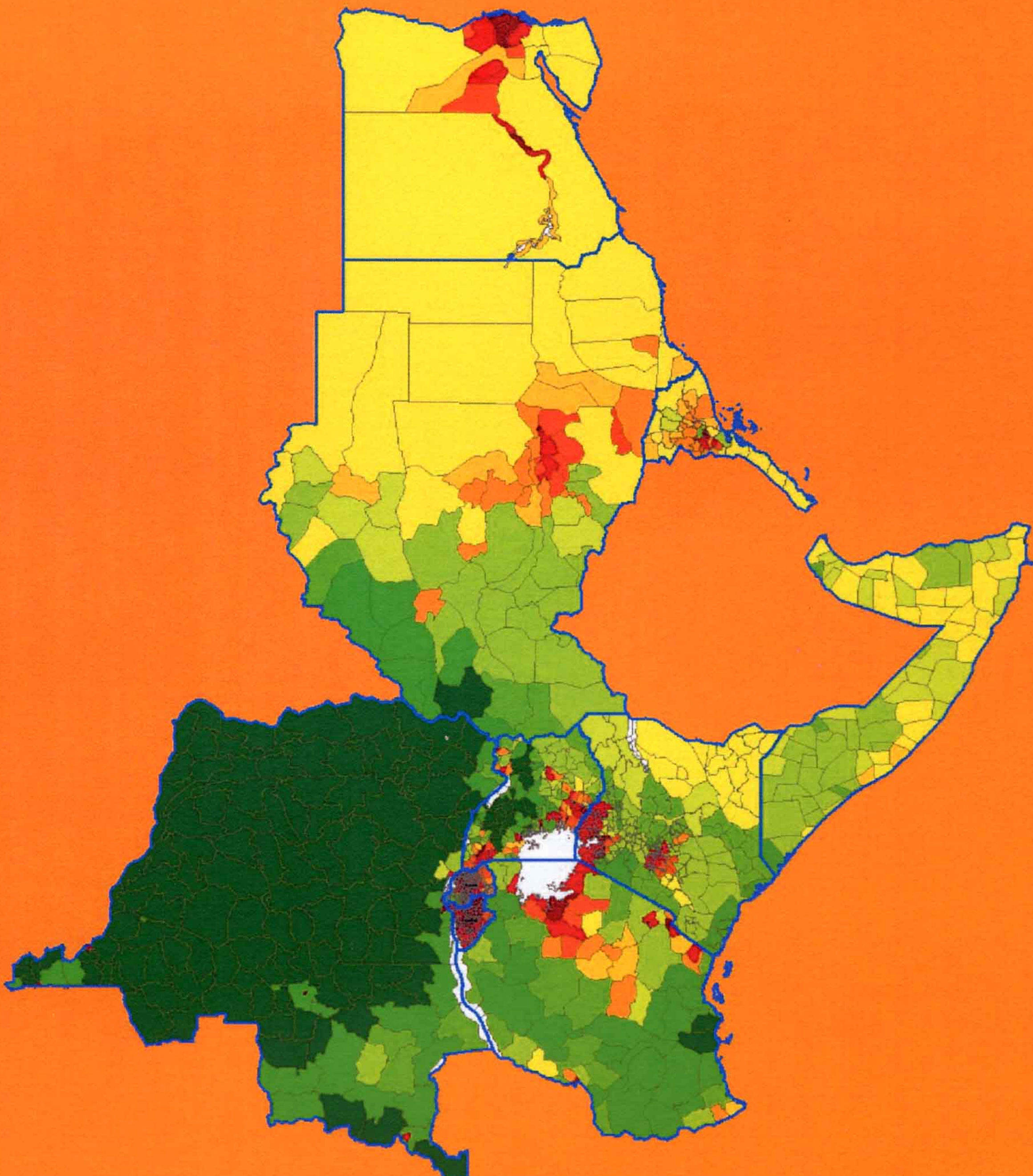
Woodfuels Integrated Supply/Demand Overview Mapping

WISDOM

East Africa

Spatial woodfuel production and consumption analysis



Forestry Department - Wood Energy

FAO – Forestry Department – Wood Energy

WISDOM – East Africa

Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) Methodology

Spatial woodfuel production and consumption analysis of selected African countries

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Foreword

The patterns of woodfuel production and consumption, and their associated social, economic and environmental impacts, are site-specific. An analysis of the sector requires a holistic view of the people and places most affected by these resources.

WISDOM is a database that provides a spatial analysis of woodfuel states through a GIS platform designed to show woodfuel production and consumption patterns for a given geographical area. The methodology behind WISDOM overcomes the limitations of site-specific or national level analyses that fail to comprehensively integrate the data from all the relevant sectors.

While designed for wood energy planning, data layers can be overlaid with poverty statistics and used to analyse alternative development scenarios for energy, agriculture, forestry and other national policies. The data supporting WISDOM can be used to produce maps and statistical information to support strategic planning—providing “big picture” information while highlighting local level impacts. More than just a tool for energy specialists, it can be used to identify vulnerable populations and ecosystems that require the attention of policy makers in all sectors.

The scope of the study was to apply WISDOM for the analysis of wood energy and poverty situations at regional level, studying the situation over a large geographic area. This particular case involves ten countries of east and central Africa: Rwanda, Kenya, Egypt, Burundi, DR Congo, Eritrea, Somalia, Sudan, Tanzania and Uganda, and makes use of information derived from the FAO’s Land Cover Classification System (LCCS) and field data from a variety of sources.

This exercise shows that WISDOM is a flexible tool that can be applied for the analysis of woodfuel situations and associated sectors at regional level with several important benefits:

a) it allows for a consistent and holistic view of wood energy systems over entire countries or regions and helps determine priority areas for intervention;

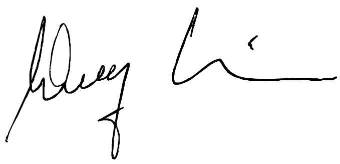
b) it helps to improve understanding of the area-based flow of woodfuels under different ecological and socio-economic conditions;

c) the database can be used to collect existing scattered data from different sources and identify gaps in wood energy data;

d) it promotes cooperation and synergies among stakeholders and institutions and helps to combat the fragmentation (of information, of responsibility) that presently impedes the development of the sector; and

e) it allows action to be concentrated on targeted areas and thus optimises the use of available resources (human, institutional, financial and others).

The East Africa WISDOM report describes the data collection and analysis process that was used to create the database and provides maps of the various thematic layers that can be produced at local, regional and national levels. The results can be used to identify the number and location of wood energy deficit areas where the lack of sustainable energy might be a threat to agricultural production, food security and nutrition, whilst at the same time highlighting areas where opportunities for increased/improved woodfuel production could benefit local populations.



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Summary

In Africa, woodfuel accounts for over 90 percent of total African wood consumption. In the countries of East Sahelian Africa, Central Africa and Tropical Southern Africa woodfuels, mainly fuelwood, contribute from 75 to 86 percent of total primary energy consumption (FAO 1999). Numerous studies have analyzed the wood energy sector in these countries and most of them have failed to provide a clear understanding of the different wood energy situations.

In the context of poverty and food security, energy issues are also particularly significant. Access to energy –or lack thereof—adds an essential dimension to the analysis of global poverty as it has a critical and immediate impact on the health and nutrition of poor rural households.

The scope of the study is to analyze wood energy and poverty situation in ten countries of East and Central Africa: Rwanda, Kenya, Egypt, Burundi, DR Congo, Eritrea, Somalia, Sudan, Tanzania and Uganda.

The study intends to contribute to the identification of areas where rural and suburban populations that depend primarily on woodfuels for their subsistence energy supply, are likely to suffer severe shortages, thus adding a new important dimension to the mapping of extreme poverty.

The definition of wood energy situations and priority areas was done applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology with information derived from cartographic layers of the FAO's Land Cover Classification System (LCCS)[1] and field data from a variety of sources.

The data collected in the for the WISDOM database allowed for the creation of **maps of woody biomass stocking and potential sustainable productivity** with high spatial resolution. Similarly, the integration of population distribution maps with fuelwood and charcoal consumption values by sector and by rural settlements and urban areas resulting from the review of a wide variety of sources, allowed the creation of **woodfuel consumption maps** at the spatial resolution of less than 1 km.

The combination of supply and demand data within cells of approximately 9 x 9 km for 1172 administrative units allowed the creation of **balance maps** showing the deficit or surplus of fuelwood in a local context, which represents the gathering horizon of poor rural and sub-urban households that cannot afford marketed woodfuels or that live far from market centres

In some cases, the areas with pronounced deficit conditions imply (i) the use of non-sustainable sources such as land clearings for conversions to permanent agriculture and shifting cultivations that may temporarily release large amounts of wood and/or (ii) a non sustainable pressure on more accessible natural formations with their inevitable progressive degradation (a common condition for Burundi, Rwanda and probably Eritrea). Another probable effect may be a widespread shift to lower grade biomass fuels such as straw, residues and cow dung. All effects that pose further burden on the environment, on agricultural productivity and inevitably on the poorest segments of the society that depend on these resources.

Key findings are:

- the areas that present a more or less marked deficit in the local demand/supply balance encompass some 12.5 percent of the total area being analyzed.
- there are countries literally dominated by deficit areas, such as Burundi and Rwanda, others that present important deficit areas, such as Eritrea, Tanzania, Uganda, Kenya and Sudan.
- in the study area over 41% of rural populations face medium-high to high deficit conditions. In absolute numbers this corresponds to some 59.2 million people.
- in countries like Burundi and Rwanda virtually the entire population face deficit conditions.

The thematic geo-statistical layers produced with this WISDOM exercise and reported in this paper represent the beginning rather than the conclusion of an analytical process. They may, and hopefully will, support further level of analysis at both lower and higher geographical levels. At lower levels, i.e. national and sub-national, they can serve as basis of WISDOM analyses aimed at supporting and guiding energy and forestry policies. At higher levels, i.e. regional and global, they can contribute and provide qualified reference to regional and global wood energy mapping.

[1] LCCS land cover maps and ecological zoning

Contents

Acronyms and Abbreviations

WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping
FAO	Food and Agriculture Organization of the United Nations
FIVIMS	Food Insecurity Vulnerability Mapping System
FOPP – WE	Forest Products Service – Wood Energy (FAO)
GFPOS	Global Forest Products Outlook Study (FAO)
GLCN	FAO/UNEP Cooperative Programme Global Land Cover Network
i-WESTAT	Interactive Wood Energy Statistics (FAO)
IAO	Istituto Agronomico per l'Oltremare (Florence, Italy)
IEA	International Energy Agency
JPOI	Johannesburg Plan of Implementation
LCCS	Land Cover Classification System
MAI	Mean Annual Increment
MDG	Millennium Development Goals
SADC	Southern African Development Community
SDRN	Sustainable Development Environment and Natural Resources Services (FAO)
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNOPS	United Nations Office for Project Services
Ch	Charcoal
CUM	Cubic meter (m^3)
Fw	Fuelwood
inh	inhabitant
MJ	Megajoules (10^6 joules)

Acknowledgements

The study benefited from collaborations and synergies between FOPP-WE, the Natural Resources Service (SDRN) of the Sustainable Development Department of FAO and the *Istituto Agronomico per l'Oltremare* (IAO) of Florence.

In addition, the study benefited from the FAO/UNEP Cooperative Programme Global Land Cover Network (GLCN) that was already in the process of collecting and analyzing biomass data for the assessment of carbon stock in relation to LCCS parameters.

Concerning the module of woodfuel consumption, the study benefited from the collaboration with the Geographic Information Systems Group of SDRN working on the Food Insecurity Vulnerability Mapping System (FIVIMS), which provided most recent cartographic representations of the spatial distribution of rural and urban population for Africa for the year 2000.

Given the interdisciplinary and inter-sectoral character of the study, many persons and institutions contributed with specific information and competent advice, either directly or indirectly.

In particular, FOPP-WE wishes to express his gratitude to:

Miguel Trossero of the Wood Energy Programme, FAO-FOPP, for the coordination and supervision of activities;

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Introduction

The wood energy sector in Africa, specifically in the eastern and central sub-regions, plays a major role in both the forestry and energy sectors. In Africa, woodfuel accounts for over 90 percent of total African wood consumption. In the countries of East Sahelian Africa, Central Africa and Tropical Southern Africa woodfuels contributed from 75 to 86 percent of total primary energy consumption (FAO 1999).

Given this important role in energy and forestry, wood energy mapping at national and international levels, serves several inter-sectoral purposes. It supports both sustainable forest management and energy planning; it helps to identify the potential for bioenergy development; and it helps to identify vulnerable geographic areas (in terms of pressures on the poor and/or the environment).

In the context of poverty and food security, energy issues are particularly significant. Access to energy—or lack thereof—adds an essential dimension to the analysis of global poverty as it has a critical and immediate impact on the health and nutrition of poor rural households. At the same time, lack of accessible wood resources creates an added burden on the rural poor who rely on them, triggering a vicious cycle in which essential soil nutrients (such as agricultural residues and cow dung) are burnt rather than returned to the soil, creating additional negative consequences on the production of food crops.

Wood energy mapping, based on the integration of woodfuel demand with sustainable supply capacities, allows for the identification of potential wood resources as well as critical areas where livelihoods or the environment might be under threat. The East Africa Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology was applied to illustrate the contribution made by woodfuels to poverty, forestry and the environment in ten countries: Rwanda, Kenya, Egypt, Burundi, DR Congo, Eritrea, Somalia, Sudan, Tanzania and Uganda.

