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Forest Landscape Restoration (FLR) Options for Oromia Regional State

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Acronyms

AFR100	Africa's 100 million ha restoration program
ANR	Assisted natural regeneration
CBD	Convention for biological diversity
CGRE	Climate Resilient Green Economy
CSA	Central Statistical Agency
ENACT-NMA	Enhancing National Climate Services (ENACTS) from Columbia University and NMA of Ethiopia
ERA	Ethiopian Road Authority
FDRE	Federal Democratic Republic of Ethiopia
FLR	Forest and landscape restoration
GDP	Gross domestic product
GTP II	Growth and Transformation Plan second phase
INBAR	International Bamboo and Rattan Organization
IPCC	Intergovernmental panel for climate change
LULC	Land use and land cover
MEFCC/EFCCC	Ministry of Environment Forest and Climate Change/ Environment, Forest and Climate Change Commission
NDVI	Normalized difference vegetation index
NFPAs	National Forest Priority Area
NMA	National Meteorological Agency of Ethiopia
NP	National parks
NTFP	Non-timber Forest Products
PA	Protected area
PES	Payment for ecosystem services
PFM	Participatory Forest Management
REDD+	Reduce emission, land degradation and deforestation
SDGs	Sustainable development goals of the United Nations
SLM	Sustainable land management

SNNP	Southern Nations, Nationalities and Peoples (SNNP) Regional State
SRTM	Shuttle Radar Topographic mission of the United States
SWC	Soil and water conservation
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
WDPA	World Database Protected Areas
WLRC-AAU	Water and Land Resource Center of Addis Ababa University
WRI	World Resources Institute

Executive Summary

Environmental deterioration and land degradation are two of the most pressing global environmental and developmental challenges of the 21st century. To curb these serious challenges, countries are developing various adaptation and mitigation programs and executing them in coordination with international collaborators. Ethiopia has launched several initiatives and programs to protect the environment and reduce land degradation as part of its growth and transformation plans (GTP) to boost the economic development of the country. One of the country's biggest initiatives is the climate resilient green economy (CRGE) strategy, which is part its economic development agenda. The government of Ethiopia is working in collaboration with an international alliance to enhance CRGE strategy and programming to respond to the above-mentioned climate challenges. One program affiliated with the CRGE is the forest landscape restoration (FLR) initiative. The FLR program was initiated by Environment, Forestry and Climate Change Commission (EFCCC) and the World Resources Institute (WRI) in 2016, with the goal of identifying forest landscape restoration options at the national level.

The activities detailed in this report, carried out by WRI and WLRC-AAU in collaboration with the EFCCC, are part of the effort to identify forest landscape restoration options at the regional-level in Oromia Region. WLRC-AAU carried out all technical and stakeholder analyses of this regional-level work. We conducted both stakeholder participatory planning and validation workshops before and after biophysical analysis to identify spatial locations where appropriate restoration options can be executed. During participatory planning, we identified ten potential restoration interventions and set criteria for each option at regional level. Based on these criteria, we identified suitable spatial locations where we could implement one or more restoration intervention. Our results show that Oromia Region has a highest potential area for agroforestry (8.75 million ha), lowland bamboo restoration (3.86 million ha), home-gardens and woodlots (2.77 million ha), highland bamboo (2.74 million ha), commercial plantation (2.1 million ha), and fuelwood plantation (1.9 million ha). The potential area for the remaining options ranged from 0.005 to 1.01 million ha (Table 6). In some cases, areas may be suitable for more than one intervention. For example, areas which are suitable for agroforestry could be suitable for home gardens and woodlots. Hence, we tried to combine and prioritize interventions based on the stakeholders' desired environmental, social and economic benefits in the given area and the region at-large. Our analysis of combined potential for tree-based restoration shows that over 24.4 million ha of land is suitable for one or more potential restoration option in Oromia Region (Table 6). Furthermore, we recommended the details of each option that will be carried out during activity development plan at district/woreda level.

1 Introduction

Land degradation is one of the most pressing global environmental and developmental challenges of the 21st century (Gashaw et al., 2014). Recognizing that healthy ecosystems on land are essential to the future of both people and the planet, Sustainable Development Goal 15 aims to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss." Section 15.3 of the goal specifically addresses the issue of land degradation, setting the target to "combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world" by 2030 (SDG15.3). Progress made towards each SDG target is measured using a specific indicator framework developed for each goal. In the case of SDG 15.3, progress towards a land degradation-neutral world will be assessed by measuring the "proportion of land that is degraded over total land area". Despite the targets set by SDG 15, the global rate of land and forest degradation and deforestation continues to increase, resulting in desertification and decreased land productivity, and contributing to overall climate change (Source). However, various land restoration and conservation efforts are underway at different scales to reverse the tide of land degradation and implement more sustainable land use practices.

Since the 1970s, Ethiopia has implemented comprehensive land management practices to curb land degradation in the country. However, considering the existing scope and severity of the country's land degradation, and its negative impact on food security and economic development, the Ethiopian government is now more heavily investing in one of the world's largest land restoration efforts as a means of climate change adaptation and mitigation. As part of this effort, several soil and water conservation (SWC) and sustainable land management (SLM) programs have been implemented across the country (Abera et al., 2019). Moreover, a 2018 report by the Ministry of Environment, Forest, and Climate Change (MEFCC, 2018) stated that increasing the number of trees in Ethiopia would 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; and the African (AFR100) and global (Bonn Challenge and New York Declaration on Forests) restoration targets. (MEFCC, 2018)

The government has also included the Climate Resilient Green Economy (CRGE) Strategy in Ethiopia's current five-year national development plan, the Growth and Transformation Plan II (GTP II 2015-2020). The CRGE Strategy aims to ensure that the country's development goal to reach middle-income status by 2025 is achieved through the creation of a robust, climate resilient green economy.

The GTP II aligns with the CRGE Strategy by aiming to reduce land degradation and improve the productivity of natural resources by promoting sustainable forest production and increasing investments to improve product quality and processing (Streck et al., 2015). The GTP II also aims to put 2 million hectares of existing forests under Participatory Forest Management (PFM) and identify and demarcate 4.5 million hectares of degraded land for afforestation or reforestation. Additionally, the country will sponsor national tree planting initiatives to increase national forest cover by 4.5% (Leminih & Kassa 2014).

Protecting and augmenting existing forests, through assisted natural regeneration (ANR) and other tree-based landscape restoration interventions, is central to achieving the goals outlined in the GTP II, since tree-based restoration initiatives not only contribute to economic development by raising incomes and living standards, but also help communities mitigate the effects of climate change. Consequently, one of the main focuses of Ethiopia's restoration program is to increase forest cover by adding more trees to various landscapes. Another component of the restoration program is the National REDD+ Investment Program, which aims to implement large-scale community forest programs, increase capacity in the forest sector, secure additional funding for the forest sector, and design more profitable forestry-related livelihoods. The ultimate goals of the REDD+ program is to increase the forest sector's contribution to Ethiopia's GDP to 8% and to sequester/reduce carbon emissions by 26MM tCO_2e by 2020.

Despite the government's commitment to tree-based restoration, the spatial distributions of potential restoration options have not been previously modelled and identified according to the biophysical requirements of each option. Therefore, the goal of this project was to identify the potential restoration options for Oromia Regional State that could enhance the implementation of restoration efforts and achieve desired ecosystem services in the region.

2 Objectives

The following are the main objectives of the study:

1. Identify biophysical challenges.
2. Identify potential forest and landscape restoration (FLR) options.
3. Identify criteria to map the potential of identified restoration options.
4. Identify and compile best available data and assess its suitability to map potential restoration options.
5. Map the biophysical suitability of each potential restoration option based on set criteria and datasets in Oromia.
6. Validate the outputs and identified tree-based restoration options.

3 Approach and Methodology

Our methodology relied heavily on stakeholder engagement. National and regional stakeholders were engaged throughout the process, specifically in steps 1, 2, 3, and 6.

Workshops were held on 20-21 August 2019 in Oromia region to initiate participatory planning with stakeholders and accomplish most of the above objectives, including identifying challenges, potential restoration options and identifying mapping criteria for the identified options. During the participatory planning workshops, stakeholders (Appendix 1) broke into working groups and participated in six sessions. The goal of the first session was to identify biophysical challenges in the region that hinder ecosystems services and decrease the productivity of a given area, watershed, region or the country at-large. The goal of the second session was to identify potential restoration options for the region. The third and fourth sessions were dedicated to identifying datasets and mapping criteria for each potential restoration option. The fourth and fifth objectives were primarily relied on WLRC experts with WRI help. However, during the fifth session, participants helped with identifying potential local, regional, national, or international data owners.

Finally, the project team conducted a validation workshop on 20 December 2019 with stakeholders who participated in the initial workshop. During the validation workshop, participants agreed on the mapping methodology, reviewed input datasets, and analyzed whether the outputs reflect current and future expectations. Feedback from the participants is included in Appendix 2.

3.1 Identifying Biophysical Challenges

During the first session of the participatory workshop, local experts identified the most pressing challenges to natural resource management their communities were facing. The identified challenges were categorized into two major types: biophysical and other (e.g., institutional, political, or social challenges).

Table 1 lists, in no specific order, the major biological challenges identified by the three working groups. Using this list, the project team identified which restoration interventions could be implemented to address those problems.

Table 1 | Identified biophysical challenges

• Deforestation • Forest degradation • Land degradation • Loss of water quantity and quantity (water resources degradation) • Pollution • Over exploitation on Natural Resources • Soil acidity • Landslides and gullies (soil erosion) • Loss of land production and productivity • Intensive use and expansion of agriculture land • Wildlife habitat shrinkage • Over-mining	• Loss of biodiversity • Ecosystem disturbances • Urbanization • Drought and flood (due to climate change) • Disease outbreak • Invasive species expansion • Land fragmentation • Fire hazards • Soil degradation • Overgrazing/ grazing land degradation • Lack of restoring degraded landscape • Water logging and wetland degradation

Other important challenges related to natural resource management were also reported during the working group discussions and are listed in Table 2. While the project team was unable to map the restoration potential for these challenges in the same manner as the biophysical challenges, they are crucial to understanding the local context of the region.

Table 2 | Other challenges related to natural resource management

• Absence of skill and technology to use data • Internal immigration • Lack of livelihood diversification • Lack of proper data • Improper EIA • Lack of rehabilitation commitment after mining • Absence of land use policy and strategy (e.g., policy stated only five tree species and is not inclusive) • Absence of law enforcement for NRM • Lack of institutional arrangement • Lack of investment plan and implementation • Institutional arrangement problem (responsibility and accountability overlap and gaps) • Lack of policy and strategies of land use • Widespread unemployment and poverty	• Resource limitation (human, financial, and technological) • Population density (pressure on land) • Lack of awareness creation, knowledge, and skill • Property rights (land tenure) • Corruption • Declined acceptance of social norm • Lack of environmental and policy and proclamation enforcement • Lack of restoration of degraded landscapes • Lack of government commitment • Security problem to manage remote and bordering areas • Political intervention on investment land (e.g., forest used for mining) • Lack of equity to youth and gender • Lack of integration of institutions (including vertical links in the same sector)

3.2 Identifying Potential Restoration Options to Restore Landscapes

After thorough discussions with the three working groups, we summarized the potential restoration options to be considered for the region. Several potential restoration options were identified and suggested and are listed in Table 3 below.

Table 3 | Identified potential restoration options

• Restocking of degraded natural forests • Agroforestry • Water harvest • Establish nursery sites • Bamboo restocking and rehabilitation • Buffer zones along rivers, national parks, and lakes • Agro-silvo-pastoral • Area closure • Buffer around roads	• Afforestation and reforestation • Restore wetlands and buffer zones • Disease, pest, and invasive species control • Commercial plantations • Promote individual planting (home-gardens) • Infrastructure development to national parks & high forests • Forage tree development • Seed source site for forest • Buffer around towns

Not every potential restoration option listed could be easily mapped at the regional level. Several interventions, such as nursery sites, require less than 0.5 ha and are more easily mapped at the site-specific level. Though not included in the maps developed for this regional exercise, the project team acknowledges the importance of small coverage interventions and notes that they should be included in local mapping exercises. From the options listed in Table 3, we selected and mapped 12 potential restoration options:

1. **Potential for afforestation and secondary forest restoration:** Establish forests such as natural high forests and woodlands through reforestation, tree planting on land that recently had tree cover, or afforestation, tree planting on land that has long been deforested (adapted from IPCC 2014). These interventions will reestablish forests' ecosystem services. In Ethiopia, common practices to restore secondary forests include assisted natural regeneration and area enclosure (MEFCC, 2018).
2. **Potential for restocking degraded natural forests:** Increase the stock of existing degraded natural forests, including degraded high forests and woodlands. Common practices to restock degraded natural forests are enrichment planting and assisted natural regeneration (MEFCC, 2018).
3. **Potential for agroforestry on cropland:** Use agroforestry techniques to increase the number of trees on existing croplands in highland areas (agri-silviculture) and in lowland areas (agro-silvo-pastoralism).
4. **Potential for commercial plantations:** Expand income-generating commercial plantations for the production of wood and other timber products. This includes establishing commercial plantations on communal/public, state-owned, and private land (MEFCC, 2018).

