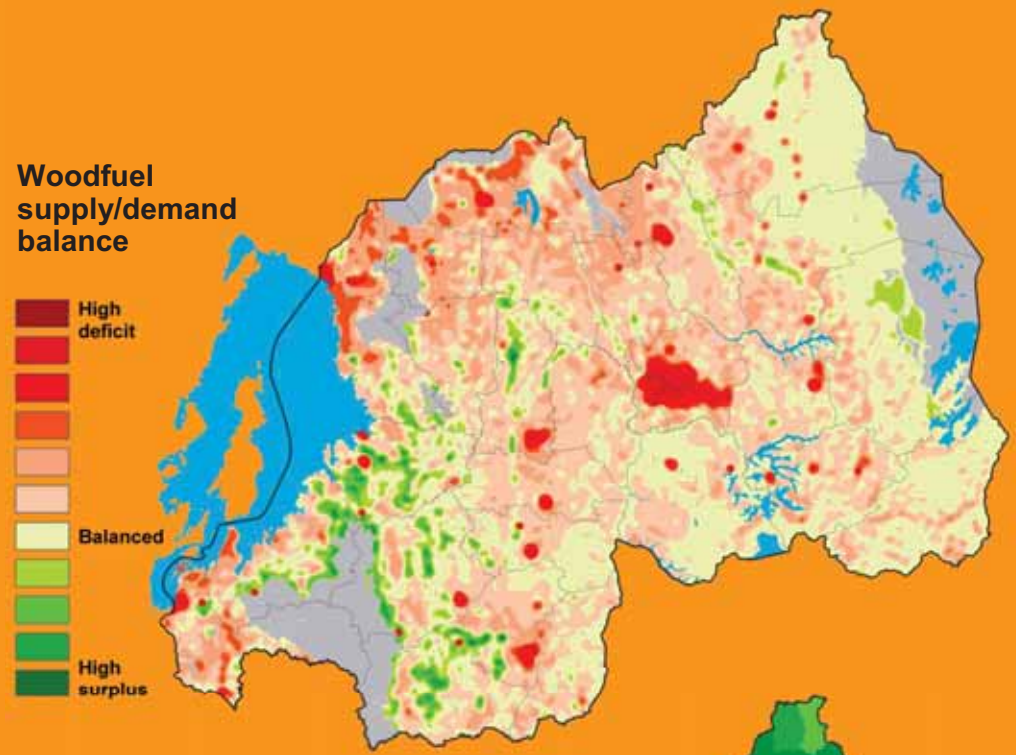
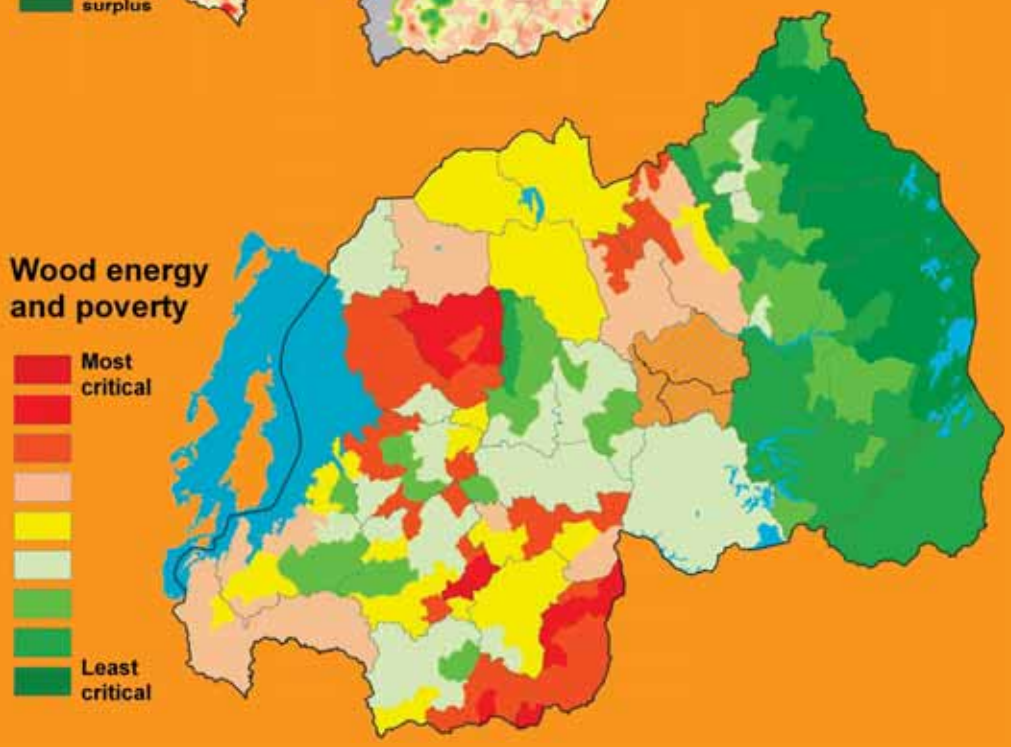
WISDOM RWANDA

Spatial analysis of woodfuel production and consumption in Rwanda applying the WISDOM methodology





FAO – Forestry Department – Wood Energy

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WISDOM Rwanda

Spatial analysis of woodfuel production and consumption in Rwanda applying the Woodfuel Integrated Supply/Demand Overview Mapping methodology (WISDOM)

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Based on the work carried out in the framework of the FAO/Government of Rwanda Project "*Rationalisation de la filière bois-énergie*" TCP/RWA/3103

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Foreword

With a population of almost 9 million and an accessible territory of only 2.1 million hectares, Rwanda is striving to meet its food and fuel requirements in a crowded landscape (less than ¼ hectare per capita). The Government of Rwanda intends to meet future energy needs of its population through careful planning and policies that will satisfy wood energy demand. To address this complex wood energy situation, the Government of Rwanda requested assistance from FAO's Technical Cooperation Programme. This background formed the basis for the project "Rationalisation de la filière bois-énergie", (Rationalization of wood energy) TCP/RWA/3103, implemented by the National Forest Authority (NAFA) of the Ministry of Forestry and Mines (MINIFOM) with financial support and the technical assistance of FAO.

A specialized system for examining wood energy issues has been used to assess Rwanda's needs and supply constraints. The Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) examines the spatial distribution of woodfuel supply and addresses issues of sustainability as key elements in wood energy planning. WISDOM has been designed by the Forestry Department of FAO and applied in a number of countries seeking to promote sustainable wood energy systems through careful management of wood resources.

Within the framework of the project, the WISDOM methodology was applied with the scope of improving the knowledge on woodfuels supply and demand in the Country, supporting sound policy formulation and planning, and strengthening of national capacities. Other components of the project executed field activities in six districts focussing on the creation of tree nurseries and distribution of seedlings to local farmers, and on the training of local operators on efficient charcoal making techniques and on the production of improved woodstoves.

WISDOM Rwanda provides the first geo-referenced vision of the country's productive potential, woodfuel consumption and supply/demand balance under current conditions as well as under alternative scenarios, serving as basis for the formulation of locally-tailored wood energy strategies.

The analysis benefited from the contribution of different ministries, national and international agencies, universities, and projects who shared maps, statistical data, reports and knowledge on the many facets of wood energy. In this process, WISDOM improved the cross-sectoral dialogue among the numerous institutional stakeholders and promoted the establishment of institutional synergies that are necessary for the formulation of sound wood energy policies and implementation of action programmes.

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Acronyms and abbreviations

ad	Air dry (biomass, usually measured in kg or t, with approx. 12% moisture content)
AME	"ameliorated" woodfuel demand scenario assuming (i) a higher penetration of improved stoves from 50 to 80 % and (ii) a higher efficiency in charcoal production from 12 to 18%.
BAU	Business as usual. Used to indicate current conditions in demand and supply scenarios
BEST	The Biomass Energy Strategy (BEST) initiative, a joint effort of the EUEI Partnership Dialogue Facility together with GTZ, Germany. Implementation by the Ministry of Infrastructure.
C GIS NUR	Centre d'Information Géographique et de Télédétection de l'Université Nationale du Rwanda
ISAR	Institut des Sciences Agronomiques du Rwanda
MAI	Mean Annual Increment
MAN	"managed" productivity variant assuming an increased annual productivity for eucalyptus plantations to 15 m^3 ha^{-1} $year^{-1}$ (from the current 9.6 m^3) as result of appropriate management
MINAGRI	Ministère de l'Agriculture, de l'Elevage et des Forêts
MINALOC	Ministère de l'Administration Locale, du Développement Rural et des Affaires Sociales
MINERENA	Ministère des Ressources Naturelles (establ. March 2008)
MININFRA	Ministère des Infrastructures
MINITERE	Ministère des Terres, de l'Environnement, des Forêts, de l'Eau et des Ressources Naturelles (now MINIRENA)
MINITRAPE	Ministère des Travaux Publics, de l'Energie et de l'Eau
MT	Million metric tonnes
NAFA	National Forestry Authority (under MINIRENA)
NISR	Institut National de Statistiques, Rwanda
od	Oven dry (biomass, usually measured in kg or t, with 0% moisture content)
PAREF	Programme d'Appui à la Reforestation (MINIRENA Programme)
RITA	Rwanda Information and Technology Agency (under MININFRA)
TOF	Trees Outside Forest (survey)
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping (methodology)
CFSVA	Comprehensive Food Security and Vulnerability Analysis and Nutrition Survey (WFP and NISR, 2009)

Summary

The present report describes and documents WISDOM Rwanda, the first geo-referenced database on the demand for fuelwood and charcoal in the various sectors and on the sustainable supply potential of woody biomass of the country.

The development of a uniform vision of woodfuel demand and sustainable production potential has been the main objective of the first two components of the project "Rationalisation de la filière bois-énergie". The main aims are an improved understanding of wood energy supply and demand in the country, in order to support sound policy formulation and planning, and the strengthening and wood energy planning capacities of the National Forestry Authority (NAFA).

The combination of the georeferenced layers relative to woodfuel consumption and to the sustainable supply potential allowed the creation of detailed maps on supply/demand balance conditions, and the identification of priority areas of interventions. Most important, WISDOM Rwanda is an analytical tool that will support future planning and policy formulation. The outputs of the study include stock and productivity estimates, consumption estimates and several supply/demand balances, spatially (at 50m pixel level) as well as by administrative units of all levels.

Amongst this wealth of data and findings, the following aspects may be highlighted:

- According to the current situation, the total annual productivity of woody biomass accessible and potentially available for energy use, for the entire country, is estimated at 1.1 Mt (1.1*10,t, oven dry). With better forest and agro-forestry management, and with the current plantation area, it is realistically estimated that the annual supply potential could raise to 1.7 Mt.
- The total consumption in the residential, commercial and public sectors with current carbonization and stove efficiency is estimated at 2.9 Mt. With realistic improvements in charcoal making efficiency and further dissemination of improved stoves the demand could lower to 2.47 Mt.
- The national supply/demand balance, according to current situation shows an annual deficit of 1.8 Mt. With improved management and conversion efficiencies, the balance could raise to a deficit of "only" 0.75 Mt.
- Over 1.5 million people (20% of people of rural provinces) live in areas with concomitant conditions of serious woodfuel deficit and high poverty, which are cause of extreme vulnerability. These populations and the areas where they live (delimited on WISDOM maps) should be given highest priority in future projects.

These summary figures are highly significant but they tell little about what and where the remedial actions should be concentrated. In fact, the true operational value is in the WISDOM geodatabase and its underlying geo-referenced supply and demand details that facilitate the discrimination of local conditions and the formulation of adequate remedial actions.

It is evident from the analysis conducted that there is no single-variable solution to the wood energy equation. In order to achieve sustainable wood energy systems the study recommends:

- Orient the remedial action in all possible direction (management, efficiency, new planting areas, promotion of affordable fuel alternatives, etc.) through strong institutional synergies and with clear territorial priorities.
- Tailor the character and emphasis of the actions to locally varying supply/demand situations.
- Share WISDOM for evaluation, update and, most important, use, with all concerned institutions.
- Update FAO ForeSTAT values for Rwanda with the new consumption estimates made in the context of the present study.
- Provide NAFA with appropriate technical and financial support to develop the technical capacities required for maintenance and full exploitation of WISDOM Rwanda.

- Join institutional resources and multilateral/bilateral development aid in order to upgrade the WISDOM knowledge base with data adequate to high intensity planning.
- Strengthen the WISDOM dataset with improved information for the following aspects:
    - Detailed and up-to-date land use/cover mapping based on the new orthophoto coverage produced by the National Land Centre
    - Reliable data on the sustainable productive capacities of plantations, tree and shrub in natural formations and in farm areas as well as residues from agricultural crops.
    - Precise data on rural consumption patterns by households and non-households, specifically on the amounts and the specific mix of fuelwood and farm residues.
    - Reliable information on wood-processing industries (sawmills and furniture making) and on woodfuel-consuming industries (brick-making).
    - Complete the analysis of woody biomass in rural areas through the interpretation of the remaining sample units as soon as the remaining 30% of the national orthophoto coverage is finalized.

Introduction

The challenge posed by wood energy in Rwanda is emblematic. The resources are limited and the demand is high, and increasing. There is no doubt that the demand for fuelwood and charcoal is greater than today's sustainable wood production. It is also clear that in the short and medium term wood, complemented by farm residues, will remain the only affordable fuel for the majority of Rwandese population.

Securing essential energy levels and at the same time protecting the productive capacity of forest plantations, natural vegetations and farmlands represents a major planning challenge, which calls for the country's best technical and institutional capacities. Given its multiple connections, wood energy is at the core of the national debate regarding forestry, deforestation and forest degradation, energy transition, poverty alleviation, food security, and regional economic development, among other important issues.

Wood energy is clearly cross-sectoral, as it concerns forestry and energy, agriculture and rural development, land tenure and food security. This implies a fragmentation of knowledge and responsibilities that represents a serious barrier to the formulation of sound wood energy policies and effective planning.

Moreover, the high population density and the intensive land use of Rwanda call for a high-intensity and locally-tailored planning strategies and, therefore, for planning tools based on reliable and spatially discrete information. For this, the collection and harmonization of the knowledge that exists in the various agencies and its integration to form a complete and uniform vision is the first essential step to be undertaken.

Providing assistance on the development of such uniform vision and planning capacity has been one of the main objectives of the Project "Rationalisation de la filière bois-énergie", specifically referring to the first two Components of the Project, whose main aim are the improvement of the knowledge on wood energy supply and demand in the Country, in order to support sound policy formulation and planning, and the strengthening of national capacities.

The National Forestry Authority (NAFA), has been the executing agency and technical counterpart of FAO staff of the Project within MINIRENA.

The present report describes and documents the main product of the first two Components of the Project: **WISDOM Rwanda**, the first geo-referenced database on the demand for fuelwood and charcoal in the various sectors and on the sustainable supply potential of the Country, which was developed implementing the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology.

The combination of these layers allowed the creation of detailed maps on supply/demand balance conditions, and the identification of priority areas of interventions. Most important, WISDOM Rwanda is an analytical tool that will support future planning and policy formulation.

WISDOM is the fruit of the collaboration of many agencies, which provided essential information for its development. It is therefore a common inter-sectoral product. WISDOM Rwanda will remain effective only if such synergy will be maintained in the future and if the responsibility for updating its many thematic components is shared by all competent institutions.

WISDOM Rwanda

This section describes the rationale, the analytical steps and the data sources used in the implementation of the methodology Woodfuels[1] Integrated Supply/Demand Overview Mapping (WISDOM) for Rwanda as a diagnostic and planning tool in support to wood energy planning and policy formulation (Drigo et al. 2002; FAO 2003).

Rationale and scope

When approaching bio-energy planning it's important to recall that wood energy systems[2] are:

- **cross-sectoral** (forestry, energy, agriculture, industry and rural development),
- **interdisciplinary** (silviculture and forest management, agronomy, physics, chemistry, engineering, etc.) and, in most cases,
- **location-specific** (the patterns of biofuel production and consumption, and their associated social, economic and environmental impacts, are site specific; broad generalizations about the biofuel situation and impacts across regions, or even within the same country, have often resulted in misleading conclusions, poor planning and ineffective implementation),
- **heterogeneous concerning biomass supply sources** (dedicated crops; crop residues, agro-food industries' residues, etc. Concerning woody biomass, for instance, forests and SRF are not the sole sources of woodfuels: other natural or domesticated landscapes, such as shrublands, farmlands, orchards and agricultural plantations, agroforestry, urban green, tree lines, hedges, etc. contribute substantially in terms of woody biomass already used or potentially available for energy production).

But, given the informal character of the wood energy sector, the information available on woodfuel demand and supply is always scarce or of poor reliability. In view of the erratic character of wood-energy information generally available it is necessary to keep a flexible analytical approach, adapted as far as possible to information and parameters actually available, in order to value and fully exploit existing knowledge and to maintain the ambition of analysis within realistic terms.

In this context, a rigid model structure requiring fixed input parameters would inevitably remain very general (or incomplete for lack of input data) and thus missing the heterogeneous information locally available. On the contrary, in a more flexible analytical context the priorities (concerning information needs and planning focus) may be determined case by case, which will allow identifying critical information gaps and planning effective data collection programs.

The heterogeneity of local conditions and of the quality, quantity and detail of available statistics precludes the design of a rigidly-structured model with predefined input/output elements. It rather calls for a great flexibility of analysis and adaptability to local conditions and available information.

WISDOM was conceived as an adaptable model based on clear concepts and solid methodological elements, rather than as a rigid model with predefined input parameters. As an adaptable model, WISDOM appears best suited to support the analysis, the identification of location-specific planning alternatives and the delineation of priority areas of intervention.

[1] The terms and concepts used in this paper make reference to the definitions and terminology provided in the paper "Unified Bioenergy Terminology" (UBET) and, concerning woodfuel flows, to those described in the paper "A guide for woodfuel surveys".

[2] Expanding from FAO definition of wood energy systems (FAO 2005), bio-energy systems may be defined as «all the (steps and/or) unit processes and operations involved for the production, preparation, transportation, marketing, trade and conversion of biofuels into energy».

Scope

WISDOM is meant to create a spatially-explicit knowledge base on supply and demand of woody and non-woody biomass for energy and thus to serve as a planning tool for highlighting and determining priority areas of intervention and to focus planning options.

The benefits of WISDOM include:

- It provides a consistent and holistic vision of the wood energy sector over the entire country or region and helps to determine priority areas for intervention.
- It provide the analytical basis for the definition of the sustainable supply zones of existing or hypothetical consumption sites such as urban areas or biomass plants (bio-district or woodshed analysis)
- It constitutes an open framework and a flexible tool meant to adapt to existing information related to woodfuels demand and supply patterns.
- It allows the definition of critical data gaps resulting from the thorough review and harmonization of wood energy data.
- It promotes cooperation and synergies among demand- and supply-related stakeholders and institutions (Forestry, Agricultural, Energy, Rural Development, etc.). In this, WISDOM will combat the fragmentation (of information, of responsibility) that so heavily limits the development of the sector.
- It allows the concentration of actions on circumscribed targets and thus to optimize the use of available resources (human, institutional, financial, etc.)[3]
- It enhances the political recognition of the real inter-sectoral role and priorities of wood energy by policy makers.

Analytical steps of WISDOM methodology

The WISDOM methodology may be divided into two sequential phases/contexts of analysis:

1 - WISDOM Base. This phase include the analysis over the entire territory of the study area.

2 - Woodshed[4] analysis. This phase of analysis uses the result of the WISDOM Base to delineate the sustainable supply zone of selected consumption sites such as urban centers or existing/planned biomass plants.

The specific steps of analysis are summarized below while a graphic overview is shown in Figure 1. The detailed description of the data used and analysis conducted in each step is given in the following Sections.

WISDOM Base

The application of the standard WISDOM analysis producing supply and demand balance mapping at the local level involves five main steps (FAO, 2003b).

1. Definition of the minimum administrative *spatial* unit of analysis.
2. Development of the *demand* module.
3. Development of the *supply* module.
4. Development of the *integration* module.
5. Selection of the *priority* areas or woodfuel "hot spots" under different scenarios.

[3] One such action would probably be the collection of up-to-date local data to confirm the results of national or regional analyses (which are always based on information of lower quality and resolution), and to create a database for operational planning.

[4] Expanding from FAO definition of wood energy systems (FAO 2005), bio-energy systems may be defined as «all the (steps and/or) unit processes and operations involved for the production, preparation, transportation, marketing, trade and conversion of biofuels into energy».

Woodshed analysis

The analysis for the delineation of woodsheds, i.e. supply zones of specific consumption sites requires additional analytical steps that may be summarized as follows.

6. Mapping of potential "commercial" woodfuel supplies suitable for urban and peri-urban markets.
7. Definition of urban woodshed, or potential sustainable supply zones, based on woodfuel production potentials and physical accessibility parameters.

The flowcharts of Figures 2 and 3 provide an overview of the main "ingredients" and of the sequence of actions undertaken in the development of the Demand and Supply Modules.

The listing of data sources, contact institutions and other remarks relative to the data and to procurement process are given in Annex 1 represent the "road map" of WISDOM development.

The technical details and specific steps of analysis undertaken in the development of each Module are described in the following sections.

Figure 1: WISDOM analytical steps. WISDOM Base (steps 1 to 5) and Woodshed analysis (steps 6 and 7).

