Economic and Land Use Impacts of Rwanda's Green Growth Strategy: An Application of the Integrated Economic-Environmental Modelling Platform

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1. Introduction

The forestry sector is critical to Rwandan livelihoods, as the primary source of energy supplying 86% of Rwanda's energy, as well as the critical ecosystem services forests provides. Only 16% of Rwanda's land area is dedicated to forest plantations for the production of fuelwood and timber and this area is under continuous threat from population growth. The population was 11.61 million in 2015 and is projected to increase to over 14.59 million by 2022; this rate of growth creates great pressure for land conversion (NISR, 2009). The current plantation stock also has other issues with 50% of current plantations are reaching the end of their productive cycle and generally low genetic stock and productivity levels. Finally, species diversity of existing plantations is also low (Isaac et al., 2016).

Total forest cover in Rwanda in 2014 was 686,636 ha, which is about 28.8% of the country's terrestrial area. This extent is comprised of 37.6% natural forest (258,067 ha) and 62.4% of forest plantations (428,569 ha); 55% of forest plantations are eucalyptus species (MINIRENA, 2014). Natural forests are also under threat from encroachment and land conversion as a result of population pressures (Nduwamungu, 2011; FAO, 2006). Rwanda's natural forest areas are mostly contained within the country's four protected areas: Akagera National Park, Nyungwe National Park, Volcano National Park, Gishwati - Mukura National Park (Banerjee et al., 2017, Banerjee et al., In Review).

Rwanda's legislative framework for forestry and fuelwood is comprised of a number of key policies, laws and strategic plans. Specifically, Rwanda's first National Forestry Policy came into force in 2004. It was subsequently reviewed in 2010 to integrate forestry sector targets contained in Rwanda's Economic Development and Poverty Reduction Strategy (EDPRS I for the period of 2008 to 2012). To operationalize the Policy, the Strategic Plan for the Forestry Sector was developed. Specific to addressing challenges of the fuelwood sector, the Rwanda Supply Master Plan for Firewood and Charcoal provides strategic direction for the management of fuelwood supply. Rwanda's Forest Law was passed in 2013. Also relevant for the management of Rwanda's forests is the Forest Landscape Restoration Opportunity Assessment which aims to scale-up pilot projects to meet sustainable forestry objectives (MINIRENA, 2014).

This legislative framework for forestry and fuelwood is closely aligned with the programs and actions outlined in the EDPRS II, Rwanda's Vision 2020, and Rwanda's Green Growth Climate Resilient Strategy. In particular, Rwanda's Green Growth Strategy outlines lines of action for increasing sustainable forestry and agroforestry for the provision of ecosystem services including timber and energy provisioning services to meet current and future demand. An estimation of investment costs required to meet the objectives outlined in the Strategy has been prepared for 2016 to 2030 (Isaac et al., 2016). The EDPRS II sets the target of increasing forest cover from 28.8% to 30% of the country by 2018. For fuelwood, the target is to reduce consumption from 86% to 50% by 2020.

To evaluate the economic, environmental and wealth impacts of government lines of action to meeting these targets, we develop and apply an Integrated Economic-Environmental Modelling Platform for Rwanda (IEEM-RWA). IEEM-RWA is calibrated with Rwanda's new land and water accounts under the System of Environmental-Economic Accounting (SEEA) and a new social accounting matrix (SAM). Based on IEEM-RWA results in terms of land use and land cover change, a model is constructed to allocate land use change across the Rwandan landscape according to user defined criteria and endogenous land use change dynamics where appropriate. Assessing modelled impacts spatially can help identify tensions between existing and planned land use and serve as a basis for further land use planning in Rwanda, while the methods developed herein are transferable to other developing country contexts.

2.0 Forests and Fuelwood in Rwanda

The EDPRS II sets the target of increasing forest cover from 28.8% to 30% of the country by 2018. An even more ambitious target was declared by the Rwandan Government in 2011 when it pledged to restore 2 million hectares of forest and agricultural land under the Bonn Challenge. Agroforestry systems will comprise an important component of this commitment. The country's potential for agroforestry systems was assessed in steeply sloping areas and flat or gently sloping areas including rangeland. The aim of implementing agroforestry systems on steeply sloping areas is to stabilize hill sides and reduce erosion through terracing. Agroforestry destined for gently sloping land is aimed at integrating trees with crops to: improve soil fertility and water quality; provide shade for animals in rangeland, and; serve as a source of fuelwood. Results of the assessment are shown in Table 1 which identifies the greatest opportunity for agroforestry in

Rwanda's Eastern and Southern Provinces. Where the aim is to improve the quality of existing pine and eucalyptus woodlots, the Southern and Western Provinces exhibit the greatest potential (MINIRENA, 2014).

Table 1. Areas with high potential for agroforestry and forest plantations (hectares).

Suitable areas	East	West	North	South	Kigali	Total
New agroforestry on steep slopes	272,723	87,183	63,683	250,504	31,069	705,162
New agroforestry on gentle slopes	231,855	45,732	40,209	78,410	9,108	405,314
Improved woodlots	32,816	62,868	54,173	96,343	9,730	255,930

Source: MINIRENA, 2014.

Only 5% of Rwanda's population is connected to the electrical grid, 3% located in rural areas (Ndegwa et al., 2011). Rwanda's energy balance shows that 86% of energy is in the form of biomass, 11% in hydrocarbons and 3% in electricity. Of this 86% biomass, 57% is consumed as wood, 23% as charcoal and 3% in the form of agricultural residues and peat. In 2009, fuelwood consumption was 3.2 million dry tons with 88% of the total consumed in rural areas. Charcoal consumption in the same year was 226,000 tons which is the equivalent of 1.5 million tons of dry woody biomass. Total demand for woody biomass was 4.8 million tons or 4.2 million when marginal fuelwood is not considered. On average, fuelwood and charcoal demand are about 1.93 kg per person per day while charcoal production capacity is only about 0.46 kg per person per day (Ndegwa et al., 2011). The Province of Kigali in which the capital city of Kigali is situated accounts for 1.1 million tons or 26% of total demand (Drigo et al., 2013).

Charcoal production is one of the main drivers of deforestation in Rwanda (Nahayo et al., 2013). Current sustainable woody biomass supply was estimated as 3.2 million tons indicating a large deficit of 870,000 tons. In a business as usual scenario, demand in 2020 was projected to be equal to 5.7 million tons, while in a scenario where 30% more efficient fuelwood cookstoves are introduced, along with higher charcoal production efficiency and greater usage of liquefied petroleum gas in urban areas, demand in 2020 was forecast to be 4.4 million tons compared with 5.7 million tons in the business as usual scenario. If the area of forest plantations is increased by 10% (an additional 315,000 hectares), total woody biomass supply would increase from 3.3 million to 3.6 million tons which represents a 2.1 million ton deficit in the business as usual scenario. With improved use efficiencies, this deficit would be equal to 820,000 tons, similar to the woody biomass deficit estimated in 2009 (Drigo et al., 2013).