5. **Potential for fuelwood plantations:** Expand fuelwood plantations to meet Ethiopia's growing demand for firewood. If established in strategic locations close to villages, these plantations will not only satisfy rural and urban demand for cooking fuel and protect natural forests but will also benefit women and girls who often have to travel far distances to collect fuelwood.
6. **Potential for home gardens and woodlots:** Expand private and small-scale production of wood (e.g., timber used in construction) and non-timber forest products (e.g., fruits, forage) for domestic and commercial use on both communal and private land (MEFCC, 2018).
7. **Potential for expansion and restocking of highland and lowland bamboo:** Restock existing natural bamboo forests and establish new bamboo forests in highland and lowland areas with suitable bamboo species.
8. **Potential for tree-based buffer around rivers, lakes, and wetlands:** Develop and restock buffer zones around bodies of water.
9. **Potential for tree-based buffer along National Parks, Protected Areas, and National Forest Priority Areas:** Increase tree-based plantations within 1000 m of national parks and protected and priority areas. National park management plans and strategies are already in place inside these areas.
10. **Potential for tree-based buffer along roads and around towns:** Establish rehabilitation programs to restore areas that were deforested due to the construction of roads, towns, and other infrastructure.

3.3 Identified Criteria for Mapping Potential for Restoration Options

In collaboration with stakeholders at the participatory workshop and using data from the national potential map (MEFCC, 2018), we set the criteria for each potential restoration option (Table 4). The spatial models are presented in Appendix 2. Various biophysical, infrastructure, and population datasets were used as inputs for the models to accurately identify potential areas for restoration.

Table 4 | Criteria and datasets for each potential restoration option

SN	Options	Criteria	Rationale	Data sets	Sources
1	Potential for afforestation and secondary forest reforestation	Valleys at mountain escarpment and large gullies with >50% slope	Mountain gully treatment reduces soil erosion and enhances ground water recharge. 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)	Slope	Derived from SRTM, USGS, 2017
		Include bareland and shrub/bushland above 50% slope	This option should be implemented in areas not used for other purposes	Land use-land cover	WLRC, 2016
		Exclude altitude > 3500m	Agro-ecological above tree-line is not suitable area for tree planting	Altitude	SRTM, 2017
		Include cropland of slope > 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)	Land use-land cover Slope	WLRC, 2016 Derived from SRTM, USGS, 2017
		Include rainfall > 250mm	Afforestation/reforestation would be easily established with enough rainfall	Rainfall	ENACT-NMA, 2016
2	Potential for restocking degraded natural forests	Include moderate forests, sparse forests	It doesn't include grassland and wooded grassland	Land use-land cover	WLRC, 2016
		Include tree cover <30%	Proxy to degraded natural forest	Tree cover	Global Tree cover, 2010

SN	Options	Criteria	Rationale	Data sets	Sources
		Include areas with Average annual rainfall > 250 mm	Optimum rainfall is required for restocking degraded forest; rainfall below 250 mm may not be suitable for restocking	Rainfall data	ENACT-NMA, 2016
		NDVI < 0.6	NDVI less than 0.6 indicates the forest is degraded (based on expert input)	NDVI calculated from Landsat 8 Image of 2017	USGS, 2017
		Land productivity decline, sign of decline and stressed categories	Land productivity status is a proxy for vegetation status. Land productivity is the biological productive capacity of the land, the source of all the food, fiber and fuel that sustains humans (United Nations Statistical Commission 2016). Net primary productivity (NPP) is the net amount of carbon assimilated after photosynthesis and autotrophic respiration over a given period of time (Clark et al. 2001) and is typically represented in units such as kg/ha/yr	Land productivity	Trends.earth
3	Potential for agroforestry on cropland	Include annual and perennial croplands	Enriching both highland and lowland cropland areas with proper planting	Land use esp. cropland maps	WLRC, 2016
		Exclude areas with tree cover > 30%	Tree cover greater than 30% indicates an already well-stocked agroforestry system	Tree cover	Global Tree cover, 2010
		Exclude mechanized and large-scale farming	Mechanized and large-scale farming may not be feasible with agroforestry as we assume that owners will have their own plan	Data on mechanized and large-scale farming not readily available	

SN	Options	Criteria	Rationale	Data sets	Sources
		Average annual rainfall > 250 mm	Optimum rainfall is required for restoration	Rainfall	ENACT-NMA, 2016
		Slope <60%	Rural lands whose slope is more than 60% will not be used for farming and free grazing; they will be used for development of trees, perennial plants, and forage production (FDRE 2005)	Slope	Derived from SRTM, USGS, 2017
4	Potential for commercial plantations	Road network <10km	Access to market and transportation is required	Road network	ERA, 2006
		Exclude areas with average annual rainfall ≤ 800 mm	There should be enough amount of moisture for fast growth of commercial plantations	Rainfall	NMA, 2016
		Exclude areas with altitude ≤ 800 m or >2300m	The optimum agro-ecology for fast growth of commercial plantation	Altitude	SRTM, 2017
		Exclude areas with slopes > 60 %	Accessible topography is preferred; rural lands whose slope is more than 60% will not be used for farming and free grazing; they will be used for development of trees, perennial plants, and forage production (FDRE 2005)	Slope	Derived from SRTM, USGS, 2017
		Include open shrubland	Only open shrubland should be considered; closed shrublands are healthy ecosystems by themselves	Land use-land cover	WLRC, 2016
		Include bare and shrub/bushland with slope below 60%	Non-forested areas can be turned into commercial plantation areas if they fit both the suitability and accessibility requirements	Land use-land cover Slope	WLRC, 2016 Derived from SRTM, USGS, 2017

SN	Options	Criteria	Rationale	Data sets	Sources
		Population density <200 people per sq. km	Highly populated areas should be excluded from commercial plantations, as there would be different services and demands for the land	Woreda population density	CSA, 2007
5	Potential for fuelwood plantations	Include bareland, and shrub/bushland above 30% slope	Wasted lands can be developed for fuelwood by the community	Land use-land cover	WLRC, 2016
		Include population density <200 people per sq. km	There could be a challenge to implement this option in the densely populated areas due to population pressure for settlement and other priorities	Woreda population density	CSA, 2007
		Within 5km of roads	Fuelwood plantations located farther than 5 km from roads would result in challenges to the daily lives of children, girls and women, since these groups are primarily responsible for fuelwood collection	Road network	ERA, 2006
		Include tree cover <30%	Areas with tree cover <30 % are assumed to be degraded areas that require restoration	Tree cover	Global Tree cover, 2010
6	Potential for home gardens and woodlots	Rural settlement areas with population density <200 people/ sq.km	Home gardens are within the vicinities of individual households, but highly populated areas are challenging to spare areas for home-garden unless landowners are committed to the intervention. Less populated areas are preferred since there is more available space for home-gardens	Woreda population density	CSA, 2007

SN	Options	Criteria	Rationale	Data sets	Sources
		Within 2kms of homesteads/villages	Areas within a radius of 2 km can be considered as home gardens. Areas located at farther locations could have mixed land use types and be difficult to monitor regularly	Homestead/village	CSA, 2007 and 2018
		Include cropland, bareland, and settlement areas	Croplands, bareland, and settlement areas are suitable land use types for home garden practices	Land use-land cover	WLRC, 2016
7	Potential for expansion and restocking of highland (altitude between 1500-3200 m) and lowland (altitude between 800-1500 m) bamboo	Include areas that currently have lowland or highland bamboo	Existing bamboo areas are assumed to be degraded and could be restocked	Natural bamboo extent	INBAR, 2018
		Include areas with potential for bamboo	Areas where new bamboo sites can be developed for ecosystem services and other socio-economic benefits	Bamboo potential	National Potential and Priority Maps for Tree-Based Landscape Restoration in Ethiopia, 2018
8	Potential for tree-based buffer around rivers, lakes, and wetlands	Up to 50 m around lakes, rivers & wetlands	The areas in close proximity to a body of water play a critical role in protecting it from erosion (based on expert judgment).	Rivers, lakes & wetlands	WLRC, 2016
		Exclude forest and tree cover >30% around lakes, rivers and wetlands	Forests and other land with tree cover greater than 30% are already considered to have good tree cover.	Land use-land cover Tree cover	WLRC, 2016 Global Tree cover, 2010

SN	Options	Criteria	Rationale	Data sets	Sources
		Exclude population density > 200 people/ sq.km	Higher population densities increase pressures on the trees	Woreda population density	CSA, 2007
9	Potential for tree-based buffer around National Parks, protected areas, and national forest priority areas	Up to 1000 m buffer around NFPAs, NPs and PAs	Reserving 1000 m buffer area around existing NPs, and Pas, and NFPAS is fundamental to protect the core areas from degradation	Protected areas and national priority areas	World Database Protected areas (WDPA)
		Exclude forest and tree cover >30% NFPAs, NPs and PAs	Forests and other land with tree cover greater than 30% are already considered to have good tree cover	Land use-land cover Tree cover	WLRC, 2016 Global Tree cover, 2010
		Exclude population density > 200 people/ sq.km	Higher population densities increase pressure on trees	Woreda population density	CSA, 2007
10	Potential for tree-based buffer along roads and around towns	100m from roads and 1km from towns	Re-greening roads and urban areas is contributing to restoration and microclimate regulation	Roads and towns	ERA, 2006 and CSA, 2007
		Exclude forest and tree cover >30% around roads and towns	Forests and other land with tree cover greater than 30% are already considered to have good tree cover.	Land use-land cover Tree cover	WLRC, 2016 Global Tree cover, 2010

Table 5 | Major variables (datasets) used to model to identified spatial distributions of potential restoration options

Variable	Descriptions	Source
Land use land cover (LULC)	To mask out non-used LULC types and extract only important ones	Water and Land Resource Center, 2016
Rainfall	Rainfall is one of the constraints for different restoration options (annual average 1983 - 2016)	Enhancing National Climate Services (ENACTS data) from Columbia University and NMA of Ethiopia
Slope	Slope governs the intervention types	Derived from SRTM-30m

Variable	Descriptions	Source
Altitude	Altitude affects both rainfall and temperature	SRTM-30m
Existing bamboo extent	Existing bamboo map is a base for restocking of degraded bamboo	INBAR, 2018
National potential for bamboo	Areas that meet criteria for growing lowland and highland bamboo	MEFCC, unpublished
Tree cover	A threshold of less than 30% tree cover is assumed degraded and can sustain more trees	Global data, Tree cover, 2010
NFPA, PA and National parks	National Forest priority area, protected areas and national parks	WDPA regional office (global data)
Rivers, lakes, wetlands	Bodies of water such as rivers, lakes, and wetlands	CSA, 2007 and EthioGIS II, 2015
Roads and cities	Road infrastructure and accessibility are very important for market and access	ERA, 2006 and CSA, 2007
Settlement/villages	Settlement areas were a good proxy for homestead areas	CSA, 2007 & 2018
Population density	Population density affects the implementation of restoration	CSA, 2007
Land productivity	Land productivity indicates the status of vegetation changes 2016	Trends.earth
Normalized difference vegetation index (NDVI)	Vegetation index of a given area at a given period	Derived from Landsat 8, 2017
Administrative boundaries	Oromia regional boundaries for mask-out he area extents of those restoration options: (Note: administrative boundaries are not authoritative)	CSA, 2007

The datasets used for this model were collected from a variety of sources which use different projections, data formats (raster, shapefile, etc.), and resolutions. The team standardized all data sets and projected them into “WGS_1984_UTM_Zone_37”, using a spatial resolution of 30 m.

During the validation workshop, criteria and respective outputs for all restoration options were presented to participants from a number of different agencies in the region (Appendix 2). They discussed each of the criterion and outputs in detail and presented their comments and feedback. The majority of their comments concerned afforestation and secondary forest restoration and fuelwood plantations. They revised the criteria from 60% slope to 50% slope for afforestation and secondary forest restoration, and from 50% slope to 30% slope for fuelwood plantations. The group also decided to decrease the distance from villages to fuelwood plantations from 5km to 2km.

3.4 GIS Mapping of Spatial Distribution of Identified Restoration Options

Based on information collected during the two-day workshop in Oromia region, the project team decided to map the potential of 10 restoration options (Section 3). Geo Information Systems (GIS) experts from WLRC mapped 10 (two with sub-types) of mappable identified restoration options by translating the mapping criteria and dataset (Table 4). Note, not all suggested interventions are mappable. Model Builder of an ESRI ArcGIS software was used to map the identified restoration options (Appendix 2). Best efforts were made to collect the input data required for analysis from local, national, and global sources (Table 4), but these efforts were by no means exhaustive. Improving the product should be an iterative process as newer and better-quality data becomes available. With this in mind, the GIS database and models are delivered with this report.


Photo credit: Tesfay Woldemariam, WRI

4 Results

The potential area of each intervention is listed in Table 6. Some potential restoration options were divided into two categories to provide more accurate results. Overall, approximately 24.4Million hectares (Mha) was identified as potential area for restoration. The potential restoration options with the largest area of potential implementation are agroforestry on cropland (8.8Mha, about 36% of the total potential) and lowland bamboo expansion or restocking (3.9Mha, about 16% of the total potential). However, several potential restoration options can overlap in a specific area. Out of the 24.4Mha identified, 8.3Mha have the potential for more than one restoration option (Figure 11 and Appendix 3).