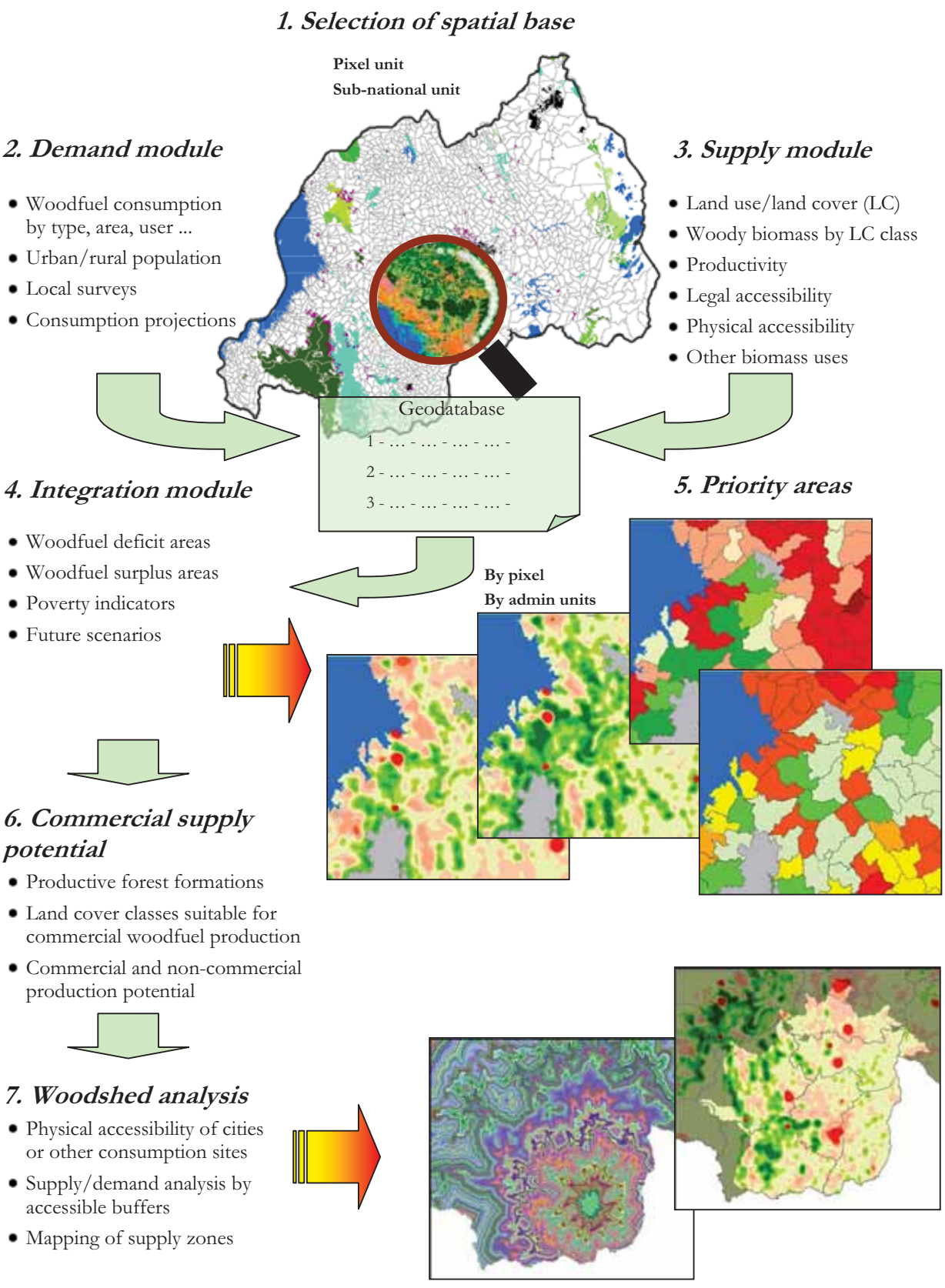


Figure 2: WISDOM Rwanda: Demand Module. Flowchart of main analytical steps

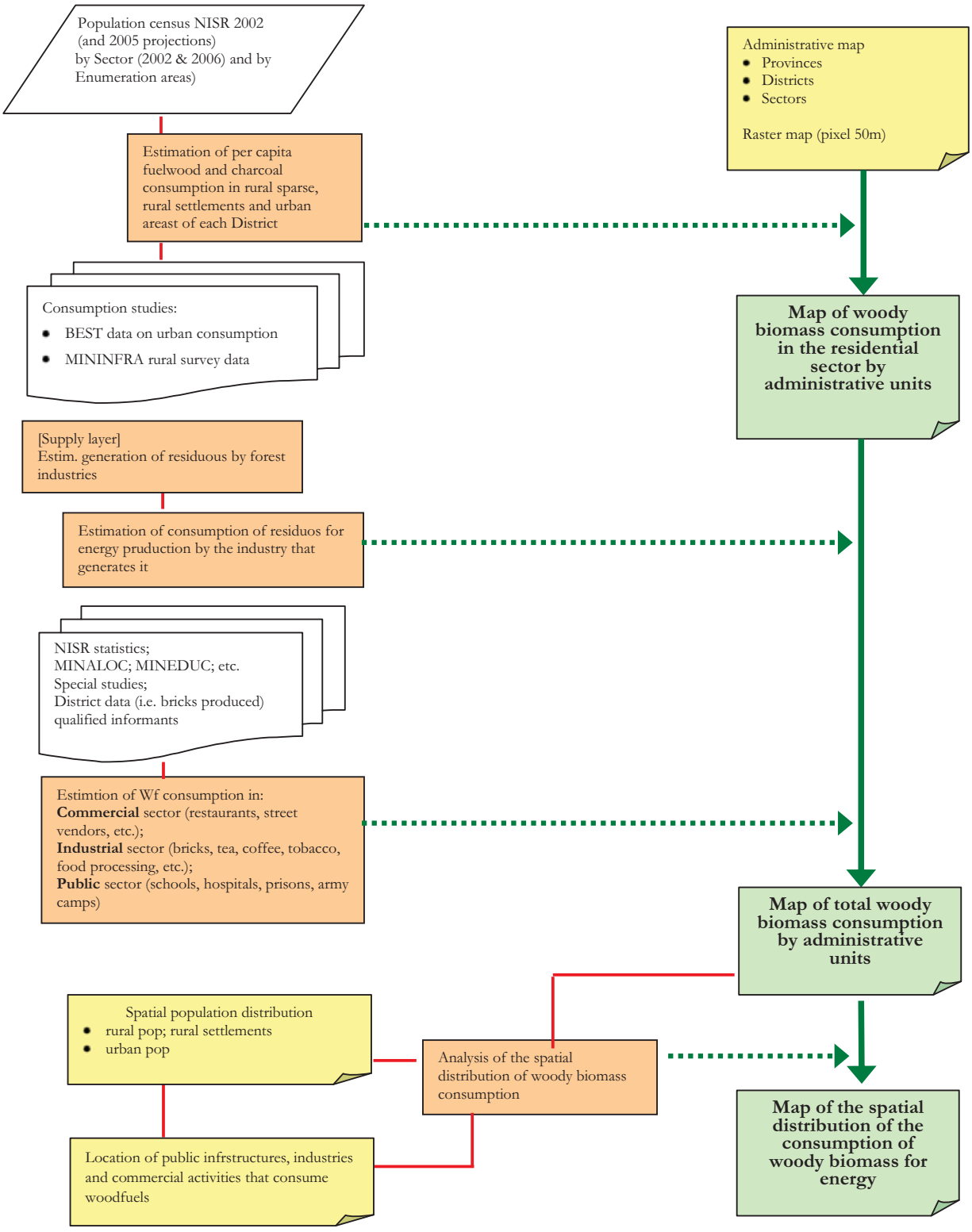
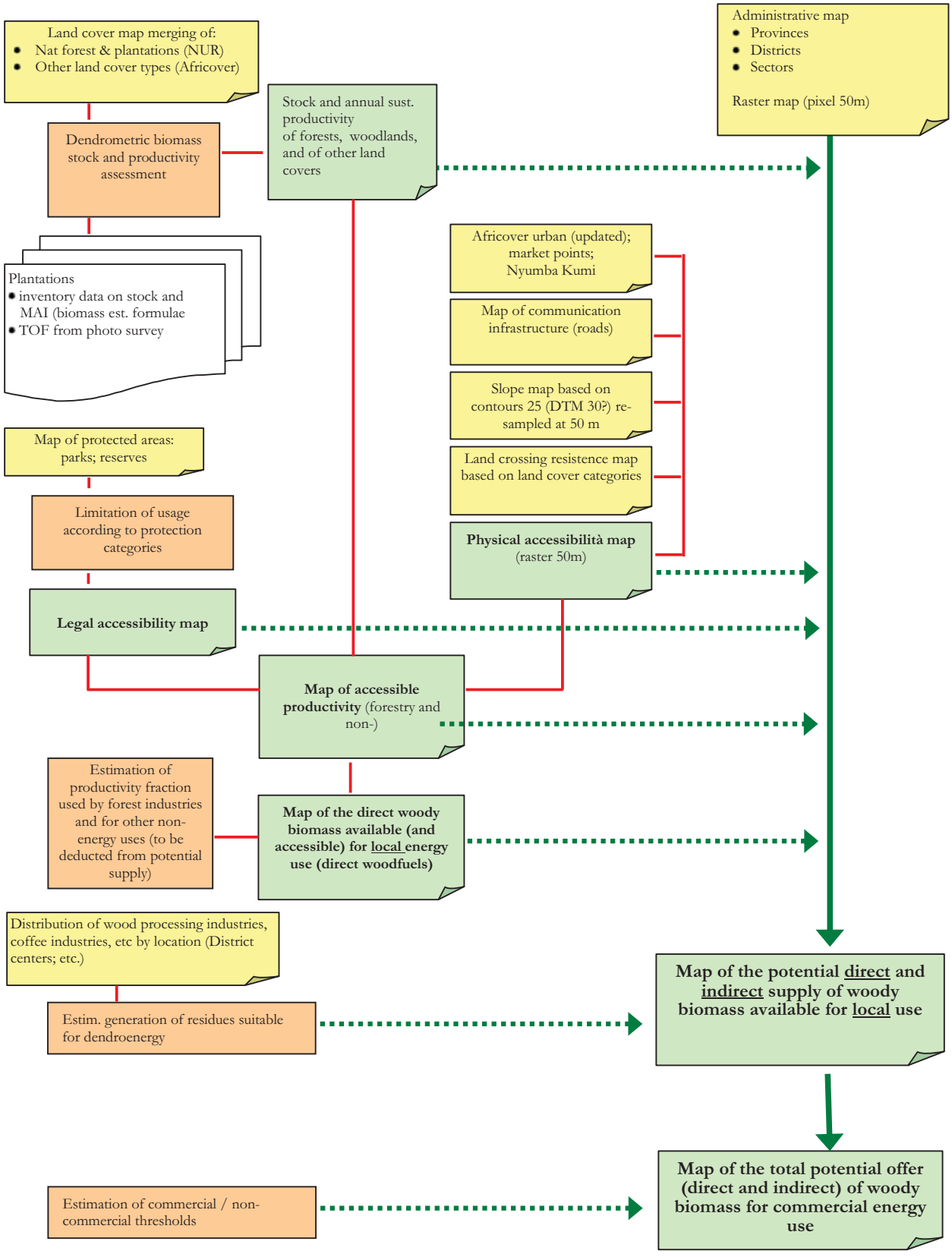


Figure 3: WISDOM Rwanda: Supply Module. Flowchart of main analytical steps



Cartographic base of analysis

Projection:

The projection selected for the cartographic data to be produced is the Arc_1960_UTM_Zone_35S (GCS = Arc_1960 ; Proj.= Transverse_Mercator), which is the one most commonly applied in Rwanda.

Raster resolution

The grid cell of the raster layers was defined in relation of the detail (minimum polygon size) of the most relevant reference data, which is that of forest plantations.

Since the Plantation inventory conducted by ISAR included areas of 0.4 hectares and above, and since the Forest Cover map produced by C GIS NUR has polygons even smaller, the pixel size was defined at 50 m, with one pixel covering ¼ of hectare.

Administrative structure

The administrative subdivisions of Rwanda are shown in Figure 4. The current administrative structure (left map) is composed by 5 regions, 31 Districts and 416 Sectors. The previous structure that included 1565 Sectors (right map) was also used in consideration of the associated 2002 demographic data, because it allowed a more detailed spatial distribution of the population.

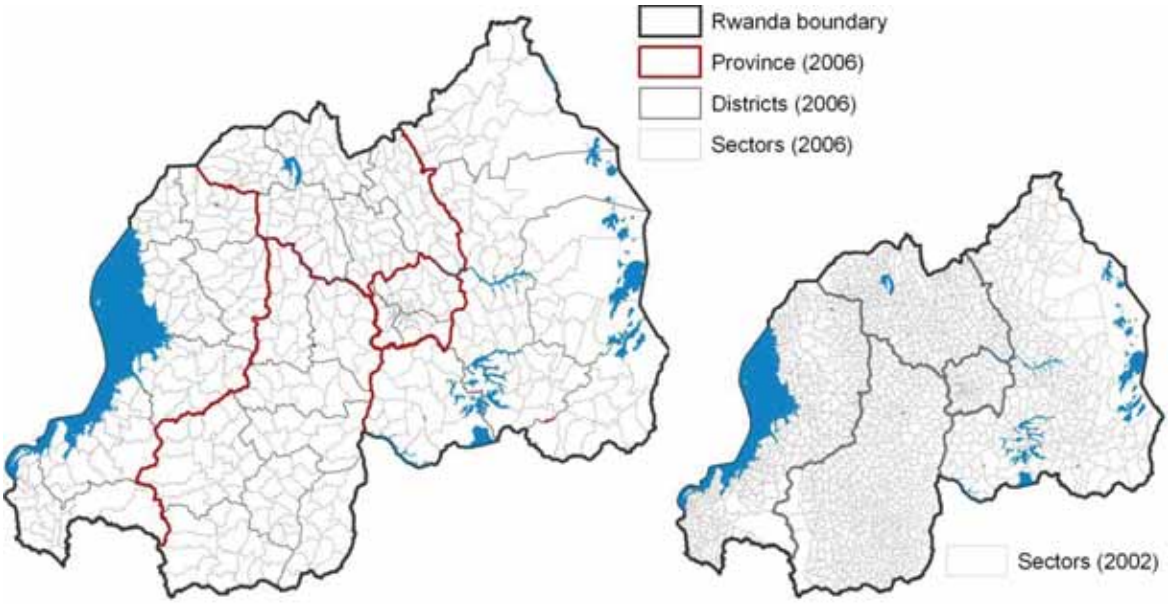
Reference year of analysis:

Given the reference dates of the most important thematic layers (land cover, forest cover and forest inventory, demographic data and survey data) the reference date of the analysis is set at **2006**.

Production of thematic maps:

The list of map names produced so far with relative description of contents is given in Annex 3.

Figure 4: Administrative structure. 2006 structure (left) and previous Sector structure related to 2002 Demographic Census (right)



Demand Module

Residential sector consumption

The consumption of woodfuels in the residential sector, which is the most important element of the Demand Module, was mapped with reference to 2002 (census year). The analysis included the following steps:

1. Spatial distribution of the urban and rural population was done through the following steps:
   i. Delineating of urban areas (Ref.: Africover Rwanda dataset complemented by Google Earth interpretation of urban areas for missing/outdated city boundaries carried out by National GIS Consultant).
   ii. Using of the georeferenced "10 Household" points[5] as proxy for the spatial distribution of rural population within census administrative units Sectors2002. The original dataset was integrated by the National GIS Consultant for the sub-national units for which the 10HH points were not available. The final 10HH map of rural data points includes 104 320 points, which supports a very detailed spatial distribution of the Country's spatial population.
   iii. Developing of a simple algorithm relating official census data with the spatial features such as urban pixels and rural pixels by sector 2002.
   iv. Creating of the population distribution map as crude pixels map as well as smoothed interpolation map based on spatial analysis whereby the pixel values in the new map are determined by the average values of the pixels in the surrounding 1 km in the source map.
2. Estimation of per capita consumption by rural and urban area and by administrative unit, depending on available reference data. Per-capita and per- household consumption rates in rural and in urban areas were based primarily on the recent studies and surveys conducted in the framework of the BEST initiative.

Two scenarios were considered: a business as usual (BAU) scenario reflecting the present situation and an "ameliorated" (AME) scenario assuming (i) a higher penetration of improved stoves from 50 to 80 % and (ii) a higher efficiency in charcoal production from 12 to 18%. Per capita consumption rates are shown in Table 1. Saturation values by District are shown in Annex 2.

Table 1: Reference fuelwood and charcoal consumption values used in the business as usual scenario (BAU) and in the ameliorated scenario (AME)

	Consumption by households				BAU			AME	
Stove	kg/HH /year	BAU	AME	Per capita kg/year	ad wood equivalent kg/person /year	oven dry wood equivalent	Per capita kg/year	ad wood equivalent kg/person /year	oven dry wood equivalent
Fuelwood									
Three stones	1642	50%	20%						
Improved	1263	50%	80%						
average	1453	1453	1339	314	314	257	289	289	237
Charcoal									
Traditional	700	50%	10%		@12% efficiency			@18% efficiency	
Improved	538	50%	90%						
average	619	619	554	134	1,115	913	120	666	545

Ref: BEST Vol 4

Figure 5 presents some of the main cartographic layers that were used in the distribution of rural and

[5] The map giving the lat/long position of the chief of the 10/15 surrounding households (Nyumba Kumi)

urban population as well as the resulting population distribution map .

Figure 6 shows a detail of the map of the residential consumption of wood and wood-for-charcoal as well as the whole country consumption, with reference to the BAU scenario.

The total residential consumption according to BAU scenario is estimated at 2.7 million tons (oven dry matter). With ameliorated efficiencies (AME scenario) the residential consumption could lower to 2.2 million tons. Detailed District-wise values are given in Table 2.

Other sectors' consumption

Commercial sector consumption

Another component of the Demand Module is the consumption in the Commercial Sector. Due to lack of data on the consumption by restaurants, bakeries, hotels, etc. the estimation of this component was preliminarily done, based on generic references. Tentatively, the commercial consumption may be estimated as 10 % of urban HH consumption (ref. Drigo 2008 [WISDOM Mozambique]; ref Ministry of Infrastructure, 2009a [BEST]). The geographic distribution of this consumption was done in relation to urban populations, as shown in the top-most map of Figure 7.

The total commercial sector consumption according to BAU scenario is estimated at 73 thousand tons (oven dry matter). With ameliorated efficiencies (AME scenario) the commercial sector consumption could lower to 48 thousand tons. Detailed District-wise values are given in Table 2.

Industrial sector consumption

Concerning the industrial demand of woodfuels, two are the important actors: Tea factories and brick making. Concerning tea factories there are sufficient elements for the estimation and mapping of fuelwood consumption, based on data received from OCIR-Tea. The consumption of fuelwood in the main tea factories is symbolized in a separate map in Figure 7.

More problematic appears the estimation and mapping relative to brick making, due to the total lack of information on the quantity and distribution of brick factories and on the quantity of bricks produced and fuels consumed. In principle, fuelwood should not be used for making bricks because it's forbidden by law. In reality, fuelwood is still used, in combination with other fuels, which include exhausted oils and sawmills residues. These latter fuels are also important in the overall wood energy equation and it's therefore recommended that this sector of consumption be investigated in good detail and the information gap filled.

The total consumption by tea factories is estimated at 26 thousand tons (oven dry matter). Detailed District-wise values are given in Table 2.

Public sector consumption

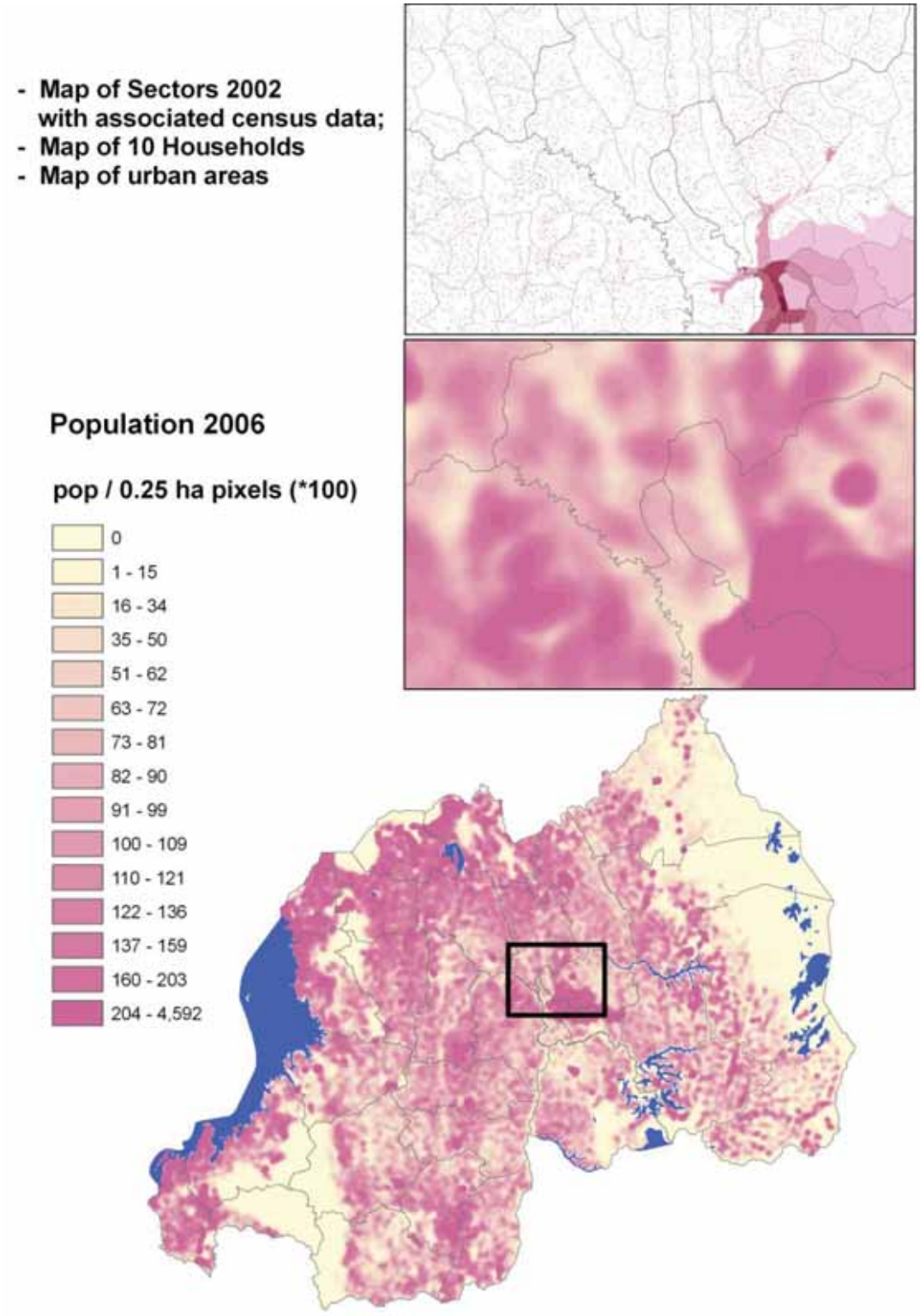
Significant amount of fuelwood is used in the public sector, by secondary schools and by prisons.

The location of secondary schools was available as separate map layer, while the number of students was estimated in relation to the students' population at District level. In absence of whatsoever data on the actual fuelwood consumption, the consumption per student was preliminarily estimated as ½ of the per capita consumption using improved stoves, over 9 months.

The mapping of the consumption by the prisons is much more reliable since actual consumption of fuelwood by each detention centre was kindly provided by the Director of Prisons.

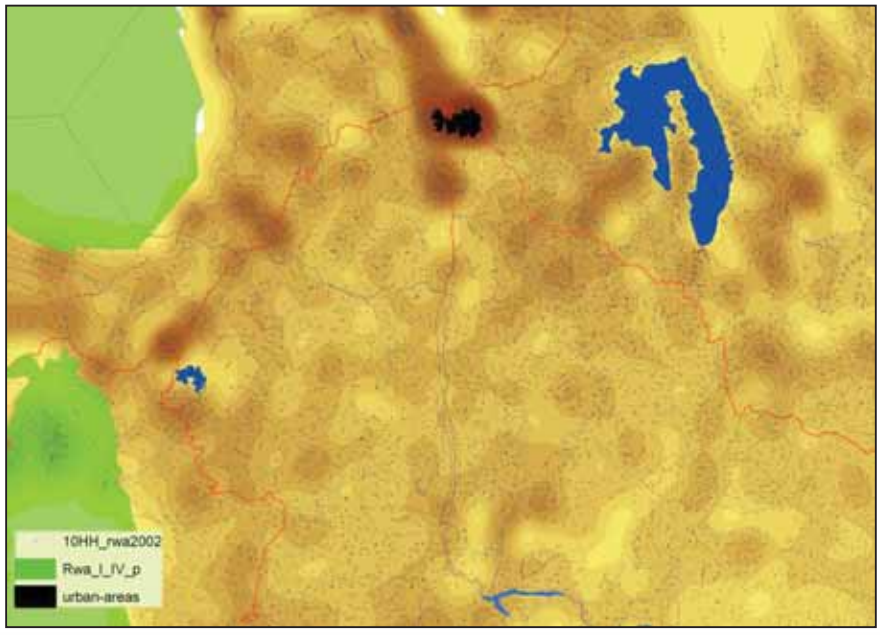
The consumption of fuelwood in secondary schools and prisons is symbolized in a separate map in Figure 7. The total consumption by secondary schools and prisons is estimated at 14,800 tons (oven dry matter) and . 32,200 tons, respectively. Detailed District-wise values are given in Table 2.

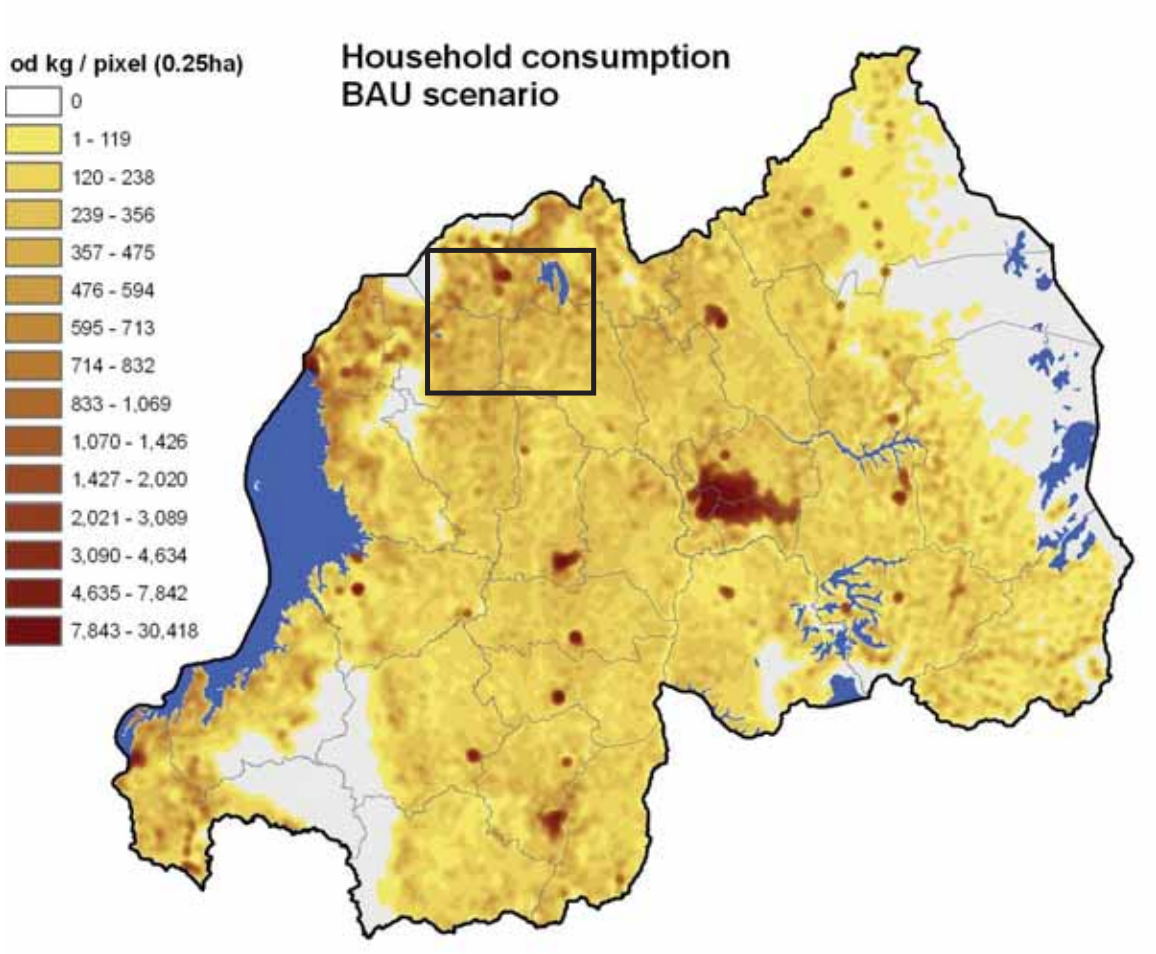
Figure 5: Population distribution maps. Top Map: Population values associated to "10 HH points " in rural areas and to urban polygons in urban areas. Bottom Map: population distribution "smoothed" by averaging pixel values within a 1 km circle.