Given the volume of trade, the fuelwood business is an important source of income and employment in Rwanda. In 2009 the value of the charcoal market was 37.9 billion Rwandan Francs (RWF) and 22.3 billion RWF of this trade was in the Kigali area alone. The fuelwood trade is more difficult to quantify, though this has been estimated at 58.9 billion RWF with the total wood energy sector contributing to about 3.4% of Gross Domestic Product (GDP). The Kigali charcoal market is the main source of income for 30,000 households and over 50,000 households for the country as a whole (Drigo et al., 2013, Ndegwa et al., 2011).

Rwanda's Green Growth and Climate Resilience Strategy and EDPRS II contain a number of lines of action to reduce fuelwood and charcoal consumption as well as increase the standing forest plantation stock. The Forest Landscape Restoration Opportunity Assessment for Rwanda (MINIRENA, 2014), the Rwanda Supply Master Plan for fuelwood and charcoal (Drigo et al., 2013), the Forest Law promulgated in 2013 (Republic of Rwanda, 2013), the Strategic Plan for the Forest Sector 2009-2012 (National Forestry Authority, 2010) and the National Forest Policy (Ministry of Forestry and Mines, 2010) contain the overarching framework and guidance for the implementation of lines of action for the reduction of fuelwood and charcoal consumption.

To respond to the challenge of fuelwood scarcity and dwindling forest plantation stocks and productivity, various lines of action are under consideration. These including increasing the area of forest plantations and agroforestry, rehabilitating old plantations, enhancing the efficiency of fuelwood cookstoves and charcoal kilns, among other complementary measures. In this analysis, we focus on two specific measures: increasing forest plantation cover to 30% of the total land area; increase agroforestry to 85% of all cultivated areas, and; measures to implement more efficient cookstoves and charcoal kilns.

Specifically, we simulate an increase in forest plantations from 686,636 hectares to a total of 790,140 which is equivalent to 30% of Rwanda's terrestrial area. In addition, agroforestry is implemented on 975,084 hectares. The cost of this investment is US$4.5 million over a 5-year period. With regards to energy efficiency, more efficient cookstoves and charcoal kilns installed in the rural landscape is estimated to result in a 25% efficiency gain as well as a health benefit arising from less fuelwood emissions in households[1]. The cost of this investment is US$4.5 million also over a 5-year period (Isaac et al., 2016). A study conducted by Nahayo et al. (2013) found that improved charcoal production techniques using an improved earth mound kiln and casamance kiln produced 19% and 20% charcoal yields, respectively, compared with 7.5% with a traditional kiln. On average, traditional methods produce up to 60 kg of charcoal from 1 m^3 of wood while improved methods can produce up to 135 kg from 1 m3 of wood, representing a 125% increase (Nahayo et al., 2013). Improved methods also reduce the emissions of greenhouse gases and other harmful volatile substances by up to 75% (Pennise et al., 2001, Bill, 1987). Potential sources for financing both investments are expected to be o be pursued This financing is expected to be sourced from largely non-reimbursable grants including the Global Environment Facility, REDD+ mechanisms and the Green Climate Fund Among others.

2.0. Methods

2.1. An Integrated Economic-Environmental Model for Rwanda: IEEM-RWA

In this paper, an Integrated Economic-Environmental Modelling Platform is developed for Rwanda (IEEM-RWA). IEEM enables the analysis of public policy and investment impacts on the economy and the environment in a quantitative, comprehensive and consistent framework. IEEM is a decision-making platform that provides a quantitative, comprehensive and consistent framework for the analysis of public policy and investment impacts on the economy, the environment and wealth. At the core of IEEM is a dynamic computable general equilibrium model, calibrated with data based on the System of National Accounts and the System of Environmental-Economic Accounting (SEEA) (United Nations et al., 2014). What sets IEEM apart from other decision making frameworks is: its integration of rich environmental data based on the SEEA; customized environmental modelling modules that capture the particular dynamics of environmental resources and their use, and; the indicators IEEM generates capture policy and investment impacts not only on measures of income flows such as Gross Domestic Product (GDP), but also on wealth which is a more holistic measure of welfare and the foundation of the economic growth and development prospects of a country.

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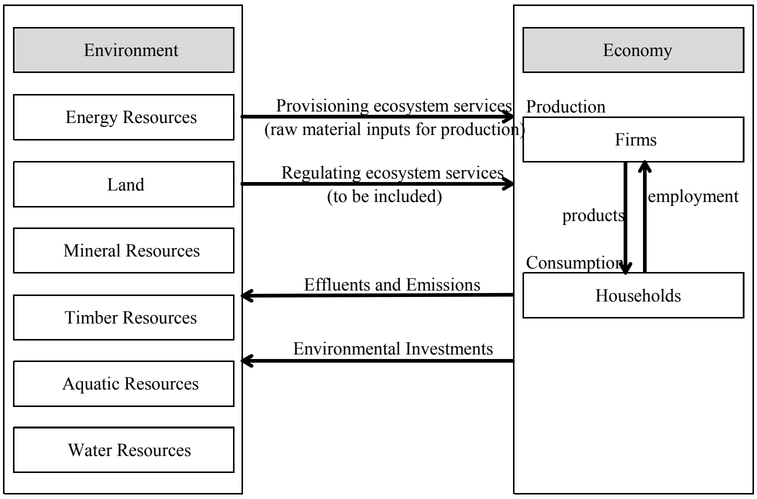
IEEM reduces the need for making strong assumptions in reconciling environmental and economic data; it reduces analytical start-up costs and increases the timeliness of evidence-based policy advice. IEEM considers quantitatively how economic activities critically depend on the environment both as a source of inputs in the form of environmental resources, and as a sink for outputs in the form of emissions and effluents. For the first time in an ex-ante economic analytical framework, IEEM captures how depletion and degradation of the natural resource base and emissions affects national wealth and prospects for future economic growth, which is reflected in the indicators generated by IEEM.

