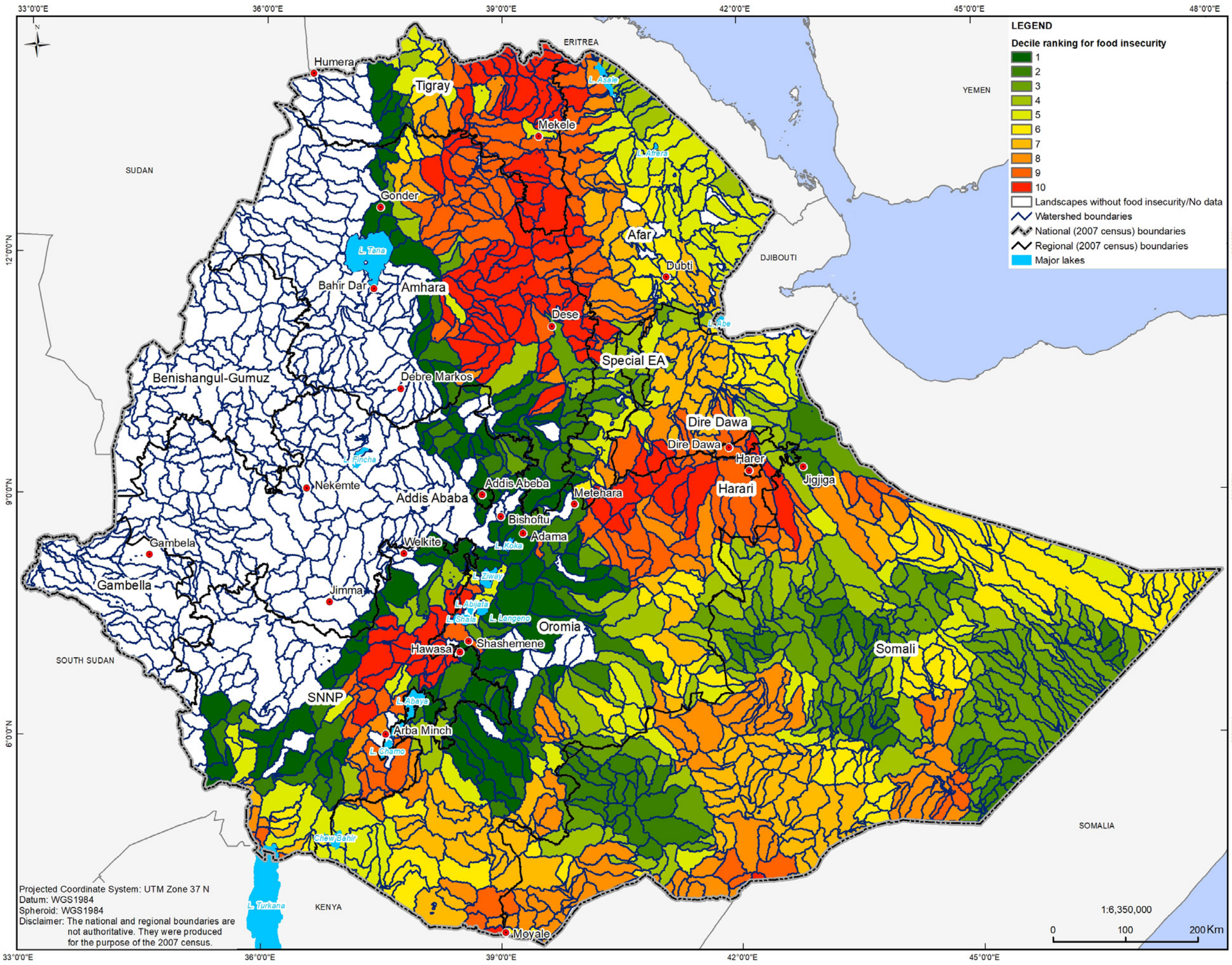


CAPTION: Map 5a shows the incidence of food insecurity inside (in shades of brown) and outside (in shades of green) Productive Safety Net Program (PSNP) woredas. PSNP woredas are differentiated according to the density of PSNP beneficiaries, from low (in light brown) to high (in dark brown). Non-PSNP woredas are characterized according to their Integrated Food Security Phase Classification (IPC) between 2009 and 2016. This classification scheme aims to inform humanitarian aid needs (IPC Global Partners 2012). The six-year average status of non-PSNP woredas as per the IPC goes from "minimal"[34] (in light green) to "stressed,"[35] to almost "crisis"[36] (in dark green).

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. PSNP beneficiaries' density: calculations based on MoANR 2015. IPC: FEWSNET 2016.

34. Minimal: More than four in five households are able to meet essential food and non-food needs without engaging in atypical, unsustainable strategies to access food and income, including any reliance on humanitarian assistance (IPC Global Partners 2012).
35. Stressed: Even with any humanitarian assistance at least one in five households in the area have the following or worse: minimally adequate food consumption but are unable to afford some essential non-food expenditures without engaging in irreversible coping strategies (IPC Global Partners 2012).
36. Crisis: Even with any humanitarian assistance at least one in five households in the area have the following or worse: food consumption gaps with high or above usual acute malnutrition or are marginally able to meet minimum food needs only with accelerated depletion of livelihood assets that will lead to food consumption gaps (IPC Global Partners 2012).