Note: The map shows number of person by 0.25 ha pixels (multiply by 400 to obtain standard density by sqKm).

Figure 6: Residential woodfuel consumption map – Business as usual (BAU) scenario.





Note: The map detail (top) shows in the background the point data defining households concentrations in rural areas, urban areas, main roads and protected areas (green).

Consumption of construction material

The consumption of poles for construction of houses, huts, stables, fences, etc., (*bois de service*) represents alternative uses (to energy) that need to be estimated and mapped in order to be deducted from the total sustainable productivity and to estimate the resources finally available for energy uses.

It may be mentioned that in the long term old construction wood is also in good part used as fuel at the end of its "service" life. However, in spite of this retarded energy role, it is essential to exclude "fresh" construction wood from the productivity potentially available for energy.

As for several other items, no information was available concerning the quantity and location of the construction material annually consumed. In order to assign a preliminary value to this component, reference was made to other studies (Drigo 2008 [WISDOM Mozambique]) and resulting values were discussed with qualified informants. The value we arrived at is 20 air dry kg per capita (corresponding to 16.4 oven-dry kg), which was applied to the population of rural areas, where the use of this material is common. The (tentative) map of construction material annually consumed is shown at the bottom of Figure 7.

The total consumption of construction material is estimated at some 125 thousand tons (oven dry matter). Detailed District-wise values are given in Table 2.

Total consumption

The maps of the total consumption of woody biomass in all sectors according to the BAU and AME scenarios are shown in Figure 8.

The total consumption of woody biomass (as fuelwood and wood for charcoal or as construction material) according to BAU scenario is estimated at almost 3 million tons (oven dry matter). With ameliorated efficiencies (AME scenario) the total consumption could lower to some 2.5 million tons.

The total District-wise consumption statistics relative to the two scenarios as well as those relative to each sector of consumption are given in Table 2.

Comparison with FAOStat reported figures

The on-line Forestry Statistics database of FAO, ForeSTAT[6], provides time series of forest products statistics for all the countries of the world. The sources of such statistics are the countries' forestry institutions through designated country correspondents. In case of missing official country data for some items or for some years, FAO proposes best estimates based on model results. The latter is the case for the ForeSTAT figures on the production of woodfuel and charcoal in Rwanda in 2006 (reference year of WISDOM analysis). The reference used in the case of Rwanda is the GFPOS[7] model F3 for fuelwood consumption, which is based on previous national references on per capita fuelwood consumption and income parameters, and model G for charcoal consumption, which is a very generic global model applied to the countries particularly poor of historical references.

The woodfuel figures proposed by ForeSTAT for Rwanda in 2006 is 9,415,894 m^3, including fuelwood and wood used for charcoal production, which corresponds to approximately 6.5 million tons of oven-dry woody biomass. Concerning charcoal, ForeSTAT figure for 2006 is 251,763 tons, corresponding to approximately 1.7 million tons of oven-dry woody biomass. These figures are more than twice the currently estimated amounts, which indicates that the per capita consumption values used in the GFPOS models were far too high. In fact, the ForeSTAT value assumes an annual per capita consumption of more than 1 m^3 of wood applied to the entire population, which, in case of a country with a marked shortage of woody biomass appears as an evident overestimation.

[6] See: http://faostat.fao.org/site/626/default.aspx#ancor

[7] Global Forest Products Outlook Study (GFPOS) in Bahdon et al., 2001 and Broadhead et al., 2001

In the specific case of Rwanda it is highly recommended that the Rwanda National Correspondent of forestry information make reference to the consumption estimates made in the context of the present study in order to replace the current unrealistic GFPOS model figures.

Figure 7: Other components of the Demand Module: Commercial sector; Tea factories; Secondary schools; Prisons. Construction material, although not an energy use, is a non-industrial consumption component directly related to rural households distribution to be deducted from the supply potential.

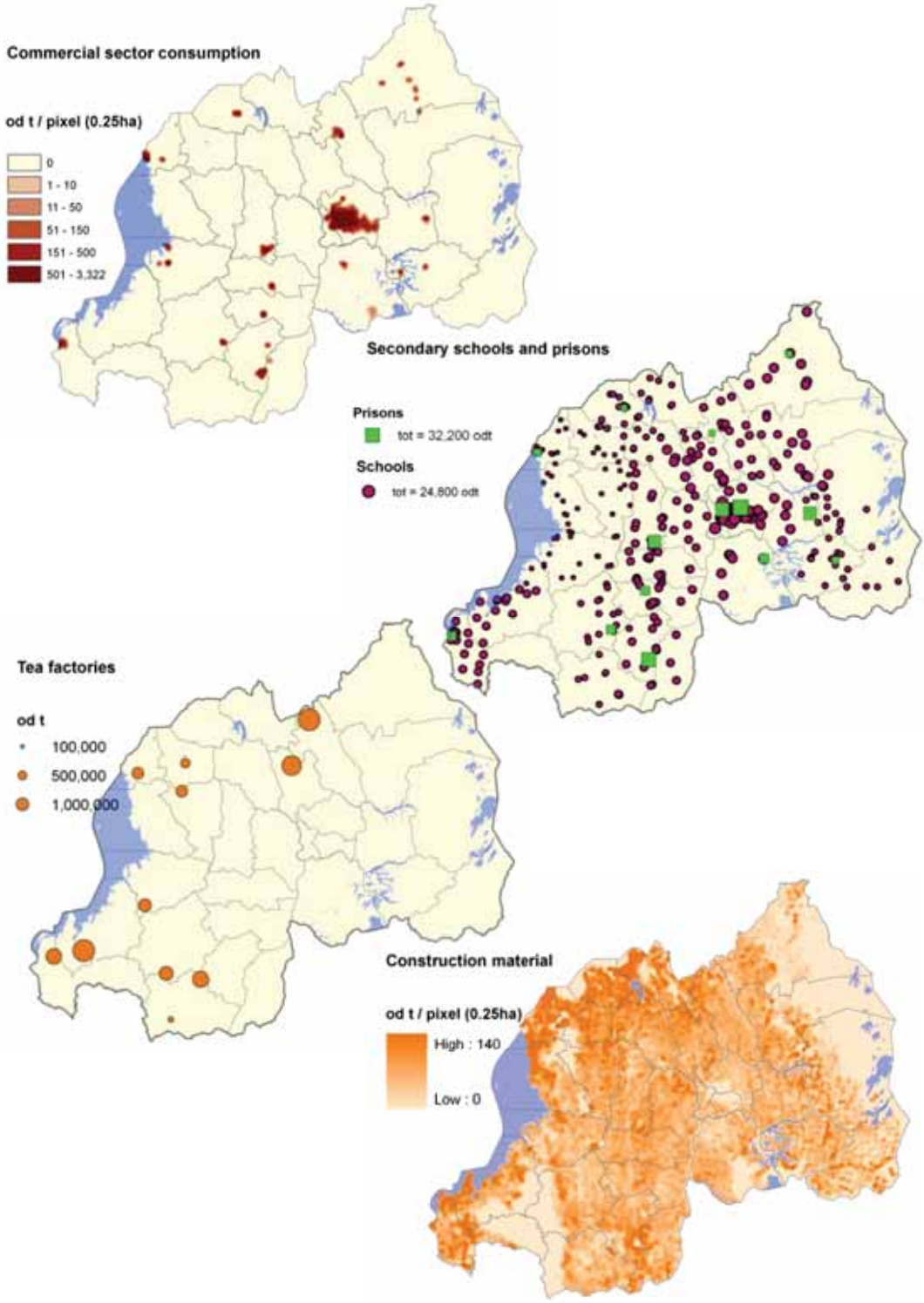


Figure 8 : Spatial distribution of 2006 woody biomass consumption. Values report the estimated consumption of oven-dry woody biomass (as fuelwood and wood for charcoal or as construction material) in Kg per 0.25 ha pixel.

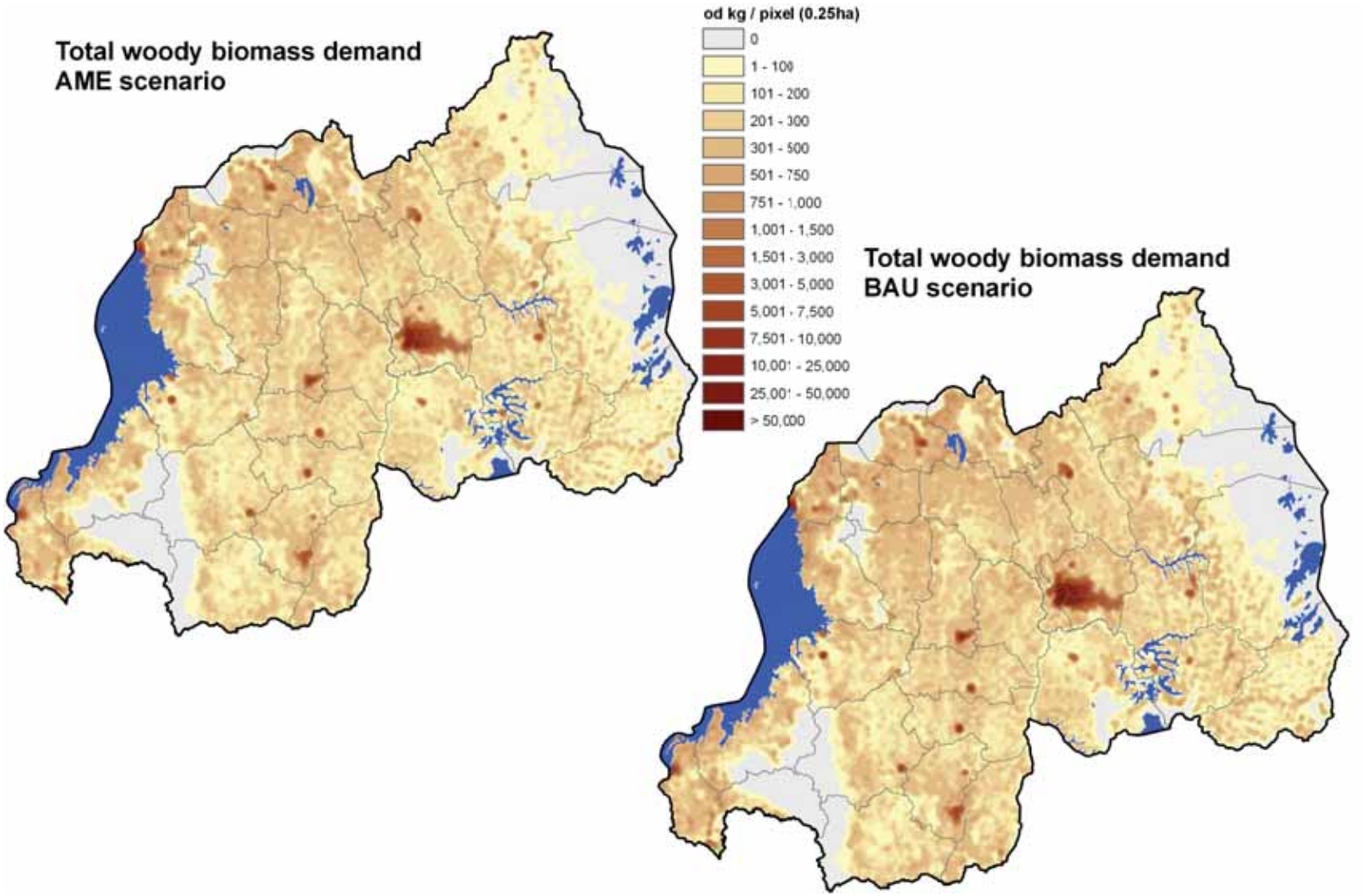


Table 2: Summary of demand module map values by District (oven dry t of wood)

District (2006)	Code	AREA_ha	Households BAU	Households AME	Commercial sector BAU	Commercial sector AME	Secondary schools	Prisons	Tea factories	Constraction material	Total demand - BAU	Total demand - AME
NYARUGENGE	101	13,398	182,034	114,612	17,079	10,546	1,320	3,643		452	204,529	130,574
GASABO	102	42,922	232,128	149,141	18,622	11,482	1,153	4,833		1,745	258,481	168,353
KICUKIRO	103	16,673	168,129	105,914	15,685	9,676	1,279	0		446	185,540	117,315
NYANZA	201	67,216	66,509	58,290	1,137	869	548	1,976		3,621	73,791	65,303
GISAGARA	202	67,922	69,913	62,454	247	188	288	0		4,419	74,868	67,349
NYARUGURU	203	101,019	60,270	54,180	0	0	239	0	2,920	3,952	67,380	61,289
HUYE	204	58,158	85,816	74,028	2,349	1,793	446	4,229		4,096	96,936	84,592
NYAMAGABE	205	109,040	79,087	69,920	908	694	436	1,839	2,041	4,595	88,907	79,524
RUHANGO	206	62,683	71,266	62,721	1,029	786	497	0		4,005	76,797	68,009
MUHANGA	207	64,766	96,996	82,966	3,177	2,427	629	3,300		4,285	108,387	93,607
KAMONYI	208	65,551	67,740	60,901	2	1	331	0		4,439	72,512	65,673
KARONGI	301	99,309	83,282	70,671	1,562	1,091	404	0	1,706	4,166	91,120	78,039
RUTSIRO	302	115,695	71,977	62,633	0	0	252	0		4,363	76,591	67,248
RUBAVU	303	38,839	97,364	78,373	3,459	2,293	504	1,229	1,488	3,869	107,913	87,756
NYABIHU	304	53,133	73,117	65,479	0	0	379	0	934	4,566	78,995	71,357
NGORORERO	305	67,895	77,106	69,174	0	0	313	0	1,404	4,823	83,645	75,713
RUSIZI	306	95,813	100,048	83,154	1,812	1,229	570	1,667	2,488	4,940	111,525	94,048
NYAMASHEKE	307	117,358	88,563	74,930	0	0	546	0	4,770	5,220	99,100	85,466
RULINDO	401	56,696	65,129	58,375	0	0	561	0	3,790	4,260	73,740	66,987
GAKENKE	402	70,408	83,269	74,794	0	0	390	0		5,478	89,137	80,662
MUSANZE	403	53,025	86,264	74,483	1,273	968	396	822		4,745	93,499	81,414
BURERA	404	64,445	82,827	74,141	0	0	257	0		5,432	88,516	79,830
GICUMBI	405	82,955	104,286	90,860	1,992	1,515	436	943	4,739	5,543	117,939	104,036
RWAMAGANA	501	68,201	68,614	59,273	696	529	408	3,675		3,932	77,325	67,816
NYAGATARE	502	191,941	79,222	69,754	921	699	411	999		4,581	86,134	76,444
GATSIBO	503	158,218	82,636	73,444	77	59	526	0		5,322	88,562	79,352
KAYONZA	504	193,474	60,467	53,998	0	0	387	0		3,945	64,798	58,330
KIREHE	505	118,371	66,699	59,580	0	0	174	0		4,353	71,226	64,108
NGOMA	506	86,772	71,499	61,777	550	408	436	1,048		4,214	77,747	67,883
BUGESERA	507	129,038	80,737	69,901	532	402	287	1,981		4,807	88,344	77,377
	Total	**2,530,933**	**2,702,991**	**2,219,919**	**73,112**	**47,656**	**14,804**	**32,184**	**26,280**	**124,613**	**2,973,983**	**2,465,455**

Note: These totals and those presented in Annex 2 for household consumption differ slightly due to spatial smoothing applied in the mapping process.

Supply Module

Land cover map

The land cover map that was be used to map woody biomass stock and productivity is based on the integration and updating of several existing map layers. These include:

- Forest Cover Map produced by CGIS-NUR and ISAR in 2007 (based on 2004 data, approx.), representing plantation and natural forest areas;
- Africover land cover map based on LCCS produced with FAO assistance in 2002 (on 1999 satellite data), revised concerning plantation areas;
- Updated urban areas of selected cities based on Google Earth;
- Districts administrative subdivision (2006 layout) necessary to allocate District-wise plantation inventory results.

The resulting land cover map combining all layers above is shown in Figure 9, while the legend and class coding are shown in Annex 2.

Woody biomass stock and productivity

Stock and productivity of forest plantations

Stock and productivity of forest plantations were based primarily on the forest inventory results published by ISAR in May 2008. In absence of original inventory data, the only reference available for stock and productivity estimates were the tables of the report, most of which at District level. Plantation stock values are reported in Table 3.

Table 3: Average total volume / hectare by species and by province based on plot data provided in the ISAR Inventory Report

Volume/ha in m^3	Province					
Species name	**EST**	**NORD**	**OUEST**	**SUD**	**V. KIGALI**	**Total**
Eucalyptus spp.	**45.2**	**54.9**	**122.8**	**104.4**	**41.6**	**90.5**
Acacia mearnsii		22.3	98.1	136.8		112.3
Acacia melanoxylon			227.1	237.7		231.5
Albizzia spp.			106.9			106.9
Callitris robusta	78.1	47.1	108.6	123.6	112.3	116.2
Casuarina spp.	113.2	56.3				84.7
Cedrela serrata				115.0		115.0
Cinchona officinalis			351.1			351.1
Cupressus lustanica		61.7	336.9	131.4		156.9
Grevillea robusta		371.0	175.5	179.9	128.4	193.0
Maesopsis eminii		121.3				121.3
Polyscias fulva			84.5			84.5
Ecalyptus et al.	**48.9**	**58.0**	**136.6**	**115.4**	**53.0**	**103.1**
Pinus spp.	**132.5**	**152.4**	**201.9**	**156.1**	**260.2**	**173.2**

Table 4: Number of plots by species and by province based on plot data provided in the ISAR Inventory Report)

Number of plots	Province					
Species name	**EST**	**NORD**	**OUEST**	**SUD**	**V. KIGALI**	**Total**
Eucalyptus spp.	**425**	**2,366**	**1,547**	**1,714**	**255**	**6,307**
Acacia mearnsii		1	19	55		75
Acacia melanoxylon			70	64		134
Albizzia spp.			5			5
Callitris robusta	13	10	41	194	20	278
Casuarina spp.	2	1				3
Cedrela serrata				2		2
Cinchona officinalis			9			9
Cupressus lustanica		8	4	106		118
Grevillea robusta		3	2	11	1	17
Maesopsis eminii		1				1
Polyscias fulva			1			1
Ecalyptus et al.	**440**	**2,390**	**1,698**	**2,146**	**276**	**6,950**
Pinus spp.	**172**	**46**	**1,489**	**1,374**	**4**	**3,085**
Total # plots	**612**	**2436**	**3187**	**3520**	**280**	**10035**

Productivity

The inventory report presents the list of the 82 sample plots for which the age of the stand was known, with age, volume, production (volume * age-related factor) and MAI calculated as production /age. Average MAI by District and by species is presented in Table 14 of ISAR Report (a typing error on Eucalyptus MAI in Huye reports 5.582 rather than 1.582). National-level MAI values are shown in the graph in Figure 7 of ISAR Report but it's not clear how the reported values were calculated because they differ significantly from the results derived from plot data and from District averages.

Besides the issues of reported values, it appears that the procedure of estimation of the MAI did not adequately consider the coppicing capacities of eucalyptus spp. The elements considered were the age from the establishment of the plantations, the current volume and an age-related expansion factor to determine the production from which MAI was calculated. No explanation is given in the report but it appears that the factor (1.2 for age <= 10; 1.3 for age 11-20; 1.5 for age >20) was meant to add previous production. The values appear insufficient to reflect the powerful regrowth capacity of eucalyptus and the intensive coppicing practiced, properly and improperly by rural populations. This is likely the reason why the productivity of eucalyptus appears lower than most of other species.

According to the MAI values calculated as described above for the age-known plots, the eucalyptus average MAI is 5.5 m3/ha/year, which appears really low.

Without knowing the age from the last coppicing it's not possible to review the values of eucalyptus productivity with acceptable precision. However, a tentative re-estimation was done by applying a different production factor based on the generally applied rotation period (approx. 10 years or less), as follows: Age < 10 = 1.2; age 10 – 20 = 2 ; age 20 – 30 = 3 ; age > 30 = 4

Given the high stock of some plots, it may be that these plantations were never coppiced or that were coppiced less than usual. For these "outsiders" a lower factor was applied.

Mapping of plantation stock and productivity

The mapping of plantation productivity required the integration of two main components:

- the map classes available: Eucalyptus, Pinus and "Young or open forest plantation or coppices" ;
- the average productivity by species and by province presented/discussed above.

In the setting up of a relation between these two components, the following assumptions were made:

Pinus plantations contain only or prevalently Pinus species and the inventory results (stock and productivity) apply directly to map class. For the provinces for which there are no productivity values, the national average values apply.

All other plantations are a mixture of species dominated by Eucalyptus species. This is valid for both mapped classes "Eucalyptus plantation" and "Young or open forest plantation or coppices". The values of stocking and productivity for both classes is calculated as weighted average of the species mix found in the provinces according to plot data provided by the ISAR Inventory Report. The productivity values applied are provincial averages for Eucalyptus and national averages for the other species.

Table 5: Estimated annual productivity by species and by province. Values based on the 152 plots with age data reported in ISAR Inventory Report. Values highlighted by a * are those used for the supply map.

	Provonces					
	EST	**NORD**	**OUEST**	**SUD**	**V. KIGALI**	**Total**
Species	$m^3\ ha^{-1}\ yr^{-1}$					
Eucalyptus spp	7.2*	7.2*	12.3*	10.2*	4.5*	9.6
Acacia melanoxylon			18.8	7.4		15.0*
Callitris robusta		3.6		7.2	10.0	6.9*
Cupressus lustanica		4.0		4.8		4.6*
Grevillea robusta			10.0	3.6		6.8*
Euc. & al.	7.2	6.7	12.8	9.2	6.3	7.0
Pinus spp.	8.6*****		14.2*	12.7*		13.0*
	Number of plots considered					
Eucalyptus spp	4	**22**	**18**	**36**	2	**82**
Acacia melanoxylon			2	1		3
Callitris robusta		2		**11**	1	**14**
Cupressus lustanica		1		2		3
Grevillea robusta			1	1		2
Pinus spp.	2		**16**	**30**		**48**
G Total	6	25	37	81	3	152

The productivity of eucalyptus plantations, even with the correction applied on account of repeated copping, appears still below the productivity levels expected for these regions under adequate forest management practices. In order to estimate the productivity that could be obtained with adequate management of present-day planted area a higher productivity as been assumed as "managed" (MAN) productivity variant. This was based on an average annual productivity of 15 m^3 ha year for eucalyptus species.

Two productivity levels were therefore applied, one "Business as Usual" (BAU) and one Managed (MAN). Table 6 shows the values applied at province level for both variants.

A similar approach was followed for the other land cover types, applying a BAU productivity on the basis of medium-low growth function and one MAN productivity through a medium-high function. The MAI values of both variants for each land cover class are reported in Annex 2.

The poor coherence between the cartographic and forest inventory elements (in addition to the other aspects mentioned above) made the whole process rather uncertain and the results produced should be considered provisional.