Figure 1 shows how environment-economy interactions are modelled within IEEM. On the left side of the figure, the environment is represented by the environmental accounts contained in the SEEA, namely energy, land, minerals, timber, aquatic resources, and water. On the right side of the figure is the economy, represented by firms that use labor, capital and other factors of production, and intermediate inputs to produce goods and services that are consumed by households, the government and exports markets. IEEM captures the two-way interactions between the economy and the environment, with the environment serving as an input for productive processes in the form of provisioning ecosystem services. Through productive processes and through household consumption of goods and services, emissions and waste are produced and returned to the environment. To mitigate environmental damage and improve environmental quality, investments are also made in the environment. The data structure that underpins IEEM captures all of these interactions quantitatively.

Figure 1. Environment-economy interactions embodied in IEEM.



Source: Authors' own elaboration.

To calibrate IEEM, a SAM was constructed for Rwanda with the base year of 2011 based primarily on Rwanda's National Accounts data for that same year. As with the System of Environmental-Economic Accounting, IEEM has a modular design whereby the model can be calibrated with one or more environmental accounts; it is thus not necessary for the full suite of environmental accounts shown in figure 1 to be available to calibrate IEEM. In the case of IEEM-RWA, the Platform is calibrated with Rwanda's recently published (February 2017) land and water accounts. As additional accounts become available, IEEM-RWA can be readily calibrated with this new information. Given that the land and water supply and use tables for Rwanda were available for the year 2014, the 2011 SAM was updated to 2014 by targeting observed economic growth over the period.

Table 1 provides a snapshot of the Rwandan economy as described by the SAM and key macroeconomic indicators. GDP in 2014 was US$7.9 billion while total demand was equal to US$10.2 billion. Imports were almost double of exports at US$2.3 billion. Fixed investment was equal to US$1.9 billion.

Table 1. Macroindicators in 2014; billions of USD.

Item	USD
Demand	
Private consumption	6.2
Government consumptioı	1.1
Fixed investment	1.9
Exports	1.0
Total demand	10.2
Supply	
GDP	7.9
Imports	2.3
Total supply	10.2

Source: Authors' own elaboration based on 2014 SAM for Rwanda.

Once IEEM has been calibrated, scenarios can be designed to evaluate different public policy and investment scenarios, in this case, the establishment of forest plantations and enhanced efficiency in the use of fuelwood and charcoal. Scenarios are implemented in IEEM and results are generated in tabular format in terms of economic, wealth and land use outcomes. In the sections that follow, the scenarios are described and results reported. To understand the spatial distribution of land use change an algorithm is developed to allocate future land use change arising from each scenario, across the Rwandan landscape.

4. Scenario Design and Results

4.1. Scenario Design

A baseline and three policy scenarios simulating specific lines of action of Rwanda's Green Growth Strategy. These are described in turn.

BASE: The first scenario is the baseline or 'BASE' scenario which projects the Rwandan economy from 2014 to 2040 and is the reference scenario to which all other scenarios are compared to. In the baseline, we assume that average past trends will continue from 2014 to 2040. In fact, in the absence of better projections, it is assumed that Rwanda is on a balanced growth path, which means that real or volume variables grow at the same rate while relative prices do not change.

FOR1: The second scenario is the 'FOR1' scenario where increasing forest plantations and agroforestry activities are increased. Specifically, forest plantation area is increased to account for 30% of the total land area, and agroforestry is implemented in 85% of cultivated land (975,084 ha). With current forest cover at 28.8% or 686,636 ha, to increase coverage to 30%, this implies planting an additional 103,504 hectares. The rate of planting is approximately based on the rate of planting in 2015 (MINIRENA, 2014) and is equal to 7,393.14 hectares planted per year starting in 2018 with the final 7,393.14 hectares planted in 2031. In 2014, the area of forest plantations was equal to 428,569 ha. An additional 103,504 ha implies a total of 532,073 ha of plantation which is an increase of 24.15%. With regard to the increased area devoted to agroforestry, this scenario only considers the investment cost, while benefits attributed to agroforestry systems such as enhanced soil fertility, stope stability and biomass accrue to households and society, but are unmonetized. The total investment cost of this scenario is US$285,581,699 over a 14-year period, for an annual investment of US$20,398,693.

FOR2: The third scenario, 'FOR2' is the same as FOR1, however where in FOR1, the overall land endowment is fixed and therefore forest plantation expansion causes a reduction in the land available for agriculture, FOR2 assumes that forest plantations can expand on land other than agricultural land.

FUEL: The fourth scenario is the 'FUEL' scenario where more efficient cook stoves and charcoal kilns are introduced. Based on Isaac et al. (2016), a conservative estimate on the potential efficiency gains from more efficient cookstoves and kilns is used and is equivalent to 25%. This efficiency gain introduced in this scenario implies that current energy produced from fuelwood can be achieved using only 75% of the woody biomass currently used. The total investment cost in this scenario is US$4,529,051 and is implemented over a 5-year period beginning in year 2018 for an annual investment of US$905,810.

Various studies have measured improvements in household air quality arising from the more efficient use of fuelwood (Ahmed et al., 2005, Duflo et al., 2008, Lambe and Ochieng, 2015, McCracken and Smith, 1998, Smith et al., 2013, Smith-Sivertsen et al., 2009, Smith et al., 2011). There are a handful of studies that have used this information to estimate the economic benefits that improved fuelwood use efficiency can generate. For example, García-Frapolli et al (2010), using data from Habermehl (2007), account for the number of work hours lost that were attributable to sickness (acute respiratory diseases, eye disease and burns) arising from open cookstoves (García-Frapolli et al., 2010, Habermehl, 2007).

In this scenario, figures from Garcia-Frapolli et al (2010) are used to estimate the number of hours saved due to improved efficiency of household fuelwood use. The hours saved translate into the equivalent of 0.5% of labor value added in the baseline. Given that a large proportion of fuelwood use occurs in rural areas (51% of the population), a conservative approach is taken in this scenario and a 0.125% productivity shock is implemented on rural household labor productivity.

4.2. Results: Economic and Well-Being Indicators

Table 2 presents scenario impacts on macroindicators for the Rwandan economy expressed as the difference from the baseline in 2035. Figure 1 shows the trends in impact on GDP as a difference from the baseline year on year.