Table 6 | Tree-based landscape restoration potential area (ha) for Oromia Region, including double counted areas that have potential for multiple options

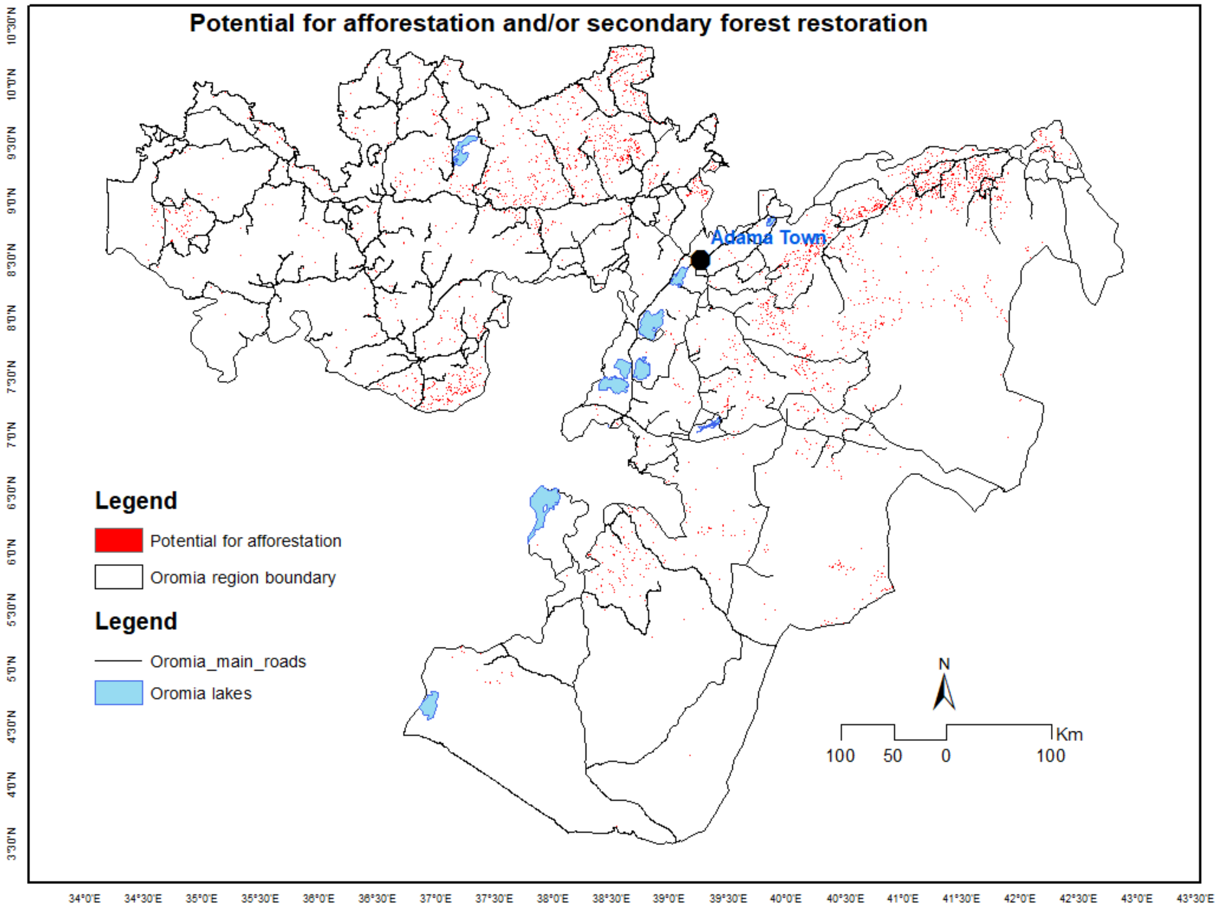
Option	Potential Area (ha)	% of total restoration potential
1. Afforestation and secondary forest restoration	324,049	1.3
2. Restocking degraded natural forests	225,539	0.9
3. Agroforestry on cropland	8,750,848	35.9
4. Commercial plantations	2,057,645	8.4
5. Fuelwood plantations	1,901,633	7.8
6. Home-garden and woodlots	2,773,595	11.4
7. Bamboo expansion and restocking: highland	2,742,527	11.3
8. Bamboo expansion and restocking: lowland	3,859,5352	15.8
9. Buffer around rivers, lakes, and wetlands	5,438	0.02
10. Buffer around National Parks, protected areas, and NFPA	1,009,702	4.2
11. Buffer around roads	513,474	2.1
12. Buffer around towns	215,619	0.9
Total[1]	**24,379,600.50**	

4.1 Potential for Afforestation and Secondary Forest Restoration

There is a potential of 324,049 ha of land for afforestation and secondary forest reforestation in Oromia Region (Table 6). Most of the potential area is located within the central section of the region (Fig. 1).

[1] Including double counted areas that have potential for multiple options

Figure 1 | Spatial location for potential afforestation and secondary forest restoration for Oromia region

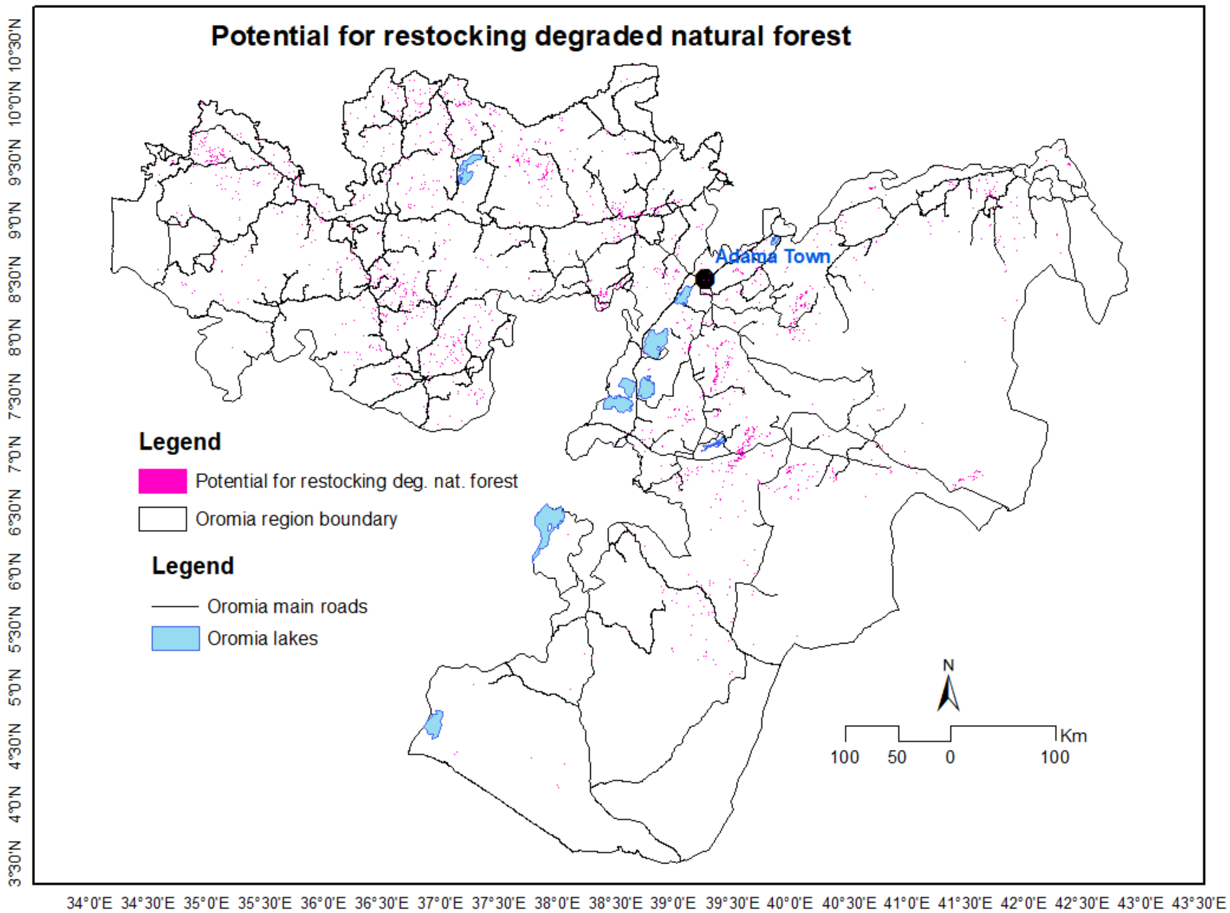


Note: The administrative boundaries used in this map are not authoritative.

4.2 Potential for Restocking Degraded Natural Forests

In Oromia, there is approximately 225,539 ha of degraded natural forests with the potential to be restocked (Table 6 and Fig. 2).

Figure 2 | Location of potential for restocking degraded natural forest areas in Oromia region

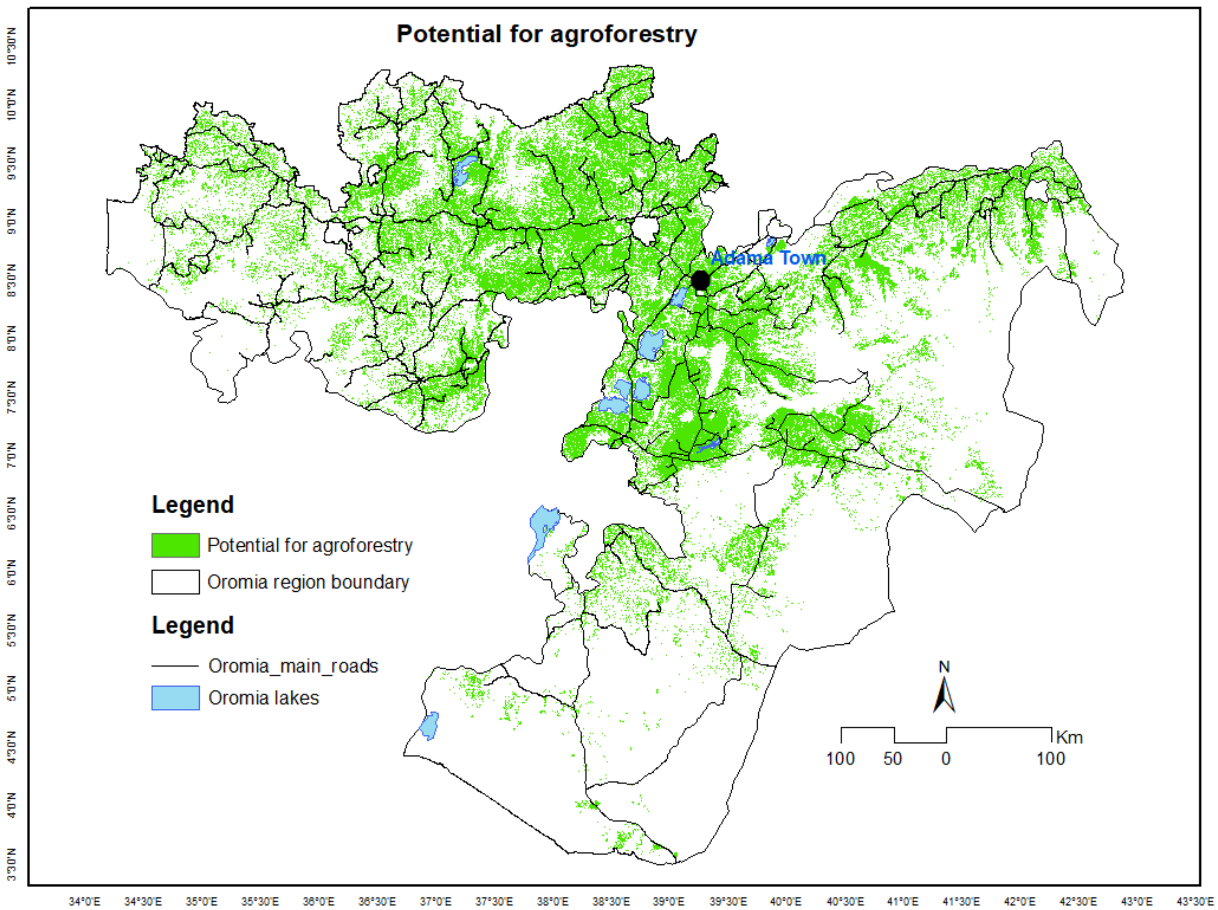


Note: The administrative boundaries used in this map are not authoritative.

4.3 Potential for Agroforestry on Cropland

Based on the results of the spatial modeling analysis, there is approximately 8.8Mha of potential land for agroforestry development and enrichment in Oromia region (Table 6). The central and northern sections of the region have the most potential for agroforestry (Fig. 3). Our analysis shows these sections are ideal candidate areas where agroforestry practices can be developed (if tree cover is less than 30%).