Table 6: Values used for the mapping of stock and productivity of plantations. For Eucalyptus-dominated plantations two productivity variants are given: the Business as Usual (BAU) variant and the "Managed" (MAN) variant.

	Provinces					
Species groups	EST	NORD	OUEST	SUD	V. KIGALI	Total
Total volume m^3 ha^{-1}						
Ecalyptus et al.	48.9	58.0	136.6	115.4	53.0	103.1
Pinus spp.	132.5	152.4	201.9	156.1	260.2	173.2
Productivity m^3 ha^{-1} yr^{-1}						
Ecalyptus et al. - **BAU**	7.2	7.1	12.5	9.5	4.9	9.5
Ecalyptus et al. - **MAN**	11.1	11.1	18.6	14.0	13.4	14.5
Pinus spp.	8.6	*13.0*	14.2	12.7	*13.0*	13.0

Estimation of woody biomass resources in rural areas

The estimation of the woody biomass available in rural areas and its role in the satisfaction of energy demand was based on the preliminary results of a systematic sample survey of trees outside forests specifically designed to fill, at least preliminarily, this critical information gap (see Annex 6).

The variables measured are the crown cover of trees and shrubs in rural areas. The sampling universe was the entire land area of Rwanda excluding the following: the forest areas (natural and planted) covered by the ISAR-NUR Forest Cover Map, the protected areas, including IUCN-WCMC areas, marshlands and swamps.

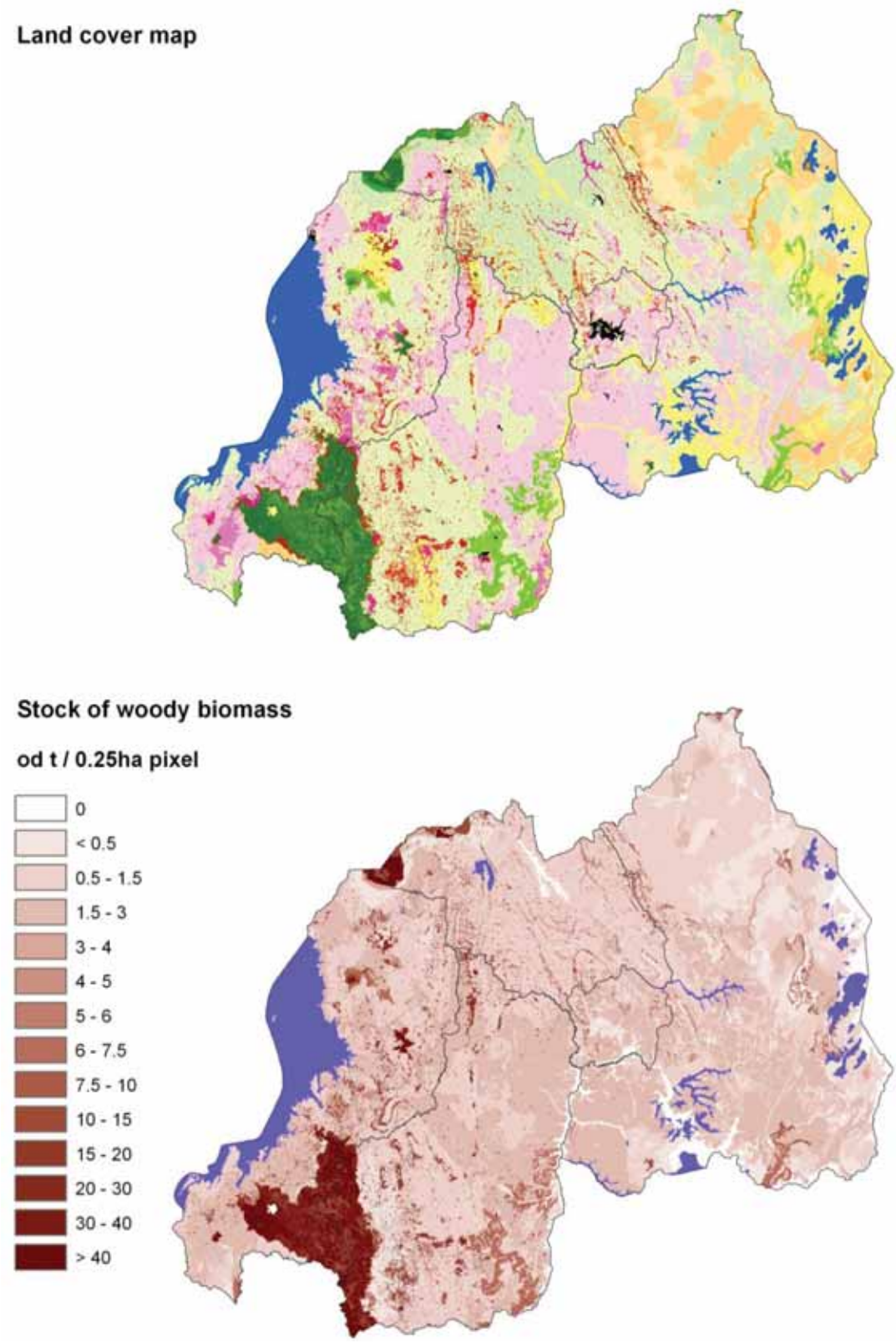
Unfortunately, the national orthophoto coverage produced by Swedsurvey for the National Land Centre is still incomplete in the north and western portions of the country (RDC border areas). In order to assess, at least preliminarily wood resources in rural areas the estimation was based on the 446 sampling units analyzed, out of 616. Tree and shrub cover values from the sampling units so far completed, associated to forest inventory results, were therefore used to produce a first estimation of woody biomass stock and sustainable productivity. Table 7 provides the preliminary TOF survey results subdivided by rainfall zones (see rainfall zones in Figure A6.1 in Annex 6). According to the data available the stock of the trees and shrubs outside forest is approximately 14 million oven-dry tons of woody biomass.

The spatial distribution of this resource was based on the Africover LCCS Map. The value of stock and productivity associated to the Africover classes are given in Annex 2.

Table 7: Preliminary Tree Outside Forest survey results

Rainfall zone	< 800	800-900	900-1100	1100-1500	>1500	Total
Sample area (ha)	390	1,370	2,000	600	100	4,460
Young trees (ha)	3.0	31.8	41.8	31.3	2.4	110.3
Old trees (ha)	15.6	34.5	84.4	42.2	8.4	185.1
Total tree cover area (ha)	18.7	66.3	126.1	73.5	10.8	295.4
Tree cover %	4.8	4.8	6.3	12.3	10.8	6.6
tree stock in odt (@80 od t ha^{-1})	**3.8**	**3.9**	**5.0**	**9.8**	**8.7**	**5.3**
Shrubs (ha)	71.4	90.2	109.2	4.6	0.8	276.3
coffee (ha)		0.7	14.3	5.0		19.9
Tea (ha)				0.2	0.6	0.8
Young fruit trees (ha)			0.1	0.1		0.2
Old fruit trees (ha)		0.6	2.8	1.4	0.3	5.1
Total shrubs subtotal (ha)	71.4	91.5	126.3	11.3	1.8	302.2
Shrubs cover %	18.3	6.7	6.3	1.9	1.8	6.8
shrub stock in od t (@25 od t ha^{-1})	**4.6**	**1.7**	**1.6**	**0.5**	**0.4**	**1.7**
ToF stock in odt ha^{-1}	**8.4**	**5.5**	**6.6**	**10.3**	**9.1**	**7.0**
Non-forest area (km^2)	1,088	3,888	6,778	6,916	1,406	20,075
ToF total stock (milliion od t)	**914**	**2,154**	**4,489**	**7,105**	**1,281**	**14,039**

Figure 9: Land cover map merging ISAR-NUR Forest Cover Map and Africover Map (top map). Map of estimated woody biomass stock (bottom map).



Note: See Annex_ for land cover class description and coding as well as for the associated stock and productivity values.

Accessibility and availability

Accessibility

The physical and legal accessibility of the existing sources of woody biomass was analyzed through the integration of the data layers that are summarized in Figure 10, which shows (i) the result of the cost-distance analysis based on slope, road network, market locations and populated places and (ii) the IUCN-WCMC map of protected areas that was used to map access limitation to wood resources due to legal reasons.

Physical accessibility

Given the extremely high density of rural population, with over 360 inhabitants per km^2, and its diffuse distribution, there are no significant constraints to the physical accessibility of the woody biomass resources in Rwanda. Moreover, discussions with forest managers revealed that even at high slope the exploitation is allowed if basic soil protection prescriptions are followed, such as selective felling and coppicing rather than clearfelling.

Consequently, the cost-distance map was not used for resources accessibility in the supply module. The slope map and the cost-distance analysis are very useful anyhow, for the analysis and delineation of woodshed, for instance, and for the identification of the land areas above 55% slope that are suitable for new plantations according to recent land protection prescriptions.

Legal accessibility

Legal accessibility constraints were taken from IUCN-WCMC categories (Figure 10, bottom map) and their application in the country. Accordingly, no access is allowed to these areas. Another layer used concerns the protected marshlands. Several protection levels are associated to the map provided. On the basis of such definitions, no access was associated to the areas with "total protection" while for the other marsh areas no limitation was given. In any case, the grass swamps of the marshlands are not significant producers of woody biomass and therefore non suitable to wood extraction.

Availability

The woody biomass resource potentially available for energy applications is estimated by deducting from the accessible sustainable productivity the other no-energy uses. These include the industrial roundwood and the construction material.

Industrial roundwood

Missing other references, the industrial roundwood production value reported in the FAOstat Country Statistics (495,000 m3 / year) was deducted from plantation productivity as a percent of the entire accessible plantation productivity. It should be highlighted, however, that this is an estimation offered by FAO in absence of official country data.

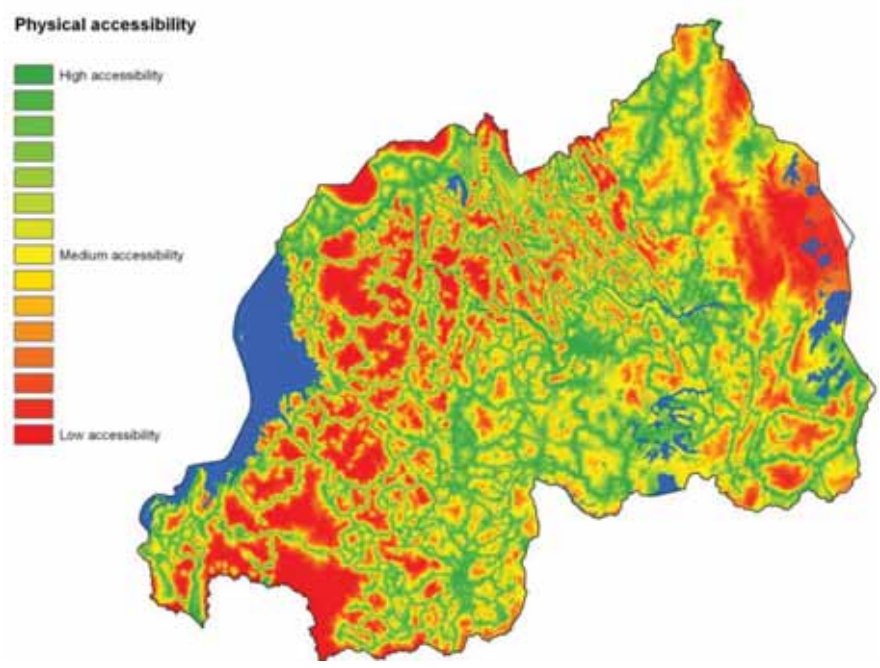
Construction material

The construction material used for huts and houses construction in rural areas was estimated, tentatively only due to lack of data, as 20 air dry kg per rural inhabitant per year, as discussed in the section on "Consumption of construction material" in the previous chapter. This corresponds to some 16.4 oven dry kg/rural person/year. Given its population-related character this component was added to the demand layers, rather than deducted from the supply layers. The estimated spatial distribution of construction wood consumption in the lower map in Figure 7, while summary statistics by District are given in Table 2, both in the previous chapter.

Total woody biomass supply potential

The map in Figure 11 shows the distribution of the total sustainable woody biomass potentially available for energy uses according to BAU and MAN variants. Respectively, these are estimated at 1.1 and 1.7 million tons (oven dry). The District-wise statistics of stock, accessible and available increments according to BAU and MAN variants are reported in Table 8.

Figure 10: Accessibility mapping. Top map: physical accessibility based on slope, motorable road network, urban areas and market locations. Bottom map: protected areas (ref. IUCN-WCMC 2009 and Protected Marshlands) that determine the legal accessibility of resources.



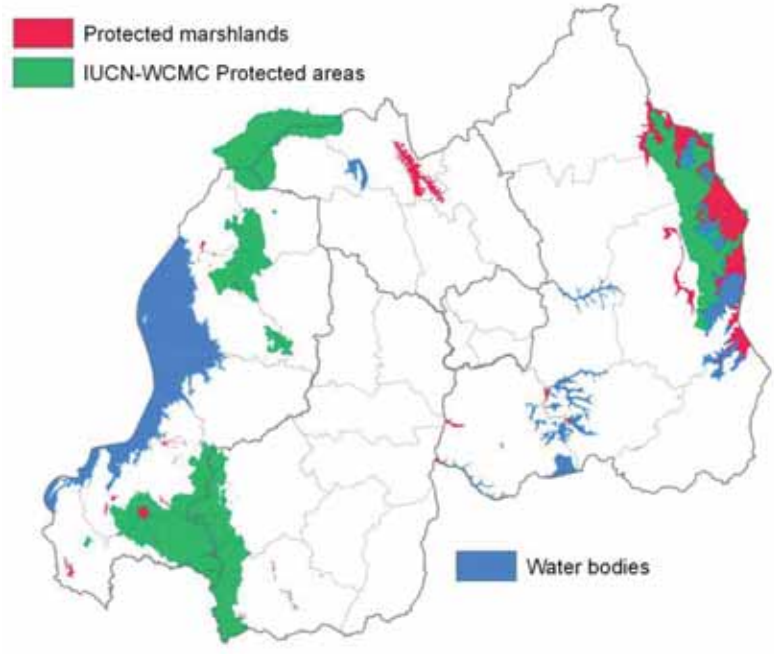


Figure 11: Maps of sustainable and accessible woody biomass increment potentially available for energy use.

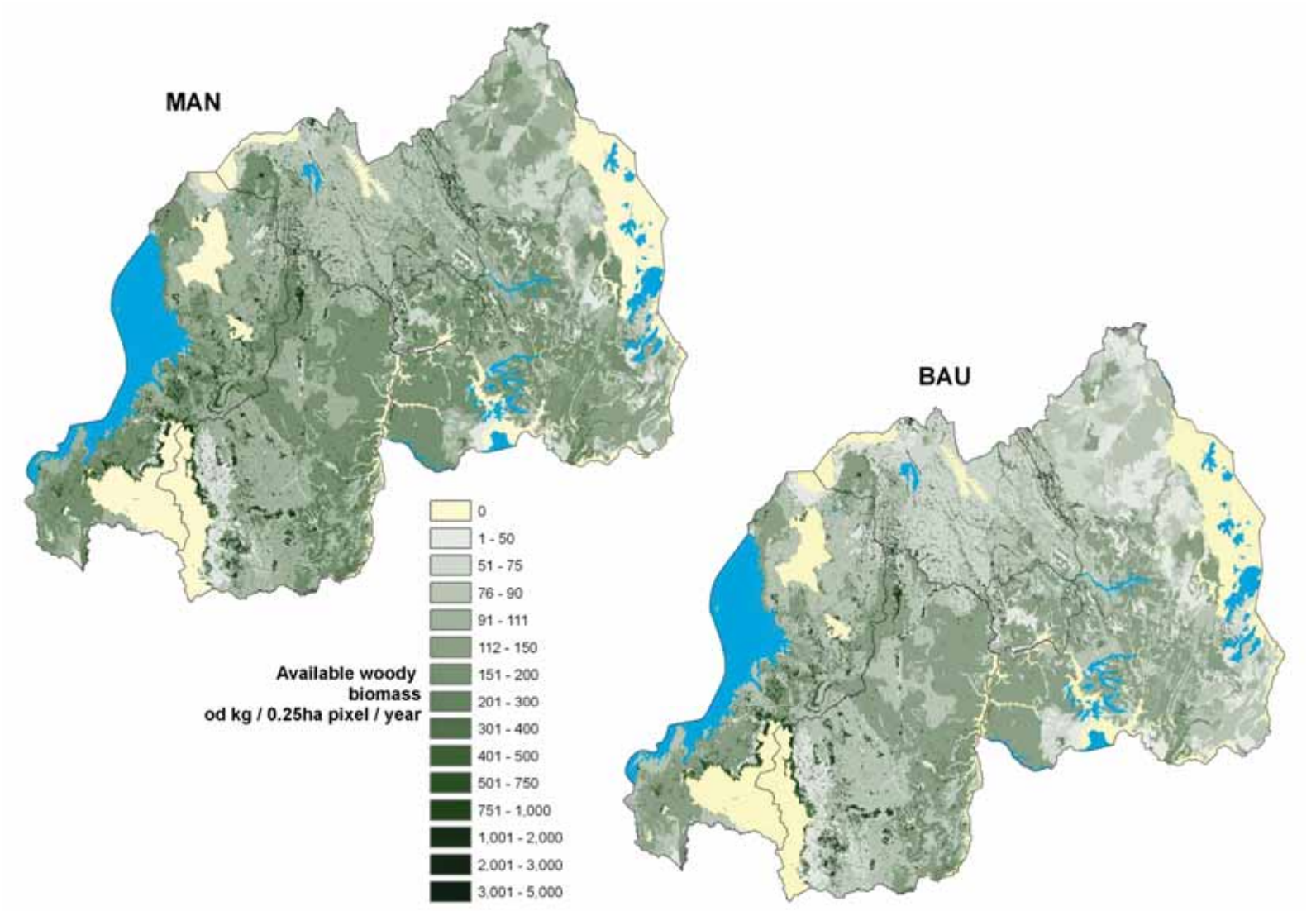


Table 8: WISDOM summary of Supply Module results at District level according to Business as Usual (BAU) and Managed (MAN) scenarios. Values are oven-dry t of woody biomass.

		AREA_ha	Stock	Mean Annual Increment (MAI)		Accessible MAI		Available MAI	
District (2006)	Code	hectares		BAU	MAN	BAU	MAN	BAU	MAN
NYARUGENGE	101	13,398	114,692	8,036	17,095	8,036	17,095	6,176	13,757
GASABO	102	42,922	425,367	22,946	41,101	22,946	41,101	19,827	35,512
KICUKIRO	103	16,673	135,068	6,460	9,853	6,460	9,853	6,091	9,190
NYANZA	201	67,216	908,681	43,224	58,618	43,224	58,618	36,962	52,711
GISAGARA	202	67,922	955,765	43,085	58,544	43,085	58,544	36,689	52,455
NYARUGURU	203	101,019	5,207,770	128,702	176,067	95,446	135,840	63,785	105,837
HUYE	204	58,158	822,509	50,321	69,216	50,321	69,216	37,820	57,650
NYAMAGABE	205	109,040	5,478,440	142,854	188,581	109,588	149,296	73,802	117,046
RUHANGO	206	62,683	627,428	30,450	41,289	30,450	41,289	27,968	38,880
MUHANGA	207	64,766	1,023,940	64,117	89,996	64,117	89,996	47,018	73,739
KAMONYI	208	65,551	705,998	34,060	46,307	34,060	46,307	30,621	42,981
KARONGI	301	99,309	2,015,940	127,620	183,347	126,033	181,465	85,120	141,867
RUTSIRO	302	115,695	1,484,130	65,985	91,544	49,994	70,132	36,745	57,546
RUBAVU	303	38,839	405,638	24,403	33,948	19,270	26,922	16,092	23,796
NYABIHU	304	53,133	1,318,180	63,613	87,835	37,343	54,220	26,439	43,517
NGORORERO	305	67,895	925,191	61,665	86,673	52,926	75,483	39,677	62,549
RUSIZI	306	95,813	6,968,620	92,579	119,588	32,432	44,505	28,157	40,343
NYAMASHEKE	307	117,358	6,194,880	130,719	170,204	96,665	129,579	69,654	105,378
RULINDO	401	56,696	426,911	36,787	53,989	36,787	53,989	27,832	44,912
GAKENKE	402	70,408	548,296	57,258	85,760	57,258	85,760	40,038	68,311
MUSANZE	403	53,025	1,834,970	42,095	58,467	29,487	43,106	22,423	35,919
BURERA	404	64,445	416,432	32,707	48,055	30,263	44,895	22,855	37,348
GICUMBI	405	82,955	568,470	45,987	67,067	45,936	66,995	36,143	57,019
RWAMAGANA	501	68,201	578,088	31,867	44,090	31,866	44,089	28,446	40,630
NYAGATARE	502	191,941	954,658	60,389	83,603	55,732	77,187	52,888	74,311
GATSIBO	503	158,218	880,516	59,959	84,566	53,717	76,095	46,402	68,699
KAYONZA	504	193,474	1,205,640	55,929	75,067	45,669	61,169	45,360	60,856
KIREHE	505	118,371	735,473	34,511	46,419	34,495	46,396	34,315	46,214
NGOMA	506	86,772	671,872	30,017	40,123	29,994	40,093	29,442	39,534
BUGESERA	507	129,038	1,041,210	45,604	60,985	45,564	60,933	44,310	59,665
Total Rwanda		**2,530,933**	**45,580,773**	**1,673,948**	**2,317,999**	**1,419,161**	**2,000,168**	**1,119,096**	**1,708,170**

Integration Module

The scope of the Integration Module is to combine, by discrete land units (pixels-level and sub-national unit-level), the parameters developed in the demand and supply modules, in order to discriminate areas of potential deficit or surplus according to estimated consumption levels and sustainable production potentials.

The first and most important result of the integration module is the balance between the fraction of the potential sustainable productivity available for energy and the total consumption of woody and non-woody biomass for energy generation.

Supply/demand balance

Pixel-level balance

The supply/demand balance at pixel level is calculated by deducting the pixel-level consumption from the pixel-level available productivity (see productivity categories in Section "Definition of supply potentials").

Local neighborhood balance

The calculation of supply/demand balance by pixel has a useful accounting function but it represents a somewhat virtual balance since individual cells are usually either a production or a consumption site. More meaningful is to represent the relation between the consumption and the supply potential within a surface somewhat related to the real supply context. In case of local household consumption in rural areas such horizon is represented by the distance that household's members are prepared to go to fetch fuelwood, on foot or by local transport means.

In order to visualize this factor the balance of each cell is calculated as the balance between the mean supply and consumption values within a chosen circle around each cell.
In this case a circle of 1.5 km (30 pixels) was applied.

The maps in Figure 12 show the supply/demand balances resulting from the combination of the two supply (BAU and MAN) and the two demand (BAU and AME) variants.

The first one (BAU-BAU), with an overall annual deficit of approximately 1.83 million tons is the most realistic one, given current conditions.

The other three ones are meant to provide a "what if" perception: what would be the impact if

- the stoves and charcoal making become more efficient = deficit of some 1.34 million t;
- if current wood resources are better managed = deficit of some 1.24 million t;
- if these two improved scenarios are combined = deficit of some 0.75 million t.

Table 9 shows the District-wise summary results of the various supply and demand combinations as well as the percent of the demand fulfilled by the available resources.

The left-hand maps in Figure 13 show the balances relative to the two extreme variants (BAU-BAU and MAN-AME) calculated at Sector level. to the two extreme variants (BAU-BAU and MAN-AME) calculated at Sector level.

The right-hand maps in Figure 13 show the Sector-level percent of the demand fulfilled by the available resources according to the two extreme variants (BAU-BAU and MAN-AME).

The results achievable by implementing improved stoves, carbonization and forest/agro forestry management programmes, given current land uses, appears important but still insufficient, as can be seen by the fact of the overall balance remains negative. Its is evident that more plantation areas are needed, otherwise the eating out of the forest stock, rather than the sustainable increment, is inevitable.