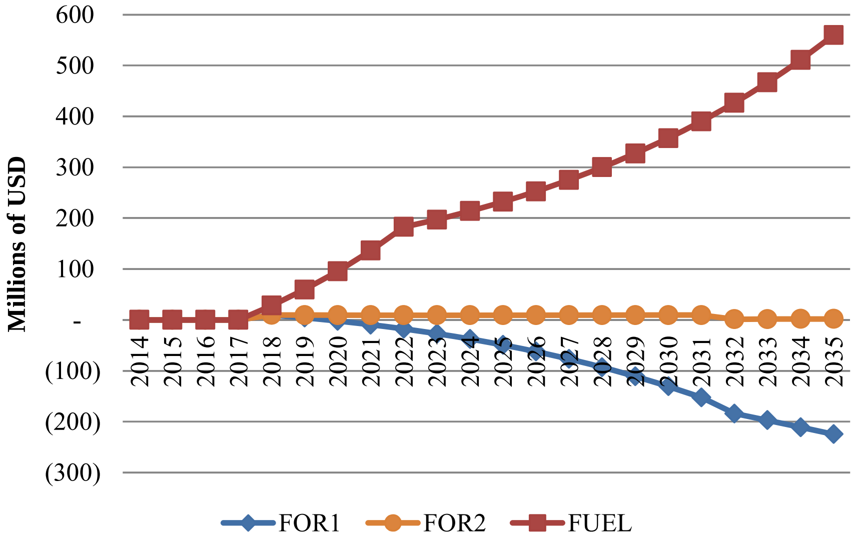
Table 2. Difference from baseline in 2035; millions of 2014 USD.

Item	FOR1	FOR2	FUEL
Absorption	-345	-4	476
Private consumption	-262	-4	466
Fixed investment	-84	1	10
Exports	104	-1	167
Imports	-17	-6	83
GDP	-225	2	560
Genuine savings	-129	4	114

Source: Authors' own elaboration.

The FOR1 scenario shows negative impacts for the overall economy with a decline in GDP of US$225 million. Private consumption falls by US$262 million while genuine savings falls by US$129 million. This decline in genuine savings, while forest cover increases in FOR1, it is the drop in household savings that generates this negative impact. Of course, as agriculture is the mainstay of the rural economy, substitution of agricultural area for forests has a significant impact on rural income and savings. The FOR2 scenario generates small but positive impacts for GDP and genuine savings. The FUEL scenario has a large and positive impact on the economy, boosting GDP by US$560 million and genuine savings by US$114 million. Exports are also favored by US$83.4 million.

Figure 1. GDP impact, difference from baseline; millions of USD (2014).

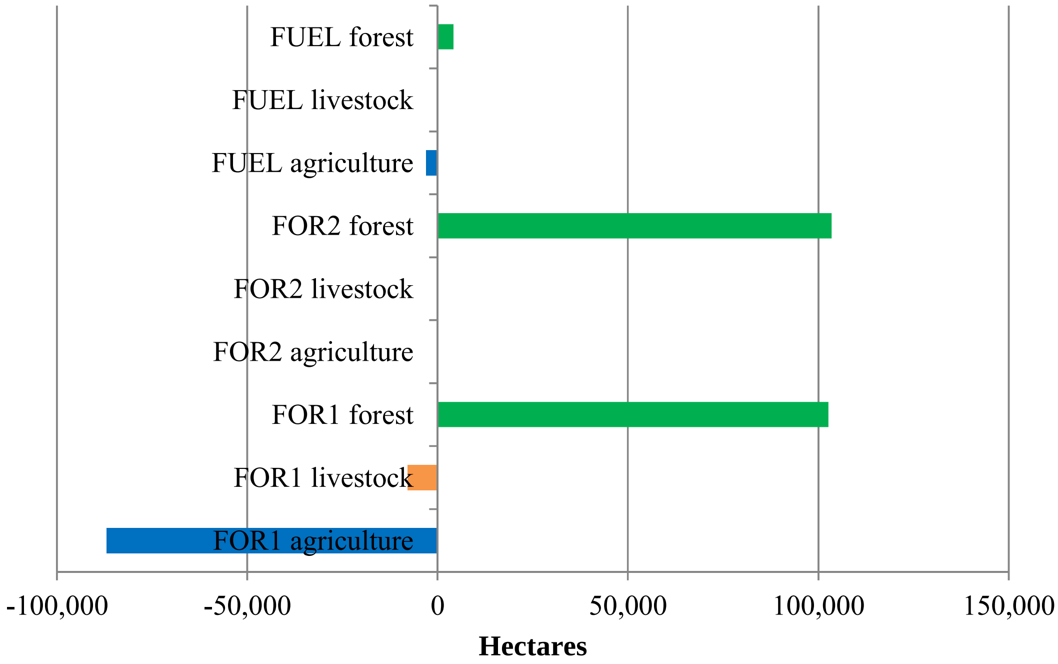


Source: Authors' own elaboration.

There is a real exchange rate appreciation in both FOR1 and FOR2 of 0.07% and 0.10%, respectively on average between the first and final year, compared with 0.14% in the case of the FUEL scenario. WAGES grow slightly slower in FOR1 and FUEL on the order of 3.61% and 3.81% in FOR1 and FUEL, respectively, compared with 3.85% in the baseline and in FOR2. The unemployment rate is also negatively impacted in FOR1 and FUEL, on average 7.70% and 7.36% compared with 7.24% in the baseline and FOR2.

Figure 2 shows the difference in land use between the baseline and 2035. In the baseline in 2014, agricultural, livestock and forest land use was equal to 1,251,181 hectares, 118,583 hectares and 499,874 hectares for a total of 1,869,638 hectares. In the baseline, by 2035 agricultural land use grows to 1,374,473 ha, livestock to 130,722 ha and forest land use to 499,874 ha for a total of 2,005,069 ha. Comparing FOR1 with baseline land use projections, as forest expansion occurs at the cost of other land uses, agricultural land use falls by 86,917 ha, livestock falls by 7,909 hectares and forest land use expands by 102,633 hectares. Comparing FOR2 with baseline land use projections, there is a negligible decline in agricultural land use of 26 hectares; livestock increases by 18 ha while forestry expands by 103,468 ha. Comparing the FUEL scenario with baseline land use projections, agricultural land use falls by 2,926 ha, livestock falls by 257 ha while forestry expands by 4,168 ha.