Map 5b | Food Insecurity National Ranking

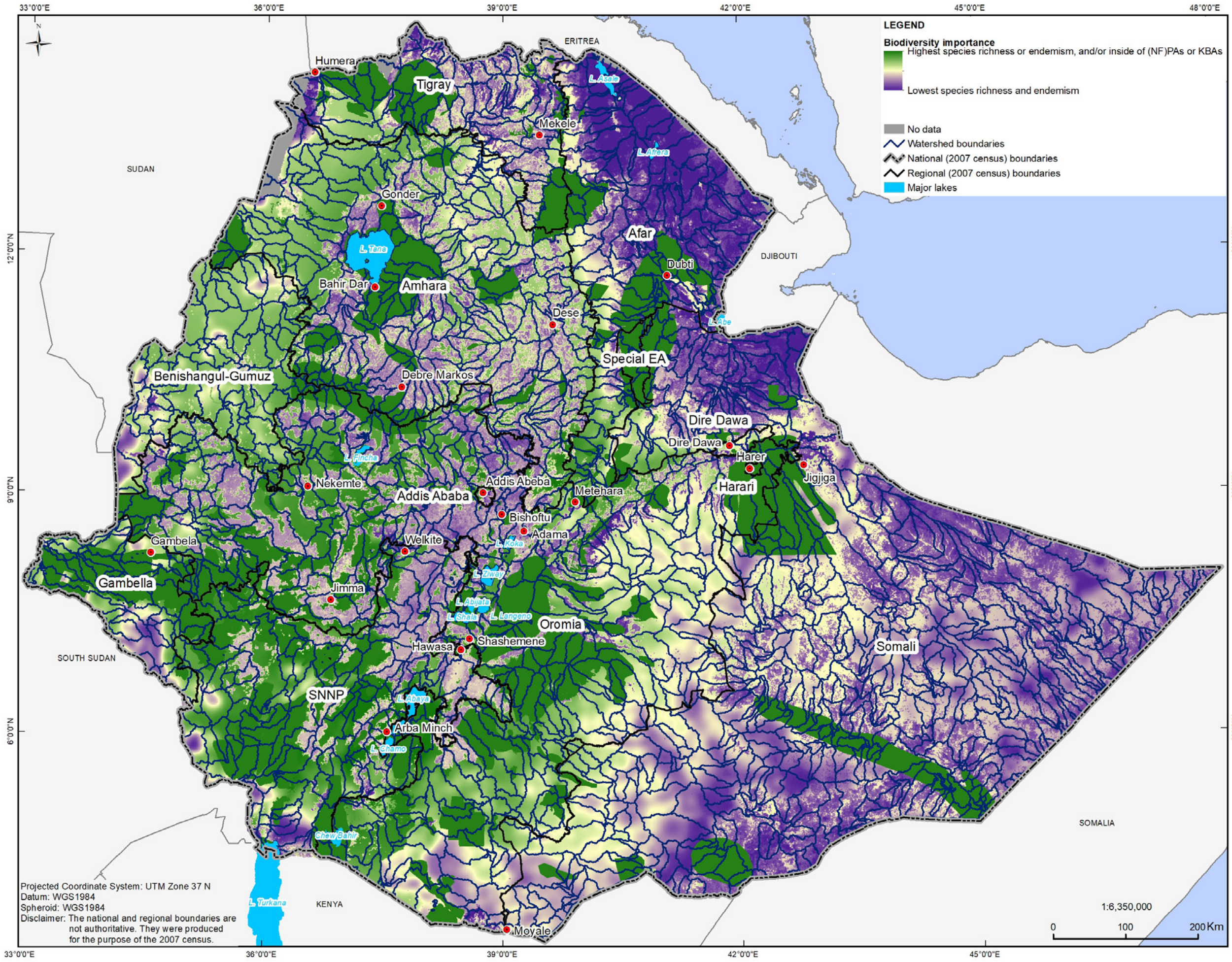


CAPTION: Map 5b shows the decile ranking of landscapes based on their average food insecurity, where each class contains approximately 10 percent of the values. Landscapes in dark green are in the bottom 10 percent in terms of average food insecurity, while landscapes in bright red are in the top 10 percent.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Food insecurity national ranking: MEFCC 2018e.