Figure 3 | Spatial location for potential agroforestry on cropland in Oromia region

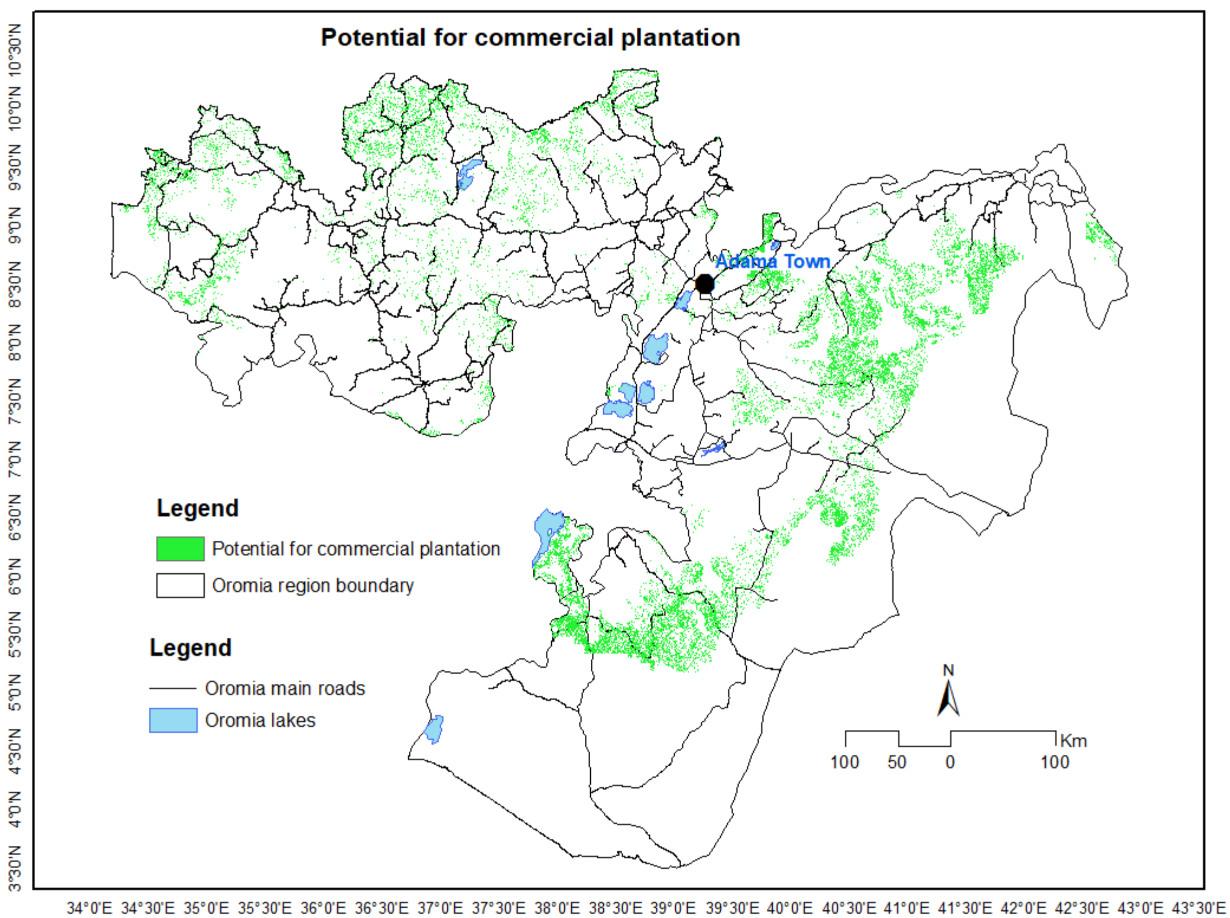


Note: The administrative boundaries used in this map are not authoritative.

4.4 Potential for Commercial Plantations

The creation of more commercial plantations was identified as a potential tree-based restoration option. Although established for commercial purposes and cleared when needed, these plantations provide natural vegetation, particularly forests, relief from deforestation. From this analysis, about 2.1 Mha of land was identified for commercial plantations in Oromia region (Table 6). Most commercial plantation potential areas are found in the northern and eastern parts of the region (Fig. 4).

Figure 4 | Commercial plantation development sites in Oromia region

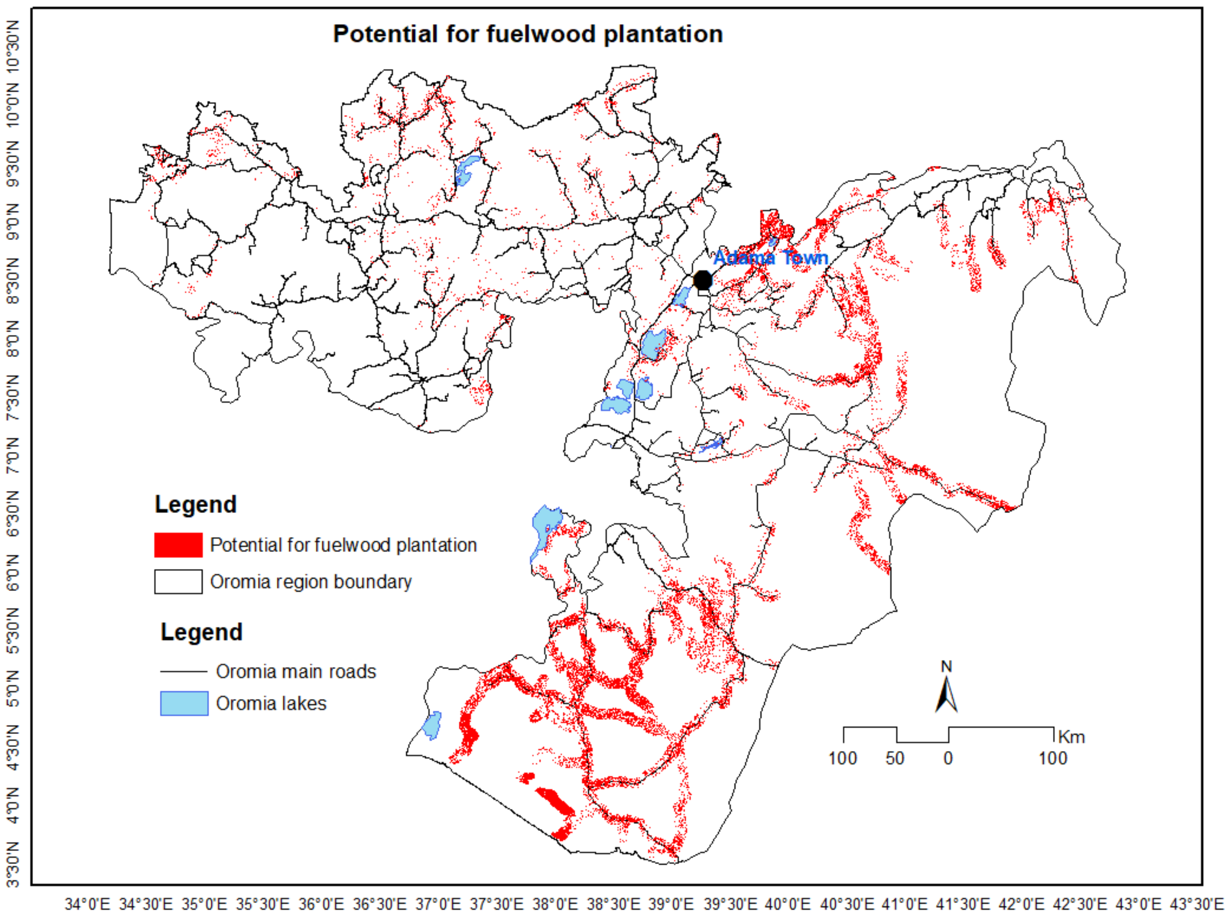


Note: The administrative boundaries used in this map are not authoritative.

4.5 Potential for Fuelwood Plantations

The expansion of fuelwood plantations is considered an integral part of the tree-based landscape restoration program, since greater availability of fuelwood could protect natural forests from being cut for this purpose. Additionally, this option will be implemented in the proximity of the villages, saving local communities time and energy during the collection process. In Oromia region, there is approximately 1.9Mha of land with the potential for fuelwood development (Table 6 and Fig. 5).

Figure 5 | Location of potential fuelwood plantations in Oromia region

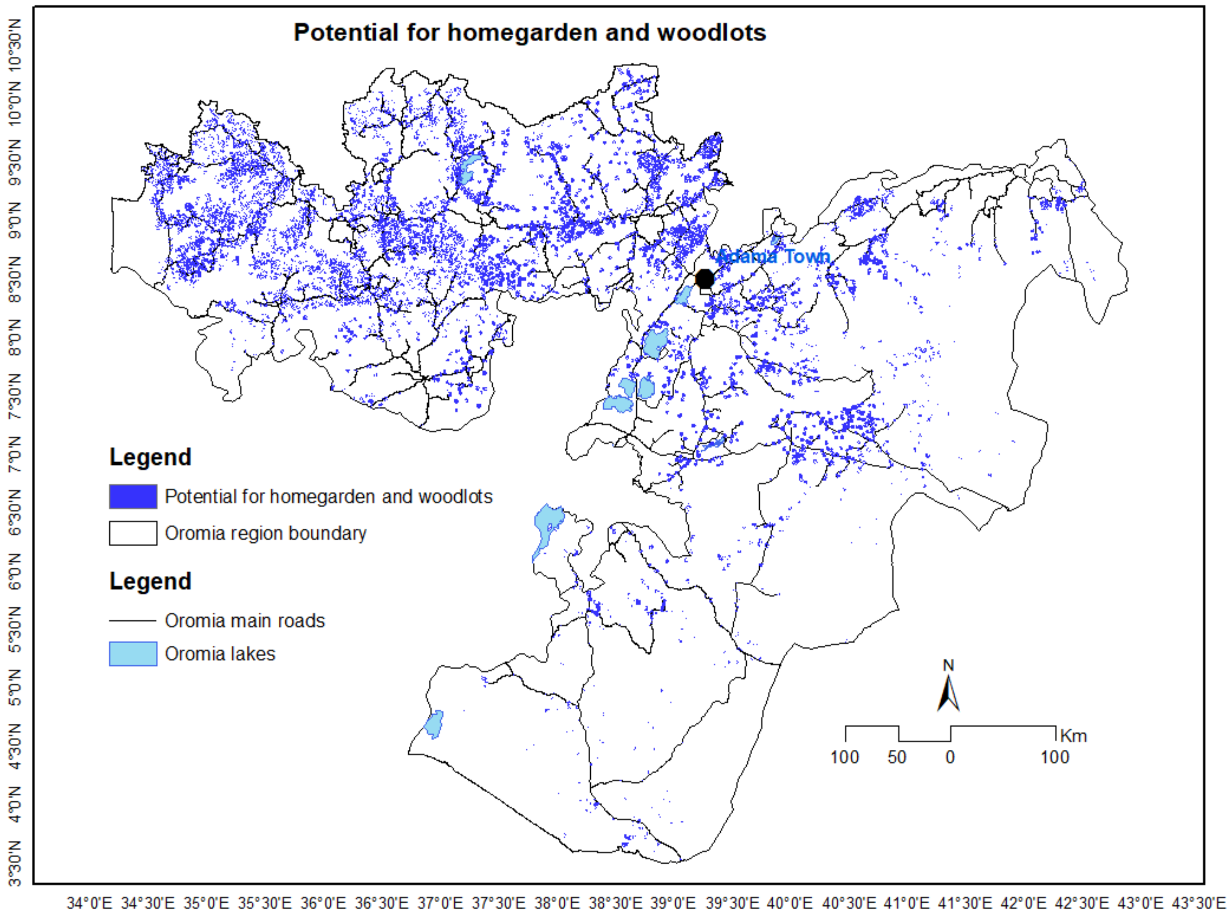


Note: The administrative boundaries used in this map are not authoritative.

4.6 Potential for Home Gardens and Woodlots

Based on our analysis, there is approximately 2.8M ha of land that can potentially be used for home gardens and woodlots in the Oromia region (Table 6 and Fig. 6).