Rationale of the study

Many factors contribute to the marginal attention that the wood energy sector receives at national as well as international levels, all of which generally relate to lack of information on the sector. Among them, we can highlight the following:

- lack of a coherent perception of the magnitude (importance) of wood energy in the energy and forestry sectors of both industrialized and developing countries;
- drawback derived from the attitude, especially common in poor countries, that perceives fuelwood and charcoal as obsolete and backward, relative to more "modern" fuels;
- the secondary role assigned to woodfuel production by forestry authorities worldwide, in spite of the fact that energy is one of the main uses of wood;
- fragmentation and frequent inconsistencies within, and between, woodfuel production and consumption statistics; and
- the lack of information on the distribution and size of potential woodfuel sources hampers the implementation of international conventions and the complying to declarations and commitments concerning renewable energy and sustainable development—both in terms of production (biomass stocking and potential sustainable productivity) and consumption (expanding bioenergy applications).

In response to these problems, the Forest Products and Economic Division of FAO with its Wood Energy activities (FOPP-WE) promotes actions designed to clarify the role of wood energy and the opportunities that this sector has to offer to forestry, energy, poverty alleviation, food security and to the environment.

More specifically, the study is designed to:

- visualize current wood fuel situations at national, regional and global level
- reveal the role of wood fuels vis-à-vis energy, poverty and food security issues
- demonstrate the role of wood fuels in forestry sectors
- assess woodfuel production potentials from forests and other land uses

- promote the recognition of woodfuels as a primary forest management objective.
- promote the recognition of wood energy as an economically and environmentally efficient energy alternative to fossil fuels.
- monitor/support the use of biomass in industrialized countries.

FOPP-WE intends to achieve these objectives through a series of activities aimed at providing a coherent and updated overview of the wood energy situation, including demand and supply aspects, and its relation to poverty and food security. This will include the analysis of national wood energy data using FAO's interactive Wood Energy Information Statistics (i-WESTAT version 2) and an overview of the current wood energy situation in relation to woody biomass available for energy purposes.

In recent years FOPP-WE has already conducted national-level wood energy analyses in Mexico, Senegal and Slovenia applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology and now intends to develop a global overview of wood energy situations in relation to poverty, food security, climate change and sustainable forest management.

Scope

The scope of this report was to present sub-regional wood energy maps applying WISDOM for visualizing current woodfuel supply source levels and consumption patterns in selected African countries in order to improve the understanding of the role played by wood energy in the countries analyzed.

Making use of the information available under the FAO's Land Cover Classification System (LCCS)[2], this exercise includes 10 countries of East and Central Africa: Rwanda, Kenya, Egypt, Burundi, DR Congo, Eritrea, Somalia, Sudan, Tanzania and Uganda.

This task represented the first application of the WISDOM analysis on a group of countries in a given region and contributed to: estimates of woody biomass for energy purposes and also represented an important contribution to poverty mapping, to which it will add an essential energy dimension.

[2] LCCS was developed and implemented in the framework of the FAO Africover Programme of the Natural Resources Service (SDRN). The countries covered are :
Rwanda, Kenya, Egypt (NEPAD countries), Burundi, DR Congo, Eritrea, Somalia, Sudan, Tanzania and Uganda.

PART 1: Methodology

The methodological approach followed in the study is based on the following key characteristics of wood energy systems[3]:

Geographic specificity. The patterns of woodfuel production and consumption, and their associated social, economic and environmental impacts, are site specific [Mahapatra and Mitchell, 1999; RWEDP, 1997; Masera, Drigo and Trossero, 2003]. Broad generalizations about the woodfuel situation and impacts across regions, or even within the same country, have often resulted in misleading conclusions, poor planning and ineffective implementation.

Heterogeneity of woodfuel supply sources. Forests are not the sole sources of woody biomass used for energy. Other natural landscapes such as shrub lands, and other land uses such as farmlands, orchards and agricultural plantations, agro-forestry, tree lines, hedges, trees outside forest, etc. contribute substantially in terms of fuelwood and, to a lesser extent, as a raw material for charcoal production.

Users' adaptability. Demand and supply patterns influence each other and tend to adapt to varying resource availability. This means that quantitative estimates of the impacts that a given demand pattern has on the environment are very uncertain and should be avoided [Leach and Mearns, 1988; Arnold *et al.*, 2003].

Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM)

In order to cope with the characteristics mentioned above, the FOPP-WE has developed and implemented the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM)[4] methodology, a spatially-explicit planning tool for highlighting and determining woodfuel priority areas or woodfuel hot spots (Masera, Drigo and Trossero, 2003). To date, the WISDOM approach has been implemented in Mexico (Masera et al, 2004), Slovenia (Drigo, 2004) and Senegal (Drigo, 2004b) as a tool to support national-level wood energy planning.

WISDOM, especially when applied at regional level, does not replace a detailed national biomass demand/supply balance analysis for operational planning but rather it is oriented to support a higher level of planning, i.e. strategic planning and policy formulation, through the integration and analysis of existing demand and supply related information and indicators.

More than absolute and quantitative data, WISDOM is meant to provide relative/qualitative values such as risk zoning or vulnerability ranking, thus highlighting, with the highest possible spatial detail, the areas deserving urgent attention and, if needed, additional data collection. In other words, WISDOM should serve as an assessing and strategic planning tool to identify priority places for action.

A detailed description of the WISDOM approach can be found in Masera, Drigo and Trossero*,* (2003).

The use of WISDOM involves five main steps:

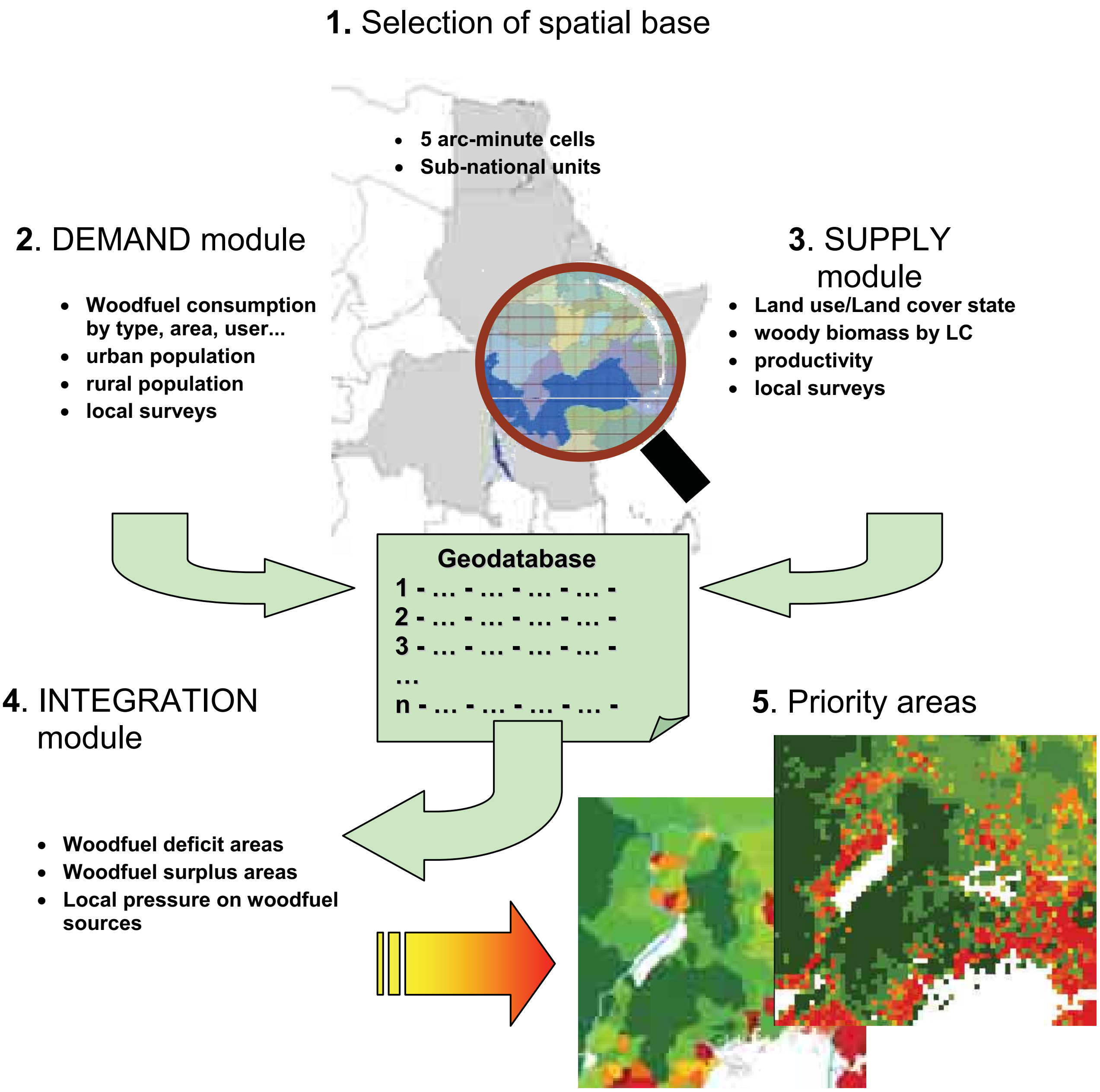
1. Definition of the minimum administrative spatial unit of analysis
2. Development of the DEMAND module
3. Development of the SUPPLY module
4. Development of the INTEGRATION module
5. Selection of the PRIORITY areas or "woodfuel hot spots"

The diagram in Figure 1 provides an overview of WISDOM main steps.

[3] Definitions of main terms are reported in Annex 1

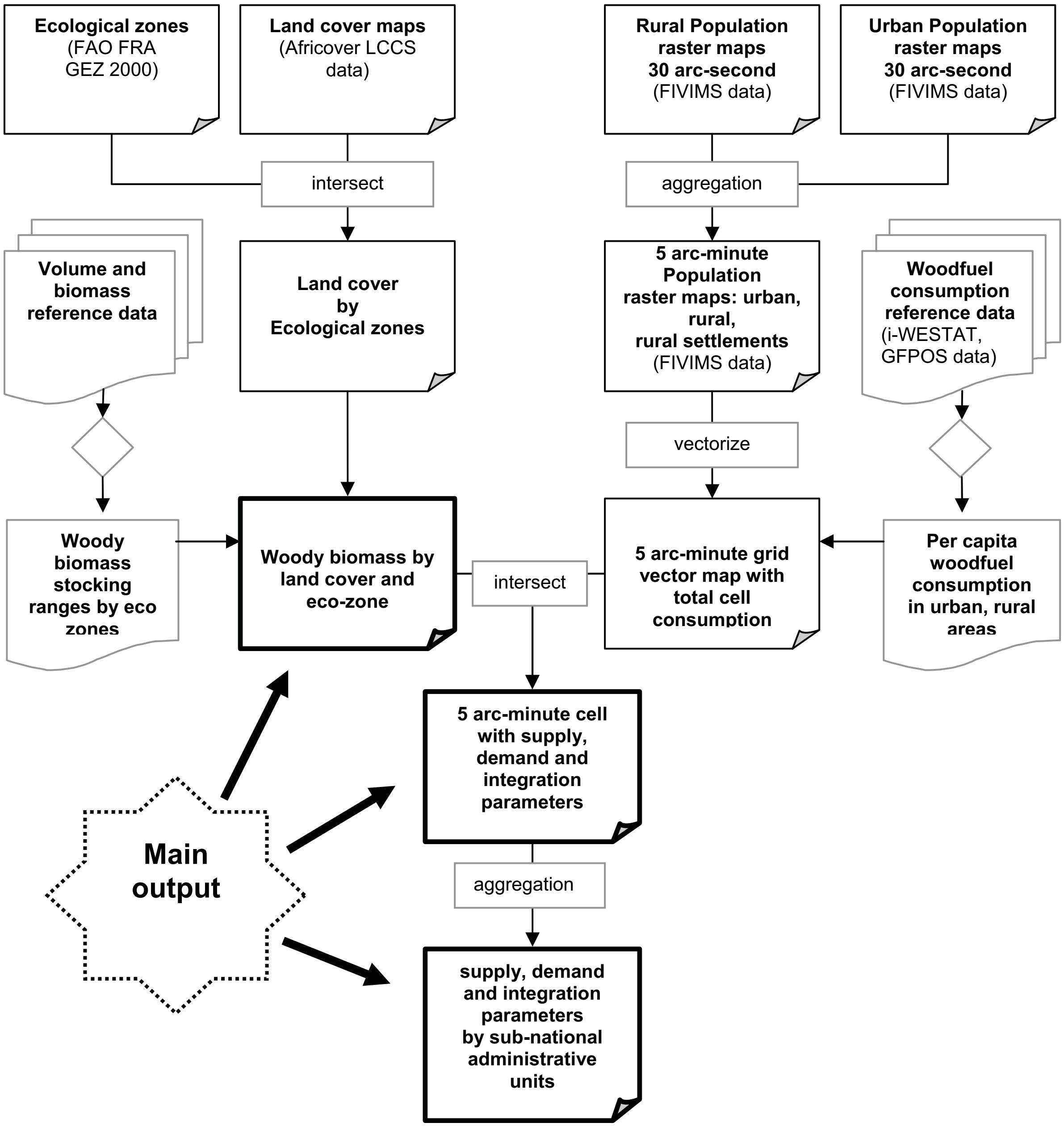
[4] WISDOM is the fruit of collaboration between FAO's Wood Energy Programme and the Institute of Ecology of the National University of Mexico. To date, WISDOM was implemented in Mexico (Masera *et al*.,2005), in Slovenia (Drigo 2004) and Senegal (Drigo, 2004).

Figure 1: WISDOM steps



The flowchart of the estimation process is shown schematically in Figure 2.