National Ranking According to Biodiversity

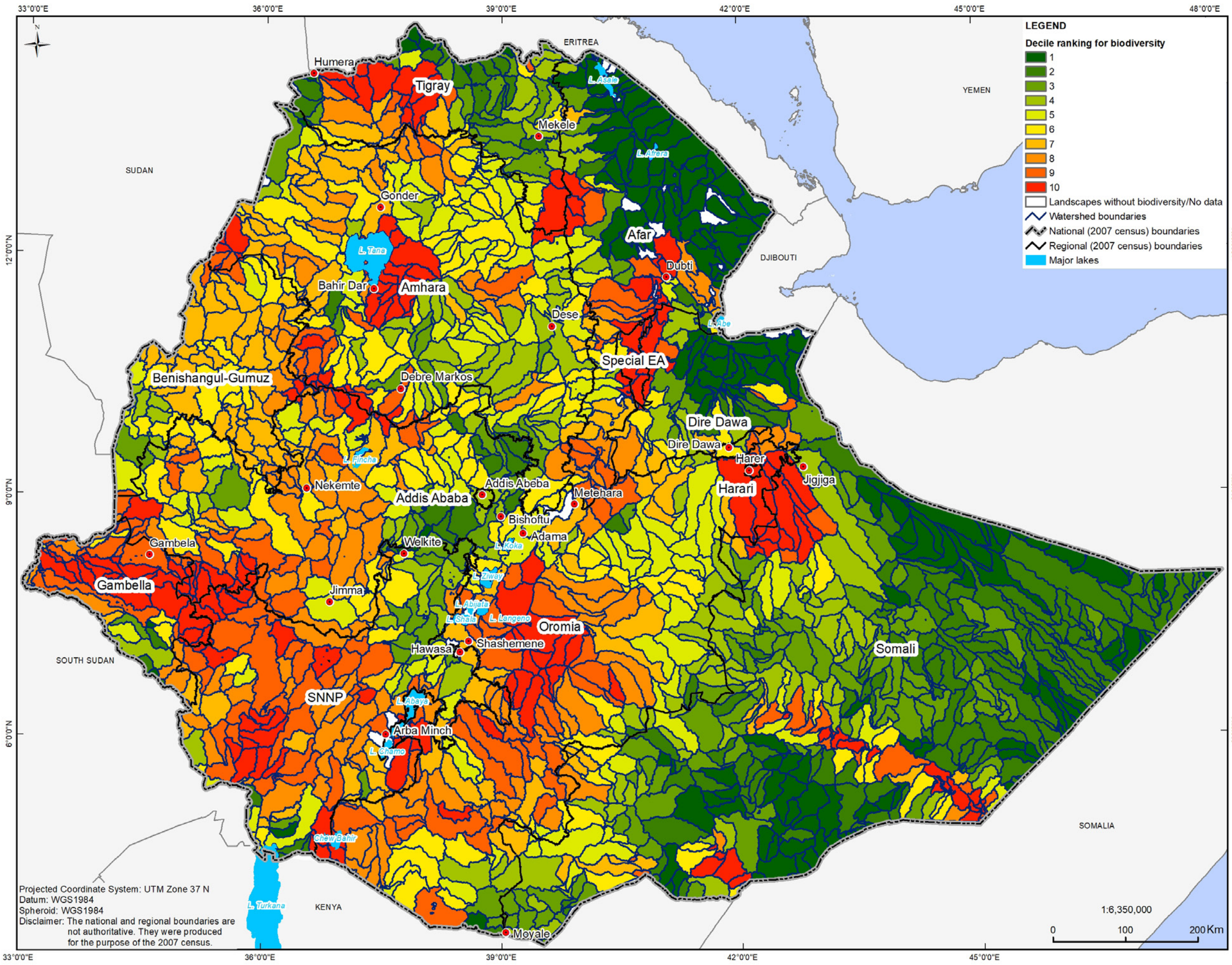
Map 6a | Biodiversity



CAPTION: Map 6a shows the distribution of biodiversity importance inside and outside national forest priority areas (NFPAs), protected areas (PAs) and Key Biodiversity Areas (KBAs). All NFPAs, PAs, and KBAs were considered important for fauna and/or flora biodiversity (in dark green). Outside these areas, biodiversity importance was based on an area's richness and endemism for bird, amphibian, reptile, or mammal species (Kier and Barthlott 2001) and varies between relatively low species richness and endemism (in purple) to relatively high species richness or endemism (in green).

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. PAs: EWCA 2015. NFPAS: IUCN and UNEP-WCMC 2016; Tigray BoARD 2016; Amhara BoA 2016; and OFWE 2016. KBAs: BirdLife International and CI 2016. Species richness and endemism for bird, amphibian, reptile, or mammal species: Costingnature 2016.