Figure 6 | Location of potential home-garden and woodlot areas in Oromia region

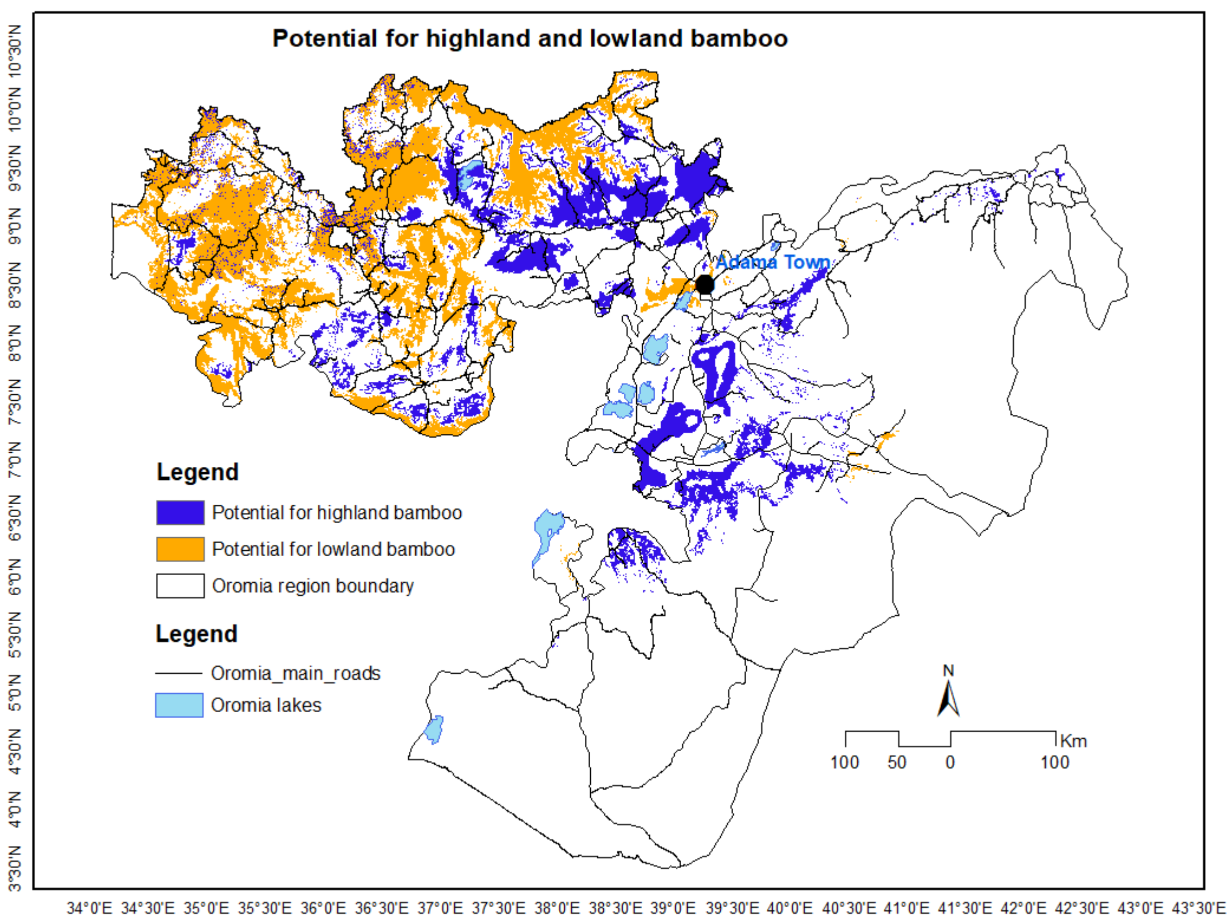


Note: The administrative boundaries used in this map are not authoritative.

4.7 Potential for Expansion and Restocking of Highland and Lowland Bamboo

Using the national restoration database, the project team combined areas of existing degraded bamboo stocks and potential areas for bamboo expansion in both highland and lowland areas. In Oromia region, there are 2.7 Mha and 3.9Mha that have potential for highland and lowland bamboo restocking and expansion, respectively (Table 6). The northern section of the region is most suitable for lowland bamboo restocking and expansion. Areas with potential for highland bamboo development are more scattered throughout the region, except for the south-west corner (Fig. 7).

Figure 7 | Spatial location of areas with potential for expansion and restocking of highland and lowland bamboo in Oromia region

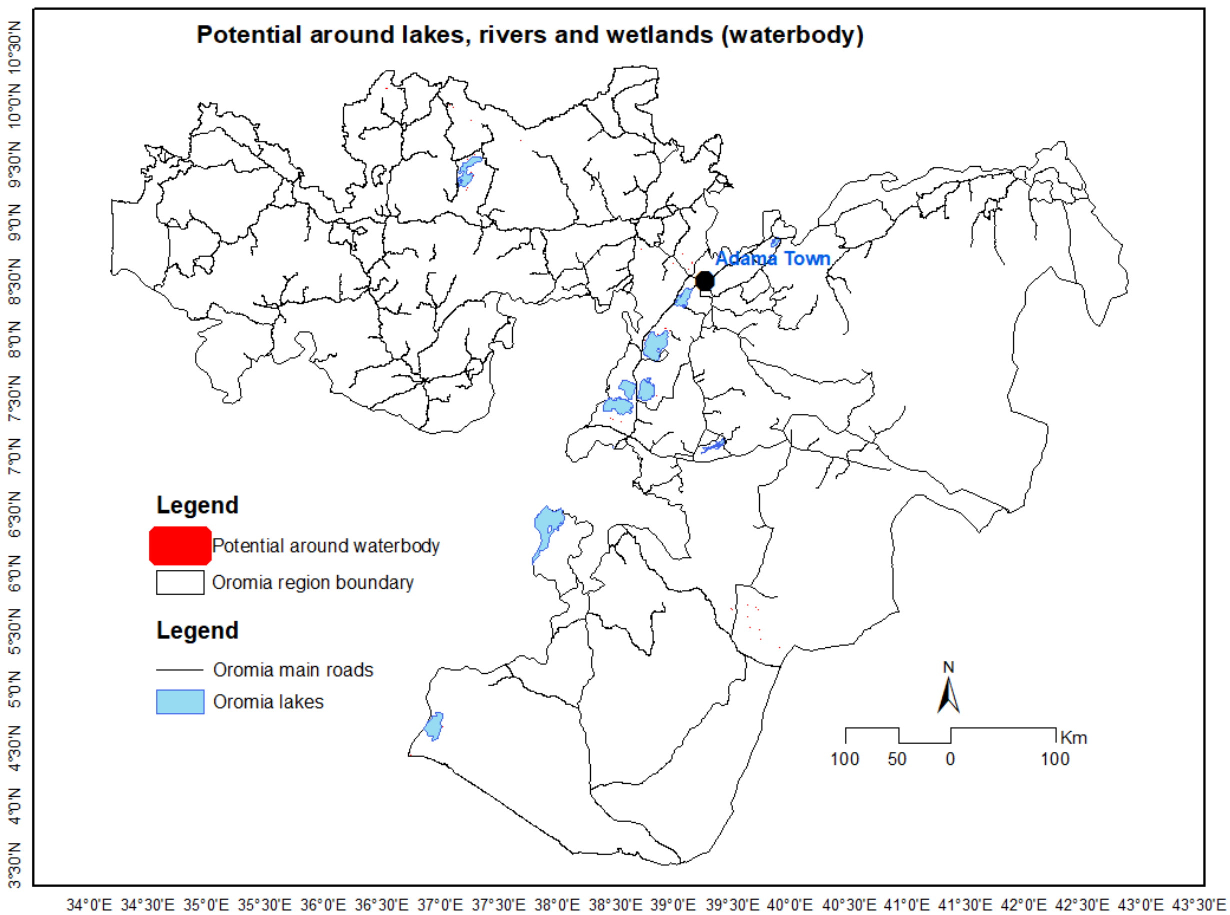


Note: The administrative boundaries used in this map are not authoritative.

4.8 Potential for Tree-Based Buffer Around Rivers, Lakes, and Wetlands

Tree-based restoration has a potential to be implemented along the peripheries of lakes, rivers, and wetlands. The potential area for this restoration intervention in Oromia region is estimated to be 5,438 ha of land (Table 6). These potential areas are limited and sporadically located along riparian areas in the region (Fig. 8).

Figure 8 | Spatial location for buffer around lakes, rivers and wetlands in Oromia region

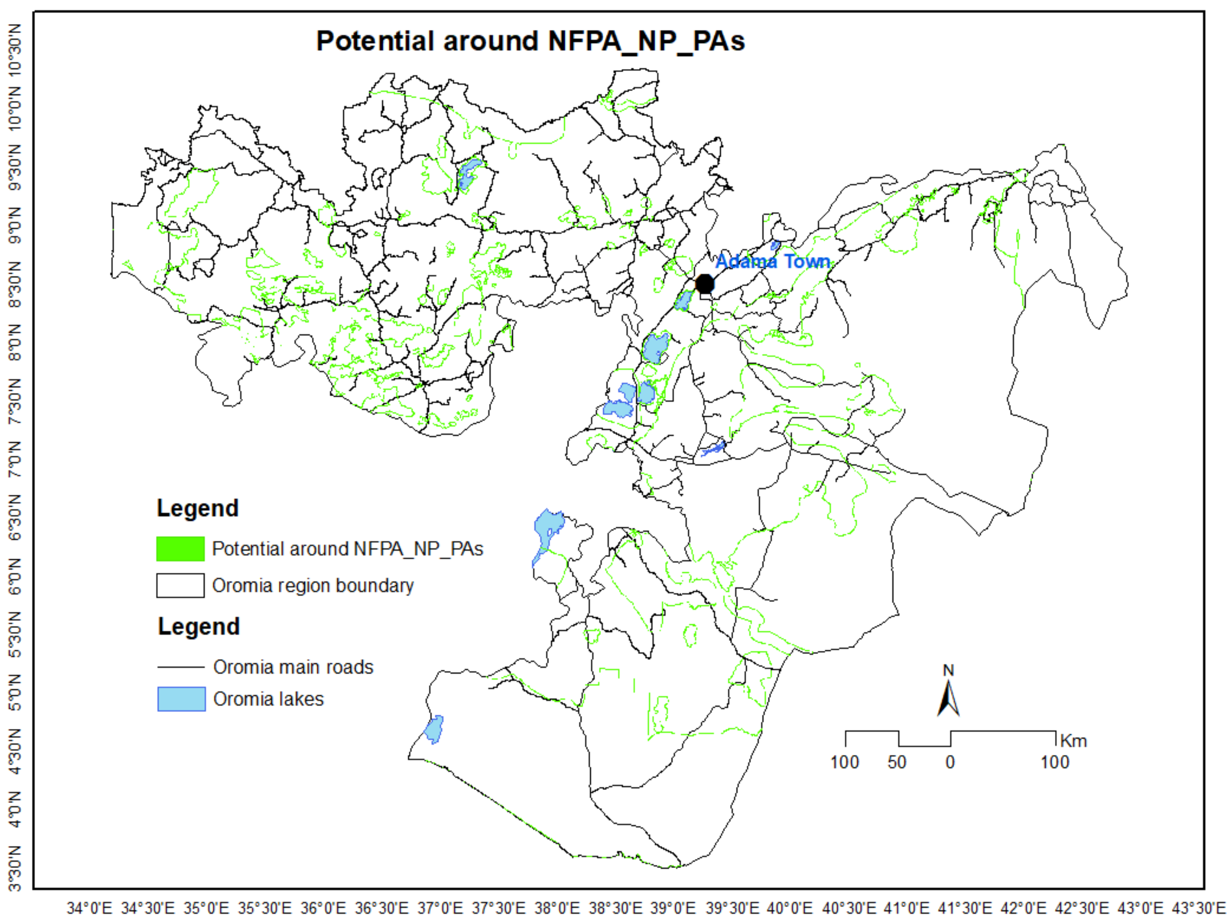


Note: The administrative boundaries used in this map are not authoritative.

4.9 Potential for Tree-Based Buffer Along National Parks, Protected Areas, and National Forest Priority Areas

Most national parks, protected areas, and national forest priority areas have their own management plans and strategies for land rehabilitation and restoration. However, these plans lack provisions to extend restoration practices along the peripheries of such areas. The project team created a 1km buffer around each area that we recommend be considered as potential restoration sites. Restoring buffer zones will help strengthen the ecosystem services derived from these areas and create an additional layer of protection around the core areas within each zone. In total, the estimated potential for this intervention is 1.0Mha of land (Table 6). The potential areas for this intervention are spread throughout Oromia region due to the substantial number of national parks, protected areas, and national forest priority areas in the region (Fig. 9).

Figure 9 | Spatial location for potential tree-based buffer along National Parks, Protect Areas, and National Forest Priority Areas in Oromia region

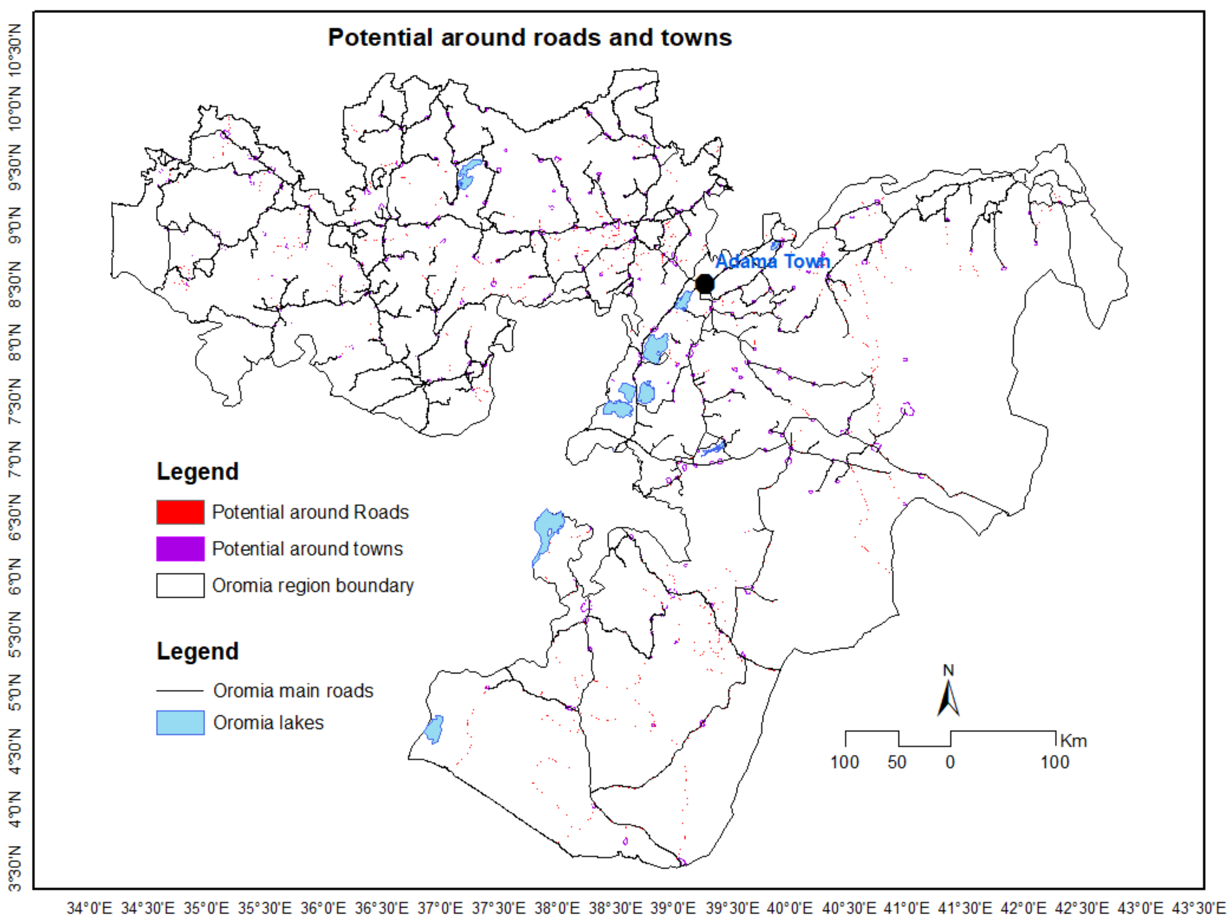


Note: The administrative boundaries used in this map are not authoritative.