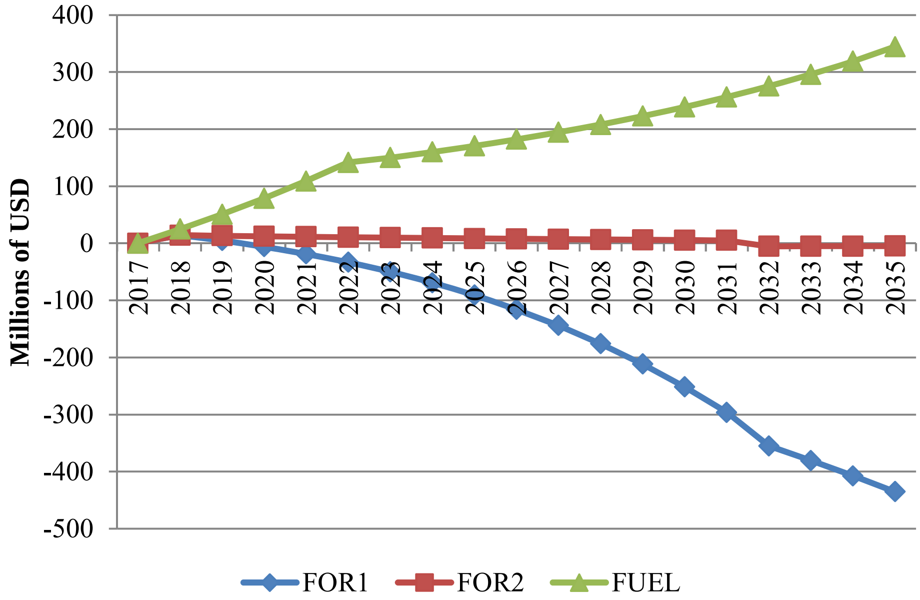
Figure 2. Land use change; difference between first and last year.



Source: Authors' own elaboration.

Figure 3 shows scenario impacts on equivalent variation, a measure of welfare. Equivalent variation tends to follow a similar trend as GDP with a significant decline in well-being in FOR1 on the order of US$435 million, US$5 million in the case of FOR2 and an increase in well-being of US$344 million in FUEL.

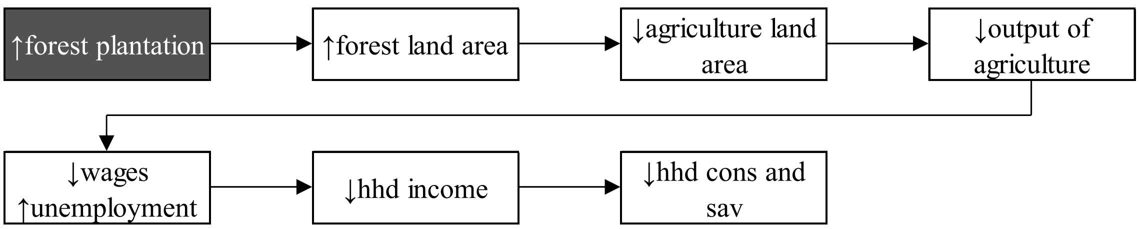
Figure 3. Equivalent variation, welfare impacts, year on year; millions of USD (2014).



Source: Authors' own elaboration.

In terms of transmission pathways of the scenarios, figure 4 describes how FOR1 results in a general decrease in economic performance.

Figure 4. FOR1 transmission pathway.

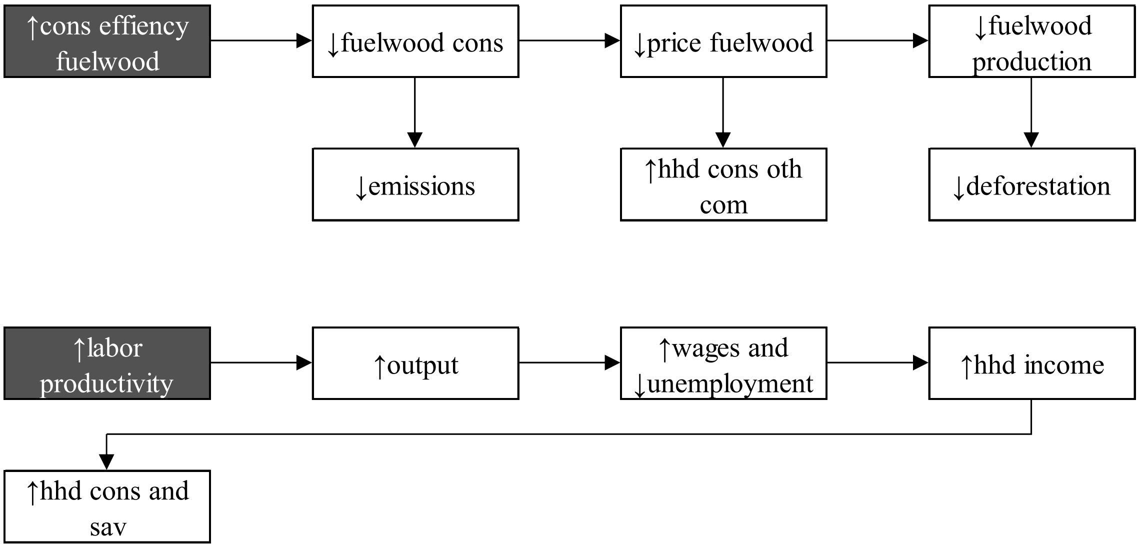


Source: Authors' own elaboration.

With the increase in forest plantations, forest land area increases at the expense of agricultural land which results in a decline of agricultural output. Given the importance of the sector for rural livelihoods, the short-run impact is a fall in wages, increased unemployment, a decline in household income and consequently, declining household consumption and savings as reflected in the fall in genuine savings in this scenario.

Figure 5 shows the transmission pathway for the FUEL scenario.

Figure 5. FUEL transmission pathway.



Source: Authors' own elaboration.