Map 6b | Biodiversity National Ranking

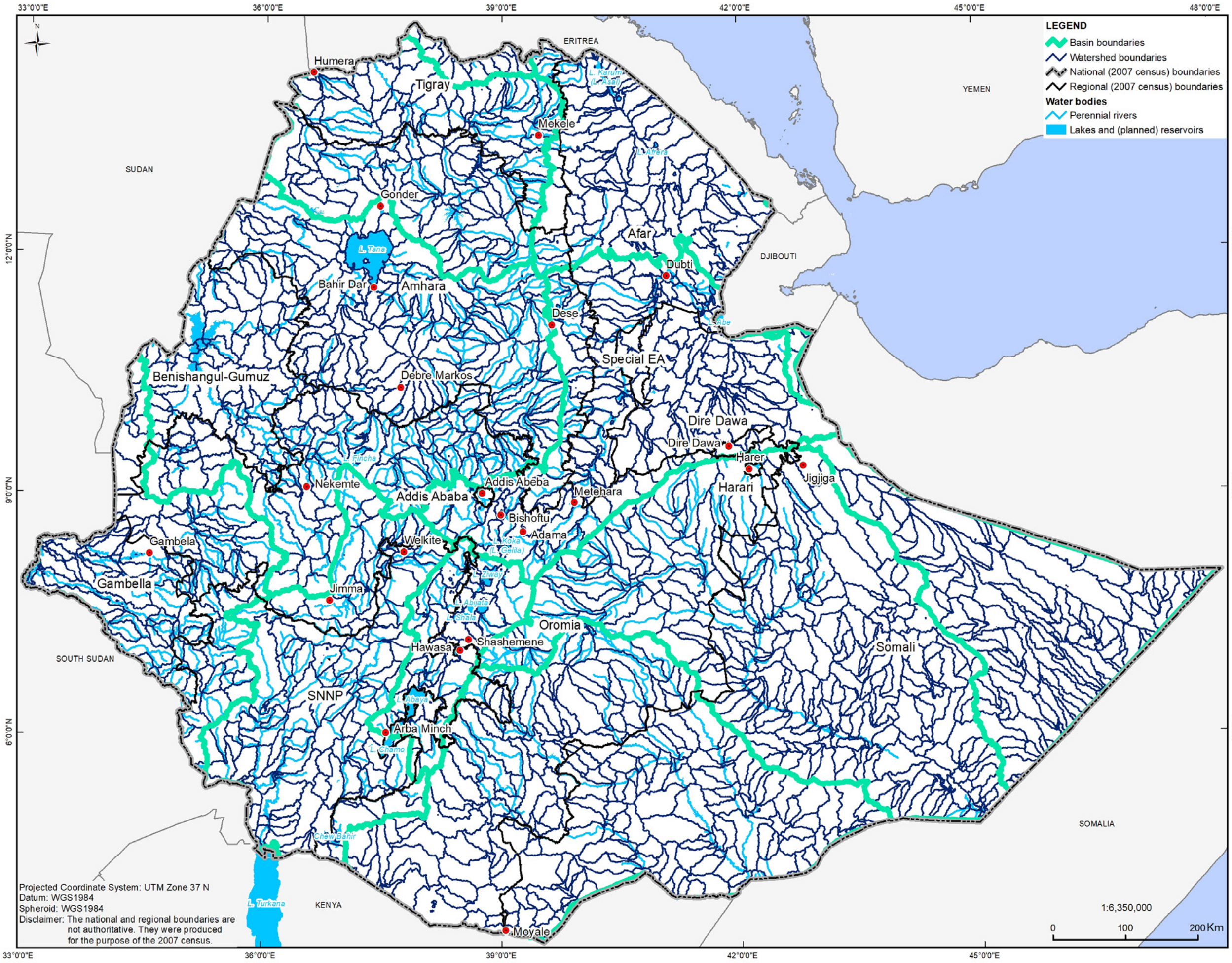


CAPTION: Map 6b shows the decile ranking of landscapes based on their average biodiversity, where each class contains approximately 10 percent of the values. Landscapes in dark green are in the bottom 10 percent in terms of average biodiversity importance, while landscapes in bright red are in the top 10 percent.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Biodiversity national ranking: MEFCC 2018f.