Figure 2: Flowchart of main analytical steps



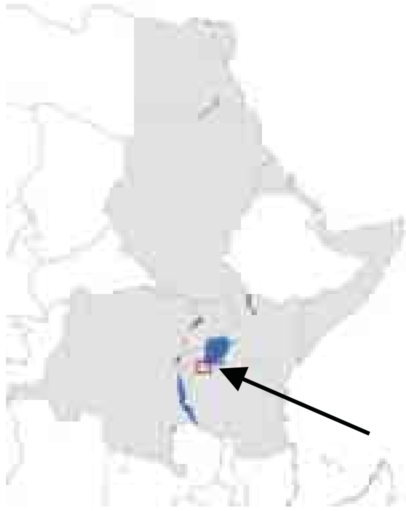
In order to visualize the various steps of the process, Figures 3 to 12 show the cartographic data layers that were used and produced in a small area of Tanzania, along Lake Victoria.

Specific aspects of the data used and processing carried out in the Demand, Supply and Integration modules are discussed in the following sections.

Example of data layers

The following maps are shown as example of the sequence of spatial data layers produced and involved in the analysis of woodfuel consumption and production potential.

Figure 3: Layout of the sample area[5]



The two following maps represent the input (original LCCS data) and the main output of the supply module (biomass stocking), which was created through the allocation of biomass density values to each of the 2947 individual LCCS classes according to individual tree, shrub and herbaceous layer present in the classes, and to the ecological zone.

Figure 4: Example of original LCCS data

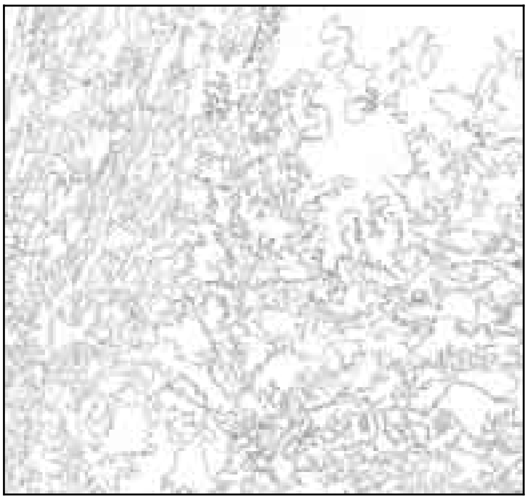
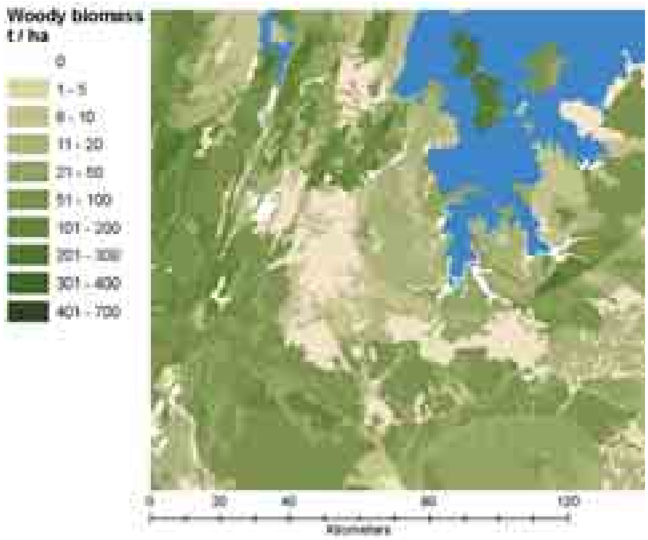


Figure 5: Example of Woody biomass stocking.



[5] The sample area is located in Northwest Tanzania, along Lake Victoria (provinces of Kagera and, partly, Mwanza and Shinyanga)

Figure 6: Example of population distribution, 30 arc-second data set.

These maps show population distribution in approximately 1 km^2 cells, then categorized as rural or urban.

Rural population data was further categorized as rural "settlements" and rural "sparse" using 2000 inhabitants/km^2 as a threshold.

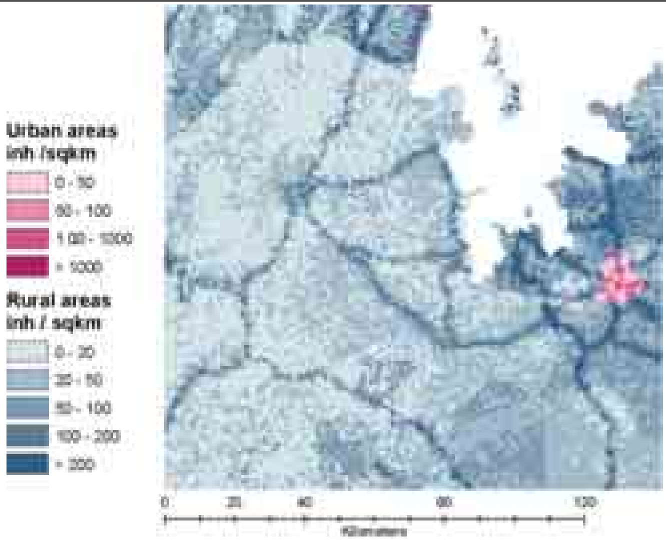


Figure 7: Example of Rural population within 5 arc-minute cells.

These maps provided number of people in approximately 9 x 9 km cells through the aggregation of 10 x 10 30 arc-second data.

Three independent maps were provided: one reporting urban population, one rural "sparse" and one rural "settlements".

(in this region no rural settlements were identified)

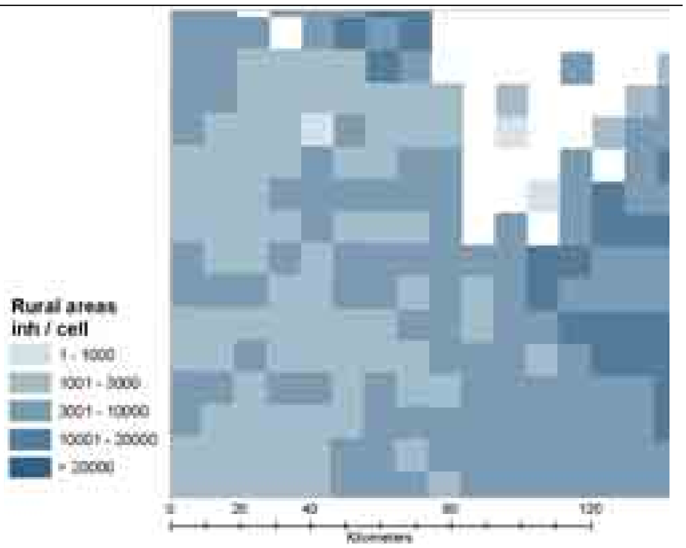


Figure 8: Example of urban population within 5 arc-minute cells.

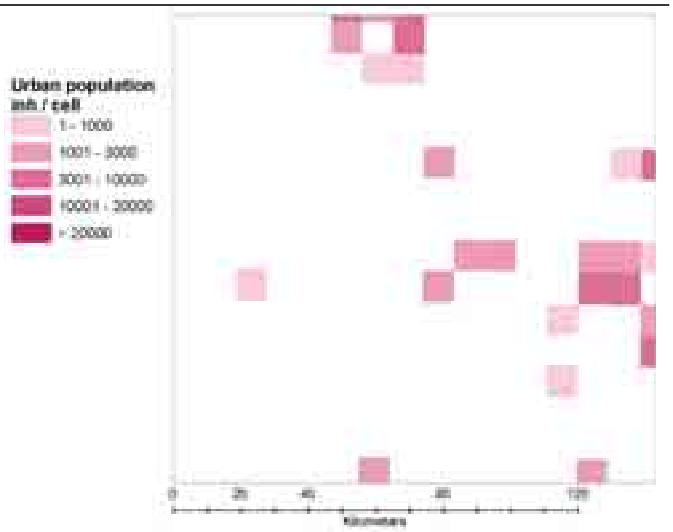


Figure 9: Example of woodfuel consumption by cell

This map was created using population data and average per capita consumption by rural, settlement and urban dwellers estimated for each country.

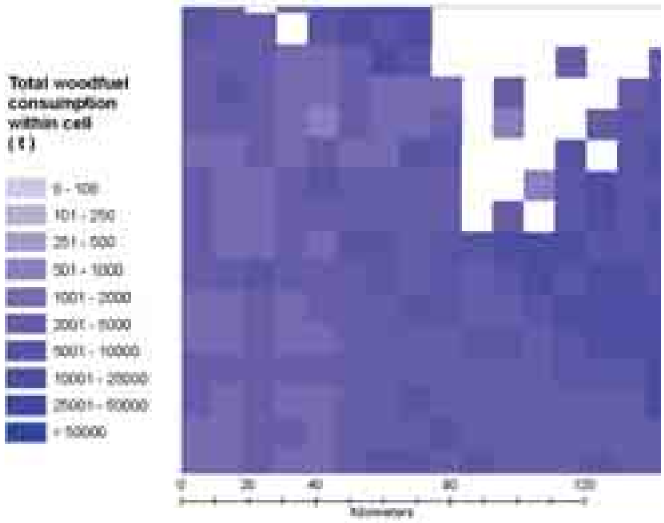


Figure 10: Example of woody biomass stock within 5 arc-minute cells.

Map created through the aggregation of the biomass stock of the original LCCS maps

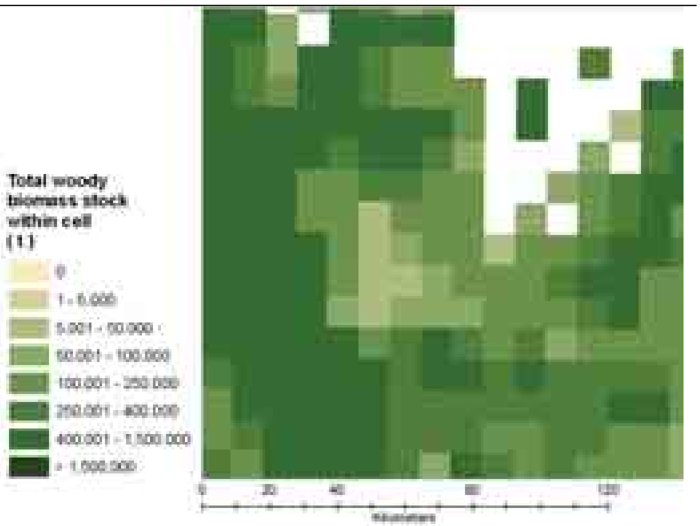


Figure 11: Example of woody biomass increment within 5 arc-minute cells.

The increment was estimated as a fraction of stocking and reduction of the proportion of wood used for other non-energy use.

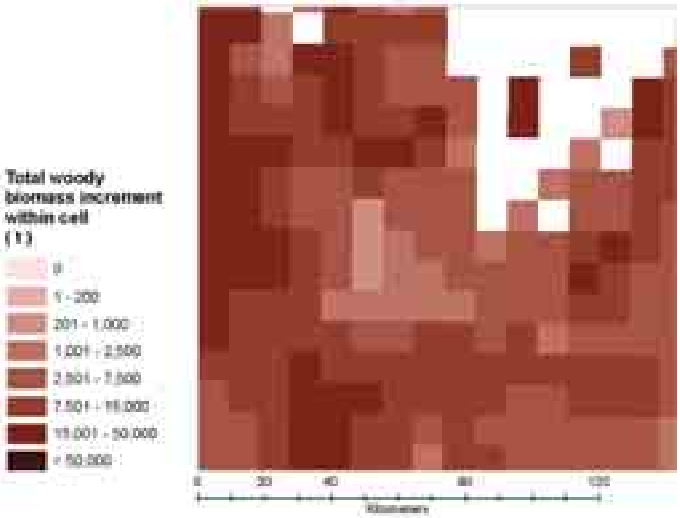
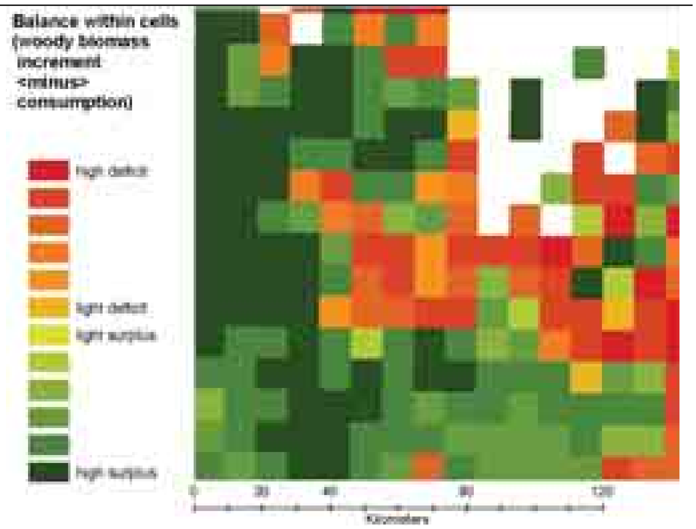


Figure 12: Example of cell-level supply/demand balance

This map was created subtracting the consumption to the average sustainable annual productivity of each cell. This map indicates the capacity of local wood resources to satisfy local demand and it is therefore meaningful for the poorest consumers depending on local supplies – though less so for marketed woodfuels.



Selection of spatial base

The spatial base, which is defined by the smallest territorial unit for which demand and supply parameter are estimated, it is the result of a compromise between the available data and the wanted level of analysis. In this case the key variables such as population for the demand module and land cover data for the supply module, presented a spatial resolution that was higher than the aimed level of analysis:

- population distribution data was available in raster format at 30 arc-second cell size, which represents individual units of 0.92 x 0.92 km in size (at the equator).
- population distribution data at 5 arc-minute resolution (9.2 x 9.2 km on the equator) derived from aggregation of 10x10 30 arc-second data.
- land cover data produced for all countries by the Africover Project using LCCS and available in vector format, presented a very high spatial resolution comparable to map scale between of 1: 100 000 and 1:200 000.