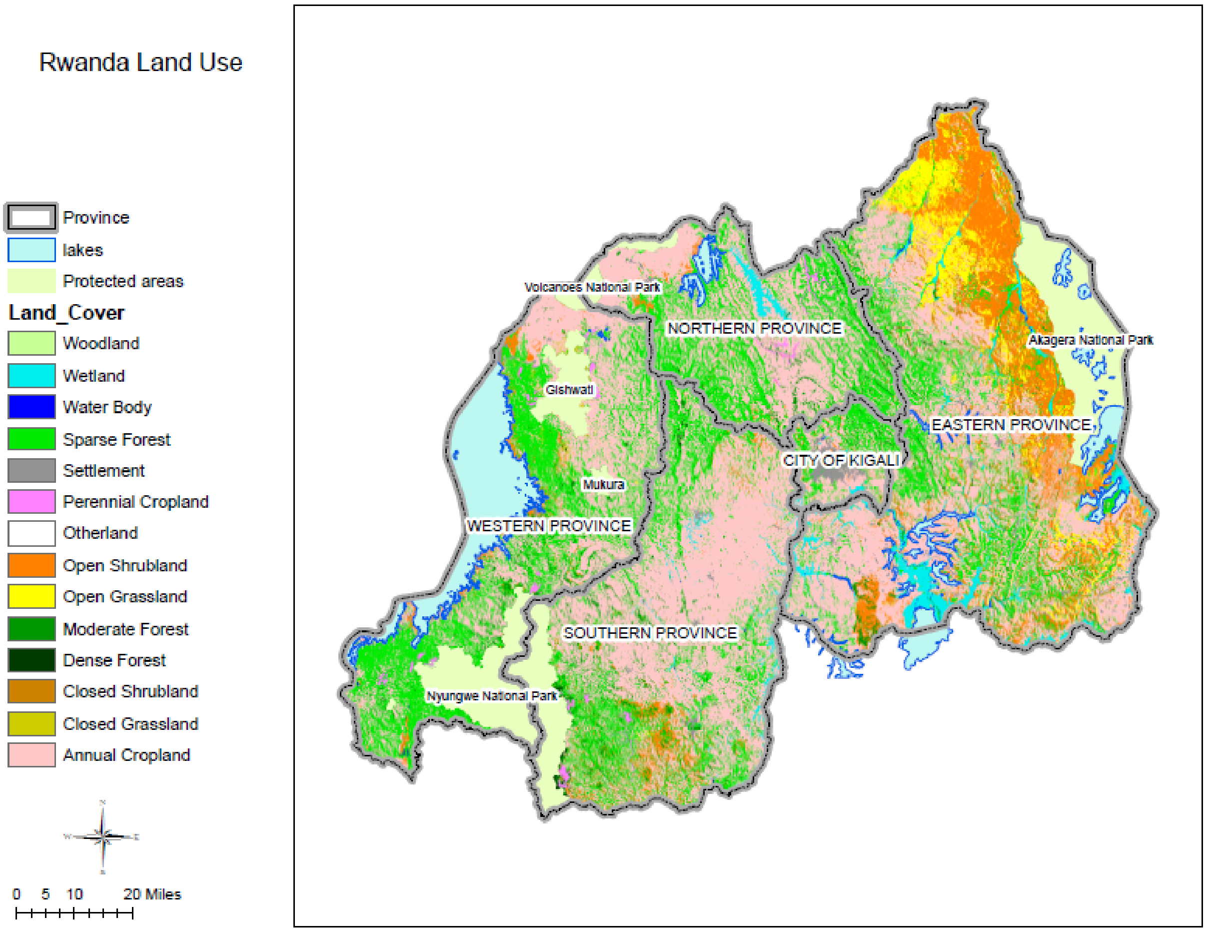
In figure 5, there are two mechanisms at work. First, with the increase in household fuelwood consumption efficiency, fuelwood consumption tends to fall as do emissions. This results in a decline in fuelwood prices which is positive for households leaving them with greater disposable income for consumption and savings. With the fall in prices, fuelwood production also falls as does deforestation. The second transmission pathway is transmitted through the positive health benefits that reduced emissions from household fuelwood consumption generate. These positive health benefits enhance rural agricultural labor productivity enabling increased agricultural sector output. Higher productivity and output is transmitted to higher wages, reduced unemployment, greater incomes and greater household consumption and savings possibilities.

5.0 Mapping Land-use Change

As reviewed in the previous section, IEEM-RWA generates estimates on economic, wealth and land-use outcomes. With a multi-regional version of IEEM-RWA, these indicators could be made spatially explicit and results presented in map form. Presentation of results in this way can be a powerful tool to guide multi-stakeholder processes in analyzing alternative policy and investment options to achieve desired outcomes in terms of green growth. Translating land use change estimates from IEEM-RWA into a spatially explicit format can be particularly useful for understanding future land use change, constraints and opportunities. In addition, the generation of new land use land cover maps (LULC) can be used as the main input into modelling future ecosystem service supply under alternative green growth scenarios.

In this paper, we develop a model algorithm in ArcGIS to annually map future land use change projected in scenario analysis with IEEM-RWA. For illustrative purposes, we focus on the FOR2 scenario. The starting point for this mapping is the baseline LULC map shown in figure 4 which shows 14 LULC types and has a spatial resolution of 30 meters by 30 meters (LANDSAT-based). Land use and land cover change is driven by numerous economic, biophysical and spatial relationships specific to each region. In the case of Rwanda, as one of the most densely populated countries in Africa, the country is currently undergoing and land use planning and reconfiguration process which is closely managed. As a consequence, it is reasonable to assume that endogenous land use change in the case of much of Rwanda is limited. In 2010, the Government of Rwanda developed the National Land Use Development Master Plan to optimize land use across the landscape. The Master Plan designates areas in Rwanda that are most suitable for agricultural development as well as for reforestation.

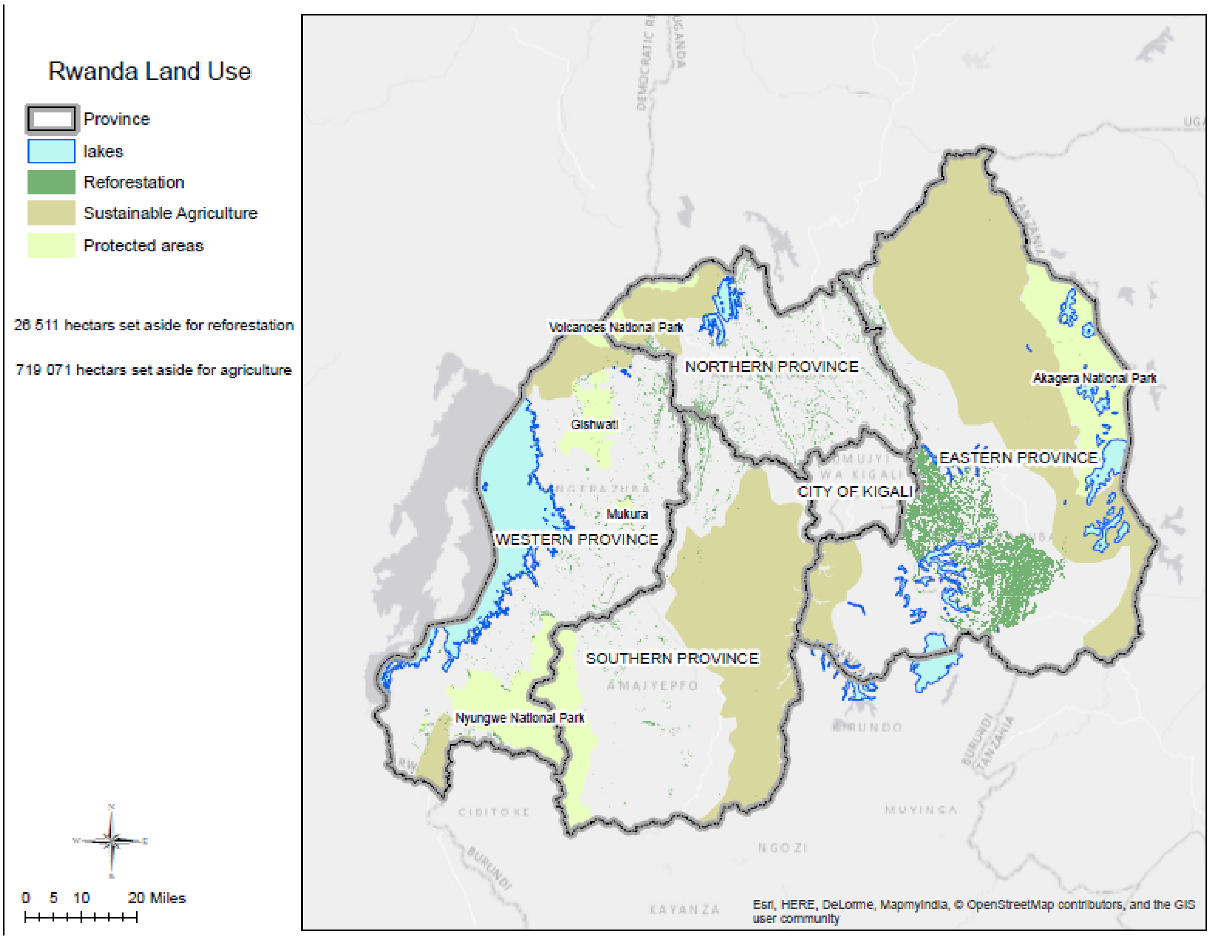
Figure 6. Land Use Land Cover Map for Rwanda (2014)