National Ranking According to Water Availability

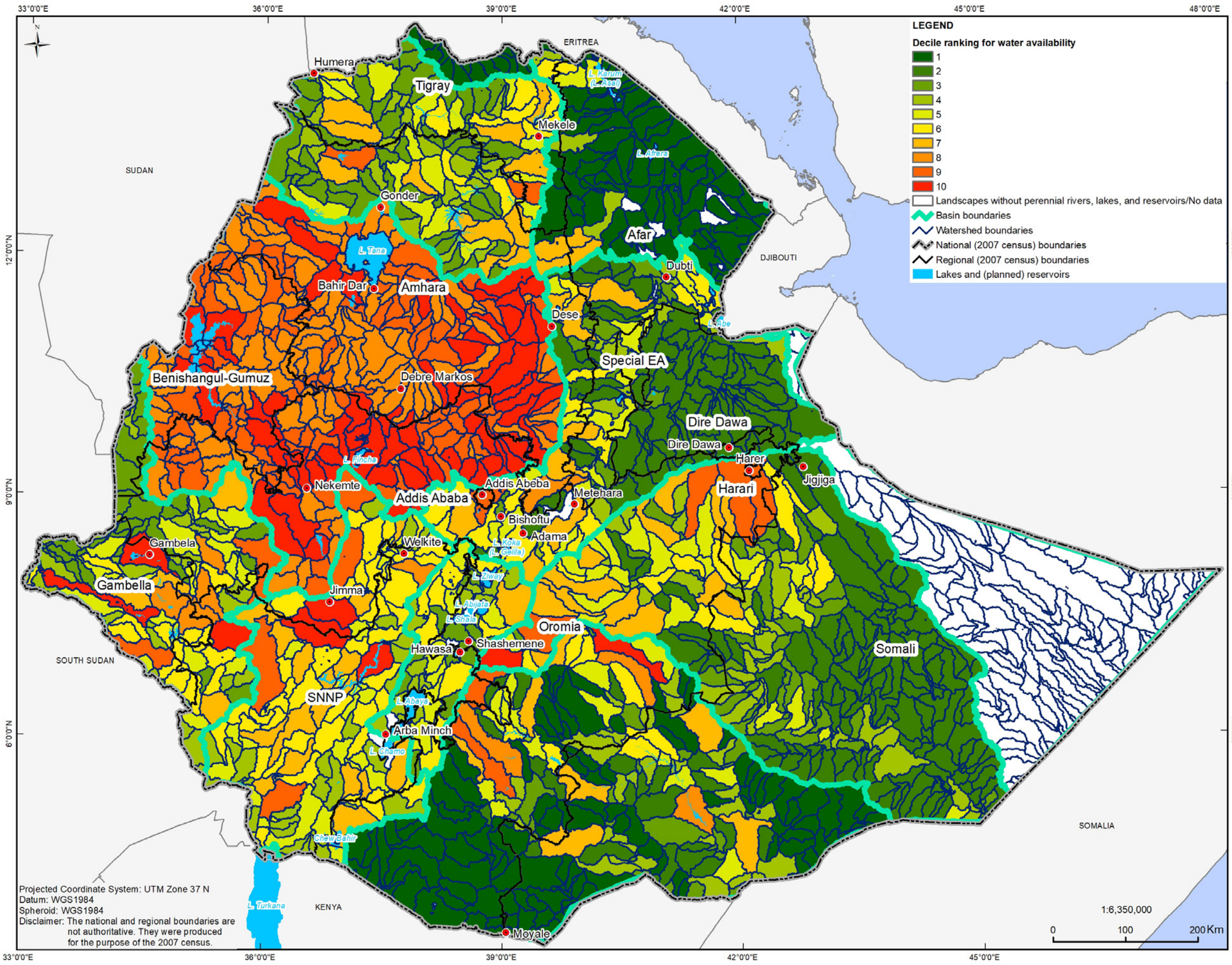
Map 7a | Water Availability



CAPTION: Map 7a shows the distribution of perennial rivers, lakes, and reservoirs (existing and planned) across landscapes and basins. Basins are hydrological units made of multiple landscapes. As such, water availability in individual landscapes affects water availability in the basin to which they belong.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed and basin boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Lakes and reservoirs: MoWIE 2015. Perennial rivers: Friis et al. 2010.