4.10 Potential for Tree-Based Buffer Along Roads and Around Towns

The project team also analyzed areas for potential tree-based restoration along roads and around towns. This option was considered for areas within a 100m radius of rural roads and 1km from town polygons. Approximately 513,474 ha and 215,619 ha of land was identified as potential tree-based buffer zones along roads and around towns, respectively (Table 6). Because Oromia region is relatively undeveloped and lacks substantial amounts of infrastructure, including roads and towns, this potential restoration option is fragmented and sparsely found throughout the region (Fig. 10).

Figure 10 | Spatial location for potential tree-based buffers along roads and towns in Oromia region



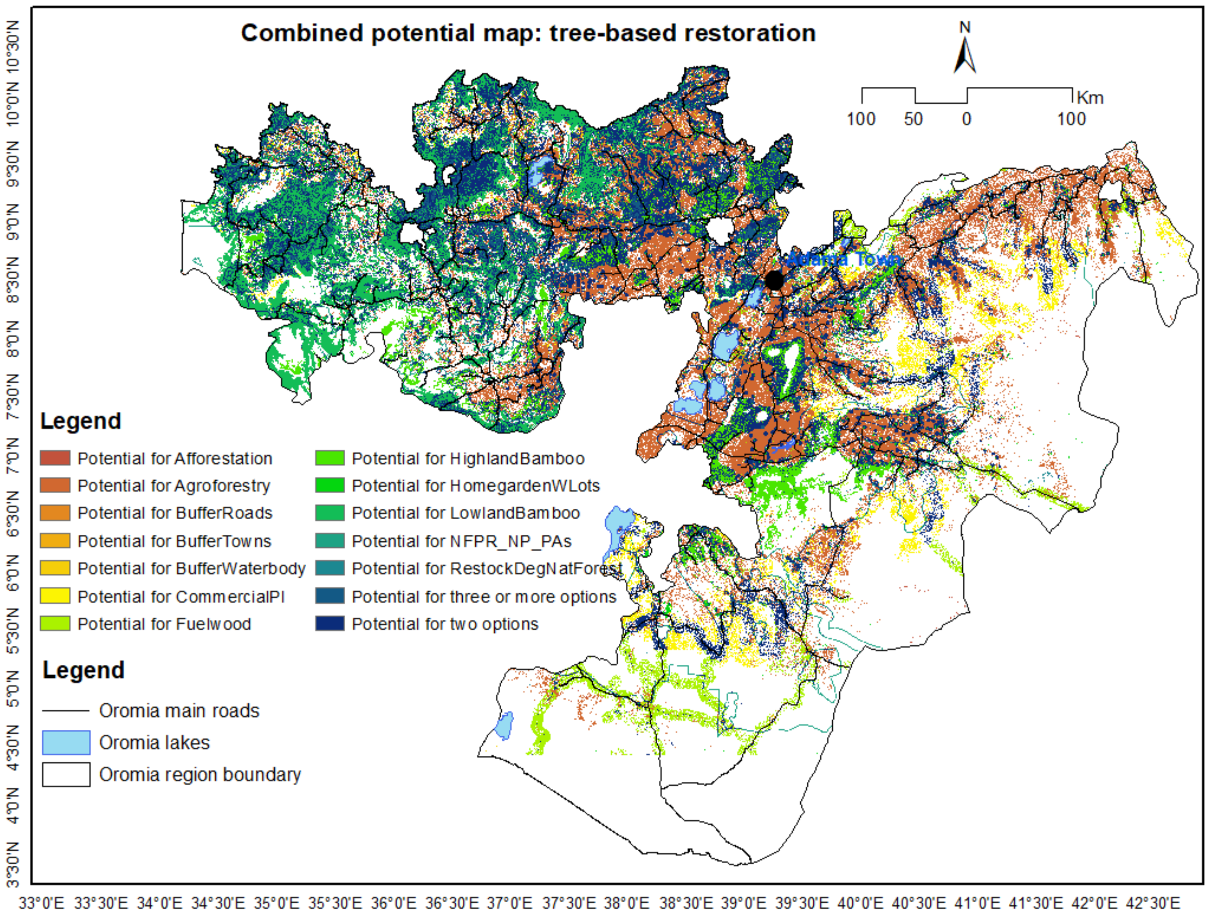
Note: The administrative boundaries used in this map are not authoritative.

4.11 Combined Potential for Tree-Based Restoration

Our analysis of combined potential for tree-based restoration shows that over 16.6Mha of land is suitable for one or more potential restoration option in Oromia region (Table 7)[2] . This number differs from the total number of hectares described in Table 6 because the latter did not account for areas where potential restoration options may overlap. After combining and mapping all potential restoration options, we see that specific areas have potential for multiple options. In these cases, the potential restoration option(s) will be prioritized based on the stakeholders' desired environmental, social and economic benefits in the given area, and the region at-large. From this analysis, we have found approximately 521 separate combinations of potential restoration options (Fig. 11) can be implemented in the region based on set criteria. For example, 4.7 Mha of the region is suitable solely for agroforestry expansion, while 2.1Mha is suitable solely for lowland bamboo. However, major areas in the region are suitable for two or more restoration options. In terms of hectares covered, the largest combined options we observed are: potential for agroforestry on cropland and home-gardens (1.22Mha); followed by potential for agroforestry on cropland and expansion and restocking of highland bamboo (902,396 ha); potential for agroforestry on cropland and expansion and restocking of lowland bamboo (723,172 ha); and potential for expansion and restocking of lowland bamboo and commercial plantations (302,487 ha). In total, approximately 4.9Mha of land is suitable for at least two potential restoration options and 1.1M ha of land is suitable for three or more potential restoration options (Table 7).

[2] OROMIA's areas of potential in the regional and national (MEFCC, 2018) assessments differ because the criteria and input data used were different.

Figure 11 | Combined map of potential restoration options in the Oromia region



Note: The administrative boundaries used in this map are not authoritative.

Table 7 | Summary of combined and individual potential restoration options

Potential restoration options	Area (ha)
Potential for afforestation and secondary forest restoration only	105,601
Potential for restocking degraded natural forest only	112,550
Potential for agroforestry on cropland only	4,705,743
Potential for commercial plantation only	944,232
Potential for fuelwood plantation only	779,404
Potential for home-garden and woodlots only	324,156
Potential for highland bamboo expansion and restocking only	1,059,569
Potential for lowland bamboo expansion and restocking only	2,097,316
Potential for tree-based buffer around rivers, lakes & wetlands only	667
Potential for tree-based buffer around NFPA, NP & Pas only	356,546
Potential for tree-based buffer around roads only	39,367
Potential for tree-based buffer around towns only	41,572
Potential for two options	4,870,796
Potential for three or more options	1,175,047
Total	**16,612,567**

5 Conclusions

In total, there are over 16 Mha of land in Oromia that are suitable for one or more than one forest and landscape restoration option. The largest potential restoration option is agroforestry on cropland (4.7Mha) and expansion and restocking of lowland bamboo (2.1 Mha). There is also substantial potential for the expansion and restocking of highland bamboo (1.1 Mha) and the development of commercial plantations (0.9 Mha). Oromia Region has, overall, a high potential for various tree-based restoration options. Given the data collected as part of this project, and the urgent need to address land degradation in the region, it is imperative to begin planning and implementing these tree-based restoration options. Doing so will not only maintain and contribute to more sustainable land management practices, but also deliver additional ecosystem services and socio-economic benefits to local communities.

6 Acknowledgements

First and foremost, we appreciate the efforts of the Environment Forest and Climate Change Commission (EFCCC) of Ethiopia, particularly H.E. Ato Kebede Yimam, for supporting the vision to carry out a broad, tree-based landscape restoration plan, developed in coordination with the World Resources Institute (WRI), the Water and Land Resource Center (WLRC), and local partners.

During this project, the WLRC of Addis Ababa University (delegated by Dr Hailu Shiferaw), in collaboration with EFCCC (delegated by Mr. Adugna Abebe) and WRI, was responsible for all technical work. The WLRC, particularly Dr Gete Zeleke, was fully committed to the project and played an instrumental role in stewarding the technical aspects of the assignment.

We would like to recognize the contributions of regional and local stakeholders from Oromia, who have supported the project from its inception through the validation stages. We also appreciate the support of the WRI staff, particularly Tesfay Woldemariam, Meseret Shiferaw and Florence Landsberg, whose contributions were helpful in achieving the planned objectives of the project. We also thank Mary Gronkiewicz of WRI for editing the report.

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8 Appendix 1: List of Participants

The planning workshop was conducted on 20-21 August 2019 to discuss and identify restoration potential for Oromia.

8.1 Planning Workshop Participants

S N	Name	Institution
1	Daniel Negassa	OEFCCA (E/Wollega)
2	Adugna Merga	Agriculture at Zone
3	Gezahagn Kinati	Agriculture at Zone
4	Deresu Alagawowerdb	OWERDB
5	Tamiruu Beyene	OANRB
6	Esmael Mohammed	E/Hararghe Agri. Office
7	Melkamu Teshome	Agriculture of IAB Zone
8	Mulugeta Merara	West Sh/Zone Envo.Rorest & CC.
9	Sultan Mohammed	West Hararghe NR-Team
10	Adam Dawid	West H/Zone (ATEN
11	Samuel Meried	Wlra QQU (Shew Baha)
12	Muluneh Abdisa	South West Showa Agri & N/R Office
13	Abdurkadir Tufa	West Asela EFCC
14	Tegegne Terefa	Bale EFCCA
15	Asefa Abera	OEFCCA
16	Shiferaw Diriba	OEFCCA (Jimma)
17	Teshaye Gebeyehu	K/W/Z/A/ Office
18	Wondo Shorbote	Gusi Zone Agri. Office
19	Shibiru Tola	Bu/Bedele Agriculture Office
20	Addisalem Belete	E/Wolega Agriculture office
21	Ebrahim Kaso	Arsi Zone Agri. & NR Office
22	Sara Mamo	Gusi zone
23	Tewodros Bebre	EFC Authority/Guji Zone (East Guji
24	Wondo Shorbote	West Arsi Zone

8.2 Validation Workshop Participants

S N	Name	Institution
1	Daniel Negassa	OEFCCA (E/Wollega)
2	Esmael Mohammed	E/Hafarghe Agri. Office
3	Melkamu Teshome	Agriculture of IAB Zone
4	Mulugeta Merara	West Sh/Zone Envo.Rorest & CC.
5	Samuel Meried	Wlra QQU (Shew Baha)
6	Muluneh Abdisa	South West Showa Agri & N/R Office
7	Abdurkadir Tufa	West Asela EFCC
8	Tegegne Terefa	Bale EFCCA
9	Asefa Abera	OEFCCA
10	Wondo Shorbote	Gusi Zone Agri. Office
11	Addisalem Belete	E/Wolega Agriculture office
12	Sara Mamo	Gusi zone
13	Tewodros Gebre	EFC Authority/Guji Zone (East Guji)
14	Tsedeke Iticha	Jimma Zone Agr Office
15	Fekadu Lebecha	OWERDB
16	Shoga Hussen	West Arsi Zone Agr Office