Figure 12: Supply/demand balances resulting from the combination of the two supply (BAU and MAN) and the two demand (BAU and AME) variants

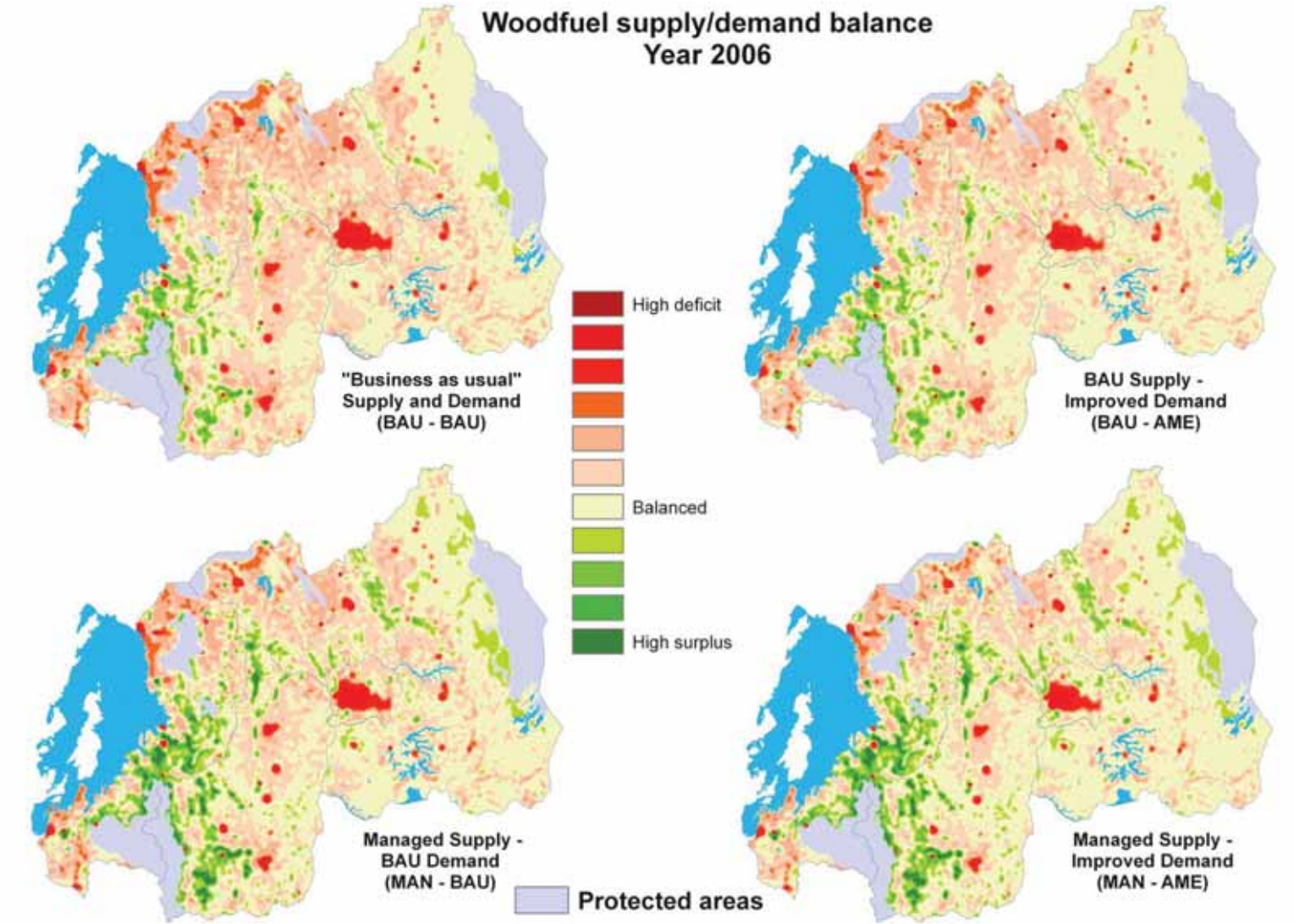
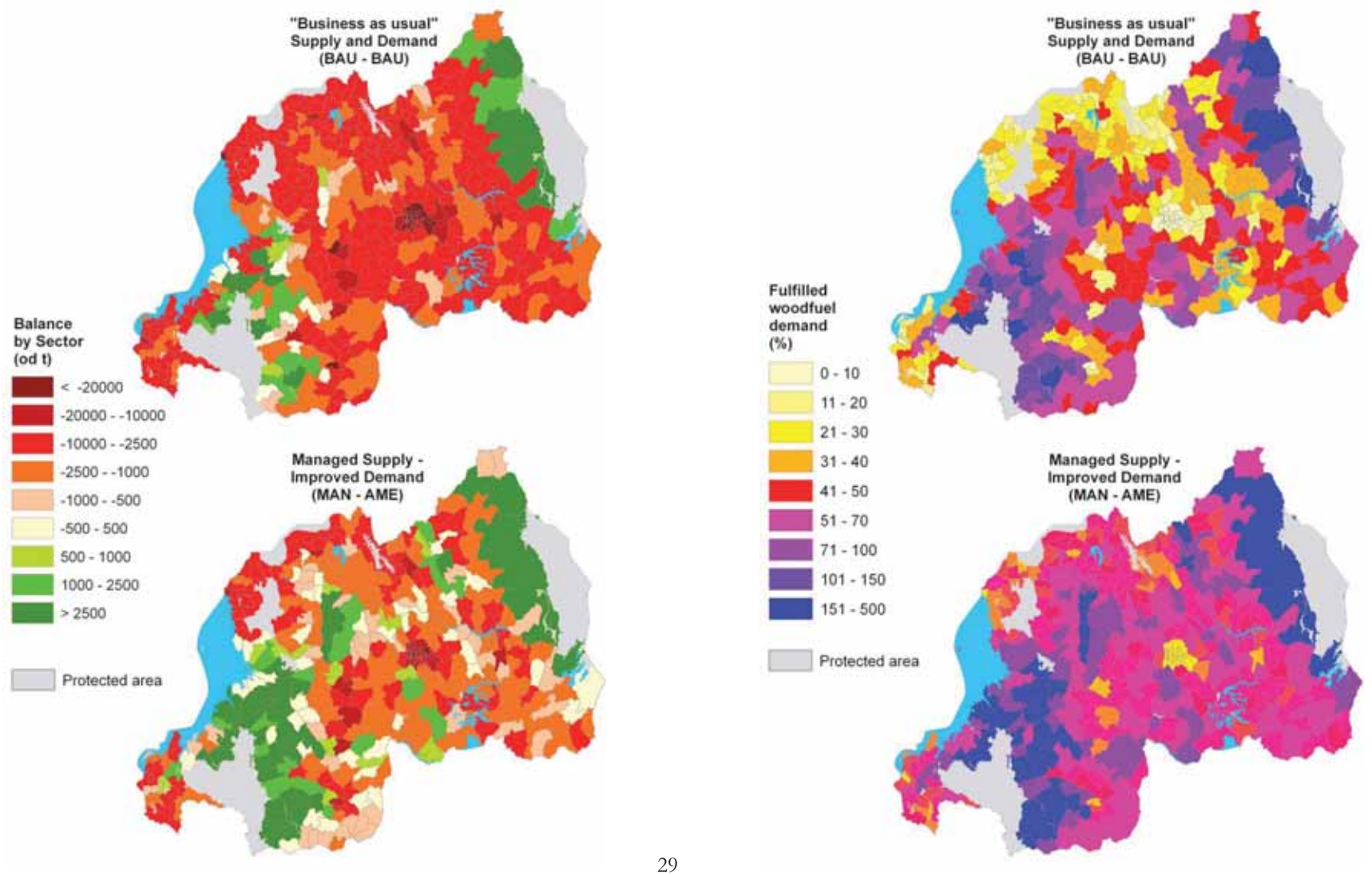


Table 9: District level summary results of supply/demand balances relative to the various supply and demand scenarios. Values are oven-dry t of woody biomass.

			Balance (od t)				Demand (od t)		Supply (od t)		Percent fulfilled (%)	
District (2006)	Code	AREA_ha	BAU-BAU	BAU-AME	MAN-BAU	MAN-AME	BAU	AME	BAU	MAN	bau-bau	man-ame
NYARUGENGE	101	13,398	-194,693	-122,091	-187,092	-114,490	204,529	130,574	6,176	13,757	3.0	10.5
GASABO	102	42,922	-241,516	-150,397	-226,004	-134,886	258,481	168,353	19,827	35,512	7.7	21.1
KICUKIRO	103	16,673	-179,526	-111,252	-176,409	-108,135	185,540	117,315	6,091	9,190	3.3	7.8
NYANZA	201	67,216	-36,993	-28,500	-21,284	-12,791	73,791	65,303	36,962	52,711	50.1	80.7
GISAGARA	202	67,922	-38,291	-30,733	-22,529	-14,971	74,868	67,349	36,689	52,455	49.0	77.9
NYARUGURU	203	101,019	-3,910	2,186	38,066	44,163	67,380	61,289	63,785	105,837	94.7	172.7
HUYE	204	58,158	-58,789	-46,478	-38,789	-26,478	96,936	84,592	37,820	57,650	39.0	68.2
NYAMAGABE	205	109,040	-15,124	-5,761	28,155	37,518	88,907	79,524	73,802	117,046	83.0	147.2
RUHANGO	206	62,683	-48,815	-40,026	-37,908	-29,120	76,797	68,009	27,968	38,880	36.4	57.2
MUHANGA	207	64,766	-61,542	-46,777	-34,944	-20,178	108,387	93,607	47,018	73,739	43.4	78.8
KAMONYI	208	65,551	-41,798	-34,909	-29,209	-22,320	72,512	65,673	30,621	42,981	42.2	65.4
KARONGI	301	99,309	-3,814	7,554	52,189	63,556	91,120	78,039	85,120	141,867	93.4	181.8
RUTSIRO	302	115,695	-37,688	-29,865	-16,977	-9,154	76,591	67,248	36,745	57,546	48.0	85.6
RUBAVU	303	38,839	-85,454	-69,532	-77,888	-61,967	107,905	87,756	16,092	23,796	14.9	27.1
NYABIHU	304	53,133	-52,614	-45,032	-35,682	-28,100	78,993	71,357	26,439	43,517	33.5	61.0
NGORORERO	305	67,895	-43,680	-35,755	-20,723	-12,798	83,645	75,713	39,677	62,549	47.4	82.6
RUSIZI	306	95,813	-78,258	-64,190	-66,354	-52,286	111,521	94,048	28,157	40,343	25.2	42.9
NYAMASHEKE	307	117,358	-24,671	-14,445	10,272	20,497	99,100	85,466	69,654	105,378	70.3	123.3
RULINDO	401	56,696	-45,842	-39,011	-28,378	-21,547	73,740	66,987	27,832	44,912	37.7	67.0
GAKENKE	402	70,408	-49,391	-40,974	-21,459	-13,042	89,137	80,662	40,038	68,311	44.9	84.7
MUSANZE	403	53,025	-69,341	-58,306	-55,847	-44,812	93,499	81,414	22,423	35,919	24.0	44.1
BURERA	404	64,445	-65,325	-56,909	-51,040	-42,624	88,510	79,830	22,855	37,348	25.8	46.8
GICUMBI	405	82,955	-81,712	-67,863	-60,863	-47,014	117,939	104,036	36,143	57,019	30.6	54.8
RWAMAGANA	501	68,201	-48,094	-39,079	-36,173	-27,157	77,325	67,816	28,446	40,630	36.8	59.9
NYAGATARE	502	191,941	-33,465	-23,784	-12,140	-2,460	86,129	76,444	52,888	74,311	61.4	97.2
GATSIBO	503	158,218	-41,536	-32,610	-19,298	-10,371	88,562	79,352	46,402	68,699	52.4	86.6
KAYONZA	504	193,474	-19,582	-13,228	-4,251	2,103	64,798	58,330	45,360	60,856	70.0	104.3
KIREHE	505	118,371	-36,759	-29,766	-24,902	-17,909	71,218	64,108	34,315	46,214	48.2	72.1
NGOMA	506	86,772	-46,683	-37,836	-36,963	-28,116	77,747	67,883	29,442	39,534	37.9	58.2
BUGESERA	507	129,038	-42,523	-32,581	-27,401	-17,459	88,342	77,377	44,310	59,665	50.2	77.1
	Total	**2,530,933**	**-1,827,428**	**-1,337,948**	**-1,241,825**	**-752,345**	**2,973,945**	**2,465,456**	**1,119,096**	**1,708,170**	**37.6**	**69.3**

Figure 13: Left-hand maps: Supply-demand balance calculated and represented at Sector level. BAU-BAU scenario (top) and MAN-AME scenario (bottom). Right-hand maps: Percentage of sector-level demand fulfilled by the available productivity therein. BAU-BAU scenario (top) and MAN-AME scenario (bottom)



Woodfuel deficit and agricultural residues

Obviously, the unsustainable pressure on the forest stock is only occurring where the stock exists. In fact, in the rural areas where there is no forest the most likely effect of woodfuel shortage is the use of a higher proportion of agricultural residues in the mix of fuels used to satisfy basic households needs. The impact in this case is on the reduced re-integration of residues' nutrients into the soil and thus a loss of soil fertility, with consequent reduction of crop productivity and an increased level of vulnerability and worsened living conditions. The nexus between rural subsistence energy and soil fertility in Rwanda appears deep and far reaching and it certainly deserves a dedicated analysis.

With the scope of visualizing this aspect, a new balance analysis was conducted assuming that 25% of the fuel demand is provided by agricultural residues rather than woody biomass from trees and shrubs. The results of this hypothesis applied to the BAU-BAU scenario are shown in Table 10 and mapped in Figure 14.

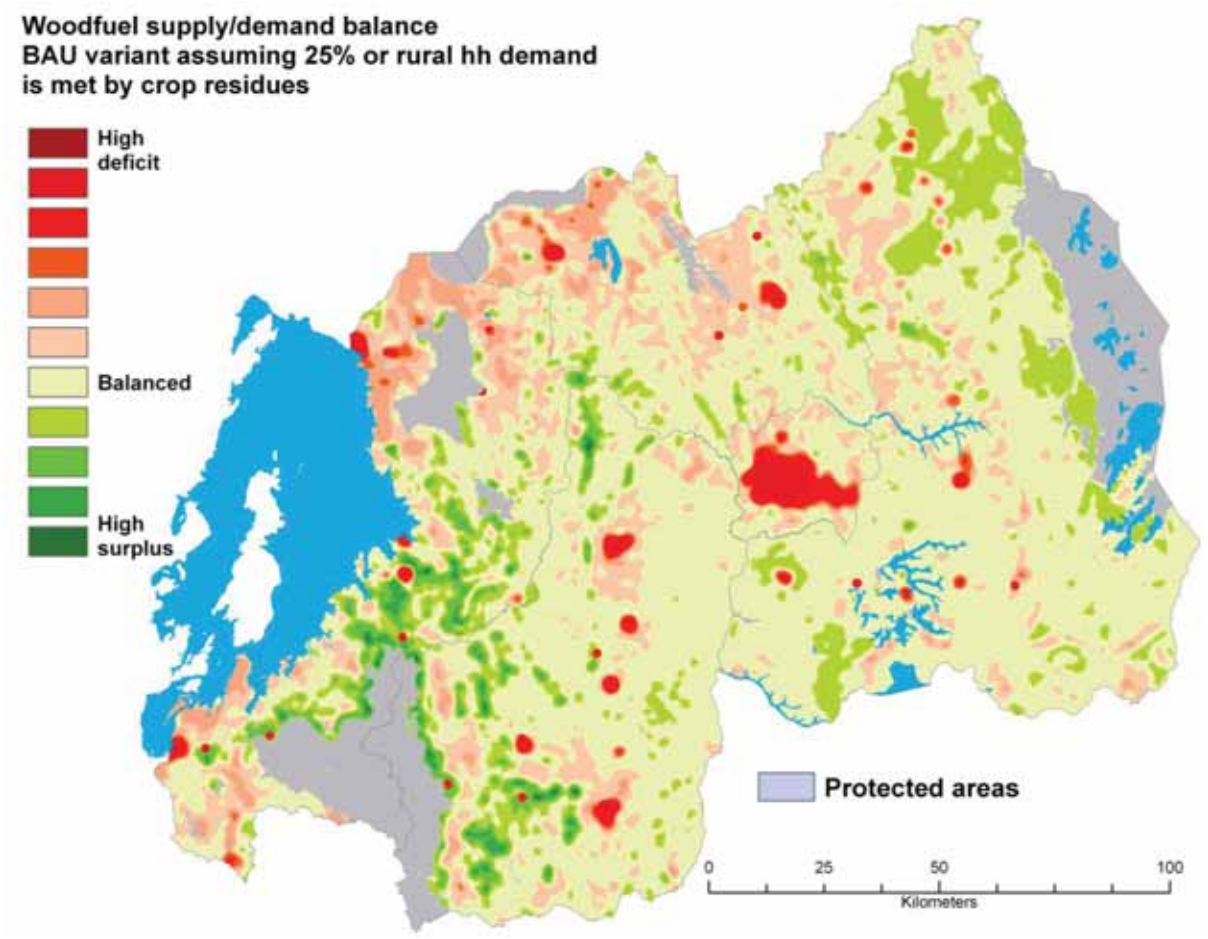
Table 10: District-wise woodfuel supply/demand balance as per original BAU scenario, 25% fraction of the rural households demand expressed in wood-equivalent od t and consequent new woody biomass balance.

District (2006)	Code	Supply/demand balance – BAU BAU scenario	25% of rural hh demand met by residues (wood-equivalent)	resulting wood biomass balance
NYARUGENGE	101	-194,693	3,011	-191,682
GASABO	102	-241,516	11,718	-229,798
KICUKIRO	103	-179,526	3,008	-176,518
NYANZA	201	-36,993	13,793	-23,200
GISAGARA	202	-38,291	16,832	-21,459
NYARUGURU	203	-3,910	15,056	11,146
HUYE	204	-58,789	15,601	-43,188
NYAMAGABE	205	-15,124	17,508	2,384
RUHANGO	206	-48,815	15,255	-33,560
MUHANGA	207	-61,542	16,333	-45,209
KAMONYI	208	-41,798	16,930	-24,868
KARONGI	301	-3,814	16,633	12,819
RUTSIRO	302	-37,688	17,993	-19,695
RUBAVU	303	-85,454	15,668	-69,786
NYABIHU	304	-52,614	18,279	-34,335
NGORORERO	305	-43,680	19,277	-24,403
RUSIZI	306	-78,258	20,445	-57,813
NYAMASHEKE	307	-24,671	22,136	-2,535
RULINDO	401	-45,842	16,281	-29,561
GAKENKE	402	-49,391	20,817	-28,574
MUSANZE	403	-69,341	18,391	-50,950
BURERA	404	-65,325	20,714	-44,611
GICUMBI	405	-81,712	21,104	-60,608
RWAMAGANA	501	-48,094	15,411	-32,683
NYAGATARE	502	-33,465	17,492	-15,973
GATSIBO	503	-41,536	20,464	-21,072
KAYONZA	504	-19,582	15,113	-4,469
KIREHE	505	-36,759	16,655	-20,104
NGOMA	506	-46,683	16,494	-30,189
BUGESERA	507	-42,523	18,825	-23,699
	Total	**-1,827,428**	**493,237**	**-1,334,191**

A first-level impression that we can derive from the new balance map (Figure 14) is that, compared to the original BAU-BAU balance map shown in Figure 12, it appears that most of the rural area has moved to a condition of balance. From a "woody biomass perspective", excluding the farm residues, the map in Figure 14 is probably more realistic than the original BAU-BAU map.

The relation between the use of woody biomass and farm residues for energy is an issue that deserves further analysis based on the present WISDOM dataset and, most important, that requires further investigation and data collection.

Figure 14: Map of the woodfuel supply/demand balance in the BAU scenario assuming that 25% of the rural demand is met by farm residues rather than wood.



Priority zoning

Integration of wood energy and poverty

The impact on the population of a deficit condition in woodfuel supply/demand balance depends primarily on the capacity of such population to acquire marketed woodfuels transported from distant production sites, or other commercial fuels. In synthesis, the poorer the populations living in deficit woodfuel conditions, the stronger the impact on their subsistence energy supply and overall living conditions. The integration of spatially-discrete poverty indicators with woodfuel supply/demand balance data can therefore considerably enhance definition of vulnerable areas and populations in relation to subsistence energy supply.

The poverty-related spatial data set used for the combined poverty-wood energy analysis was derived from the study "RWANDA – Comprehensive Food Security and Vulnerability Analysis and Nutrition Survey" conducted in early 2009 (WFP and NISR, 2009) over the whole country with exclusion of Kigali Province. The parameter considered in the combined analysis was the fraction of the population in the "poorest" category according to the Wealth Quintiles applied in that study. The WFP-NISR study presents many other important indicators that could be considered in the combined analysis. The combined analysis here discussed is intended as example of integrated analysis rather than as an exhaustive coverage of the important nexus between wood (biomass) energy and population vulnerability.

Figure 15 shows the areas of the country (Sectors) ranked by various combinations of woodfuel balance conditions and poverty according to the BAU-BAU scenario and to the MAN-AME scenario. The first is the more realistic representation of today's conditions, while the second one helps to identify the areas that would remain critical even if best practices are efficiently adopted. The matrix combining poverty parameters of the CFSVA study and the supply/demand balance conditions is reported below the maps in Figure 15. This matrix is the basis of the criticality ranking used for the map legend.

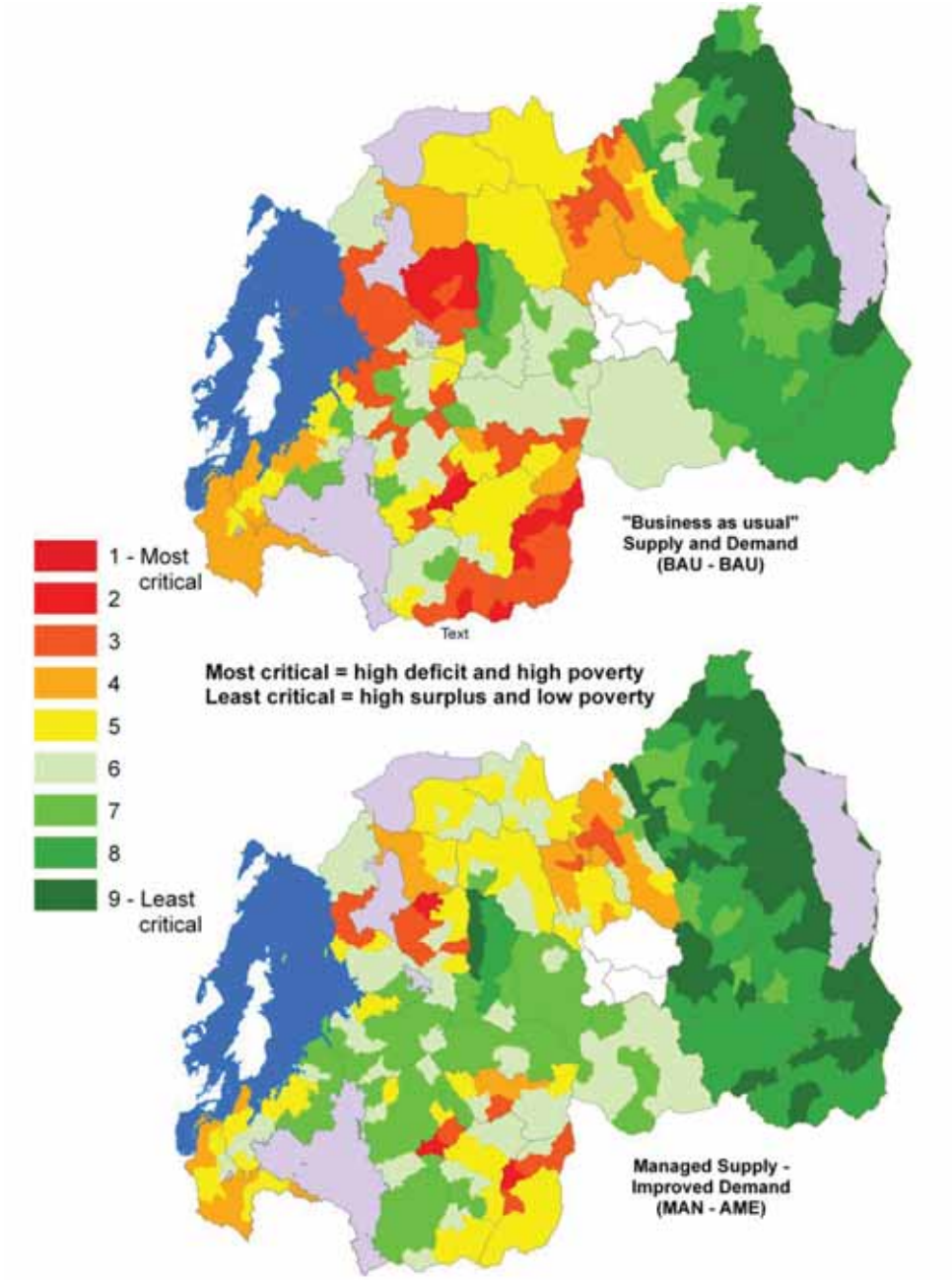
Besides knowing areas and locations where critical conditions occur, it's important to quantify the number of persons that suffer from concomitant conditions of extreme poverty and shortage of subsistence energy resources. Table 11 provides an estimation of the population living in the various criticality categories in current BAU-BAU conditions and how improved demand and supply conditions could change the situation.