Map 7b | Water Availability National Ranking

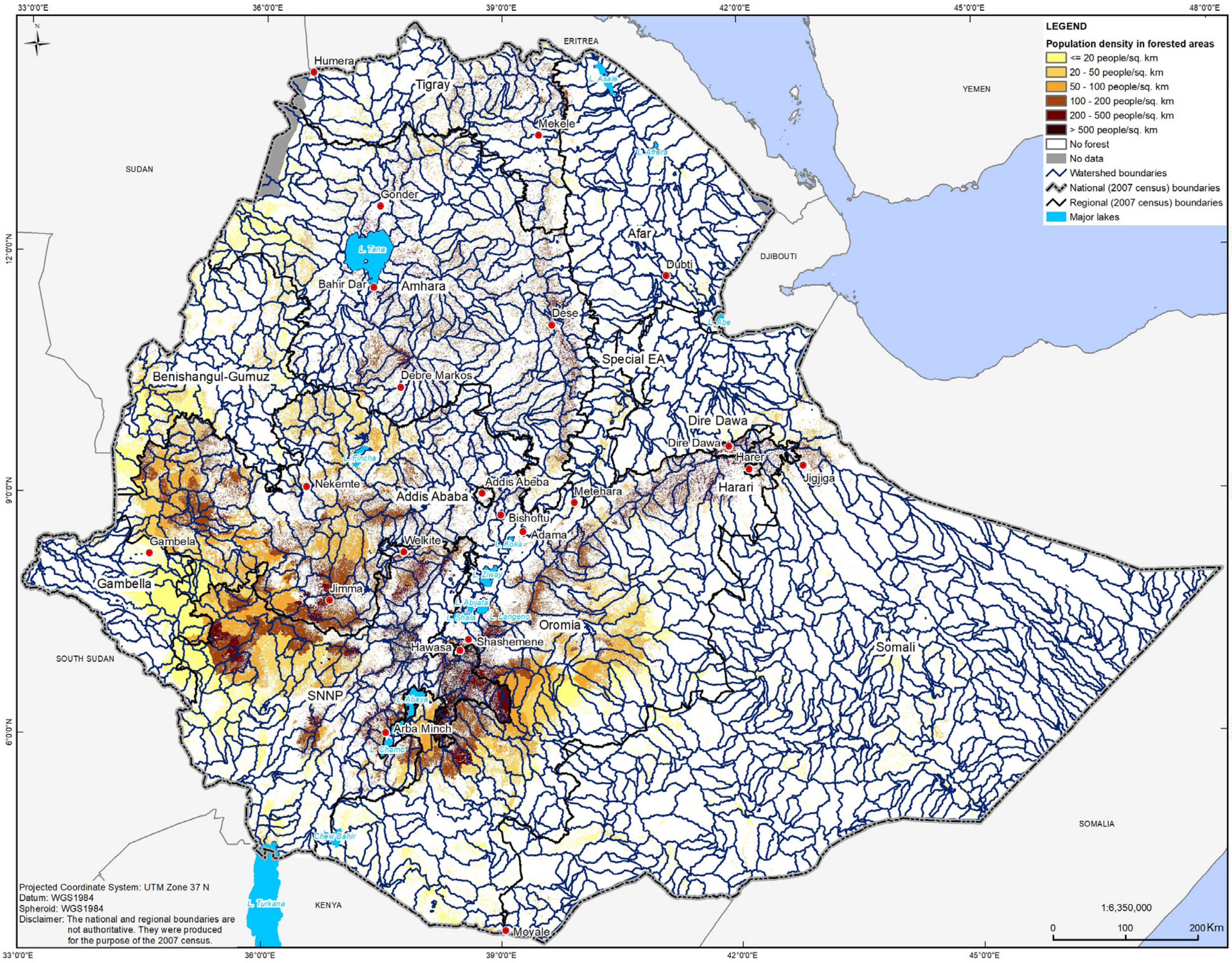


CAPTION: Map 7b shows the decile ranking of landscapes based on their water availability. Each class contains approximately 10 percent of the values. In the absence of data on water flows and volumes, water availability was approximated by calculating the area of perennial rivers, lakes, and reservoirs (existing and planned). Water availability for one landscape is a combination of the area of water bodies within the landscape and the area of water bodies in the basin to which it belongs. This allows the ranking to reflect the interconnectedness between individual landscapes and their basin. Landscapes in dark green are in the bottom 10 percent in terms of water availability, while landscapes in bright red are in the top 10 percent.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed and basin boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Lakes and reservoirs: MoWIE 2015. Water availability national ranking: MEFCC 2018g.