Source: SERVIR.

In terms of the decision rules applied to the allocation of land use change, the Master Plan is therefore critical. Table 3 describes the land allocation process for the increase in agricultural area that occurs both in the baseline and the scenario of interest, FOR2. While the first column shows Rwanda's Provinces with the exception of the heavily built up Kigali, the second column shows the number of hectares designated as agricultural areas in the Land Use Master Plan. Clearly, it is the Eastern and Southern Provinces with the greatest availability for agricultural expansion. The total available is 718,765 hectares, while only 123,292 hectares are required by 2030 to meet the target area.

Figure 7. Land Use Master Plan areas eligible for agriculture and forestry.



Source: Land Use Master Plan.

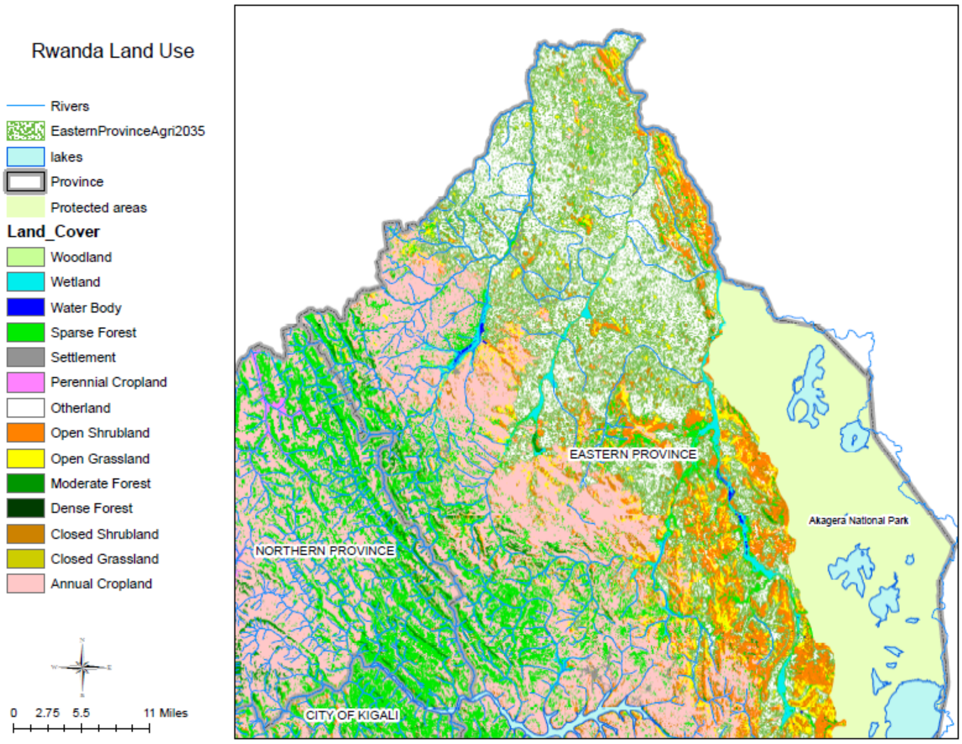
Table 3. Areas eligible for agricultural expansion.

Provinces	Agriculture Master Plan Available Hectares	<15% slope Hectares	Proportion
Eastern	401,911	160,485	0.56
Northern	41,013	2,370	0.06
Southern	229,619	3,802	0.32
Western	46,222	889	0.06
Total	718,765	167,546	1.00
Target			123,292

Source: Authors' own elaboration.

The second decision rule imposed is that only certain land cover classes are eligible for conversion to agricultural uses. These are closed grassland, open grassland, closed shrubland and open shrubland. Next, as steep slopes are less suitable for conventional agriculture, of the eligible land cover classes within Master Plan designated areas, only those areas with a slope of less than 15% are considered to be eligible. This results in an availability of 167,546 hectares for conversion to agriculture. Finally, these areas are allocated proportionally according to original availability under the Master Plan. In the case of the Northern, Southern and Western Provinces, the areas available with less than 15% slope are smaller than their original proportional allocation, therefore all of these areas are allocated to agriculture. The remainder which is equal to 115,231 hectares is allocated to the Eastern Province. The expansion of the baseline target of 12,139 hectares of new livestock grazing areas is allocated in the same way as in agriculture.

Figure 8. New agricultural areas in 2035.



Source: Authors' own elaboration.

Figure 8 is a snapshot of Rwanda's Eastern Province, highlighting new agricultural areas by 2035.