The 30 arc-second resolution, although potentially consistent with land cover data, appeared far too fine for the purpose of the study and for achieving a meaningful supply/demand relation.

The 5 arc-minute cells cover a territory in which supply/demand balance analysis is meaningful, especially for the fraction of woodfuel consumers that depend on local resources. More importantly, this format represents the spatial base of the FAO Food Insecurity Vulnerability Mapping System (FIVIMS). This means that keeping this format for WISDOM analysis and wood energy mapping guarantee a direct link and contribution to the FIVIMS thematic layer and ensures that WISDOM contributes to the analysis of food insecurity and poverty mapping.

Sub-national administrative data was also available, although the size of the units varied considerably from country to country. The sub-national unit level was also used as a secondary level of aggregation in the supply-demand balance analysis, but only for the aggregation of 5 arc-minute cell data.

Demand Module

The scope of the Demand module was to distribute the consumption of woodfuels at the defined minimum spatial level of analysis (5 arc-minute grid cells).

The statistical and spatial data available for the development of the demand module is listed below:

Woodfuel consumption data

- Estimates of total national consumption of fuelwood and charcoal at year 2000 from various sources and with occasional subdivision by rural/urban and household/non-household consumption (i-WESTAT data).
- Per capita fuelwood and charcoal consumption data by sector and by area from consumption surveys conducted (before 2000) at sub-national and local levels. Most of these surveys were carried out in the 1980s and only few references are reasonably recent (GFPOS data and other national references).

Population data

- National statistics of rural, urban and total population estimated at year 2000 (UN population statistics).
- Distribution of 2000 population by 30 arc-second cells classified as rural and urban (FIVIMS).
- Distribution of (sparse) rural population for 2000 by 5 arc-minute cells derived from the aggregation of 30 arc-second rural population cells with less than 2000 inhabitant /km2 (FIVIMS).
- Distribution of rural settlement population for 2000 by 5 arc-minute cells derived from the aggregation of 30 arc-second rural population cells with more than 2000 inhabitants /km2 (FIVIMS).
- Distribution of urban population for 2000 by 5 arc-minute cells derived from the aggregation of 30 arc-second urban population cells (FIVIMS).

The population distribution datasets were provided by the Geographic Information Systems Group of SDRN working on the Food Insecurity Vulnerability Mapping System (FIVIMS). These maps are based on Landscan Global Population Database 2002 and adjusted to 2000 UN population data. The urban boundaries, necessary to separate and distribute urban and rural populations, were generated by FAO/SDRN on the basis of Radiance Calibrated Lights of the World, 2000, and UN urban population data for 2000.

Process of estimation

The approach followed for estimating per capita consumption went as follows:

1. Identification of most reliable estimation of national consumption of fuelwood and charcoal at year 2000 through the consultation of i-WESTAT and other accessible sources. Results of this review are reported, country by country, in Annex 3.
2. Definition of total national consumption by the household sector and by all other sectors (industrial, commercial, institutional, etc.) on the based on the most recent data and the consultation of i-WESTAT, GFPOS data and other accessible sources.
3. Definition of rural/urban household consumption rates based on latest and most reliable national references (mainly GFPOS data).
4. Definition of per capita consumption of fuelwood and charcoal by the household sector in rural and urban areas according to UN rural/urban population statistics for year 2000.
5. Estimation of non-household consumption in rural and urban areas (very tentative) and definition of per capita non-household consumption in order to use population as proxy for spatial distribution.

Rural settlements

Designation of woodfuel consumption by rural settlements (in addition to rural and urban) was done for the countries with densely populated rural areas (rural areas with over 2000 persons per km^2)[6]. In these cases woodfuel consumption was assumed to have a consumption pattern somewhere between the urban and average rural levels. In general, rural settlement presented a higher charcoal consumption and lower fuelwood consumption rate relative to average rural conditions. The consumption in the remaining rural areas (with population density below 2000 inh/km^2), labelled "rural sparse", was derived from the remaining "unallocated" consumption and resulted in a higher fuelwood and lower charcoal consumption relative to average rural conditions.

The per capita consumption values, which referred to UN population statistics, were finally adjusted to the actual number of rural and urban population reported in the maps (see details in Annex 3, Summary table). The final per capita consumption values are shown in Table 1.

Table 1: Per capita consumption of wood for energy, in m^3 of fuelwood and wood used for charcoal, in all sectors (household and non-household)

	Summary values of per capita total wood consumption for energy (hh + ind) adjusted to 5min population map's values (m^3 / person / year)			
Country	**Rural sparse**	**Rural settlements**	**Rural (general)**	**Urban**
Burundi	1.48	1.08		0.70
Congo, Democratic Republic			1.17	1.97
Egypt	0.35	0.24		0.21
Eritrea	0.90	0.74		0.59
Kenya	0.78	1.03		0.83
Rwanda	0.50	1.00		1.86
Somalia			0.66	0.53
Sudan			1.09	1.09
Tanzania			1.33	1.76
Uganda	0.86	1.36		1.70

[6] Egypt, Eritrea, Kenya, Uganda, Burundi and Rwanda

Supply module

The analysis and spatial representation of woodfuel supply sources includes several phases of progressive refinement that may be summarized as follows:

- estimation and distribution of woody biomass stocking of natural formations (forests, other wooded lands) and anthropic landscapes (trees outside forests, forestry and agricultural plantations, farmlands and settlements);
- estimation and distribution of annual sustainable productivity and the share available for energy use; and
- segmentation of wood resource data by legal and physical accessibility classes.

The first phase represented an essential pre-requisite to the subsequent analytical steps on productivity and accessibility and constituted the main focus of the present study's supply module. The second phase, (estimation of annual productivity) was carried out by applying generic average growth rates due to lack of adequate reference data and to time constraints. The third phase, concerning physical and legal accessibility, requires considerable additional spatial processing work that could not be undertaken. To reduce the impact of the missing accessibility parameters, the analysis of supply/demand balance was constrained within 5 arc-minute cells (approximately 9 x 9 km) and therefore limited to the resources accessible to poor households given assumed gathering capacities.

The definition of the study areas, i.e. selected East and Central African countries, was done by taking into account the specific contribution that recent land cover data available for the 10 countries could make towards the assessment of biomass stocking. The land cover information was based on the Land Cover Classification System (LCCS), which was developed and applied in the framework of Project Africover (Di Gregorio and Jansen, 2000). The new land cover classification encompasses one third of Africa and offers a uniform and coherent support to the estimation/stratification of woody biomass into discreet density classes and subsequently, to the assessment of the state and distribution of woodfuels resources.

Of particular relevance for the present study was the on-going activity, supported by the Italian *Istituto Agronomico per l'Oltremare* and carried out by Valerio Avitabile, on the estimation and distribution of biomass and carbon stocking using LCCS data. The supply module of the present study benefited from collaboration with IAO in the definition of the methodology and in the collection and review of existing literature references on volumes and biomass stocking. The biomass stocking data used for the supply module are based on the first comprehensive set of volume/biomass reference values collected by ecological zones resulting from the FAO/IAO collaboration. However, since the IAO initiative will continue beyond the completion of the present study, a more advanced biomass and carbon stocking data set will be available at a later stage.

Estimation of woody biomass stocking and distribution

Direct field measurements of woody biomass are extremely rare. Relatively more common are forest inventories although they are usually limited to the "commercial" assortments (higher diameter classes of timber species) of productive forests. Unproductive forests, in terms of timber quality, degraded forest formations, fallows, shrub formations, trees outside forests, farm trees, etc. are systematically excluded from conventional surveys, although they usually represent the main sources of fuelwood and wood for charcoal.

The comparative advantage of LCCS data for estimating biomass stocking rests with the detailed description of the physiognomic characteristics of land units, which are qualified through a system of classifiers that provide a detailed description of tree, shrub and grass layers.

The method for the estimation of biomass density (biomass stocking in tonnes per hectare) was based on the combination of two data sets:

1. Volume and biomass indicators based on field inventory results and other surveys of the main formations and ecological zones, providing minimum, maximum and mean volume and biomass density values in "normal" conditions or referring to specific crown cover densities.[7]

[7] The main references resulting from the bibliographic search and the system of reference values adopted in this study are reported in Annex 3.

2. LCCS data providing actual crown cover conditions for the main life forms (trees, woody, shrubs and herbaceous) and for all possible combinations of agricultural and natural formations.

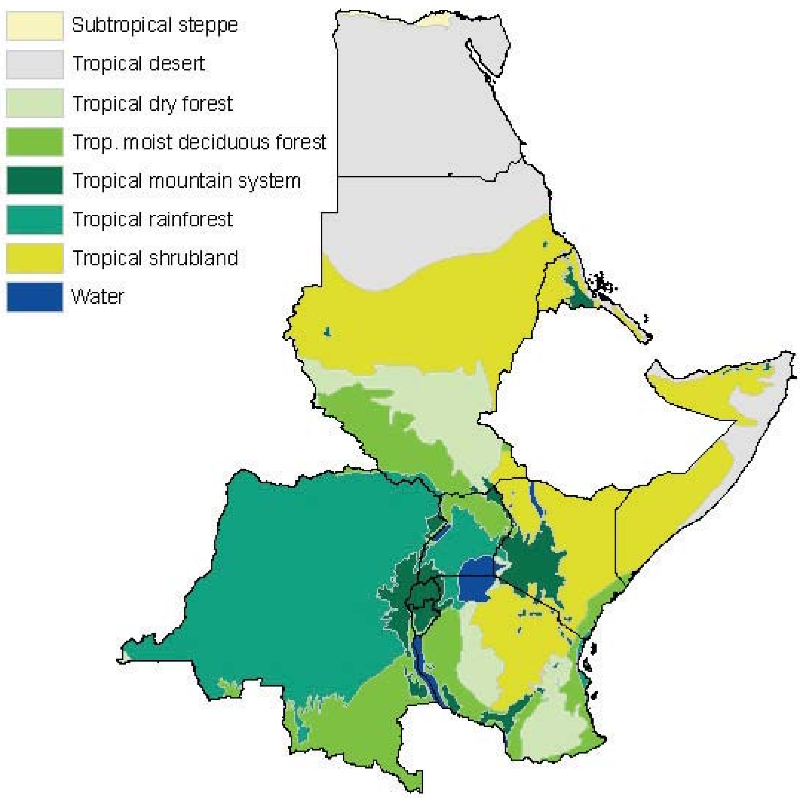
Ecological stratification

Several existing ecological classification systems were considered (ICIV 1980, White, 1983). Given the limited number and uneven spatial distribution of field data on volumes and biomass, preference was given to a relatively simple classification system, with few classes within which an acceptable number of reference values could be found.

The ecological stratification was based on the FRA 2000 ecological zone map (Figure 13), which indicates seven main zones in the ten countries covered by this study:

- Subtropical steppe
- Tropical desert
- Tropical shrub land
- Tropical dry forest
- Tropical moist deciduous forest
- Tropical rainforest
- Tropical mountain system

Figure 13: Ecological zones



For practical reasons, the drier zones (steppe, desert and shrub land) were grouped to form a single class and therefore the ecological zones of interest remained five only.

Estimating biomass density of LCCS classes

In total 525 single land cover classes were found in the maps, which gave origin to as many as 2947 individual LCCS codes, including single classes but also numerous class combinations (land units presenting a mixture of two or three single classes). These figures are a good indication of the wide variety of conditions described by LCCS and also of the relative complexity of assigning biomass values to each LCCS class.

In the process of assigning biomass density values, volume and biomass data was used as a reference for the potential stocking (minimum, maximum) in the various ecological zones while LCCS data was used to adjust the biomass stocks according to actual physiognomic conditions of land cover types and their geographic distribution. Annex 3 provides the values assigned to the LCCS crown cover categories of all life forms (trees, woody and shrubs) in each ecological zone and other land cover types.

Depending on the availability of reference data, minimum, maximum and mean values of biomass stocking were identified for all life forms, and ecological zones. In the subsequent phases of analysis, however, the mean values were used as main reference.

Biomass stocking in forest plantations

Estimates of woody biomass stocking and productivity of forestry plantation for the countries of the study are rare, scattered and probably biased since they often refer to successful plantation sites or controlled test areas while excluding poorly stocked ones. The values of Mean Annual Increments (MAI) and rotation periods reported in FRA databases provided an indication of the range of values but realistic average values are difficult to determine because the weight and representation of the existing values are not known.

On the other hand, an overview analysis of fuelwood plantation in developing countries (FRA 2000), the average productivity assumed for Africa was 6 m^3/ha/yr. For Ethiopia and Sudan, in which fuelwood plantations represent 88 and 78% of all plantations, respectively, the average productivity assumed was 11 and 5 m^3/ha/yr. Moreover, the FRA country report for Ethiopia indicated an average woody biomass stocking for plantations at 40 tons/ha, equal to the average value given for natural forests. These values are lower than those reported by plantation statistics.

Consequently, lacking reliable estimates of actual plantations, the stocking values of closed tree formations for the corresponding ecological zone were used as reference. It was assumed that a plantation of average condition could reach, at end rotation, a biomass density comparable to that of a closed canopy natural forests of the same site. Since the age class of plantations is not reported in LCCS, the stocking was assumed to be mid-term, i.e. ½ the value assumed at end rotation.

Given the limited availability of data on woody biomass of orchards, and other agricultural crops, the estimates for the classes occurring in LCCS were done on inference and more or less educated guesses. It is hoped that in time, these approximate estimates will be replaced by more reliable values.