A likely direct consequence of such critical conditions is the high pressure on the limited forest resources available in these areas and the massive use of agricultural residues for energy. These represent major threats on the environmental balance in these regions with major risks of deforestation and forest degradation and progressive impoverishment of soil nutrients and agricultural productivity.

Table 11: Population by concomitant poverty and woodfuel conditions in 2000

poverty & subsistence energy ranking	**Current scenario (BAU supply and BAU demand)**		"Managed" scenario (managed supply and improved consumption)	
	Population	**%**	Population	%
1 – most critical	**40,517**	**0.5**	0	0.0
2	**350,740**	**4.4**	98,457	1.2
3	**1,157,101**	**14.4**	484,715	6.0
4	**1,262,822**	**15.7**	881,382	10.9
5	**1,610,823**	**20.0**	1,736,042	21.5
6	**1,687,200**	**20.9**	1,840,628	22.8
7	**866,784**	**10.8**	1,454,171	18.0
8	**958,421**	**11.9**	1,072,334	13.3
9 – least critical	**122,192**	**1.5**	488,871	6.1
Total (excl. Kigali Province)	**8,056,600**	**100.0**	8,056,600	100.0

Figure 15: Map of poverty and wood energy balance. Criticality ranking codes in the map legend are based on the matrix shown below, combining poverty parameters and woodfuel balance conditions.



Percent of population in "Poorest" and "Poor" conditions (Wealth Quintiles in CFSVA strata)

Poorest	36.7	32.2	28.3	28.1	23	21.9	20.4	18.8	17.3	16.3	15.8	15.8	13.5	12.8	12.6	12.4
Poor	21.6	17.1	26.1	19.3	13.4	21.6	29.8	22.9	26.4	20.1	18.8	17.5	18.4	17.4	17.3	13.8
very high deficit	1	1	2	3	3	3	4	4	5	5	5	5	6	6	6	7
high deficit	2	2	2	3	3	4	4	4	5	5	5	6	6	6	7	8
medium deficit	3	3	3	3	4	4	4	5	5	5	5	6	6	7	8	8
low deficit	5	5	5	5	5	5	5	5	5	6	6	6	7	7	8	9
low surplus	6	6	6	6	6	6	6	6	6	6	6	7	7	8	9	9
high surplus	7	7	7	7	7	7	7	7	7	7	7	8	8	9	9	9

Conclusions and recommendations

Conclusions

General

The comprehensive and spatial-explicit vision of supply and demand is an essential pre-requisite to wood energy planning and strategy formulation at local and national levels and synergies among institutions for an integrated multi-sectoral approach are absolutely vital

WISDOM Rwanda provides a first comprehensive and spatially explicit vision for Rwanda, thanks to the application of the WISDOM methodology and to the knowledge shared by institutions and to some new data.

In addition to NAFA, the main contributors to the WISDOM data set include:

National Land Center (TOF survey)

PAREF (TOF survey, supply analysis, woosdshed analyses)

ISAR (Forest inventory results)

C GIS NUR (Forest map, etc.)

MINAGRI (crop data, food industry, GIS data)

ORTPN (protected areas details)

MININFRA (urban and rural consumption data, energy data)

NISR (admin structure; demography; projections; EICV; etc.)

MINICOM (industries, markets; etc.)

MININTER/MINADEF (prisons; fuelwood consumption)

MINEDUC (schools)

MINISANTE (hospitals, beds)

MINALOC (refugees centers; etc.)

WISDOM is a shared, common product. Given the limits of existing data, the development of the WISDOM geostatistical database implied many assumptions and tentative value attributions. Competent critics are most welcome, especially if they can correct possible misinterpretation of existing data or if they can indicate new more reliable references. As a common product, WISDOM implies common responsibility on its data

Results

WISDOM Rwanda is conceived as a strategic planning tool to be maintained, deepened and, most important, used by forestry and energy and rural development planners concerned with wood energy. In this respect, the analytical conclusions, thematic maps and tables here presented should be considered as the first step in the analysis of this sector and not its conclusion. The integrated analysis of woodfuel deficit and poverty, for instance, or the nexus between woodfuel deficit, use of residues and soil fertility are only introductory examples of the analyses that can be made.

In fact, the main result of the activity is the WISDOM geodatabase, more than the single table and map that have been produced in the process, and the possibility to "refresh" the system with new reliable parameters as they become available.

From the analysis carried out so far a wide variety of results were produced, ranging from stock and

productivity estimates, consumption estimates and several supply/demand balances, spatially (at 50m pixel level) as well as by administrative units of all levels.

Amongst this wealth of data and findings, the following aspects may be highlighted:

- According to the current situation, the total annual productivity of woody biomass accessible and potentially available for energy use, for the entire country, is estimated at 1.1 Mt (t*10^6, oven dry). With better forest and agro-forestry management, and with the current plantation area, it is realistically estimated that the annual supply potential could raise to 1.7 Mt.
- The consumption in the residential sector with current carbonization and stove efficiency is estimated at 2.7 Mt. With realistic improvements in charcoal making efficiency and further dissemination of improved stoves, the demand in the residential sector could lower to 2.2 Mt.
- Due to lack of reliable information, the estimation of the current consumption of woodfuels in the commercial and public sectors and of the consumption of construction material is only tentative. According to such estimates, the woodfuels annually consumed in these sectors is 146 thousand tons that, with increased efficiency in charcoal making and stoves dissemination could lower to 121 thousand tons. The annual consumption of construction material is tentatively estimated at 125 thousand tons.
- To be noted that the value reported by FAO in its on-line Forestry Statistics database ForeSTAT is more than double of the currently estimated consumption In absence of official country data, the value reported by ForeSTAT for Rwanda in 2006 (9.4 million m^3 or approximately 6.5 million tons oven dry) is FAO own estimation resulting from a model approach based on income parameters and previous consumption references.
- The national supply/demand balance, according to current situation shows an annual deficit of 1.8 Mt. With improved management and conversion efficiencies, the balance could raise to a deficit of "only" 0.75 Mt. It should be noted, however, that agricultural residues are often used as substitute of wood, especially in the rural areas where wood is particularly scarce. Reliable figures on the quantity of residues used are not available but it is reasonable to assume that the true wood deficit is lower than the values stated above. In this case the most important contribution of the WISDOM analysis is in highlighting the areas where there is a higher pressure on the few available resources, whether woody or farm residues, and the risk of shortage of subsistence energy in local household is higher.
- Over 1.5 million people (20% of people of rural provinces) live in areas with concomitant conditions of serious woodfuel deficit and high poverty, which are cause of extreme vulnerability. These populations and the areas where they live (delimited on WISDOM maps) should be given highest priority in future projects.
- The true value, however, is not in these summary figures that tell us very little about what and where the remedial action should concentrate. The value is in the georeferenced detail that well represents the local character of wood energy and that allows the discrimination of local conditions and the formulation of adequate remedial actions.

It is evident from the analysis conducted that there is no single-variable solution to the wood energy equation. The situation is so tight that the efforts aiming at sustainable wood energy must be oriented in all possible direction (management, efficiency, new planting areas, promotion of affordable fuel alternatives, etc.) in wide institutional synergies and with clear territorial priorities.

But generic strategies are unlikely to be effective. The character and emphasis of the action must be tailored to local conditions, and WISDOM Rwanda is meant to provide support to the formulation of georeferenced planning and strategies.

On a more general perspective, the WISDOM analysis for Rwanda already produced, or is expected to

produce in the near future, the following benefits :

- Holistic vision. For the first time the wood energy issue can be visualized and analyzed over the entire country maintaining at the same time a local perspective.
- Priority areas definition. The local perspective and national consistency of analysis and parameters permits the identification of priority areas of intervention and/or further analysis.
- Valorization of existing data/knowledge. The need to feed the WISDOM modules with the best available information on supply and consumption aspects implied the review and use of every piece of information, study, survey etc. ever done over these subjects in the country, thus attributing factual value to such knowledge and offering a comprehensive context of analysis to information otherwise fragmented.
- Critical data gaps definition. A thorough review of the information available allowed the identification of data gaps that are really critical for a good understanding and for the formulation of sound policies.
- Optimize available resources. The identification of priority areas of intervention, in geographic as well as thematic terms, allows circumscribing and focusing future actions (resource management, additional data collection, etc.) and thus enhancing the efficiency and reducing the costs of such actions.
- Promote cooperation and synergies. The inter-sectoral and interdisciplinary character of WISDOM implies the exchange of information among agencies and it favors the discussion about the multifaceted wood energy "sector" over a common shared ground built with the contribution of each party. It is hoped that the use and maintenance of the WISDOM geodatabase will further strengthen these liaisons and inter-agency collaboration in the future.
- Enhance visibility and political recognition. The integration of various aspects and the cartographic representation of result makes WISDOM easy-to-visualize and to some extents it makes a complex issue simple and, to some extent, attractive. This makes it more accessible to non technical readers and simplify the task to policy makers, who will be less reluctant towards a subject often considered "intractable".

Institutional and operational

As mentioned above, WISDOM Rwanda represents the beginning of a process and not its end. It may be considered a newborn baby who requires tending and feeding. The Project as a whole, and WISDOM as well, has been executed by NAFA with FAO assistance. But NAFA is a new institution and its human, technical and financial capacities are still limited. At present, NAFA has only 12 of the planned 32 professional staff. This has obviously a major negative impact on the its operational capacities, among which we must include the full appropriation of the WISDOM experience and the maintenance/update of its geostatistical data.

It appears evident that in order to ensure NAFA's full appropriation of WISDOM and to develop the technical capacities required for its maintenance and exploitation, there is need for additional technical and financial support.

Data

As mentioned before, several assumptions and values attributions were necessary in order to fill information gaps. Over time, it is necessary to replace these preliminary estimates with reliable data. The most important aspects that need to be reliably studied in the nearest future in order to allow the upgrade of WISDOM Rwanda for robust operational planning include the following:

- Detailed Land use/land cover. The new national orthophoto coverage produced by the National Land Centre (soon to be completed) offers an unprecedented opportunity for the production of a

detailed and reliable land use/land cover map.

- Detailed land tenure. Given the limited land resources of the country, the high population density and the intensive land use, the planning of new plantations requires reliable information on land tenure and ownership.
- Reliable productivity data (plantations and natural formations, farm residues). The sustainable management of wood resources requires reliable information on current and potential growth capacities. This should include forest plantations, tree and shrub in natural formations and in farm areas as well as residues from agricultural crops. The 2007 ISAR forest inventory provides some indication about
- Wood industry data. Including number and location of sawmills and furniture making, quantity and sources of roundwood processed and residues produced.
- Industrial demand of woodfuels. Including number and location of brick making and other woodfuel-consuming industries, quantity of end products and quantity and sources of fuels used.

Trees outside Forest Survey

The production of orthophoto coverage of the country was slower than originally anticipated. Approximately 70% of the country was covered but the remaining 30 % located in the west and north areas of Rwanda along RDC borders will only be delivered to the National Land Centre in Spring 2010 and therefore beyond TCP lifetime. The information from the covered 70% was used as first reference for the estimation of rural wood resources. The photointerpretation produced preliminary results for all photo-covered sample points.

The field component of the ToF survey supported by Belgian Cooperation (CTB) will be a follow-up activity to the TCP Project.

In the first WISDOM version the biomass from trees outside forest, shrublands and shrub crops was based on photointerpretation results, AFRICOVER mapping and existing field references, while the TOF survey supported by CTB-PAREF will allow NAFA to revise such estimates early next year.

Recommendations

- In view of the serious deficit situation of the country and in order to achieve sustainable wood energy condition it is recommended to orient the remedial action in all possible direction (management, efficiency, new planting areas, promotion of affordable fuel alternatives, etc.), through strong institutional synergies and with clear territorial priorities.
- The supply/demand situation varies considerably and therefore generic strategies are unlikely to be effective. It is recommended to tailor the character and emphasis of the action to local conditions. WISDOM Rwanda is meant to provide support to the formulation of georeferenced planning and strategies.
- Given the high discrepancy between the estimates of woodfuel consumption in Rwanda according to the present study and the GFPOS model estimates reported in the FAO on-line ForeSTAT database, it is highly recommended that the Rwanda National Correspondent of forestry information provides FAO with the new consumption estimates made in the context of the present study.
- WISDOM Rwanda integrates cartographic and statistical data from many different sectors. In order to guarantee its usefulness, it is recommended to share WISDOM for evaluation, update and, most important, use, with all concerned institutions.
- In order to support wood energy at operational planning level, project design and implementation, it is recommended to strengthen the WISDOM dataset with detailed and reliable information on the following aspects:
    - Detailed and up-to-date land use/cover mapping based on the new orthophoto coverage produced by the National Land Centre
    - Reliable data on the sustainable productive capacities of plantations, tree and shrub in natural formations and in farm areas as well as residues from agricultural crops.
    - Reliable data on rural consumption patterns, specifically on the mix of fuelwood and farm residues.
    - Reliable information on wood-processing industries (sawmills and furniture making) and on woodfuel-consuming industries (brick-making).
- In order to upgrade the WISDOM knowledge base with data adequate to high intensity planning, as mentioned above, it is recommended to join institutional resources and multilateral/bilateral development aid.
- As soon as the remaining 30% of the national orthophoto coverage is finalized, it is recommended to complete the analysis of woody biomass in rural areas through the interpretation of the remaining sample units. The interpretation results will be used as basis for the field-level Trees Outside Forest Survey to be undertaken in early 2010 by NAFA with CTB and PAREF support.
- NAFA is a new institution and its human, technical and financial capacities are still limited. At present, NAFA has only a fraction of the professional staff it requires. This has obviously a major negative impact on the its operational capacities, among which we must include the full appropriation of the WISDOM experience and the maintenance/update of its geostatistical data. In order to guarantee the full appropriation of WISDOM Rwanda by NAFA and to develop the technical capacities required for its maintenance and exploitation, it is strongly recommended to provide NAFA with additional technical and financial support.

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ANNEXES

Annex 1: Main layers, variables and data sources of WISDOM modules ("WISDOM road map")

Module /phase	Layer/ parameter	Variables	Source de information	Comments
Spatial base		Projection	Arc_1960_UTM_Zone_35S (GCS_Arc_1960 – Proj. Transverse_Mercator)	
		Raster resolution	50 m cell size (ref. most detailed reference map)	
	Map administrative (vector)	Secteurs 2002 (year of 2002 census)	NIS, GIS Unit	Provided. Useful for the spatial distribution of 2002 pop.
		Secteurs 2006 (current version)	NIS, GIS Unit	Provided
	Land cover			
		Africover spatially aggregated version	1:100,000 based on TM 1994-1999	Available; used for the East Africa Wisdom study
		Africover dataset available in RW	1:100,000 based on TM 1994-1999	Available, provided by Antoine Kagabo, Land Centre. Check against the aggregated version above. To be used to estimate biomass outside forest inventory area and to stratify TOF survey
		Forest inventory 2007 map	MINIRENA (C SIG NUR)	Available. Useful for forest and plantations > 0.5 ha
				50 m raster produced and projected
		National ecological zones	Check VN old files; Chech with Anne Charlotte	Delapierre classification of Rwanda ecosystems to be used to stratify TOF results;.10 zones represented
		Ortophoto coverage	RW Land Use and Development Master Plan Land Cover Centre; Swedsurvey. The ortocorrected data will only be available from end 2009.	Approx. 70% of the country is covered by orthocorrecteed photos. The remaining 30% will be handed over to NLC in Feb-March 2010
		Row airphoto coverage	Swedsurvey, under permission of Land Registrar (Rurangwa)	Raw orthos potentially available under payment. Considered not viable at this stage.
Spatial analysis (pix. 250m?)	DTM	DTM 90 m	DTM 90 m Should be freely available (check)	available Provided
		DTM 30 m		Check whether 30m is available on web or from NASA on request
	DTM_slope	Slope on DTM 25? m created by GENT for MINAGRI	GIS unit of MINAGRI	Mr. Daniel (?) in GIS unit of MINAGRI (to be contacted; Contours map produced for entire Rwanda ; Converted to DTM and to slope map
		Map of areas to be excluded from exploitation (protected for erosion control)	Projet	Slope is considered a limiting factor for clearfelling but not for coppice and selective felling (Mihigo). Therefore no slope threshold is applied.
	Market points	Trade centers and markets	Check with MINICOM	Available data 2002 (NIS), check if updated in MINICOM and Prepare formal letter from PS MINIRENA to MINICOM if needed; Data received from PPPMER project:

Module /phase	Layer/ parameter	Variables	Source de information	Comments
	Roads	Updated Roads network	MININFRA (BCEOM project)	Available data 2002 (NIS), check updates in MININFRA and Prepare formal letter from PS MINIRENA if needed r
	Rivers and lakes		NISR; Africover (incomplete rivers network)	To be procured. Prepare formal letter from PS MINIRENA to NIS
	Physical Accessibility			developed for all roads (cd_2) and for main roads only (cd_3)
	Protected areas	IUCN WCMC Protected areas by categories	IUCN WCMC	Available 2009 ediytion
		Detailed Protected areas by categories	ORTPN; (Office Rwandais du Tourisme et des Parcs Nationaux)	some docs received but NO maps
			REMA	Marshlands that are protected; Integrated with IUCN-wcmc data
Supply Module	Direct sources			
	Forest cover	Area of natural forest	Mapping produced by NUR GIS-RSRTC for the ISAR National forest inventory 2007 Sat data 2004 (mostly)	Data available Letter from Permanent Secretary sent on 25/02/09 to C GIS NUR provided shapefile on 4/3/09
	Land cover reference		Africover dataset 1:100,000 based on TM 1994-1999 The Africover dataset provides plantations as well but the data is old	Available. This data can be used to complement the 2007 plantation map; africover boundaries edited; class codes edited to harmonize with new plantation maps; attributes correct
		Area of plantations by mapping categories	Mapping produced by NUR GIS-RSRTC for the ISAR National forest inventory 2007	Data available Letter from Permanent Secretary sent on 25/02/09 to C GIS NUR provided shapefile on 4/3/09
	WISDOM LAND COVER BASE			Created LC_04.grd with plat_district codes
	Stock and productivity of natural forests	Stock and productivity by natural forest class	The ISAR National forest inventory 2007 did NOT produce information for natural forests	Only final report on plantations is available; Seek natural forest info from earlier sources (if any) or from similar ecological conditions in neighboring countries
	Stock and productivity of plantations	Stock and productivity by plantation spp	ISAR National forest inventory 2007; Results available (no confidence interval) by spp and by District	Only final report available; Database may be needed but reference person not available. Map classes differ from inventory categories; esp. "young or open for. plant. & coppice" for which there are no results
		Volume – biomass expansion factors and values allocation to forest classes	Literature review; ISAR library?	Check literature for plantation spp wood densities and expansion factors
		Productivity	ISAR National forest inventory 2007; Results available only for plantations (no confidence interval) by spp and by District	The productivity of Eucalyptus spp seems incorrect (too low) maybe due to wrong age definition due to coppicing
	NON-energy use	Other NON-energy use of woody biomass (i.e. timber for industry & export; construction; etc.) to be deducted from the accessible productivity	Check statistics available on: - timber and furniture industry - construction material data from housing/households surveys	Estimate quantity and define the resources from which they must be deducted. Estimate duration of wood houses in order to assess the annual requirements

Module /phase	Layer/ parameter	Variables	Source de information	Comments
		Housing material	NIS 2002 census	Content: Number of hh by material used for house walls (sector 02); Harmonized admin codes of census 2002 and EICV2 2005-6
		Wood for construction used by district 2006 (t)	EICV2 (NIS)	total wood (t) used for construction by district 06
	Spatial proxy for values distribution within the classes	Tree cover percent	MODIS Vegetation Continuous Field Tree Cover Percent at year 2000	This data probably too rough (500 m res.) to be useful. Its usefulness will be tested
Module /phase	Layer/ parameter	Variables	Source de information	Comments
	Stock and productivity of NON-Forest lands	Biomass stock and productivity allocation to non-forest classes: Trees outside forest Orchards Croplands, Urban areas etc	No data available. Some info will be produced by GTZ rural cons. survey.	TOF survey based on airphotos syst. sampling; National Land Centre agrees; Swedesurvey accepts with some resistence; Letter from PS MINIRENA prepared and sent to NPC ; Interpretation of orthophotos completed for 65%; Count crownless trees. Document interpretation by extracting images of each sample (print-screen).
		Tea plantations	data but could be obtained trough satellite imagery (C GIS NUR, Eugene) Contact office (OCIR-The, GIS-Unit)	Find reference on average woody biomass and rotation period of tea plantations. NO MAPS AVAILABLE on planted areas (except Africover class); Completed location of Tea Factories and relative productions
		Coffee plantations	OCIR Café: they have a GIS unit (Maurice: GIS officer)	Contact OCIR, Maurice 0788405963 Find reference on average woody biomass and rotation period of coffee plantations NO MAPS AVAILABLE on planted areas
	Indirect sources			
	Residues from forest industries	Geographic distribution of the forest industries (sawmills, other wood processing;	NISR stats? Ministerial stats? Some data in: WB- MICRO AND SMALL SCALE ENTERPRISES (MSSEs) IN RWANDA.doc ;	Nothing on sawmills; some data on menuisieries (number of cooperatives-small industries by old provinces) Seek new references.
		Processed material; products stats;	profileco_filieres_bois_&_bricks_FAO_FIDA.xls	No quantitative data on the residues produced; Seek new references.
		Estimation of residues generated (fraction of processed wood or final product)		No quantitative data on the residues produced ; Seek new references.
	Recovered woody biomass	Pallets; Construction wood;		No data ; Seek new references.

Module /phase	Layer/ parameter	Variables	Source de information	Comments
Demand Module	Household consumption	Consumption of fuelwood and charcoal per capita (per household) in rural and urban areas;	parameters concerning self-supply and rural fuel expenses were collected during the Enquête Intégral sur les Conditions de Vie des ménages (EICV2 2005-2006).	Review carefully the EICV2 2005-2006 questionnaires and request the original databases to NIS. (Sector level?) Prepare formal letter from PS MINIRENA to NIS; the admin codes of census 2002 and EICV2 2005-6 harmonized; Data received: consumption of woodfuel (and wood for construction) (distr.06)
		Energy sources for cooking (Electricity, wood, charcoal, biomass, other)	NISR	Xls file available (by province 2002), ask NIS for sector -level data ; the admin codes of census 2002 and EICV2 2005-6 harmonized
		Rural consumption	Rwanda BESS by MININFRA	Percapita consumption in each District; Values vary a lot (200-1000 kg/person/year) among Districts; Data received: ° hh by fuel type (sector 2002)
		As complementary variables: consumption/penetration of other fuels (gas, kerosene, electricity)	Energy Agencies	
		Electricity distribution map	Energy Agencies	
		Demographic data 2002 (households, persons) by: Rural (sparse, settlements) urban	NISR	Available
		Population 2002 distributed by Sectors 2006	NISR	Available xls file from NIS
		Zones de denombrement (ZD) used for 2002 census (very detailed)	NISR, GIS Unit	Not yet available; must be checked by NISR and then it will be provided. Useful for the spatial distribution of 2002 pop.
		Nyumba Kumi (lat/long of the chief of the 10/15 surrounding households	NISR, GIS Unit	Not yet available; must be checked by NISR and then it will be provided. VERY PRECIOUS for the spatial distribution of 2002 pop.
		Poverty and other socioeconomic aspects	NIS: Enquete integrale sur les conditions de vie des ménages au Rwanda (2000-2001) [6250 menages]	Non available at FAO. Marginal interest. Out of date. Some info on poverty and HH expenses and fuel used for lighting.
			NIS: Enquete sur les indicateurs de base du bien-etre QIBB-2003	Available at FAO.
			NIS: Enquete demographique et de santé (2005)	Available at FAO.
		NID Population database 2008	Reference made by E. Gatera for the RBESS	Check the reference year (2008?) and the growth rate applied at District level. Available summary values by District. No documentation. Documentation TO BE PROCURED
	Consumed by industrial processes	Consumption of woody biomass (residues) by the forest industries	Special studies? Min. Energia (?)	