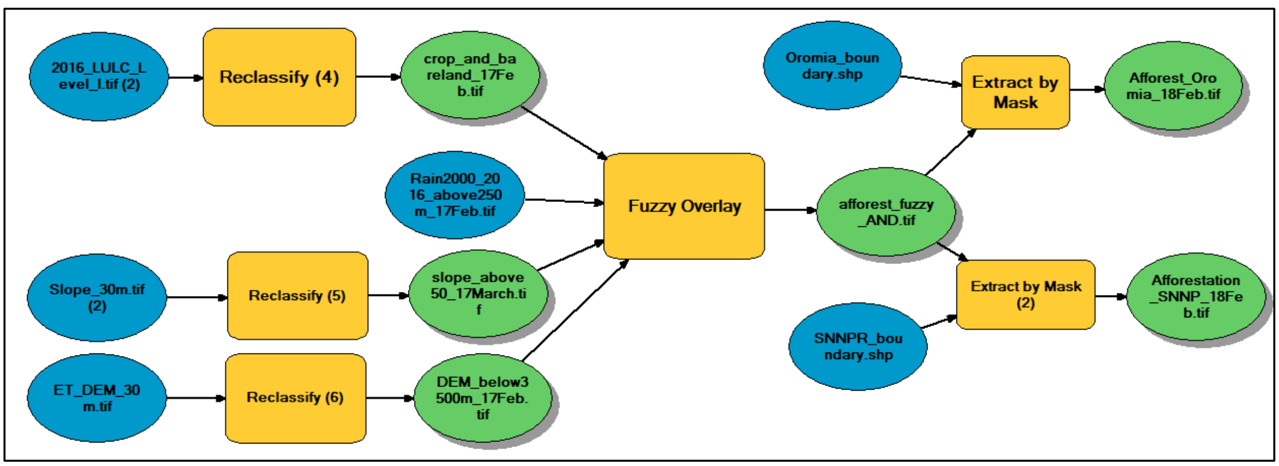
9 Appendix 2: Spatial Modelling

We developed spatial modelling tools using ArcMap Toolbox to identify potential areas for each restoration option. The spatial assessment tools include, but are not limited to, buffering, extracting, reclassifying, masking, mosaicking, and overlay (e.g., Fuzzy Overlay with AND option) to identify areas that satisfied all the given criteria for each restoration option. We list each potential restoration option alphabetically in the sections that follow.

9.1 Afforestation and Secondary Forest Restoration Potential

Afforestation refers to the process of adding trees to areas that are currently not forested. Areas considered for afforestation may previously been forested in the past. In these cases, it may not be possible to afforest an area using the original vegetation species or to the extent of its original forest cover due to changes in climate and other dynamic variables. The project team used four major datasets to model and identify the potential areas for afforestation and secondary forest restoration (Fig. 12).

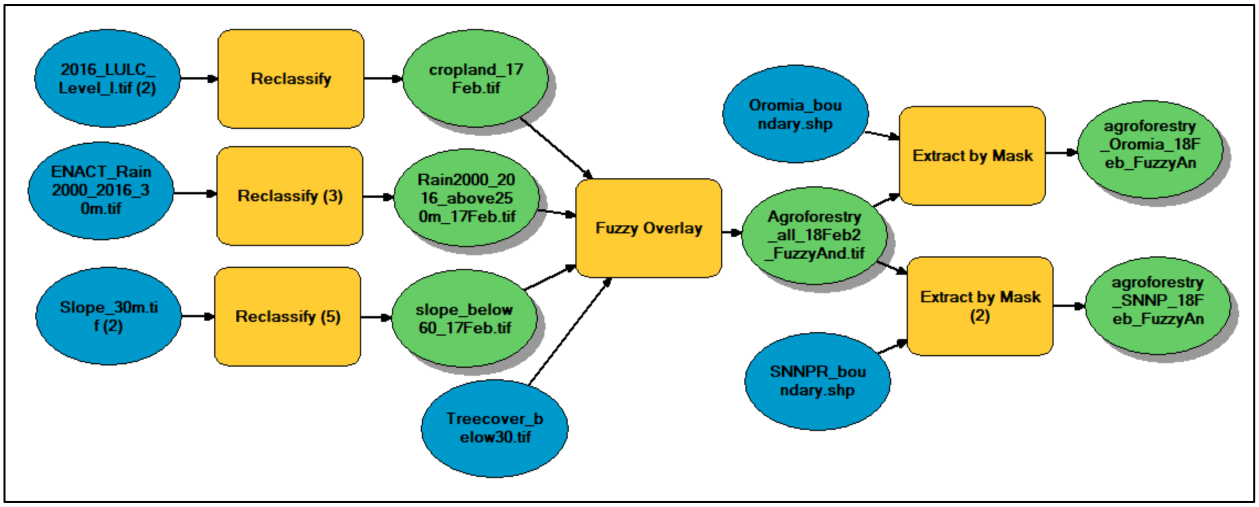
Figure 12 | Spatial modelling to identify afforestation and secondary forest restoration



9.2 Agroforestry on Cropland Potential

Agroforestry on cropland refers to intercropping tree-based landscape restoration with either temporal or permanent crops, or both. Four major input datasets were used to identify areas to potential agroforestry. The implemented spatial modeling tool for agroforestry potential is presented in Figure 13.

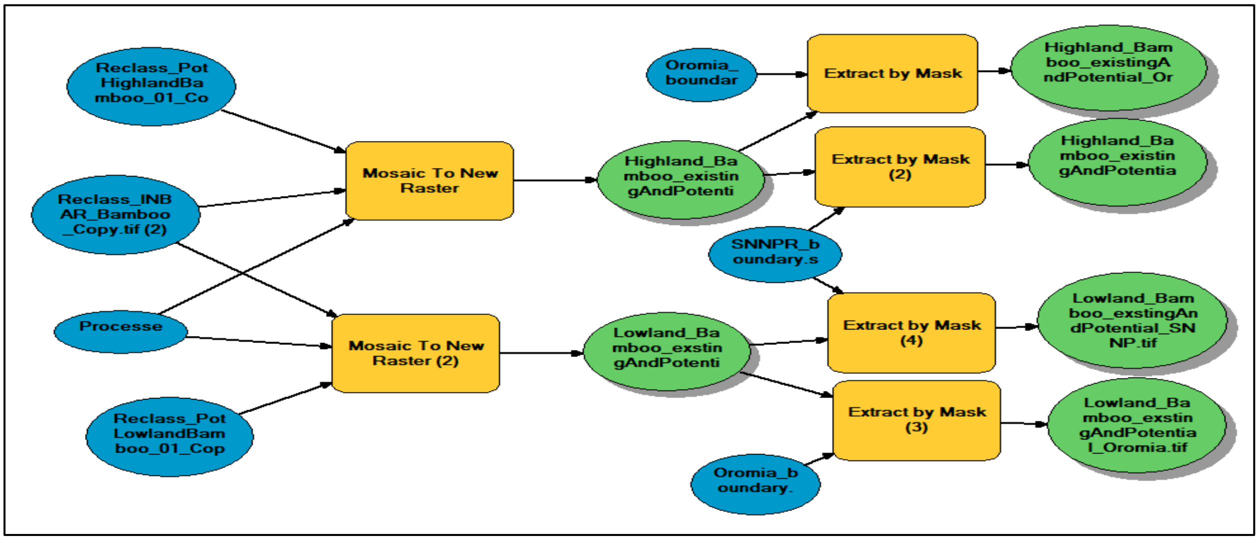
Figure 13 | Spatial modeling to identify agroforestry on cropland restoration areas



9.3 Bamboo Expansion and Restocking: Highland and Lowland Potential

For this option, we focused on highland and lowland bamboo restoration in areas with existing, degraded bamboo stocks. We also identified potential areas for new bamboo development. The datasets we used to create this potential map are from the national potential map and the existing bamboo map from the International Bamboo and Rattan Organization (INBAR). We then combined the maps of existing and potential bamboo sites to illustrate where stocks can be replenished and where they can be expanded and developed (Fig. 14).

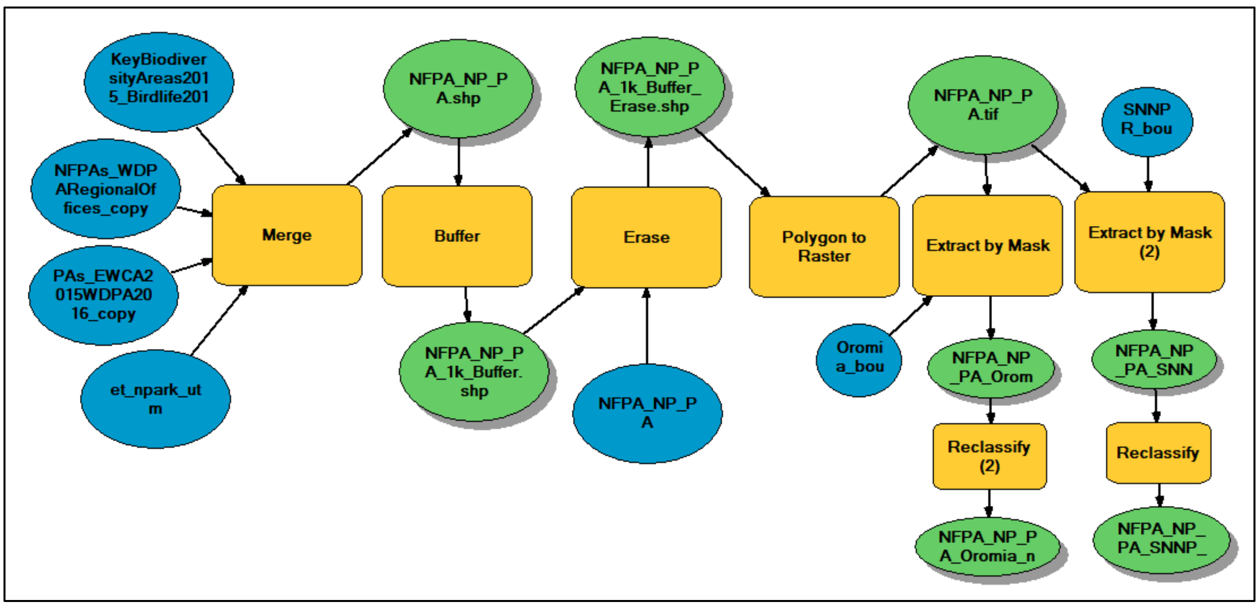
Figure 14 | Spatial location for both existing and potential bamboo forest sites



9.4 Buffering Around National Parks, Protected Areas, National Forest Priority Areas

For this option, it was assumed that national parks, protected areas, and national forest priority areas have their own management plans and restoration projects. However, these plans do not extend along the boundaries of the areas, even though they are suitable for tree-based restoration. To remedy this, the team established 1km buffer zones along the edges of the national parks, protected areas, and national forest priority areas that can add an additional layer of protection to the managed areas.

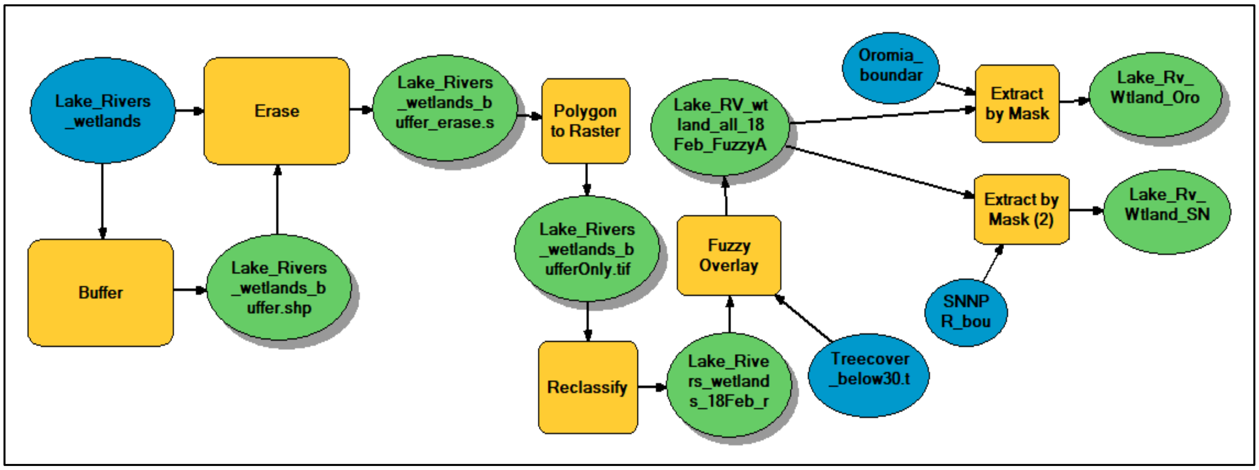
Figure 15 | Spatial modelling to identify tree-based landscape restoration potential in buffer areas around national parks, protected areas, and national forest priority areas



9.5 Buffer Around Lake, Rivers and Wetlands

The team established buffer zones with a 50m radius around lakes, rivers and wetlands to model this potential restoration option (Fig. 16).