National Ranking According to Forest Degradation Risk

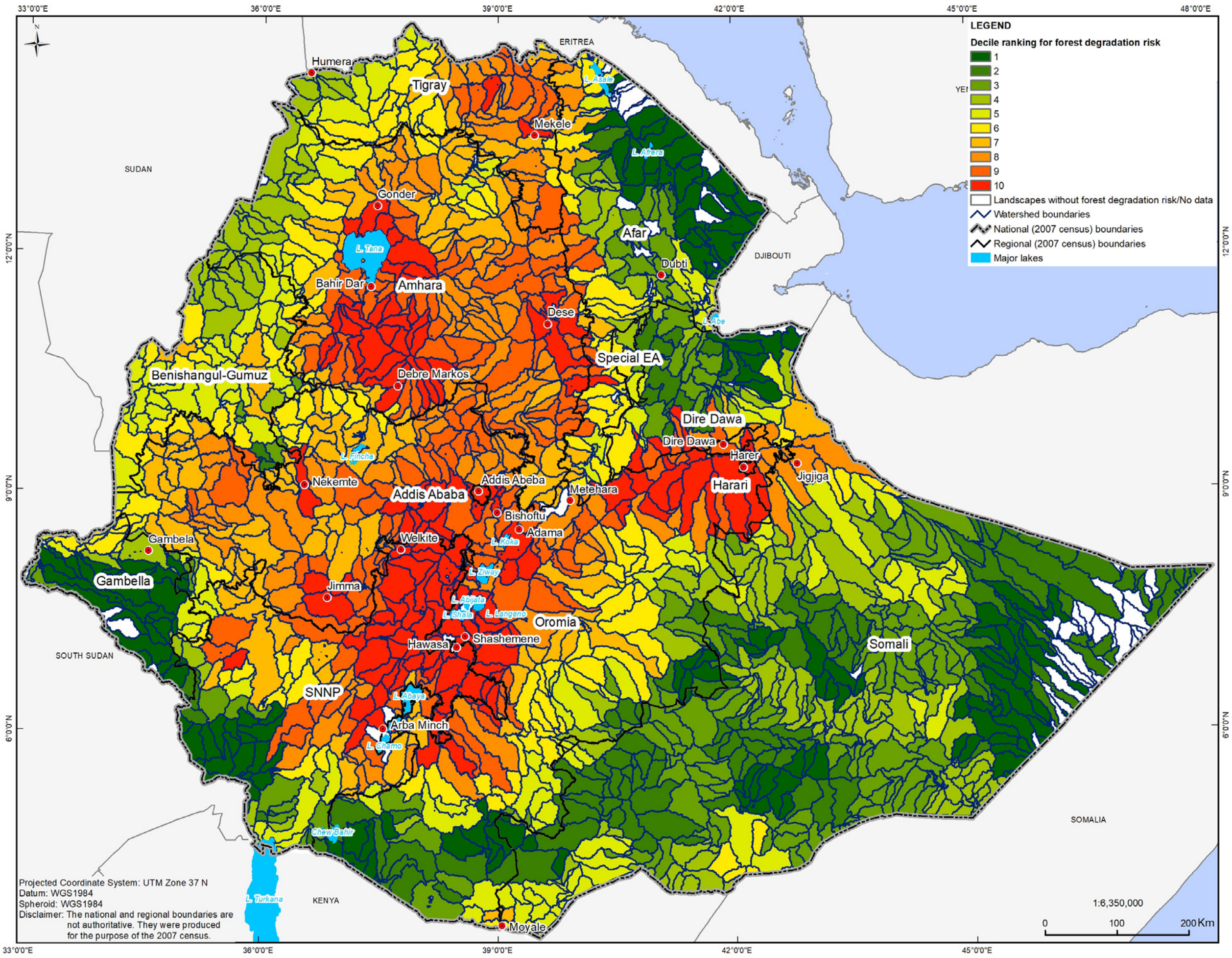
Map 8a | Forest Degradation Risk



CAPTION: Map 8a shows population density in forested areas. Assuming that population density is an indicator of forest degradation risk, forests in light yellow are at a lesser risk of forest degradation as the population density is low, while those in dark brown are at higher risk because they are in high population areas.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Forest: EMA 2015. Population density: CSA 2007b.

Map 8b | Forest Degradation Risk National Ranking

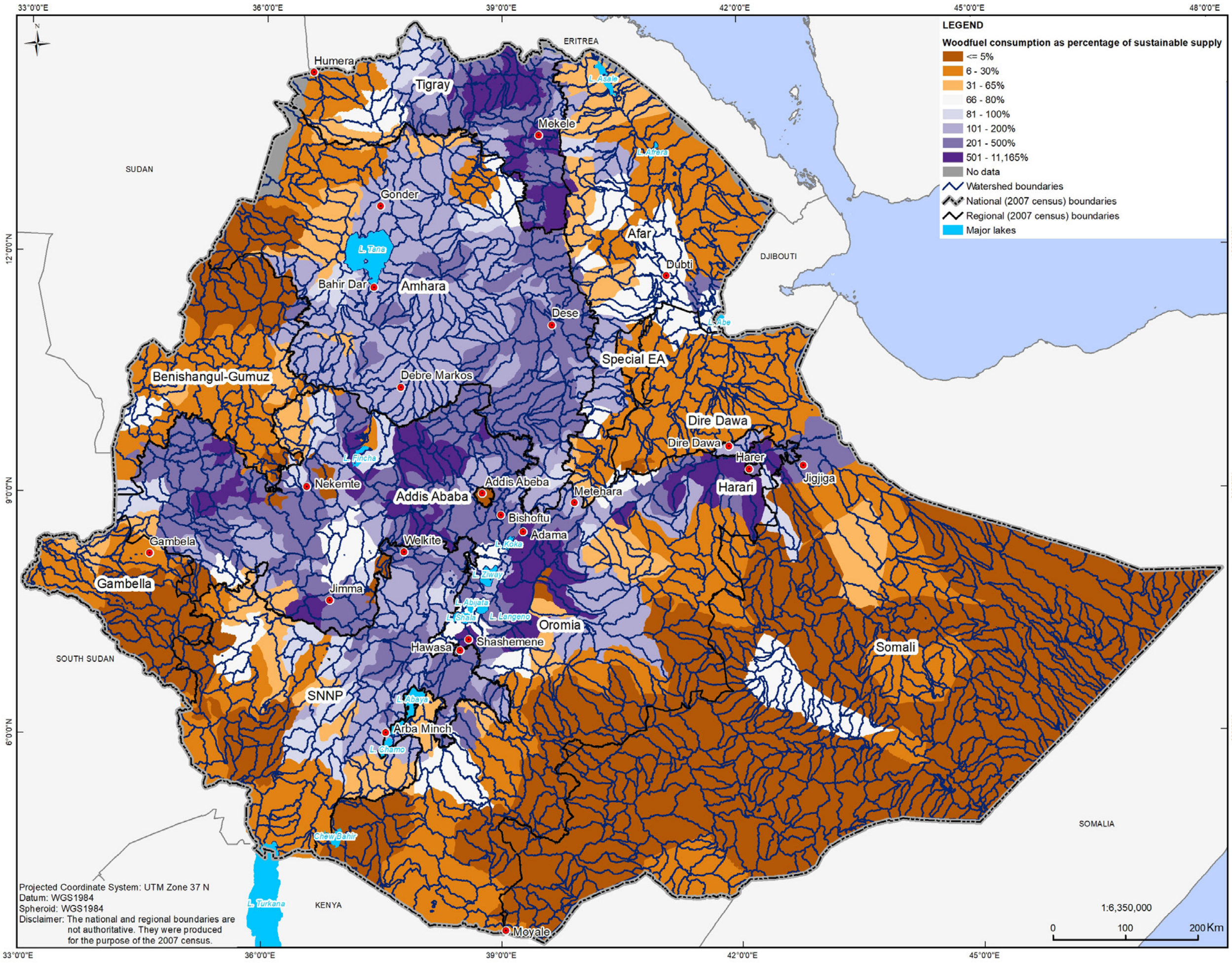


CAPTION: Map 8b shows the decile ranking of landscapes based on their average population density in forested areas, where each class contains approximately 10 percent of the values. Based on population density in forested areas, landscapes in dark green are in the bottom 10 percent in terms of average risk of forest degradation, while landscapes in bright red are in the top 10 percent.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Forest degradation risk national ranking: MEFCC 2018h.