Module /phase	Layer/ parameter	Variables	Source de information	Comments
		Consumption of woody biomass by agro-food industry and other industries: The (chá) drying; tobacco drying; fish smoking; ceramics; brick making; blacksmith; etc.)	Possible sources: … Min. Energia (?) WB- MICRO AND SMALL SCALE ENTERPRISES (MSSEs) IN RWANDA.doc ; Special studies? Interview major operators.	OCIR-The data on tea production and relative consumption of wood for 2007 2008. Available location of tea factories
		brick making	District brick production data (6 months of data will be available for Musanze Distr.); WB- MICRO AND SMALL SCALE ENTERPRISES (MSSEs) IN RWANDA.doc ; profileco_filieres_bois_&_bricks_FAO_FIDA.xls ; Estimated brick production derived from housing condition data from NIS Surveys and estimated building rates; Estimated woody biomass requirements (residues, mainly, but also wood although no longer permitted)	Seek results of FAO/FIDA mission on the "filieres des micro enterprises" (Louis Bockel, FAO). As support to estimated consumption, see FAO 1987 on woodfuel use in rural industries. Consumption ranges btw 0.3 – 1.5 kg/brick. The upper range probably applies in RW case. However, first indication received from Ruhengeri brick yards gives approx. 0.32 kg/brick. (Check further); Seek new references.
	Consumption in the Commercial sector	Commercial services; Restaurants (Grills) Bread making	NIS ? Ministerial data? Special studies?	Procedure of estimation and mapping depending on available data Location of trade centers and markets available (2002) but not consumption info.
	Consumption in the Public sector	Schools; Hospitals; Prisons; Etc.	MINALOC (or others?) District/sector data on - number of schools, hospitals and prisons and - number of students, hospitalized persons, - Fuelwood and charcoal consumption	Estimation of total and/or percapita woodfuel consumption in each institution Location of hospitals, health centers available (2002), need check updates and statistics of consumption in MINISANTE. For prisons, letter to Director of prisons
		Secondary schools	MINEDUC	To procure, Location of secondary schools available (NIS) need check updates and statistics of consumption in MINEDUC

Annex 2: Woodfuel consumption parameters

								BAU scenario			AME scenario		
District (2006)	Code	**rur_2006**	**urb_2006**	Fw sat. in rural areas	Ch. sat. in rural areas	Fw sat. in urban areas	Ch. sat. in urban areas	Rural wood cons od_t/yr	Urban wood cons od_t/yr	Total wood cons od_t/yr	Rural wood cons od_t/yr	Urban wood cons od_t/yr	Total wood cons od_t/yr
NYARUGENGE	101	26,217	252,529	66	32	23	72	12,081	181,885	193,966	10,444	92,243	122,088
GASABO	102	103,145	241,089	66	32	23	72	47,531	173,645	221,176	41,089	88,064	142,346
KICUKIRO	103	26,206	216,673	66	32	23	72	12,076	156,059	168,136	10,440	79,145	105,979
NYANZA	201	216,748	30,749	92	2	74	20	55,212	11,326	66,538	48,774	3,402	58,257
GISAGARA	202	263,770	7,060	92	2	74	20	67,189	2,600	69,790	59,354	781	62,352
NYARUGURU	203	235,439	0	92	2	74	20	59,973	0	59,973	52,979	0	53,882
HUYE	204	244,818	62,886	92	2	74	20	62,362	23,164	85,526	55,090	6,958	73,724
NYAMAGABE	205	274,830	24,872	92	2	74	20	70,007	9,161	79,168	61,843	2,752	69,895
RUHANGO	206	238,884	27,847	92	2	74	20	60,850	10,257	71,108	53,755	3,081	62,506
MUHANGA	207	257,721	85,993	92	2	74	20	65,649	31,675	97,324	57,993	9,515	83,179
KAMONYI	208	265,787	0	92	2	74	20	67,703	0	67,703	59,809	0	60,827
KARONGI	301	267,258	42,178	92	2	74	20	68,078	15,536	83,614	57,337	7,993	73,032
RUTSIRO	302	282,003	0	92	2	74	20	71,834	0	71,834	60,501	0	64,538
RUBAVU	303	245,855	92,325	92	2	74	20	62,626	34,007	96,633	52,746	17,497	82,245
NYABIHU	304	286,277	0	92	2	74	20	72,923	0	72,923	61,418	0	65,517
NGORORERO	305	301,086	0	92	2	74	20	76,695	0	76,695	64,595	0	68,906
RUSIZI	306	318,875	49,036	92	2	74	20	81,226	18,062	99,288	68,411	9,293	86,775
NYAMASHEKE	307	346,724	0	92	2	74	20	88,320	0	88,320	74,386	0	79,350
RULINDO	401	254,547	0	92	2	74	20	64,840	0	64,840	57,504	0	58,255
GAKENKE	402	326,248	0	92	2	74	20	83,104	0	83,104	73,702	0	74,664
MUSANZE	403	289,228	34,482	92	2	74	20	73,674	12,701	86,376	65,339	6,072	75,895
BURERA	404	324,948	0	92	2	74	20	82,773	0	82,773	73,408	0	74,366
GICUMBI	405	330,197	53,973	92	2	74	20	84,110	19,881	103,991	74,594	9,504	90,756
RWAMAGANA	501	239,558	18,328	92	2	74	20	61,022	6,751	67,773	48,230	2,746	59,982
NYAGATARE	502	273,525	27,193	92	2	74	20	69,674	10,016	79,691	55,069	4,074	70,250
GATSIBO	503	322,211	0	92	2	74	20	82,076	0	82,076	64,871	0	73,740
KAYONZA	504	238,397	0	92	2	74	20	60,726	0	60,726	47,997	0	54,559
KIREHE	505	260,842	0	92	2	74	20	66,443	0	66,443	52,515	0	59,695
NGOMA	506	258,189	14,979	92	2	74	20	65,768	5,517	71,285	51,981	2,244	63,303
BUGESERA	507	294,475	14,498	92	2	74	20	75,011	5,340	80,351	59,287	2,172	71,472
Total Rwanda		**7,614,009**	**1,296,690**					**1,971,555**	**727,586**	**2,699,141**	**1,675,458**	**347,537**	**2,242,336**

Note: These totals and those presented in Table 2 differ slightly due to spatial smoothing applied in the mapping process.

Annex 3 : Wood density reference values

Ref: Reyes et al., 1992

Basic wood density (d) of tropical tree species (oven-dry tonnes (moist m-3))

				oven-dry	Chosen values
Pinus caribaea	0.51	Americas	5	**0.5**	**Pinus spp**
Pinus caribaea	0.48	Asia	5	**0.6**	**undefined spp**
Pinus insularis	0.475	Asia	5	**0.7**	**Eucalyptus spp**
Pinus merkusii	0.54	Asia	5		
Pinus oocarpa	0.55	Americas	5		
Pinus patula	0.45	Americas	5		
Av. Pinus	**0.50**				

		oven-dry
Eucalypt Globulus	**mean**	0.78
subspecies maidenii		0.68
Eucalypt Tereticornis		0.78
Eucalypt Camaldulensis		0.68
Euc Spp	**mean**	**0.73**

Ref: Reyes et al., 1992

	oven-dry	
Eucalyptus citriodora	0.64	Asia
Eucalyptus deglupta	0.34	Asia
Eucalyptus robusta	0.51	Americas
Av. Eucalyptus	**0.50**	

Ref MIRANDA et. al ??. Provenances and site variationas of wood density in Eucalyptus globulus Labill. at harvesting age and its relation to a non-destructive early assessment. Universidade Técnica de Lisboa

	oven-dry	oven-dry	oven-dry
Eucalypt Globulus	0.492	0.6	0.55
subspecies maidenii			0.584

J.R- Pynton. 1979. Tree planting in Southern Africa. Vol 2 The Eucalypts. Dept. Of Forestry, Republic of South Africa.

	air-dry	oven-dry
Eucalypt Globulus	0.92	0.753
Eucalypt Glob. Maidenii	0.96	0.786
Eucalypt Camaldulensis	0.92	0.753
Eucalypt Tereticornis	0.99	0.810

Agency for International Development. 1983. Firewood crops. Shrubs and trees species for energy production.

	oven-dry		
Eucalypt Tereticornis	0.75		
Eucalypt Camaldulensis	0.6		
Eucalypt Globulus	0.90	0.8	1

Annex 4: Land cover classes of WISDOM Rwanda base map

The land cover classes to which biomass stock and productivity are associated are based on the integration and merging of several sources, including Africover data, ISAR-NUR forest maps; administrative units and updated urban areas.

The stock and productivity values for plantation areas were derived from ISAR Forest Inventory results. For the natural forest formations and the trees outside forest the values were based on the preliminary results of orthophoto interpretation, for overall stock level, and on the values applied to Africover classes in the East Africa WISDOM analysis for spatial distribution.The class codes and class description are the following:

Value	Legend	Area Ha	Stock od $t*ha^{-1}$	MAI-BAU od $t*ha^{-1}yr^{-1}$	MAI_MAN od $t*ha^{-1}yr^{-1}$
1	Open shrubs + grass / Herb crop	592	5.0	0.30	0.41
2	Open forest (med h.) + shrubs	3,541	30.0	0.74	0.94
3	Open shrubs + grass on temp. flooded	14,852	5.0	0.30	0.41
4	Shrub crop / Herb crop	610,249	12.0	0.47	0.62
5	Grass + ss	133,799	2.0	0.19	0.27
6	Herb crop	25,818	1.0	0.14	0.20
7	Open forest (med h.) + shrubs / Grass + ss	7,416	25.0	0.68	0.87
8	Grass + st ss	182,873	3.0	0.24	0.33
9	Open shrubs + grass	43,422	5.0	0.30	0.41
10	Very open shrubs + grass / Shrub crop	2,365	4.0	0.27	0.37
11	Herb crop / Shrub crop	486,676	5.0	0.30	0.41
12	Very open shrubs + grass	53,918	3.0	0.24	0.33
13	Urban Areas (general)	6,392	2.0	0.19	0.27
14	Open forest (med h.) + shrubs / Closef forest (med h.)	196	35.0	0.80	1.01
15	Open shrubs + grass + st	69,786	6.0	0.33	0.45
16	Herb crop, post flooding	11,508	1.0	0.14	0.20
17	Lake	148,632	0.0	0.00	0.00
18	Rice	2,753	1.0	0.14	0.20
19	Grass + ss / Herb crop	13,373	1.0	0.14	0.20
20	Rural Settlements	408	2.0	0.19	0.27
21	Very open shrubs + grass + st	31,944	4.0	0.27	0.37
22	Herb crop / Grass +ss	9,852	1.0	0.14	0.20
23	Closed grass on temp. flooded	5,405	1.0	0.14	0.20
24	Grass swamp	82,524	0.0	0.00	0.00
25	Very open shrubs + grass / Herb crop	23,176	3.0	0.24	0.33
26	Grass + ss / Open trees + closed shrubs	22,047	12.0	0.47	0.62
27	Tea large field	8,889	20.0	0.61	0.78
28	Herb crop / Grass + st ss	17,329	3.0	0.24	0.33
29	Multilayer forest Broadleaved evergreen	2,635	150.0	1.66	1.98
30	Closed shrubs	5,743	15.0	0.53	0.69
31	Shrub crop / Open shrub + grass	5,059	12.0	0.47	0.62
32	Open shrubs + grass + st / Herb crop	23,574	5.0	0.30	0.41
33	Shrub crop + herb crop	12,076	12.0	0.47	0.62
34	Grass + st ss / Herb crop	45,226	3.0	0.24	0.33
35	Herb crop / Very open high trees	1,322	7.0	0.36	0.48
36	Closed to very open herbaceous	6,457	2.0	0.19	0.27
37	Grass + ss / Very open trees + shrubs / Herb crop	10,937	7.0	0.36	0.48
38	Herb crop / Open shrub + grass	7,107	2.0	0.19	0.27
39	Grass + st on temp. flooded	2,170	6.0	0.33	0.45
40	River	910	0.0	0.00	0.00
41	Irrigated herb crop	8,239	1.0	0.14	0.20
42	Tea small field	377	20.0	0.61	0.78
43	Very Open Trees (Broadleaved Deciduous) + shrubs	8,609	25.0	0.68	0.87

44	Herb crop, post flood / Grass swamp	5,126	1.0	0.14	0.20
45	Sparse Herbaceous	343	1.0	0.14	0.20
46	Herb crop / Grass	819	1.0	0.14	0.20
47	Herb crop / Shrub crop / Grass + st ss	3,876	5.0	0.30	0.41
48	Shrub crop / Herb crop / Grass + st ss	8,166	10.0	0.43	0.57
49	Rural Settlements / Herb crop	489	2.0	0.19	0.27
50	Airport	80	0.0	0.00	0.00
51	Open shrubs + grass / Shrub crop	26,289	7.0	0.36	0.48
52	Cereal crop / Shrub crop	1,197	4.0	0.27	0.37
53	Grass + st ss / Shrub crop	10,132	9.0	0.41	0.54
54	Herb crop / Very open shrub + grass st	2,875	3.0	0.24	0.33
55	Open low trees + grass + ss	2,394	35.0	0.80	1.01
56	Cereal crop	36,400	1.0	0.14	0.20
57	Shrub crop / Herb crop cereal	1,206	10.0	0.43	0.57
58	Very Open Trees (Broadleaved Deciduous) + shrubs / Herb crop	28,623	25.0	0.68	0.87
59	Banana	39	4.0	0.27	0.37
60	Multilayer forest Broadleaved evergreen / Grass + ss	522	60.0	1.05	1.30
62	Shrub crop / Grass + st ss	23	10.0	0.43	0.57
63	Open shrubs + grass + st / Grass	47	6.0	0.33	0.45
64	Open Trees (Broadleaved Deciduous) + shrubs	190	40.0	0.86	1.08
65	Open Trees (Broadleaved Deciduous) + shrubs / Herb crop	1,278	25.0	0.68	0.87
66	Herb crop / Shrub crop / very open shrub + grass	19	5.0	0.30	0.41
101	Eucalyptus pl. outside Dist06	3	42.2	5.2	8.0
102	Pinus pl. outside Dist06	0	79.3	6.8	6.8
104	Humid natural forest	79,732	243.0	1.7	2.0
105	Degraded natural forest	39,094	60.0	1.1	1.3
106	Savanna	3,727	3.0	0.2	0.3
107	Bamboo forest	4,373	15.0	0.5	0.7
10101	Eucalyptus - Prov.V. KIGALI, Dist. NYARUGENGE	818	38.6	3.6	9.7
10102	Eucalyptus - Prov.V. KIGALI, Dist. GASABO	1,641	38.6	3.6	9.7
10103	Eucalyptus - Prov.V. KIGALI, Dist. KICUKIRO	211	38.6	3.6	9.7
10201	Eucalyptus - Prov.SUD, Dist. NYANZA	1,217	84.0	6.9	10.2
10202	Eucalyptus - Prov.SUD, Dist. GISAGARA	1,107	84.0	6.9	10.2
10203	Eucalyptus - Prov.SUD, Dist. NYARUGURU	7,431	84.0	6.9	10.2
10204	Eucalyptus - Prov.SUD, Dist. BUTARE	2,703	84.0	6.9	10.2
10205	Eucalyptus - Prov.SUD, Dist. NYAMAGABE	4,989	84.0	6.9	10.2
10206	Eucalyptus - Prov.SUD, Dist. RUHANGO	659	84.0	6.9	10.2
10207	Eucalyptus - Prov.SUD, Dist. GITARAMA	3,245	84.0	6.9	10.2
10208	Eucalyptus - Prov.SUD, Dist. KAMONYI	683	84.0	6.9	10.2
10301	Eucalyptus - Prov.OUEST, Dist. KIBUYE	5,389	99.4	9.1	13.6
10302	Eucalyptus - Prov.OUEST, Dist. RUTSIRO	2,505	99.4	9.1	13.6
10303	Eucalyptus - Prov.OUEST, Dist. GISENYI	1,129	99.4	9.1	13.6
10304	Eucalyptus - Prov.OUEST, Dist. NYABIHU	2,643	99.4	9.1	13.6
10305	Eucalyptus - Prov.OUEST, Dist. NGORORERO	1,712	99.4	9.1	13.6
10306	Eucalyptus - Prov.OUEST, Dist. CYANGUGU	1,995	99.4	9.1	13.6
10307	Eucalyptus - Prov.OUEST, Dist. NYAMASHEKE	3,593	99.4	9.1	13.6
10401	Eucalyptus - Prov.NORD, Dist. RULINDO	2,657	42.2	5.2	8.0
10402	Eucalyptus - Prov.NORD, Dist. GAKENKE	3,485	42.2	5.2	8.0
10403	Eucalyptus - Prov.NORD, Dist. RUHENGERI	1,642	42.2	5.2	8.0
10404	Eucalyptus - Prov.NORD, Dist. BURERA	1,351	42.2	5.2	8.0
10405	Eucalyptus - Prov.NORD, Dist. BYUMBA	3,463	42.2	5.2	8.0
10501	Eucalyptus - Prov.EST, Dist. RWAMAGANA	1,562	35.6	5.3	8.1
10502	Eucalyptus - Prov.EST, Dist. UMUTARA	691	35.6	5.3	8.1
10503	Eucalyptus - Prov.EST, Dist. GATSIBO	3,234	35.6	5.3	8.1
10504	Eucalyptus - Prov.EST, Dist. KAYONZA	113	35.6	5.3	8.1
10505	Eucalyptus - Prov.EST, Dist. KIREHE	70	35.6	5.3	8.1
10506	Eucalyptus - Prov.EST, Dist. KIBUNGO	228	35.6	5.3	8.1
10507	Eucalyptus - Prov.EST, Dist. BUGESERA	405	35.6	5.3	8.1
20101	Pinus - Prov. V. KIGALI, Dist. NYARUGENGE	1	135.4	6.8	6.8
20102	Pinus - Prov. V. KIGALI, Dist. GASABO	6	135.4	6.8	6.8
20201	Pinus - Prov. SUD, Dist. NYANZA	209	81.2	6.6	6.6
20202	Pinus - Prov. SUD, Dist. GISAGARA	148	81.2	6.6	6.6

20203	Pinus - Prov. SUD, Dist. NYARUGURU	994	81.2	6.6	6.6
20204	Pinus - Prov. SUD, Dist. BUTARE	686	81.2	6.6	6.6
20205	Pinus - Prov. SUD, Dist. NYAMAGABE	3,536	81.2	6.6	6.6
20206	Pinus - Prov. SUD, Dist. RUHANGO	3	81.2	6.6	6.6
20207	Pinus - Prov. SUD, Dist. GITARAMA	421	81.2	6.6	6.6
20208	Pinus - Prov. SUD, Dist. KAMONYI	18	81.2	6.6	6.6
20301	Pinus - Prov. OUEST, Dist. KIBUYE	715	105.1	7.4	7.4
20302	Pinus - Prov. OUEST, Dist. RUTSIRO	643	105.1	7.4	7.4
20303	Pinus - Prov. OUEST, Dist. GISENYI	143	105.1	7.4	7.4
20304	Pinus - Prov. OUEST, Dist. NYABIHU	1,098	105.1	7.4	7.4
20305	Pinus - Prov. OUEST, Dist. NGORORERO	533	105.1	7.4	7.4
20306	Pinus - Prov. OUEST, Dist. CYANGUGU	78	105.1	7.4	7.4
20307	Pinus - Prov. OUEST, Dist. NYAMASHEKE	2,709	105.1	7.4	7.4
20401	Pinus - Prov. NORD, Dist. RULINDO	46	79.3	6.8	6.8
20402	Pinus - Prov. NORD, Dist. GAKENKE	94	79.3	6.8	6.8
20403	Pinus - Prov. NORD, Dist. RUHENGERI	10	79.3	6.8	6.8
30101	Young/open/coppices pl.- Prov. V. KIGALI, Dist. NYARUGENGE	454	38.6	3.6	9.7
30102	Young/open/coppices pl.- Prov. V. KIGALI, Dist. GASABO	485	38.6	3.6	9.7
30103	Young/open/coppices pl.- Prov. V. KIGALI, Dist. KICUKIRO	42	38.6	3.6	9.7
30201	Young/open/coppices pl.- Prov. SUD, Dist. NYANZA	800	84.0	6.9	10.2
30202	Young/open/coppices pl.- Prov. SUD, Dist. GISAGARA	1,017	84.0	6.9	10.2
30203	Young/open/coppices pl.- Prov. SUD, Dist. NYARUGURU	3,120	84.0	6.9	10.2
30204	Young/open/coppices pl.- Prov. SUD, Dist. BUTARE	1,067	84.0	6.9	10.2
30205	Young/open/coppices pl.- Prov. SUD, Dist. NYAMAGABE	4,860	84.0	6.9	10.2
30206	Young/open/coppices pl.- Prov. SUD, Dist. RUHANGO	217	84.0	6.9	10.2
30207	Young/open/coppices pl.- Prov. SUD, Dist. GITARAMA	2,407	84.0	6.9	10.2
30208	Young/open/coppices pl.- Prov. SUD, Dist. KAMONYI	518	84.0	6.9	10.2
30301	Young/open/coppices pl.- Prov. OUEST, Dist. KIBUYE	5,045	99.4	9.1	13.6
30302	Young/open/coppices pl.- Prov. OUEST, Dist. RUTSIRO	1,402	99.4	9.1	13.6
30303	Young/open/coppices pl.- Prov. OUEST, Dist. GISENYI	80	99.4	9.1	13.6
30304	Young/open/coppices pl.- Prov. OUEST, Dist. NYABIHU	1,461	99.4	9.1	13.6
30305	Young/open/coppices pl.- Prov. OUEST, Dist. NGORORERO	2,152	99.4	9.1	13.6
30306	Young/open/coppices pl.- Prov. OUEST, Dist. CYANGUGU	188	99.4	9.1	13.6
30307	Young/open/coppices pl.- Prov. OUEST, Dist. NYAMASHEKE	1,752	99.4	9.1	13.6
30401	Young/open/coppices pl.- Prov. NORD, Dist. RULINDO	1,484	42.2	5.2	8.0
30402	Young/open/coppices pl.- Prov. NORD, Dist. GAKENKE	4,470	42.2	5.2	8.0
30403	Young/open/coppices pl.- Prov. NORD, Dist. RUHENGERI	1,688	42.2	5.2	8.0
30404	Young/open/coppices pl.- Prov. NORD, Dist. BURERA	2,153	42.2	5.2	8.0
30405	Young/open/coppices pl.- Prov. NORD, Dist. BYUMBA	1,131	42.2	5.2	8.0
30501	Young/open/coppices pl.- Prov. EST, Dist. RWAMAGANA	27	35.6	5.3	8.1
30502	Young/open/coppices pl.- Prov. EST, Dist. UMUTARA	631	35.6	5.3	8.1
30503	Young/open/coppices pl.- Prov. EST, Dist. GATSIBO	165	35.6	5.3	8.1
30504	Young/open/coppices pl.- Prov. EST, Dist. KAYONZA	33	35.6	5.3	8.1
30505	Young/open/coppices pl.- Prov. EST, Dist. KIREHE	14	35.6	5.3	8.1
30506	Young/open/coppices pl.- Prov. EST, Dist. KIBUNGO	29	35.6	5.3	8.1
30507	Young/open/coppices pl.- Prov. EST, Dist. BUGESERA	177	35.6	5.3	8.1

Annex 5: Names and description of main maps

Raster maps are at 50 m resolution, unless otherwise specified.