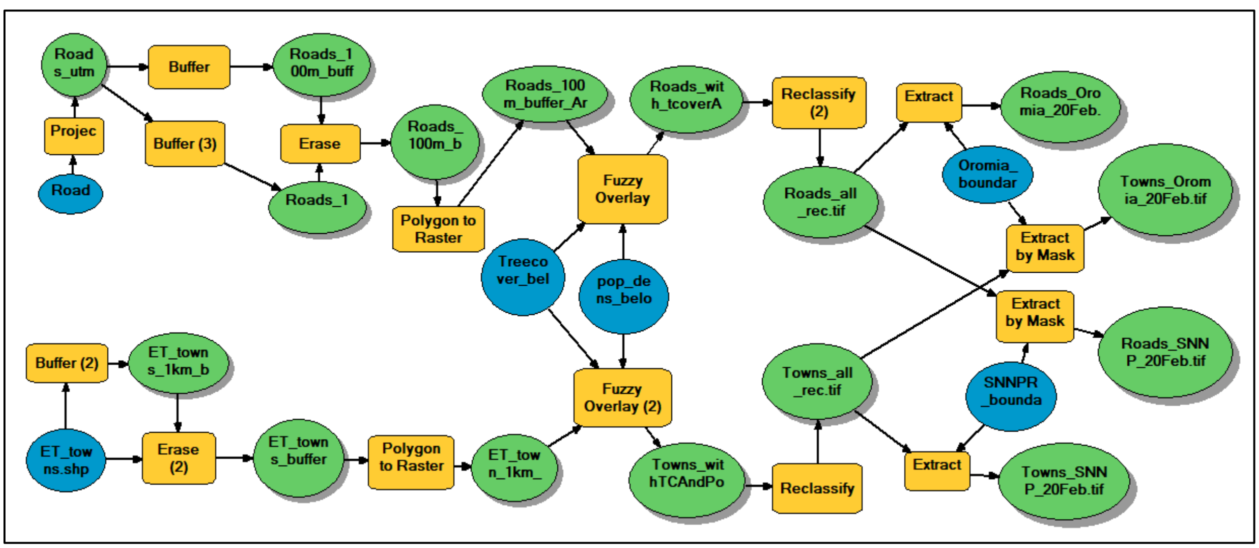
Figure 16 | Spatial modelling of buffer zones around lakes, rivers and wetlands



9.6 Buffer Around Roads and Towns

The team created buffer zones with a 1km radius around towns and a 100m radius around roads to model this potential restoration option. (Fig. 17).

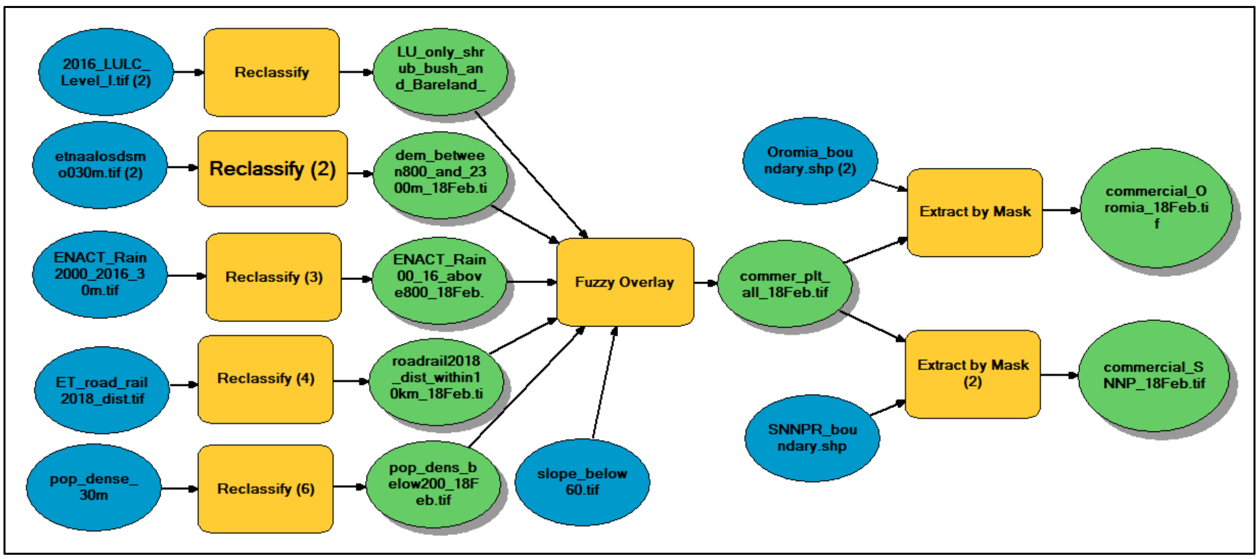
Figure 17 | Spatial modelling of buffer zones around roads and towns



9.7 Commercial Plantation Potential

Participants at the August workshop considered the establishment of more commercial plantations an important restoration option in order to enhance investment in the production of timber and non-timber related products. This development could decrease or replace the demand for imported wood materials while diversifying the local economy and creating jobs for local individuals. Six datasets were considered to identify potential commercial plantation sites: shrub/bushland and bare land, altitude between 800 and 2300m above sea level (the ideal altitude range for fast growth), mean annual rainfall above 800 mm, road access within 10km, population density below 200 people per square kilometer, and slope below 60% (Fig. 18).

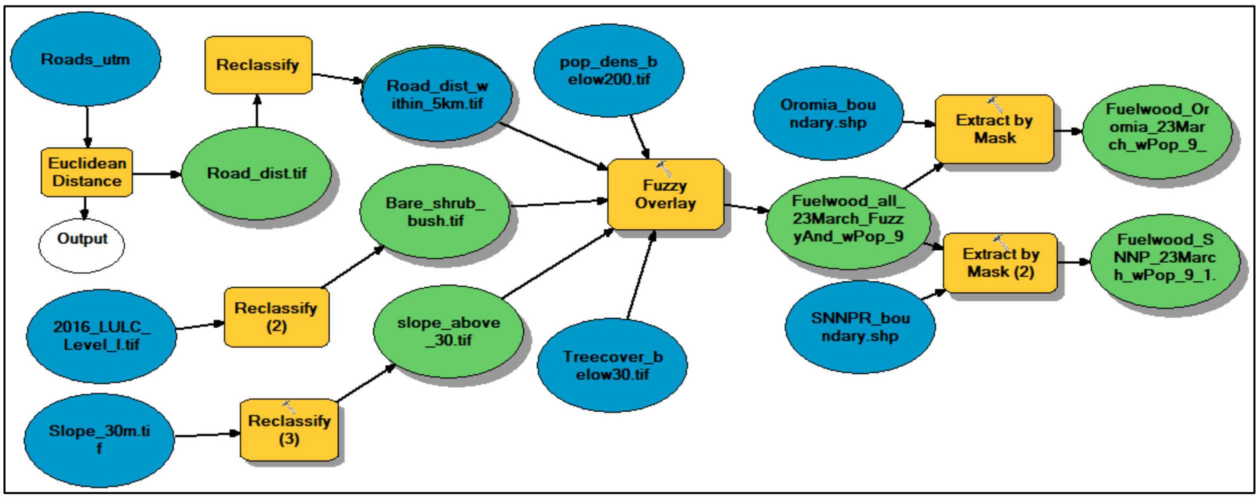
Figure 18 | Spatial modeling to identify commercial plantation potential sites



9.8 Fuelwood Plantation Potential

Stakeholders at the participatory workshop noted the development of fuelwood plantations as an important potential restoration option, since a greater availability of fuelwood could reduce pressure from inhabitants on native forests. Potential fuelwood sites were identified using the following criteria: road access within 5km, slope above 30%, population density below 200, shrub/bushland and bare land, and tree cover of below 30% (Fig. 19).

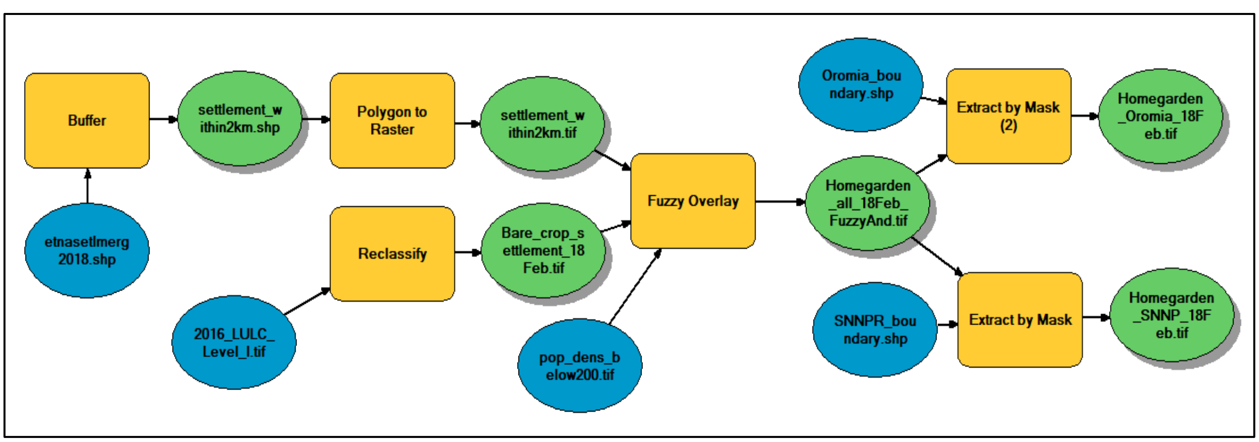
Figure 19 | Spatial modeling to identify potential fuelwood plantation sites



9.9 Home Garden and Woodlots Potential

For this potential restoration option, it was assumed that home gardens and woodlots contribute to economic, social, and ecosystems service values. Three major datasets were used to identify potential areas for this option: location of bare land, cropland, and settlement areas; proximity within 2km radius of settlement areas (villages); and population density of the woreda below 200 people per square kilometer (Fig. 20).

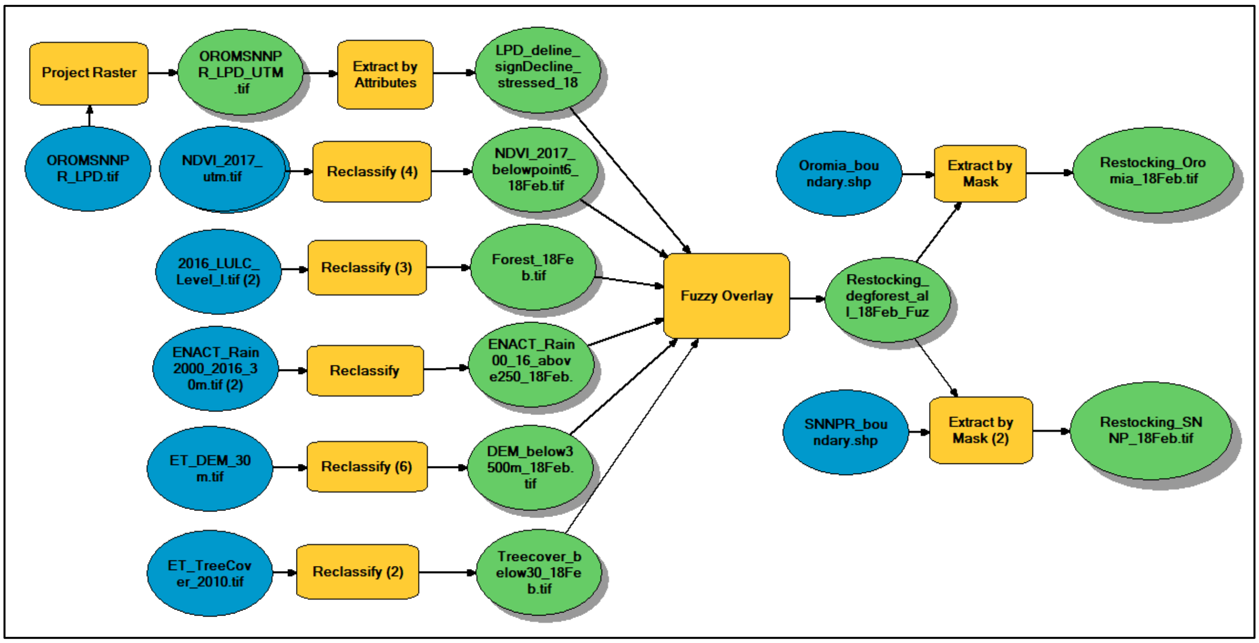
Figure 20 | Spatial modeling to identify potential areas for home-gardens and woodlots



9.10Restocking Degraded Natural Forest

This potential restoration option refers to adding trees, either through assisted natural regeneration or by strategically planting trees within specific forest blocks, to degraded or deforested natural forest areas. To identify the potential areas for this restoration option, we focused on assessing the status of existing natural forests. To design the spatial model (Fig. 21), we combined the following six variables: tree cover less than 30%; altitude below 3500m above sea level; land use type; mean annual rainfall above 250mm; normalized difference vegetation index (NDVI) below 0.6; and land productivity in decline, early stages of decline, or stressed categories (trends.earth).

Figure 21 | Spatial modeling tool to identify potential areas to restock degraded natural forests



9.11 Combined Restoration Options

After identifying each potential restoration option based on set criteria, the spatial model of each option was combined to produce one map. A single cell (site) could be a candidate for multiple restoration potentials. This can inform how to prioritize the potential restoration options based on the size of the area and suitability of option for a defined site (Fig. 22). Finally, we used a pivot table to summarize individual and combined potential restoration options.

Figure 22 | Spatial model for combined tree-based restoration potential map