Estimates for sustainable production of wood for energy

Mean Annual Increment

Estimating woody biomass in the area studied and included in the LCCS legend was a complex task, aggravated by the virtual absence of reliable field data for the study area.

For the scope of the present study a simple approach was adopted, under the assumption that in normal conditions there is a direct positive relation between the stocking and the mean annual increment (MAI) of natural formations (Openshaw, 1982). This assumption, supported by increment data (Micski, 1989, Bowen et al., 1987, FAO 1982), and the fraction applied by Openshaw (2.5 percent) appeared realistic. Therefore, the MAI was estimated as 2.5 percent of biomass stocking for all formations except forest plantations.

As mentioned above, the MAI values for forest plantations reported by the literature were extremely variable (FAO 2001, 2002). However, considering the various references available, a MAI of 5 percent of the stocking at end rotation appeared realistic. Consequently, since the biomass stocking of plantations was considered as ½ of that at end rotation, the MAI applied for forest plantation was estimated as 10 percent of the assumed “mid-rotation” biomass stocking.

Fraction of woody biomass used for energy

In the countries of this region woody biomass is predominantly used for energy. This is clearly shown in Table 2, which reports the ratio between FAOSTAT’s information on woodfuel production and on total roundwood production. On average, the ratio for year 2000 was estimated at 0.94. This factor was systematically applied to the total woody biomass productivity values to quantify the amount of woody biomass available for energy uses after deduction of the amount utilized for other purposes.

Table 2: Fraction of woodfuel production in total roundwood production at year 2000 as reported by FAOSTAT.

Country	Woodfuel / total roundwood
Burundi	0.94
Congo, Dem Republic of	0.95
Egypt	0.98
Eritrea	1.00
Kenya	0.91
Rwanda	0.93
Somalia	0.99
Sudan	0.88
Tanzania, United Rep of	0.90
Uganda	0.91
Average	0.94

Source: FAOSTAT 2005

Integration module and definition of priority areas

The scope of the integration module was to combine, by land units (5 arc minutes cells or sub-national units), the parameters developed in the demand and supply modules to highlight areas of potential deficit or surplus according to estimated consumption levels and sustainable production potentials.

The main indicator so far produced was represented by the balance, within the 5-arcminute cells, between the fraction of the potential sustainable productivity available for energy uses and the total woodfuel consumption. This parameter does not consider the transportation of woodfuels between distant production and consumption sites—an element that would require additional analytical steps.

As is, this parameter provides a useful indication of the ease, or difficulties, that poor rural households face in acquiring their daily subsistence energy.

In order to visualize these results under the administrative angle, the results by 5 arc minute cells were subsequently aggregated at sub-national unit level.

PART 2: Results

The results of the WISDOM process consist of a series of geodatabases resulting from the development of the Demand, Supply and Integration modules.

Demand module results.

The geodatabase resulting from the Demand module is based on 5 arc-minute grid cells (98 592 cells of approximately 9x9 km) and contains information on the spatial distribution of woodfuel consumption for the 10 countries covered by the study in a single sub-regional map. The themes included are:

- Consumption in rural areas with population density below 2000 inhabitants / km^2.
- Consumption in rural areas with population density above 2000 inhabitants / km^2.
- Consumption in urban areas.

Supply module results.

The geodatabases resulting from the Supply module shows the distribution of woody biomass stocking and increment at two levels of spatial resolution: national maps at full resolution and a single sub-regional map at 5 arc-minute resolution explained below:

- 10 individual national maps of biomass stocking and increment at the resolution of the original national land cover maps. The land cover maps used in this study are the spatially aggregated versions of the national Africover data sets. Their scale is approximately 1:200 000.
- One sub-regional map of biomass stocking and increment by 5 arc-minute cells of biomass stocking and increment.

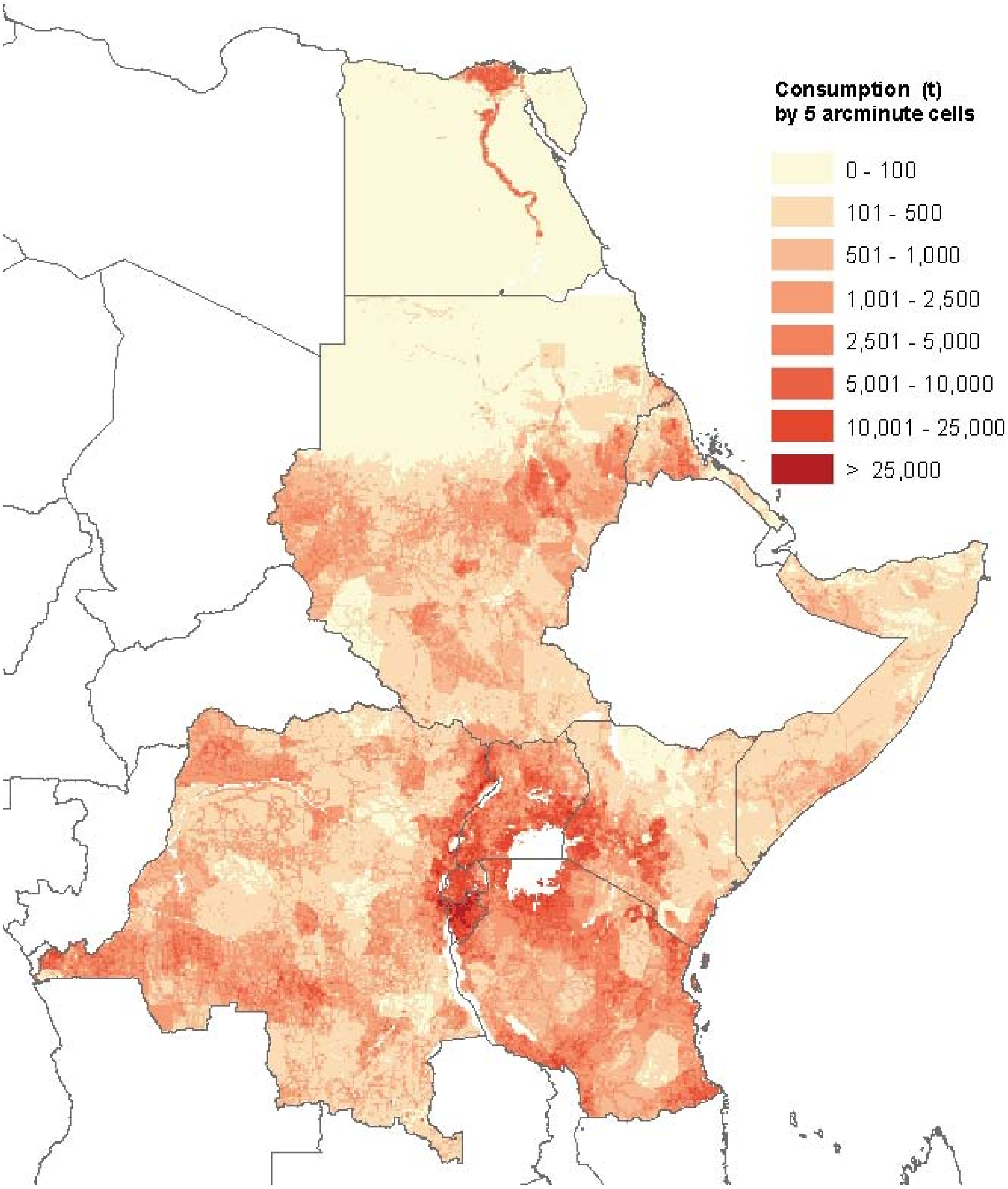
Integration module results

The geodatabase resulting from the Integration module is based on 5 arc-minute grid cells and contains information on the balance, within such cells, between the consumption of woodfuels and potential sustainable supply of woody biomass available for energy uses. Two geographic representations were made:

- Sub-regional maps of demand/supply balance by 5 arc-minute cell size (98 592 units). This data set is presented at global level as well as at national level.
- Sub-national aggregation of cell-level balance results (1 172 sub-national administrative units). This dataset is presented at global level (with enlargement for Kenya, Uganda, Rwanda and Burundi that present relatively small sub-national units).

Demand module: Spatial distribution of woodfuel consumption[8]

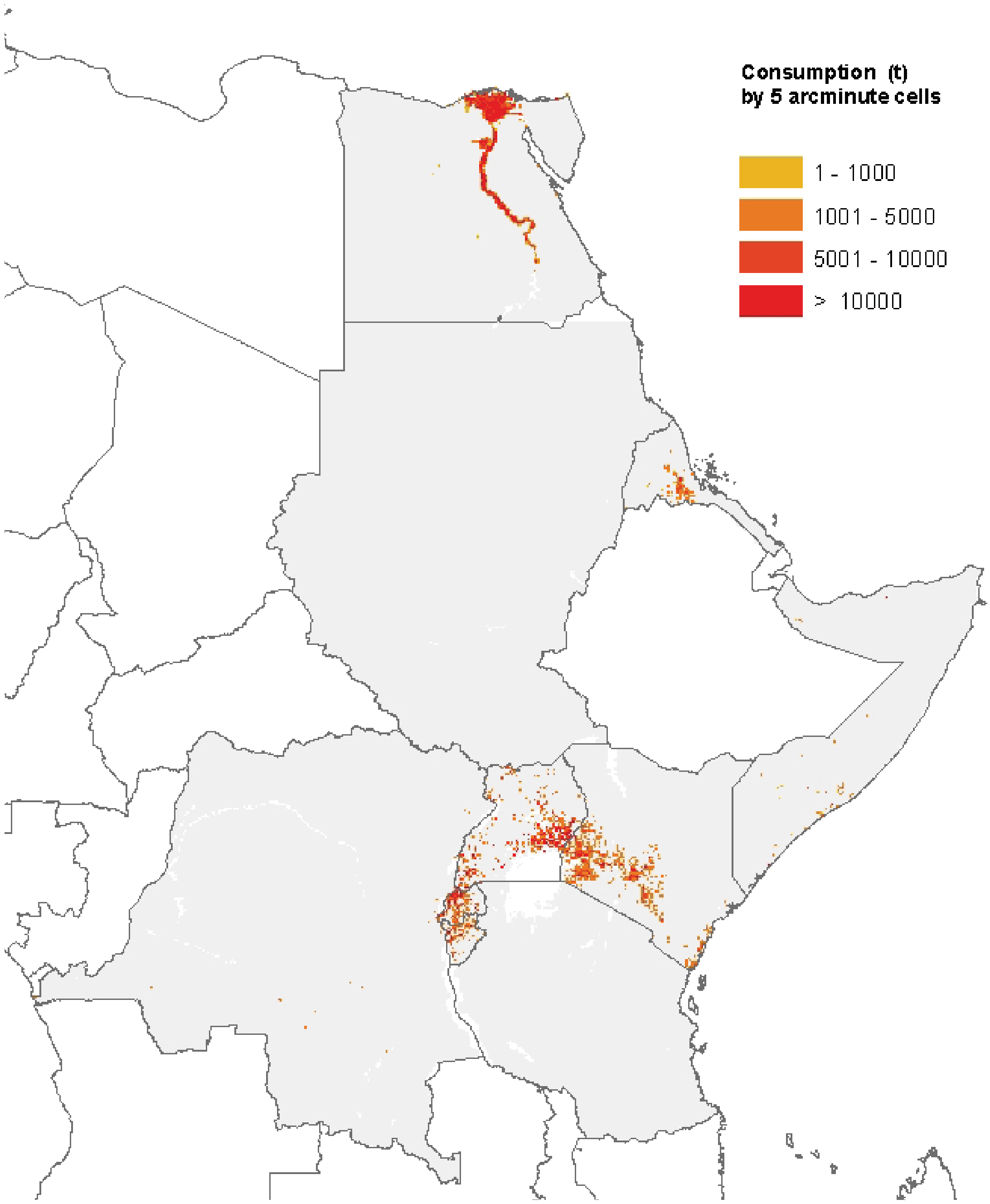
Figure 14: Consumption in rural areas with low population density[9].



[8] The consumption includes fuelwood and wood used for charcoal production.