National Ranking According to Woodfuel Deficit

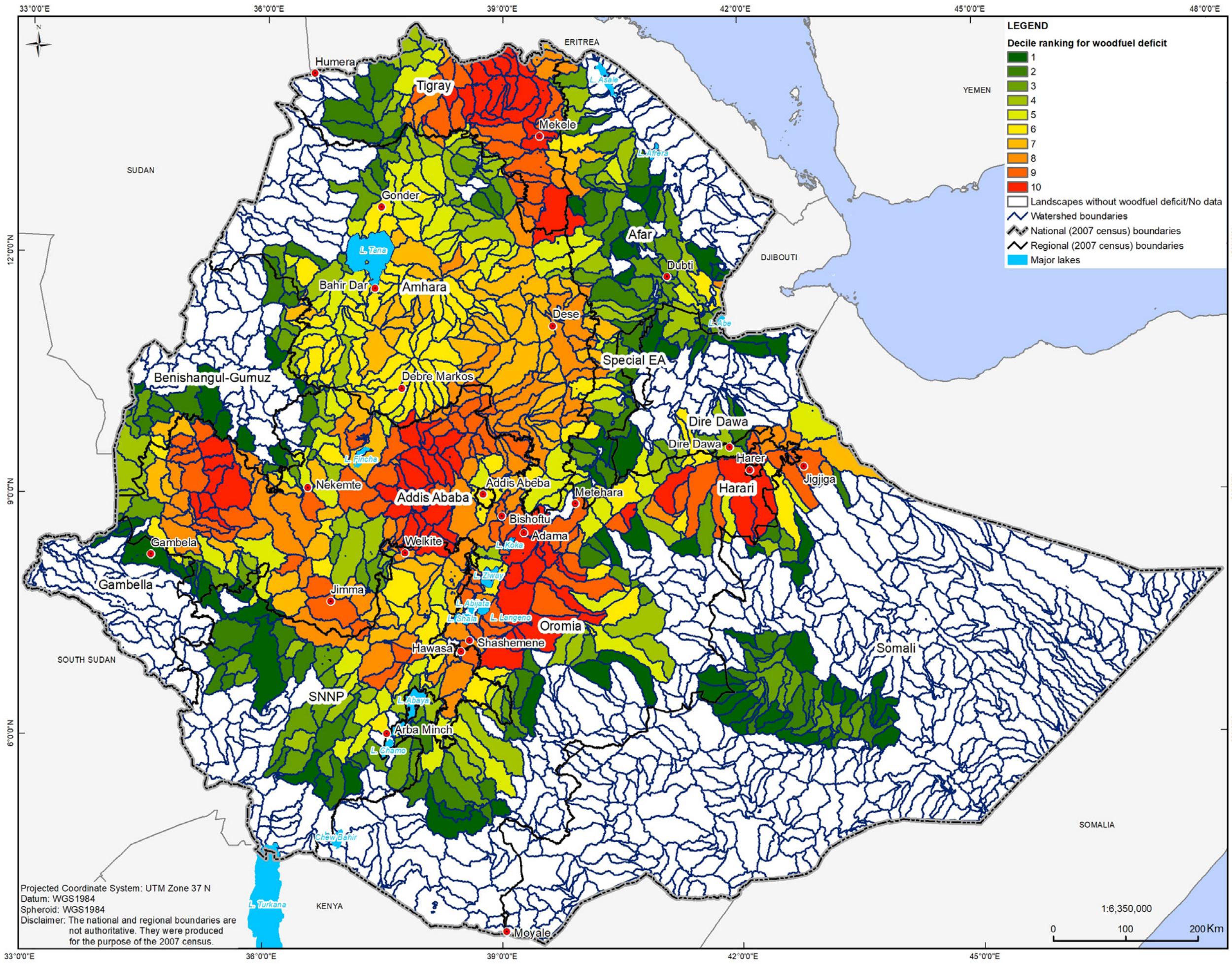
Map 9a | Woodfuel Deficit



CAPTION: Map 9a shows the consumption of woodfuel as a percentage of sustainable supply. Areas where consumption is less than 100 percent of sustainable supply (in brown and light purple) reflect sustainable consumption patterns. In areas with more than 100 percent (in darker purple), consumption has overtaken supply and is unsustainable. Areas with a consumption-to-supply ratio of 65 percent and higher were judged unsustainable and considered of interest in later steps of the prioritization process to account for the fact that areas with more than 65 percent in 2000 could be now at or over 100 percent.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Woodfuel deficit: WBISPP 2004b.

Map 9b | Woodfuel Deficit National Ranking



CAPTION: Map 9b shows the decile ranking of landscapes based on their average woodfuel deficit, where each class contains approximately 10 percent of the values. Landscapes in dark green are in the bottom 10 percent in terms of average woodfuel deficit, while landscapes in bright red are in the top 10 percent.

Sources: International boundaries: UC Berkeley et al. 2015. Watershed boundaries: WLRC 2015. Census boundaries, cities, and towns: CSA 2007a and c. Major lakes: MoWIE 2015. Woodfuel deficit national ranking: MEFCC 2018i.

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