Module/filename	Type	Description
Cartographic base		
SECTEURS_2002_m	v	Map of sectors 2002 version
SECTEURS_2006_m	v	Map of sectors 2006 version
District_2006_m	v	Map of Districts 2006 version
Province_2006_m	v	Map of Province 2006 version
Rwanda_boundary_m	v	Rwanda boundaries as per District 2006 version
sect02	r	Raster map of sectors 2002 version
sect_06	r	Raster map of sectors 2006 version
distr_06	r	Districts 06 with names (no adm code)
dist06_cod	r	Districts 06 with value = to adminisstraative code
rwa_cty	r	Mask of Rwanda administrative area (value=1)
rwa_msk0	r	Mask of Rwanda administrative area (value=0)
rw_lc_biom_odt_ha_reass	v	Africover map with East Africa WISDOM stock values, class revised for plantations (removed to be replaced by NUR data), border areas and other misclassifications
lccs_reass2	r	Raster version of re-assigned lccs class attributes
land_water	r	Land = 1; water = 0
Forest_Coverage_Rda	v	Original NUR map of natural forest and plantations
forest_cov	r	50m raster version of above with forest type attributes
forest_cov100	r	forest type attributes + 100
plant_100	r	Plantation type attributes + 100
dist06_forest	r	Combination of District code and forest type code
pl_reg_dist06	r	unique coded NUR plantation classes by district (2006) and regions/provinces
lc04_rev2	r	Land cover base for the allocation of woody biomass values (with district id associated to plantation type, but no eco zone) = merge(pl_reg_dist06, for_cov100, lccs_reass2) and clipped on rwa_cty
Accessibility maps		
Physical accessibility		
acc_50k2		Original 30arc-sec travel time map with extended values to fill data gaps along rivers and coasts.
contours	v	25 m contours digitized from topo maps
rw_dtm50	r	Digital Terrain Model derived from contours map
slope	r	Slope percent map derived from rw_dtm50
roads_m	v	Original map of roads by type (5 categories)
road_type	r	Roads by type
road_major	r	Major roads only (types 1,2 and 3)
roads	r	All roads without type distinction
markets_m	v	Original point maps of market locations
market	r	Market location as pixels
urban_lc	r	Urban areas as defined in Africover
dist_0	r	merge of all roads, markets and urban areas
dist0_b	r	merge of major roads (only), markets and urban areas
cd_02	r	Cost-distance map based on dist_0 and slope
cd_03	r	Cost-distance map based on dist0_b (major roads only) and slope
Legal accessibility		

Rwa_I_IV_p.shp	v	2009 delineation of IUCN-WCMC categories
Iucn_noacc0	r	Map of no access for IUCN-WCMC protected areas clipped on cty boundaries
Marshland_categories.shp	v	Marshland map with associated protection categories
marsh_noacc0	r	Map of no access for total protected marshlands
leg_acc		Map of non accessible areas due to legal constraints (0= no access; 1= full access) = merge (iucn_noacc0, marsh_noacc0, rwa_cty)

Supply Module

PRELIMINARY dataset based on EAST AFRICA WISDOM stock values	
stk_kg	Stock of dendromass (od kg/pixel) based on plantation data and lccs WISDOM East Africa values. = reclass(lc04_rev2, recl_lc4_DM_02.txt)
Business as usual (BAU) scenario	
MAI_kgBAU	MAI of dendromass (od kg/pixel) based on plantation data and lccs WISDOM East Africa values. BAU variant. = reclass(lc04_rev2, recl_lc4_DMAI_BAU_01.txt)
acMAI_kgBAU	Legally accessible MAI – BAU scenario = MAI_kgBAU * leg_acc
m_acmaibau	multiplier map to remove the industrial production from plantations = reclass (lc04_rev2, recl_lc4_m_acmaibau.txt)
avMAI_kgBAU	Available MAI for energy (and construction material) – BAU scenario =int((50 + acMAI_kgBAU * m_acmaibau) / 100)
"Managed" (MAN) scenario	
MAI_kgMAN	MAI of dendromass (od kg/pixel) based on plantation data and lccs WISDOM East Africa values. MAN variant. = reclass(lc04_rev2, recl_lc4_DMAI_MAN_02.txt)
acMAI_kgMAN	Legally accessible MAI – MAN variant = MAI_kgMAN * leg_acc
m_acmaiman	multiplier map to remove the industrial production from plantations = reclass (lc04_rev2, recl_lc4_m_acmaiman.txt)
avMAI_kgMAN	Available MAI for energy (and construction material) – MAN scenario =int((50 + acMAI_kgMAN * m_acmaiman) / 100)
REVISED dataset based on preliminary results of the Trees Outside Forest survey	
stk2_kg	Stock of dendromass (od kg/pixel) based on plantation data and lccs WISDOM East Africa values. = reclass(lc04_rev2, recl_lc4_DM_TOF1.txt)
Business as usual (BAU) scenario	
MAI2_kgBAU	MAI of dendromass (od kg/pixel) based on plantation data and lccs WISDOM East Africa values. BAU variant. = reclass(lc04_rev2, recl_lc4_DMAI_BAU_TOF1.txt)
acMAI2_kgBAU	Legally accessible MAI – BAU scenario = MAI2_kgBAU * leg_acc
m_acmai2bau	multiplier map to remove the industrial production from plantations = reclass (lc04_rev2, recl_lc4_m_acmaibau_TOF1.txt)
avMAI2_kgBAU	Available MAI for energy (and construction material) – BAU scenario =int((50 + acMAI2_kgBAU * m_acmai2bau) / 100)
"Managed" (MAN) scenario	
MAI2_kgMAN	MAI of dendromass (od kg/pixel) based on plantation data and lccs WISDOM East Africa values. MAN variant. = reclass(lc04_rev2, recl_lc4_DMAI_MAN_TOF1.txt)
acMAI2_kgMAN	Legally accessible MAI – MAN variant = MAI2_kgMAN * leg_acc
m_acmai2man	multiplier map to remove the industrial production from plantations = reclass (lc04_rev2, recl_lc4_m_acmaiman_TOF1.txt)
avMAI2_kgMAN	Available MAI for energy (and construction material) – MAN scenario =int((50 + acMAI2_kgMAN * m_acmai2man) / 100)

rwa_tc_00	r	Modis Tree Cover data
rwa_tc_p	r	Re-projected TC data
rwa_tc1_f10	r	Smoothed % Tree Cover (1% added to avoid 0-values over grass and shrublands) = int (focalmean of rwa_tc_p, [10 cells, circle] + 0.5) +1 ; * land_water)
selected_photo_by_district_P	v	Selected TOF sample sites
TOF_300909	v	Results of ortho photo interpretation (preliminary results at 30 Sep 2009)
Demand Module		
		Reference file for the elaboration of urban/rural population by sector, district and values allocation to pixels = "hh demand by_sect02_&_by_Dist06.xls"
Population 2002 distribution		
10HH_rwa2002	v	original 10 household data set (Nyumba Kumi)
HH10_by_Sector_Rural_2	v	10 household points limited to rural areas and integrated/reviewed for the sectors without points
hh10_rur2	r	raster of above
rur2002_0	r	rural population 2002 assigned to 10HH points on a 0-value background (pop * 100)
Urban_Areas2	v	revised urban polygons (ref: Africover and new interpretation on Google Earth)
urban_area	r	raster of above
sec2_rur02	r	Multiplier map that assign rur 2002 pop to rural pixels = reclass(sect02, recl_sec02_rurpop.txt)
sec2_urb02	r	Multiplier map that assign urban 2002 pop to urban pixels = reclass(sect02, recl_sec02_urbpop.txt)
urb2002	r	urban population 2002 assigned to urban area pixels (pop * 100)
pop2002	r	total population 2002 (by HH10 pixels and urban areas) (pop * 100)
pop2002_f20	r	total population 2002 spatially distributed through Focalmean (circle, 20 pixels=1km) (pop * 100)
Population 2006 distribution		
rur02_06fac	r	= reclass(dist06_cod, Recl_dist06_RUR_02_06_factor.txt)
urb02_06fac	r	= reclass(dist06_cod, Recl_dist06_URB_02_06_factor.txt)
rur2006_0	r	Rural population 2006 (pop * 100) = rur2002_0 * rur02_06fac
urb2006	r	Urbanl population 2006 (pop * 100) = urb2002 * urb02_06fac
pop2006_0	r	total population 2006 (pop * 100) = merge(urb2006, rur2006_0)
HH Consumption 2002		
m_hhdem02_rur	r	Multiplier map that assign rur 2002 consumption to rural population = reclass(dist06_cod, recl_dist06_multip_rur_cons2002.txt)
m_hhdem02_urb	r	Multiplier map that assign urban 2002 consumption to urban population = reclass(dist06_cod, recl_dist06_multip_urb_cons2002.txt)
hhdem02_rur	r	Rural woodfuel consumption 2002 (wood-equivalent od 10g/pixel) = rur2002_0 * m_hhdem02_rur
hhdem02_urb	r	Urban woodfuel consumption 2002 (wood-equivalent od 10g/pixel) = urb2002 * m_hhdem02_urb
hhdem02	r	Residential consumption 2002 (pixel-level, non smoothed) (wood-equivalent od 10g/pixel) = merge(hhdem02_urb, hhdem02_rur)
hhdem02_odkg	r	Residential consumption 2002 (pixel-level, non smoothed) (wood-equivalent od kg/pixel) = int(hhcon02 / 100 + 0.5)
hhdem02kgf20	r	(focalmean 20, circle) and clipped on rwa_cty (wood-equivalent od kg/pixel)
hhdem02kgf20b	r	Residential consumption 2002 smoothed twice – focalmean for 1km and then for 500m (wood-equivalent od kg/pixel)
hhdem02kgf20i	r	Integer values of above
Consumption 2006		Estimated and mapped applying the 2006 rural and urban consumption to the 2002 rural and urban population (without re-mapping population

Business as usual (BAU) scenario		
m_hhdem06_rur	r	Multiplier map that assign rur 2006 consumption to (2002) rural population = reclass(dist06_cod, recl_dist06_multip_rur02_cons2006.txt)
m_hhdem06_urb	r	Multiplier map that assign urb 2006 consumption to (2002) urban population = reclass(dist06_cod, recl_dist06_multip_urb02_cons2006.txt)
hhdem06_rur	r	Rural woodfuel consumption 2006 (wood-equivalent od 10g/pixel) = rur2002_0 * m_hhdem06_rur
resid25bau0		25%_residues consumption residues in wood-equivalent od kg/pixel = hhdem06_rur * 25
res25bau0		= int(resid25bau0 / 10000 +0.5)
res25bauf30		= focalstatistics(resid25bau0, circle,20 + 10)
hhdem06_urb	r	Urban woodfuel consumption 2006 (wood-equivalent od 10g/pixel) = urb2002 * m_hhdem06_urb
hhdem06	r	Residential consumption 2006 (pixel-level, non smoothed) (wood-equivalent od 10g/pixel) = merge(hhdem06_urb, hhdem06_rur)
hhdem06_odkg	r	Residential consumption 2006 (pixel-level, non smoothed) (wood-equivalent od kg/pixel) = int((50 + hhdem06) / 100)
hhdem06kgf20i	r	Residential consumption 2006 (pixel-level, smoothed) (wood-equivalent od kg/pixel) = int (focalmean of hhdem06_odkg [20 cells, circle] + 0.5; * rwa_cty)
hhdem06kgf30i	r	Residential consumption 2006 (pixel-level, re-smoothed) (wood-equivalent od kg/pixel) = int (focalmean of hhdem06kgf20i [10 cells, circle] + 0.5; * rwa_cty)
m_comdm06_urb	r	Multiplier map that assign 2006 commercial consumption to 2002 urban population = reclass(dist06_cod, Recl_dist06_multip_URB02_cons_comm_2006.txt)
comdem06	r	Commercial consumption 2006 (pixel-level, non smoothed) (wood-equivalent od 10g/pixel) = urb2002 * m_comdm06_urb
comdem06_odkg	r	Commercial consumption 2006 (pixel-level, non smoothed) (wood-equivalent od kg/pixel) = int((50 + comdem06) / 100)
comdem06odkg0	r	Above map on 0 background = merge (comdem06_odkg, rwa_msk0)
comdm06kgf20a	r	Commercial consumption 2006 (pixel-level, smoothed) (wood-equivalent od kg/pixel) = int (focalmean of comdem06_odkg, [20 cells, circle] + 0.5; * rwa_cty)
comdm06kgf30i	r	Commercial consumption 2006 (pixel-level, re-smoothed) (wood-equivalent od kg/pixel) = int (focalmean of comdm06kgf20a, [10 cells, circle] + 0.5; * rwa_cty)
Ameliorated (AME) scenario		
m_hdm6_rurAM	r	Multiplier map that assign rur 2006 AME consumption to (2002) rural population = reclass(dist06_cod, recl_dist06_multip_rur02_cons2006_AME.txt)
m_hdm6_urbAM	r	Multiplier map that assign urb 2006 AME consumption to (2002) urban population = reclass(dist06_cod, recl_dist06_multip_urb02_cons2006_AME.txt)
hhdem06_rurAM	r	Rural woodfuel AME consumption 2006 (wood-equivalent od 10g/pixel) = rur2002_0 * m_hdm6_rurAM
hhdem06_urbAM	r	Urban AME woodfuel consumption 2006 (wood-equivalent od 10g/pixel) = urb2002 * m_hdm6_urbAM
hhdem06AM	r	Residential AME consumption 2006 (pixel-level, non smoothed) (wood-equivalent od 10g/pixel) = merge(hhdem06_urbAM, hhdem06_rurAM)
hhdem06_kgAM	r	AME Residential consumption 2006 (pixel-level, non smoothed) (wood-equivalent od kg/pixel) = int((50 + hhdem06AM) / 100)
hdm6kgf20iAM	r	AME Residential consumption 2006 (pixel-level, smoothed) (wood-equivalent od kg/pixel) = int (focalmean of hhdem06_kgAM [20 cells, circle] + 0.5)
hdm6kgf30iAM	r	AME Residential consumption 2006 (pixel-level, re-smoothed) (wood-equivalent od kg/pixel) = int (focalmean of hdm6kgf20iAM [10 cells, circle] + 0.5; * land_water)

m_comdm6urbAM	r	Multiplier map that assign 2006 AME commercial consumption to 2002 urban population = reclass(dist06_cod, Recl_dist06_multip_URB02_cons_comm_2006_AME.txt)
comdem06AM	r	AME Commercial consumption 2006 (pixel-level, non smoothed) (wood-equivalent od 10g/pixel) = urb2002 * m_comdm06urbAM
comdm6_kgAM	r	AME Commercial consumption 2006 (pixel-level, non smoothed) (wood-equivalent od kg/pixel) = int((50 + comdem06AM) / 100)
comdm6_kg0AM	r	Above map on 0 background = merge (comdm6_kgAM, rwa_msk0)
comdm6kgf20AM	r	AME Commercial consumption 2006 (pixel-level, smoothed) (wood-equivalent od kg/pixel) = int (focalmean of comdm6_kg0AM, [20 cells, circle] + 0.5)
comdm6kgf30AM	r	AME Commercial consumption 2006 (pixel-level, re-smoothed) (wood-equivalent od kg/pixel) = int (focalmean of comdm6kgf20AM, [10 cells, circle] + 0.5; * rwa_cty)

Other consumptions

m_constr06	r	Multiplier map that assign 2006 construction material to (2002) rural population (assuming 20 air-dry kg/rural person / year) = reclass (dist06_cod, Recl_dist06_multip_rur02_constr_2006)
constr06_kg		Wood consumption as construction material (bois de service) assuming 20 air-dry kg/rural person / year (value in odkg/pixel) = int((50 + rur2002_0 * m_constr06) / 100)
constr06kgf20	r	Constraction wood consumption 2006 (pixel-level, smoothed) (od kg/pixel) = focalmean of constr06_kg, [20 cells, circle]
constr06_f30i	r	Constraction wood consumption 2006 (pixel-level, re-smoothed) (od kg/pixel) = int (focalmean of constr06kgf20, [10 cells, circle] + 0.5; * land_water)

tea:factories	p	Point locations of tea factories with estimated fw consumption
tea_odkg	r	Raster based on odkg field of above point map
tea_odkg0	r	Above map on a 0-value background = merge(tea_odkg, rwa_msk0)

prisons	p	Point locations of prisons with estimated fw consumption
pris_odkg	r	Raster based on pris_odkg field of above point map
pris_odkg0	r	Above map on a 0-value background = merge(pris_odkg, rwa_msk0)

SecSchools_Consumption	v	Point location of secondary schools with estimated number of students and fuelwood consumption
secschoolskg	r	Consumption estimated at school location (od kg / pixel)
school_kg0	r	Above map on a background of 0-values = merge(secschoolskg, rwa:msk0)

Total consumption

dem06_bau		Sum of all consumptions – BAU scenario = hhdem06kgf30i + comdm06kgf30i + constr06_f30i + tea_odkg0 + pris_odkg0 + secschoolskg
dem06_bau		Sum of all consumptions – BAU scenario = hdm6kgf30iAM + comdm6kgf30AM + constr06_f30i + tea_odkg0 + pris_odkg0 + secschoolskg

Integration Module

PRELIMINARY dataset based on EAST AFRICA WISDOM stock values

bal_b_b_f1km	r	Balance BAU supply and BAU demand within 1km local context (od kg / pixel) = focalmean ([avmai_kgbau – dem06_bau] , circle, 20)
bal_b_a_f1km	r	Balance BAU supply and AME demand within 1km local context (od kg / pixel) = focalmean ([avmai_kgbau – dem06_ame] , circle, 20)
bal_m_b_f1km	r	Balance MAN supply and BAU demand within 1km local context (od kg / pixel) = focalmean ([avmai_kgman – dem06_bau] , circle, 20)
bal_m_a_f1km	r	Balance MAN supply and AME demand within 1km local context (od kg / pixel) = focalmean ([avmai_kgman – dem06_ame] , circle, 20)

REVISED dataset based on preliminary results of the Trees Outside Forest survey		
bal2_b_b_1km	r	Balance BAU supply and BAU demand within 1km local context (od kg / pixel) = focalmean ([avmai2_kgbau – dem06_bau] , circle, 20) * land_water
bal2_b_a_1km	r	Balance BAU supply and AME demand within 1km local context (od kg / pixel) = focalmean ([avmai2_kgbau – dem06_ame] , circle, 20) * land_water
bal2_m_b_1km	r	Balance MAN supply and BAU demand within 1km local context (od kg / pixel) = focalmean ([avmai2_kgman – dem06_bau] , circle, 20) * land_water
bal2_m_a_1km	r	Balance MAN supply and AME demand within 1km local context (od kg / pixel) = focalmean ([avmai2_kgman – dem06_ame] , circle, 20) * land_water
bal2bb1km_25	r	Balance BAU supply and BAU demand within 1km local context (od kg / pixel) less 25% of rural hh consumption (added to the balance map) on account of farm residues use = bal2_b_b_1km + res25bau_f30

Woodshed analysis

Kigali		
ac_kig_197	r	
Butare		
ac_but_265	r	

Structure and fields description of Sect06wisdom.mdb geodatabase

fieldname	Description	Unit	total of numeric fields
NOMSECT	Name of Sector		
AREA_KM	Surface of Sector in km²	km²	25,313
REGION	Name of Region (or Province)		
DISTR	Name of District		
DENSITY	Population density of the Sector (ref. Census 2002)	peop/ km²	
POPULATION	Population of the Sector (ref. Census 2002)		8,128,553
COD_SECT06	Code of Sector (2006 admin structure)		
COD_DIST06	Code of Sector (2006 admin structure)		
B2T_BB	Balance BAU-BAU	od t	-1,827,422
B2T_BA	Balance BAU-AME	od t	-1,337,951
B2T_MB	Balance MAN-BAU	od t	-1,241,818
B2T_MA	Balance MAN-AME	od t	-752,349
DEMT_BAU	Demand BAU	od t	2,973,948
DEMT_AME	Demand AME	od t	2,465,467
AVMAI2_B	Available Mean Annual Increment - BAU	od t	1,119,100
AVMAI2_M	Available Mean Annual Increment - MAN	od t	1,708,177
pcdem_bb	Fulfilled demand BAU-BAU	%	37.6
pcdem_ma	Fulfilled demand MAN-AME	%	69.3
rank_bb	Balance category (text) BAU-BAU		
rank_ma	Balance category (text) MAN-AME		
WFP_CODE	WFP code of geographic strata		
WFP_STRAT	WFP name of geographic strata (District groups)		
POOREST	Percent of "poorest" quintile	%	
POOR	Percent of "poort" quintile	%	
MEDIUM	Percent of "medium" quintile	%	
WEALTY	Percent of "wealthy" quintile	%	
WEALTHIEST	Percent of "wealthiest" quintile	%	
COMB_VALbb	Ranking of balance and poverty 1 to 99 - BAU-BAU	rank	
COMB_VALma	Ranking of balance and poverty 1 to 99 – MAN-AME	rank	
Shape_Length		m	17,072,357
Shape_Area		m²	25,312,923,024

Annex 6: Main features of the Trees Outside Forest (TOF) survey

Main scope of the survey was to support the estimation of the sustainable productivity of woody biomass in rural areas and to assess its role in the satisfaction of woodfuel demand of rural households. More specifically, the variables measured will are average tree and shrub cover in the rural areas that were not covered by the 2007 ISAR National Forest Inventory. Tree and shrub cover values, associated to field measurements and inventory data, were used to provide a first estimation of woody biomass stock and of the potential sustainable productivity.

A systematic sampling approach was applied using a 5 km grid covering the entire country, as shown in Figure A6.1. Excluding forest areas already covered by the National Forest Inventory, protected areas and water bodies, a total of 616 sampling units were identified.

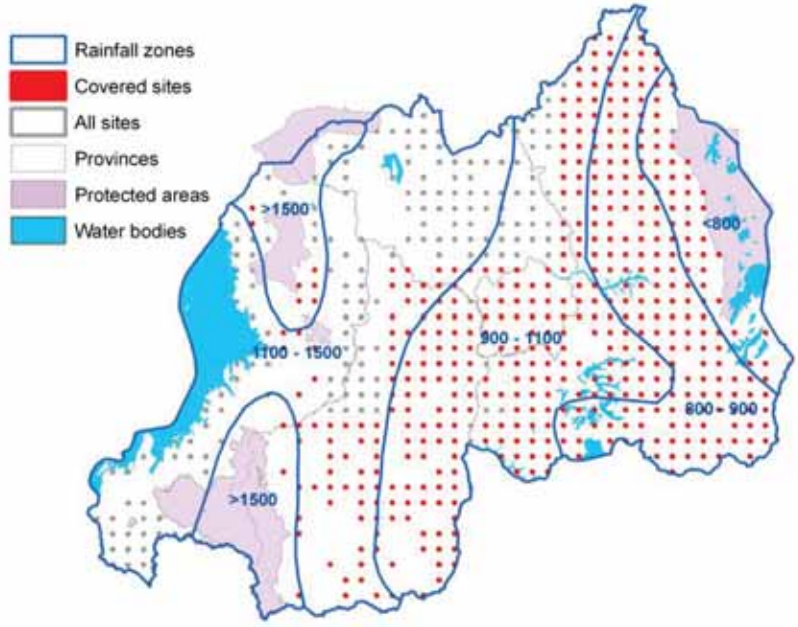
At each sample points, a circular portion of the territory around the selected grid point, covering 10 hectares, was analysed in detail on the basis of the new coverage of ortho-corrected aerial photographs made available by the National Land Centre (NLC) of Rwanda.

These orthophotos are of excellent quality and have a spatial resolution of 25 cm, which is adequate for a reliable distinction of land use and land cover features (see Figures A6.2). The NLC will use the new photo coverage as basis for the preparation of the Rwanda Land Use Coverage and of the Development Master Plan.

For the TOF survey, the following cover types were outlined through on-screen photointerpretation:

- Woody vegetation cover (outlining the portion of land covered by the crowns of trees and shrubs). The cover types applied are:
  - old trees
  - young trees
  - shrubs
- Agricultural plantations with woody biomass:
  - Old fruit trees
  - Young fruit trees
  - Coffee
  - Tea
- Number of trees (for the trees that do not present a normal crown due to pruning of all or most of the branches).

Figure A6.1: Location of TOF sample points



To be noted that at the end of the project the interpretation of the sample points in the Western and Northern Provinces could not be completed because the orthophotos of those regions were not yet available. In total, 446 sampling units were completed, corresponding to 72 % of the entire selected sample.

The tree and shrub cover parameters were subsequently used to estimate stock and productivity of woody biomass. In absence of direct field data collection, the estimation of stocking and productively was done

on the basis of volume and to mean annual increment values by species and by District produced by the ISAR Inventory.

This work have aroused keen interest within NAFA and other project and partners of NAFA. As an example, the Forest Baseline Study has selected 24 plots among the 635 plots to conduct the inventory of TOF resources. The MINIRENA Programme PAREF (*Programme d' Appui à la Reforestation*) is planning to carry out field data collection in 120 sampling units as a follow-up phase of the TOF survey in order to produce reliable estimates of stock and productivity.

Figure 2: Example of photointerpretation. The circle delimits an area of 10 hectares

Legend : 1 = Young trees 2 = Old trees 3 = Shrubs
5 = Coffee plantation 6 = Tea plantation 7 = Young fruit trees 8 = Old fruit trees

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MININFRA	Ministère des Infrastructures
MINITERE	Ministère des Terres, de l'Environnement, des Forêts, de l'Eau et des Ressources Naturelles
MINITRAPE	Ministère des Travaux Publics, de l'Energie et de l'Eau
MINERENA	Ministry of Natural Resources, since March 2008)
NAFA	National Forestry Authority
RITA	Rwanda Information and Technology Agency (MININFRA)
PAREF	Programme d'Appui à la Reforestation (MINIRENA Programme)
ISAR	Institut Des Sciences Agronomiques Du Rwanda
NISR	Institut National de Statistiques, Rwanda

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