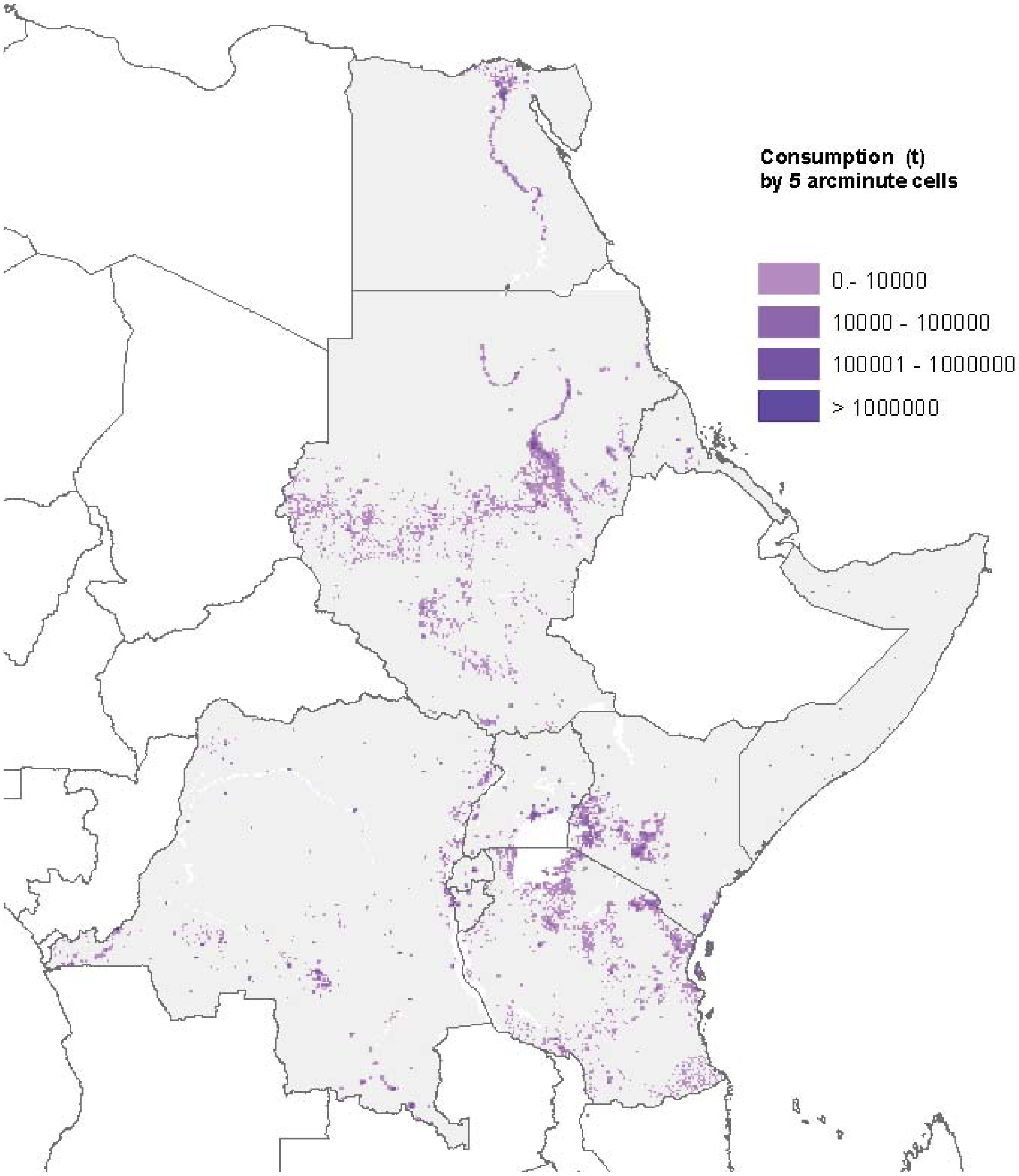
[9] Rural areas with population density below 2000 inhabitant / km^2.

Figure 15: Consumption in rural areas with high population density (rural settlements)[10]



[10] Rural settlements are defined as rural areas with over 2000 inhabitants /km2.

Figure 16: Consumption in urban areas



Supply module: Spatial distribution of woody biomass resources

Coarse resolution maps (5 arc minutes regional dataset)

Figure 17: Woody biomass stocking

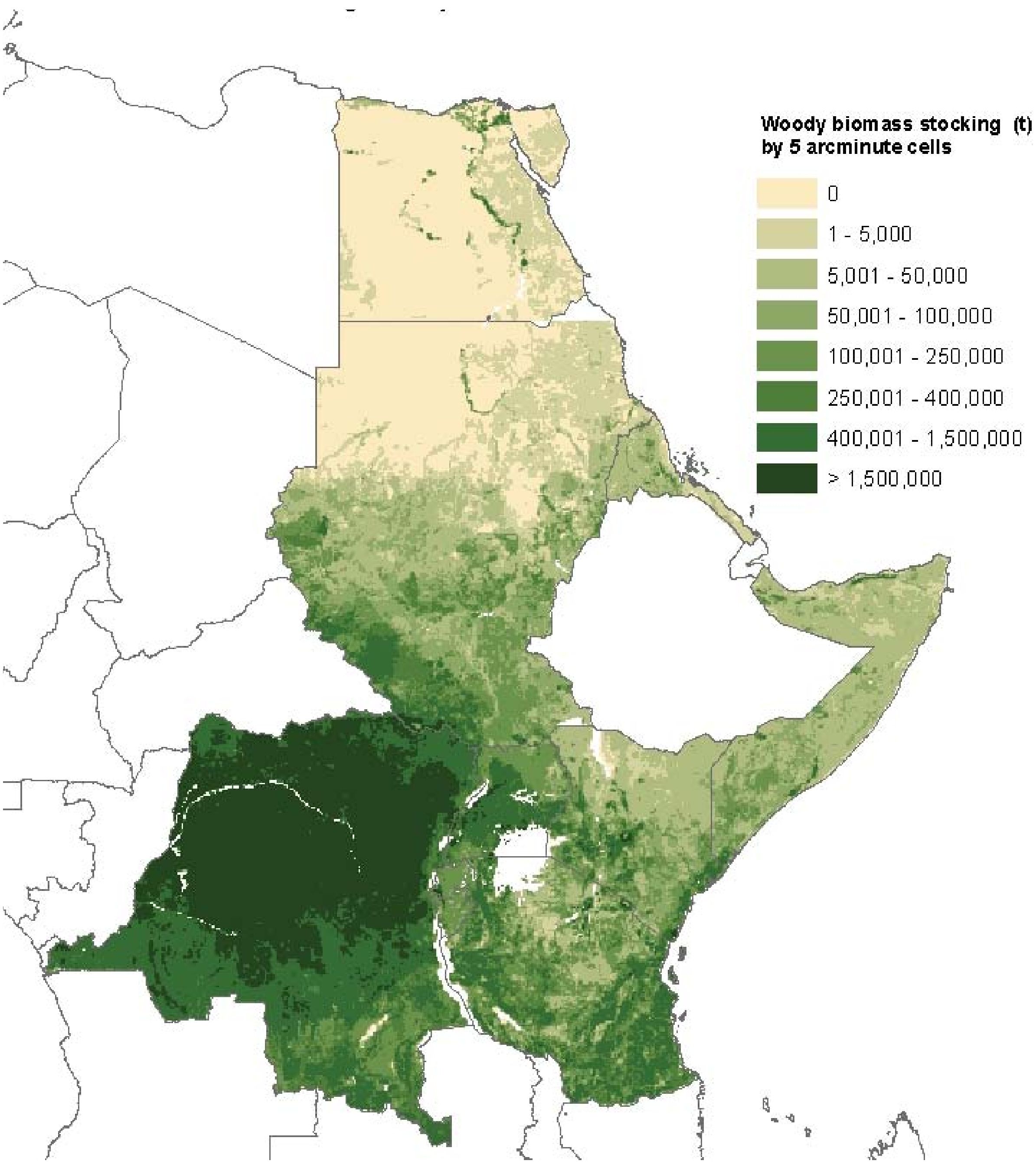
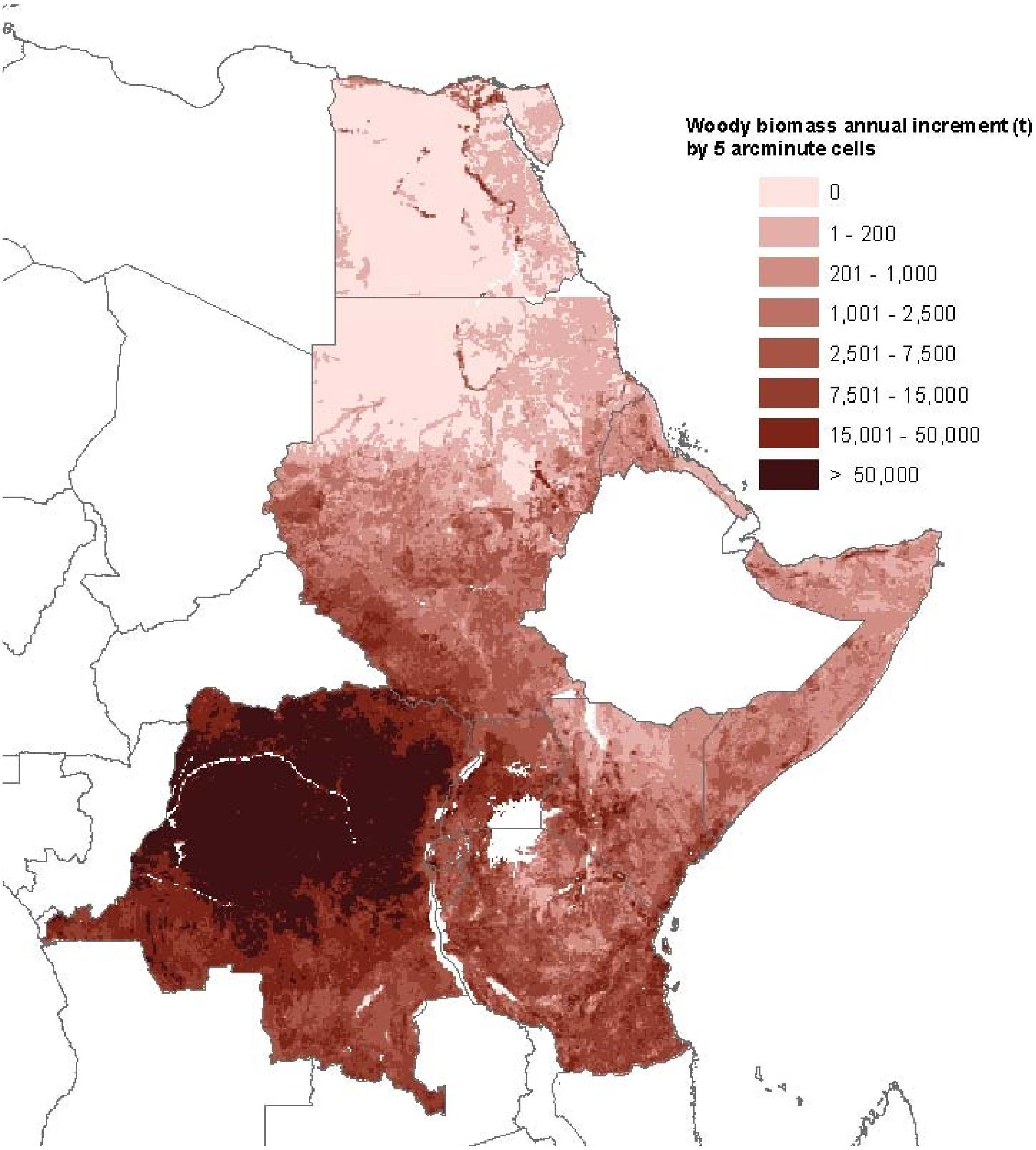


Figure 18: Estimated potential annual increment of woody biomass



Full resolution maps (1:200 000 national data set)