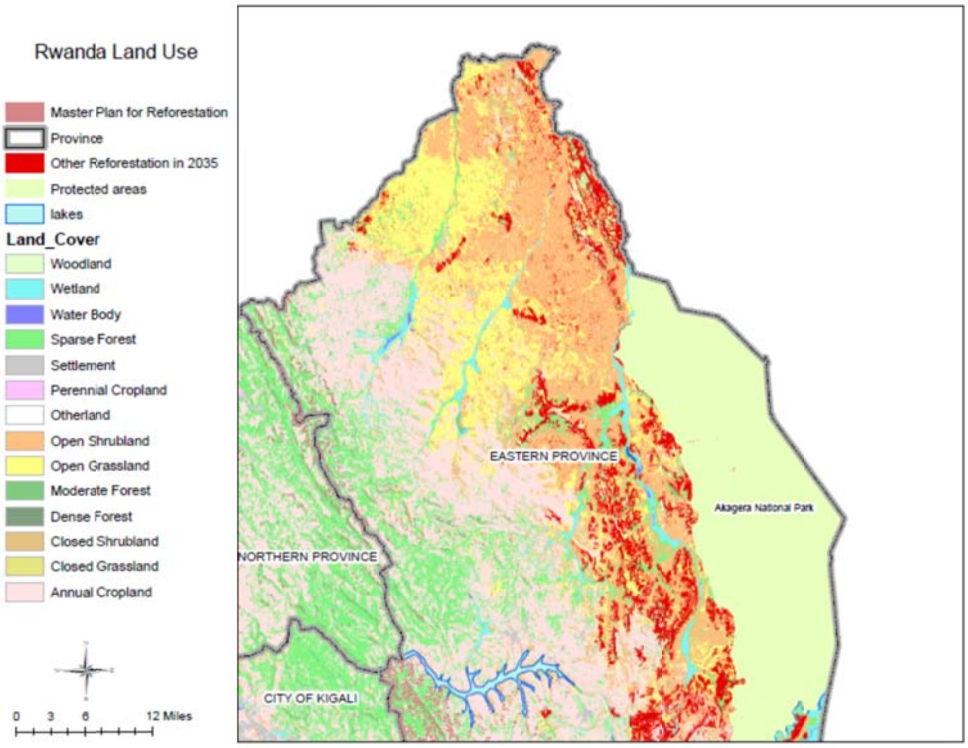
Table 4. Areas eligible for forest expansion.

Provinces	Forestry Master Plan Available Hectares	Outside Master Plan Slope <60%; Hectares	Proportion	Selected Hectares
Eastern	11,163	148,401	0.77	58,661
Northern	7,325	2,835	0.01	1,121
Southern	3,309	26,515	0.14	10,481
Western	4,639	15,013	0.08	5,934
Total	26,436	192,764	1.00	76,197
Target	102,633	Remainder	76,197	

Source: Authors' own elaboration.

Table 4 shows the areas eligible for forestry expansion according to the Land Use Master Plan. The target to reach 30% forest cover across the country is an additional 102,633 hectares. According to the Master Plan, however, there are only 11,163 hectares eligible for forest-based activities in the Eastern Province and even less in the other Provinces, thus there is an additional 76,197 hectares that must be sourced from areas outside of those designated in the Master Plan. As was the case in allocating areas for agricultural expansion, the only areas eligible for conversion to forest uses are closed grassland, open grassland, closed shrubland and open shrubland. An additional criterion is imposed which limits the slope of eligible areas to less than 60%. Finally, the remaining target of 76,197 hectares is selected based on their proportional availability outside of Land Use Master Plan areas.

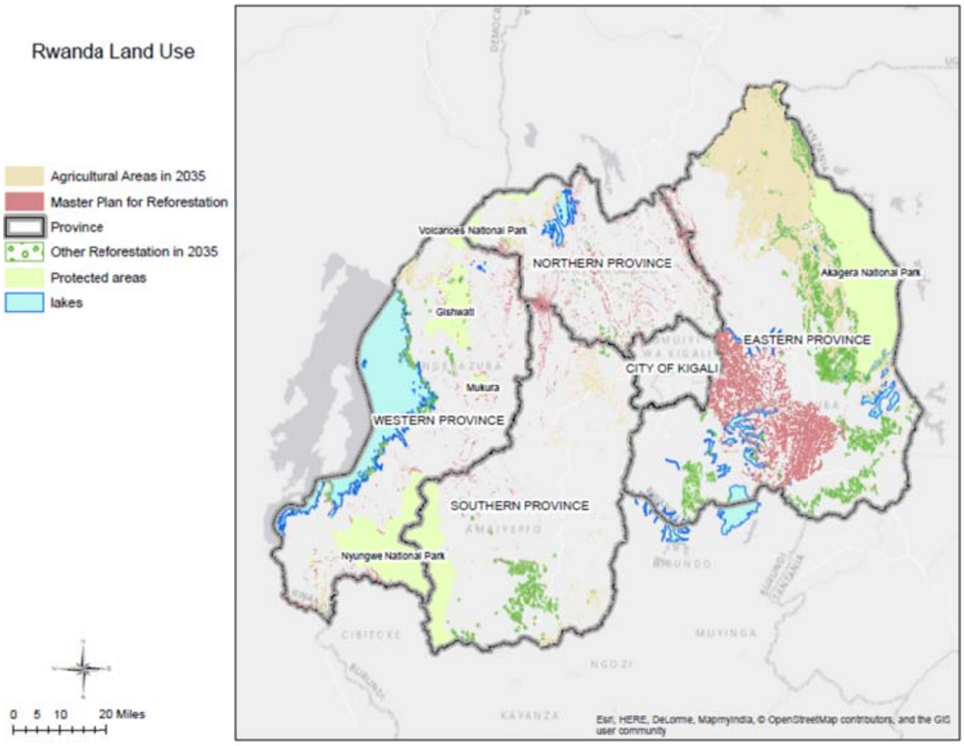
Figure 9. New forestry areas in 2035.



Source: Authors' own elaboration.

Figure 9 shows new forestry areas in 2035, both those that fell within the Master Plan designated forestry areas and those that were required to be sourced outside of these areas based on the established decision criteria. Figure 10 shows the result of the land use allocation process under the FOR2 scenario with new agricultural and forestry areas identified for the year 2035.

Figure 10. Agriculture and forestry expansion under the FOR2 scenario.



Source: Authors' own elaboration.

6.0. Discussion and Conclusions

TO BE COMPLETED.

NOTES.

- Significant scope for evaluating lines of action for Vision 2020/2030, Green Growth, Sustainable Development Goals etc; scenarios can be refined, modified with new data.

- IEEM is built to integrate all accounts under the System of Environmental Accounting; built-in poverty analysis module.

- Currently working on modelling future ecosystem service supply under each scenarios and building in feedback mechanisms between IEEM-RWA and the ecosystem service modelling (carbon value; dam siltation; fertilization and eutrophication).

- An integrated economic-environmental modelling approach is required to show difficult trade-offs and impacts on long-run economic development particularly where resource scarcity is so acute.

- It is necessary to reconcile government plans and targets with the realities of current resource availability, threats and vulnerabilities. Land use planning must consider both economic and spatial dimensions of production and consumption.

- Agricultural expansion is not without its consequences for the environment in terms of trade-offs between agriculture and forestry, water use and environmental contamination.

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