Figure 19: Burundi – Woody biomass density map

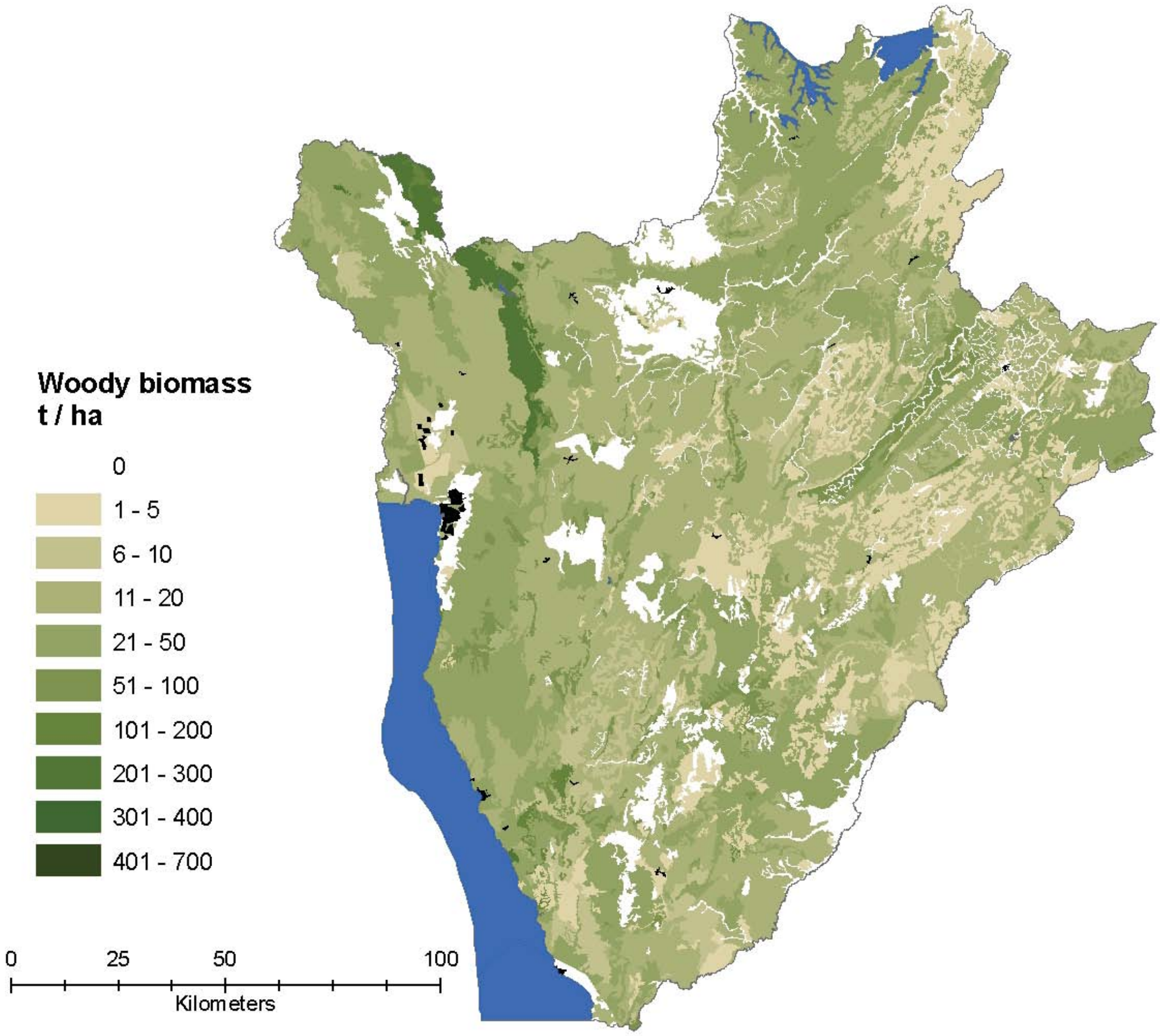


Figure 20: Democratic Republic of Congo – Woody biomass density map

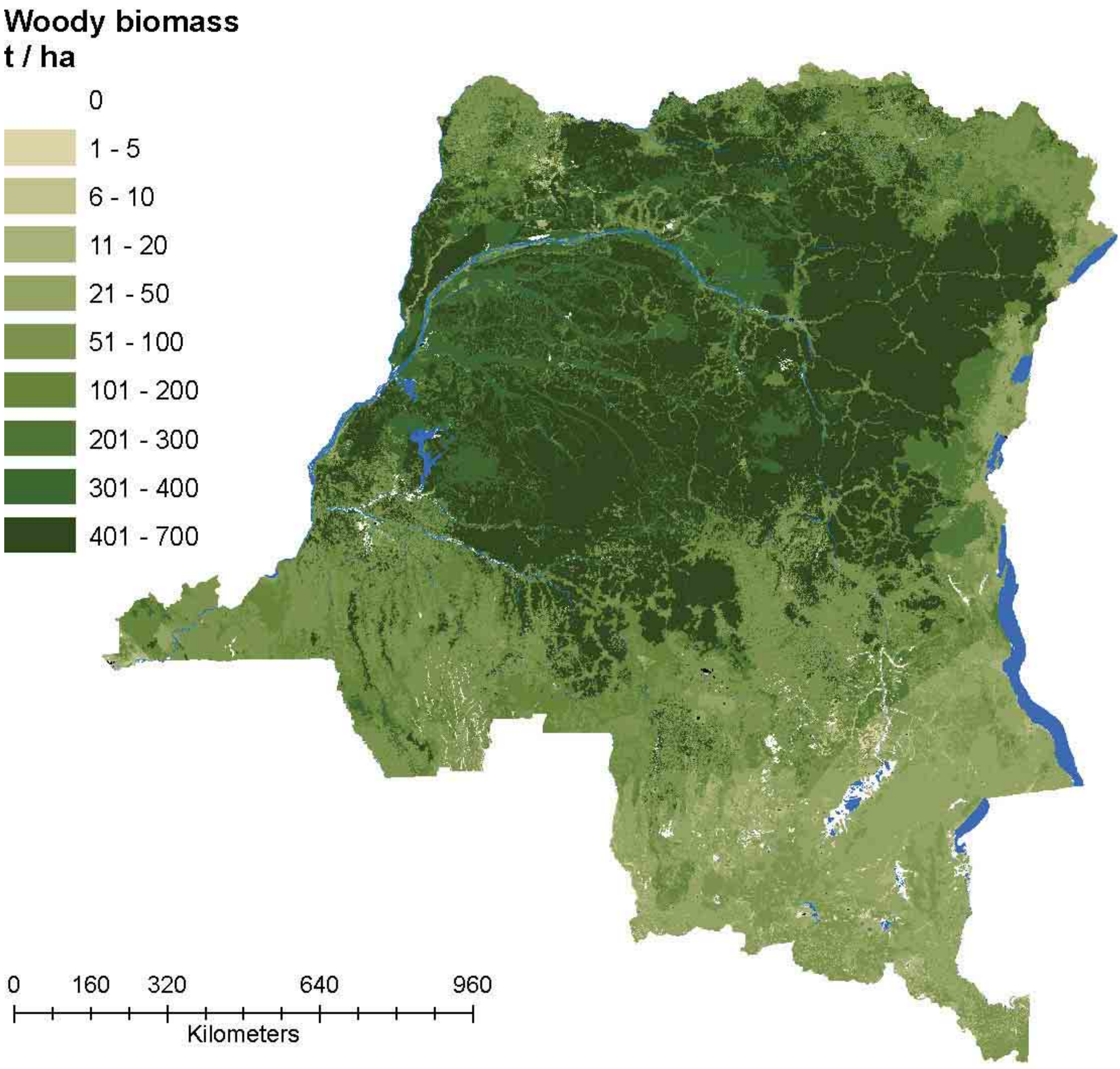


Figure 21: Egypt – Woody biomass density map

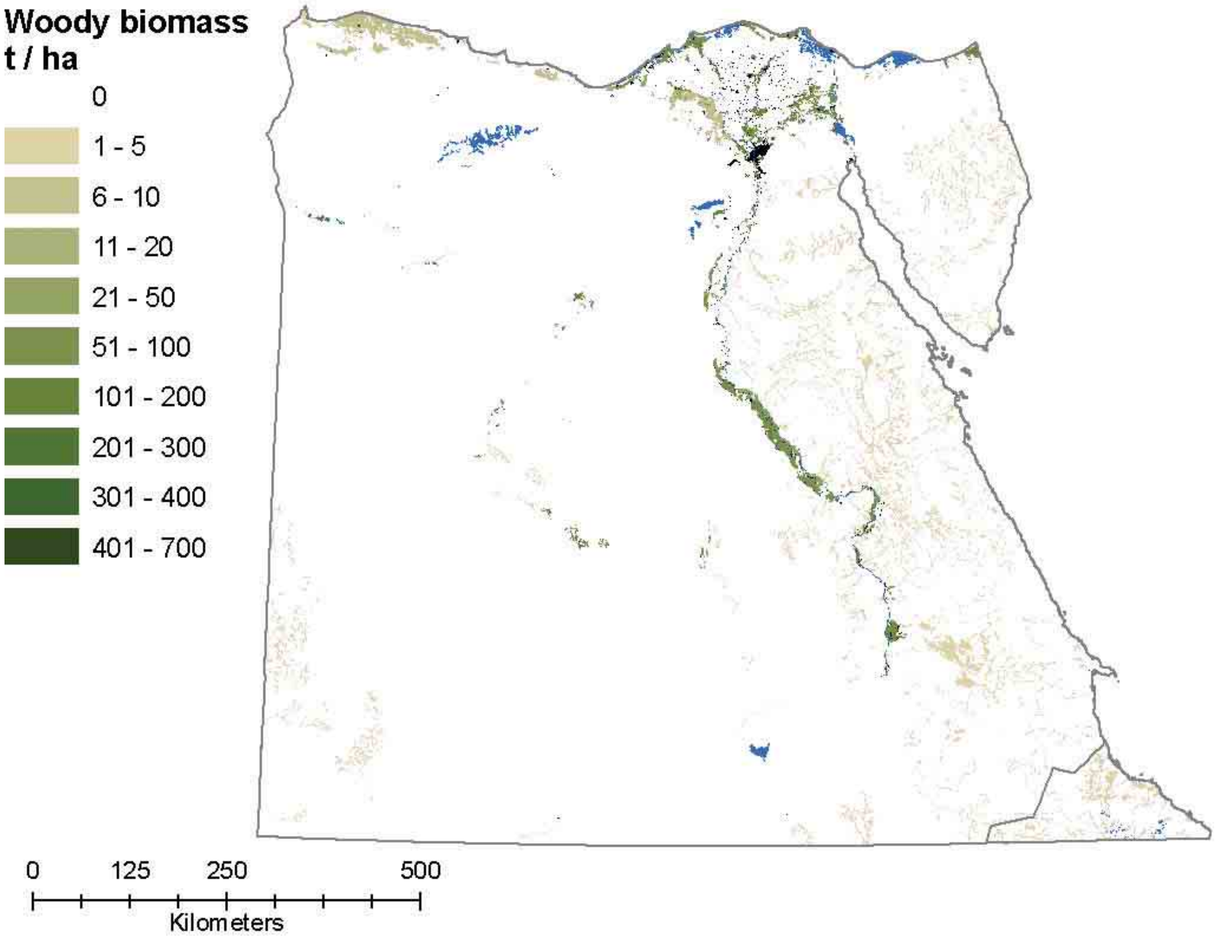


Figure 22: Eritrea – Woody biomass density map

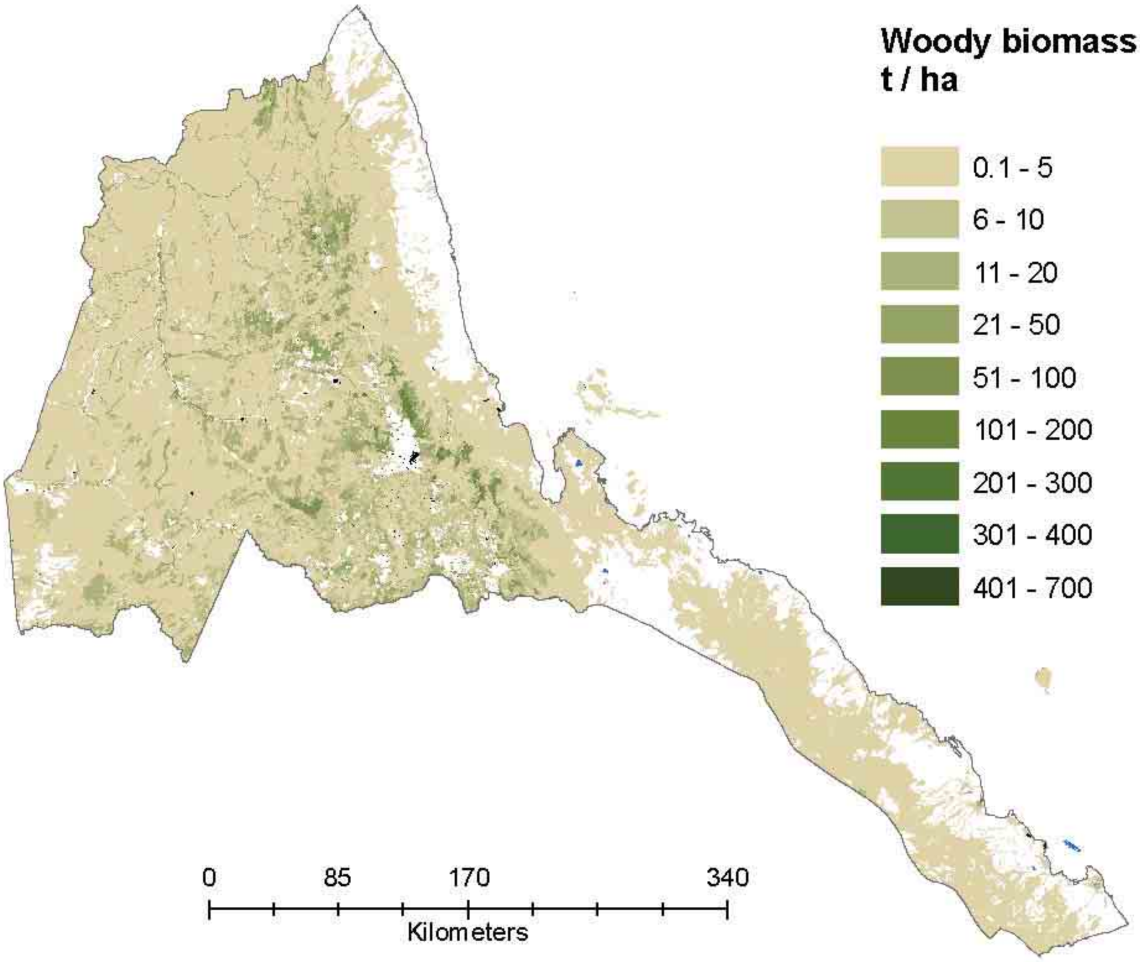


Figure 23: Kenya – Woody biomass density map

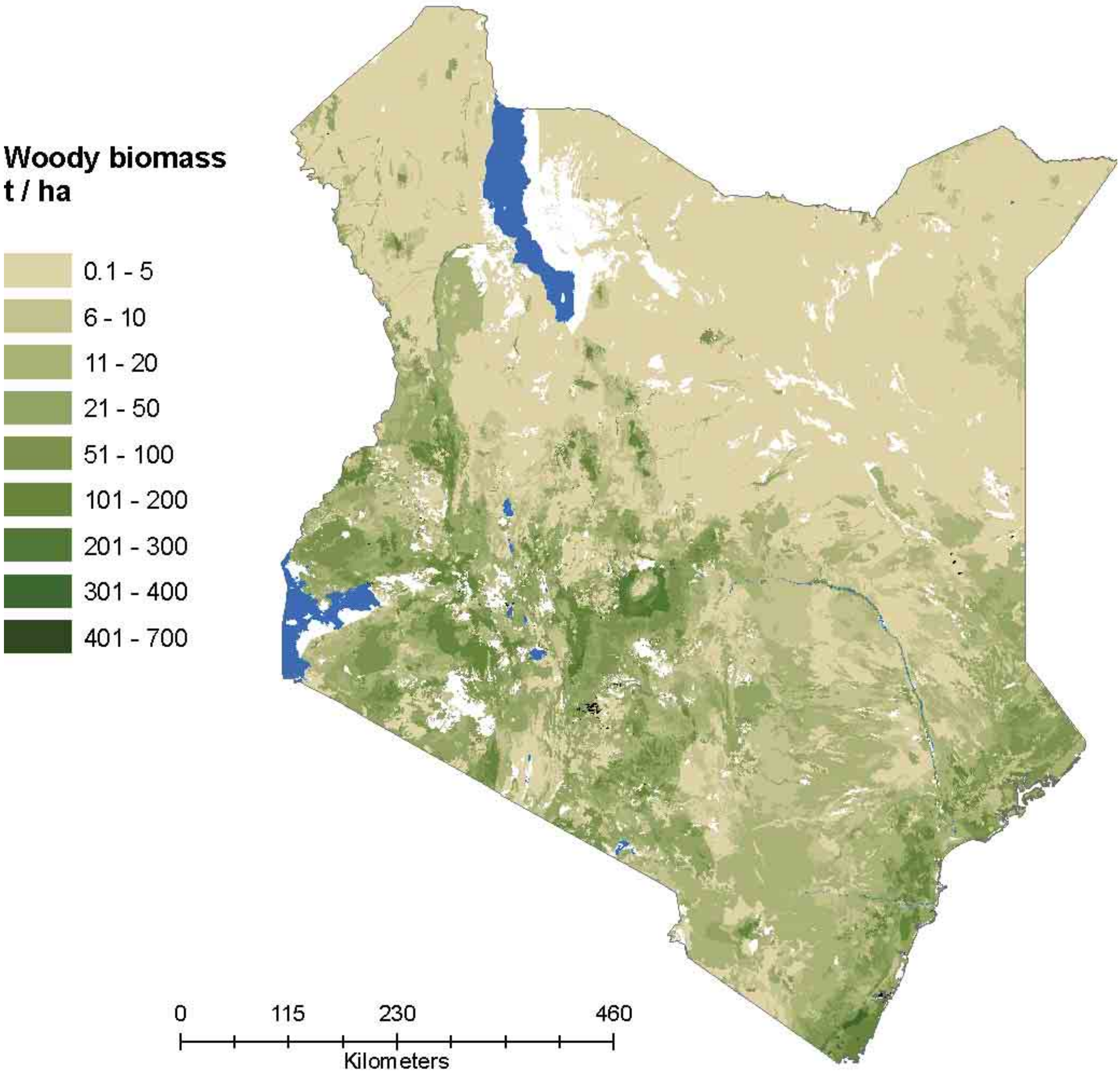


Figure 24: Rwanda – Woody biomass density map

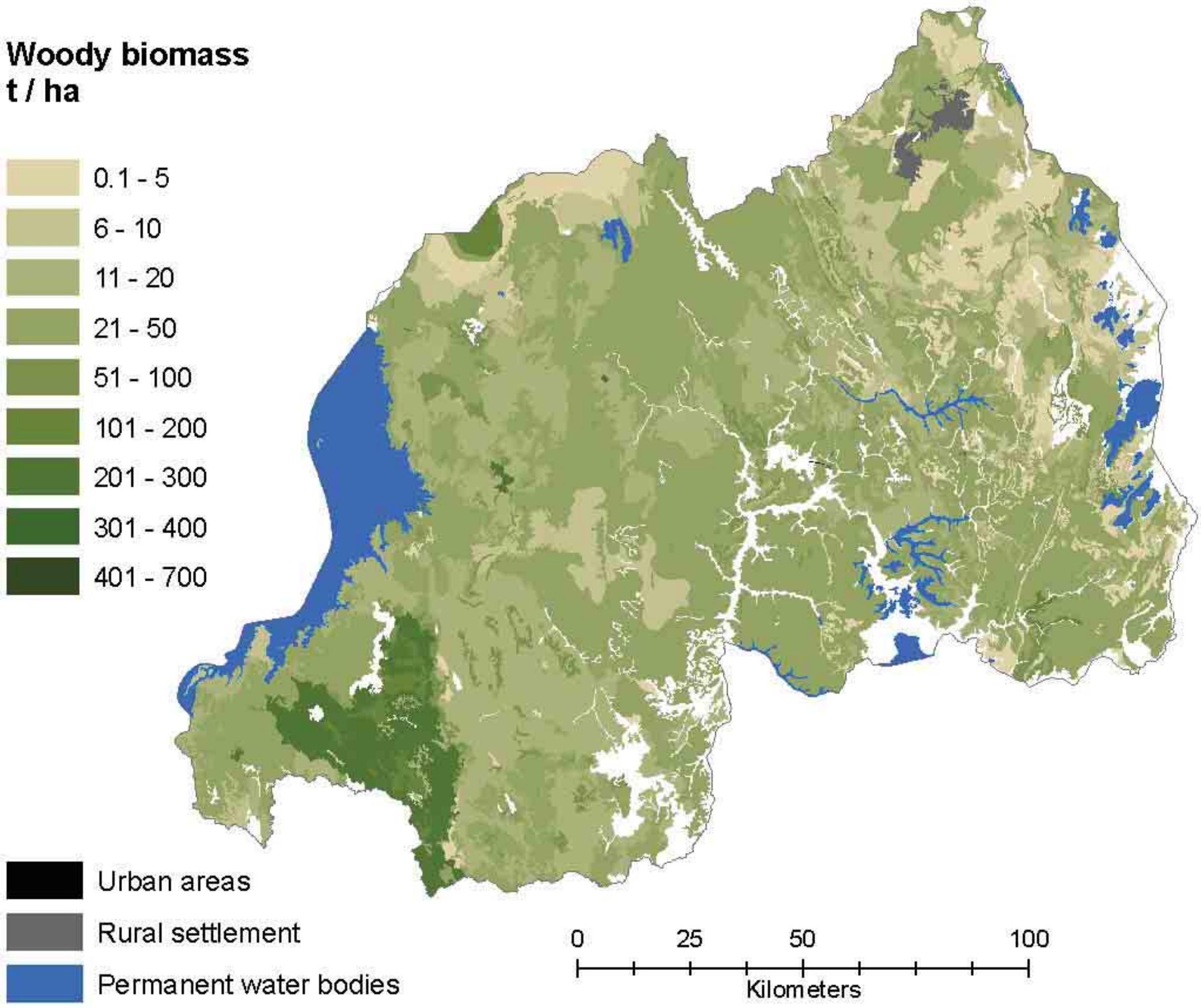


Figure 25: Somalia – Woody biomass density map

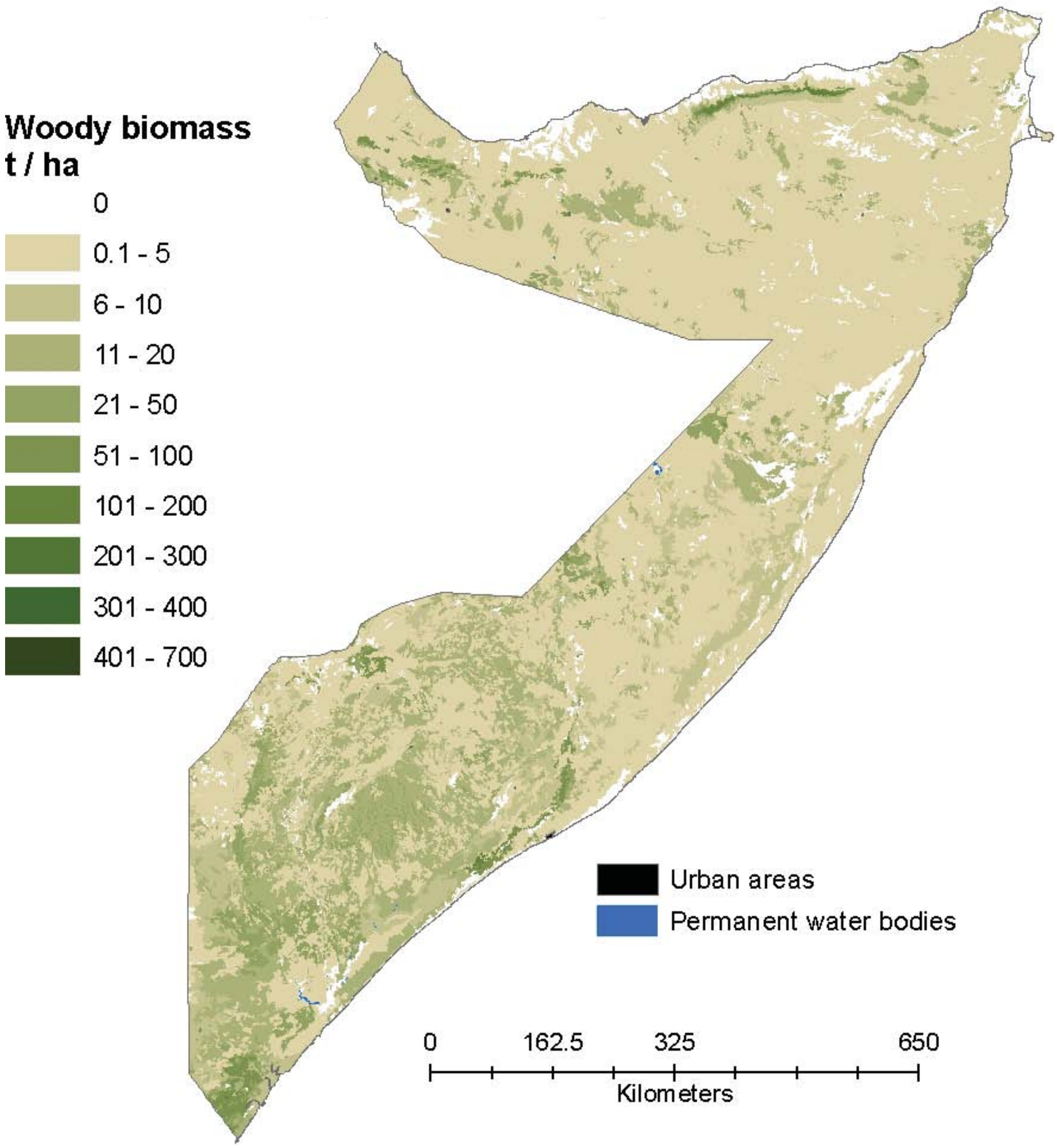


Figure 26: Sudan – Woody biomass density map

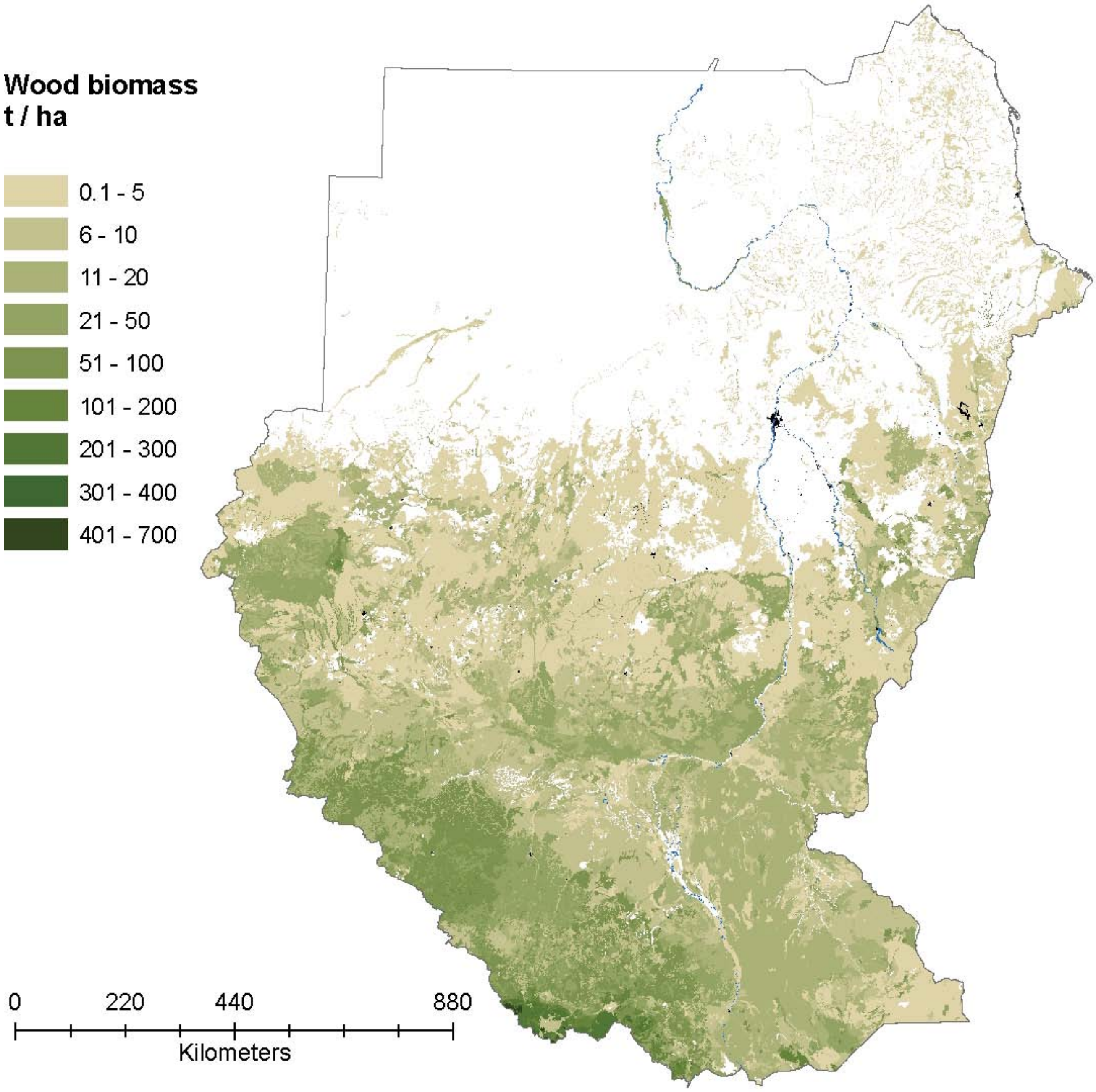


Figure 27: Tanzania – Woody biomass density map

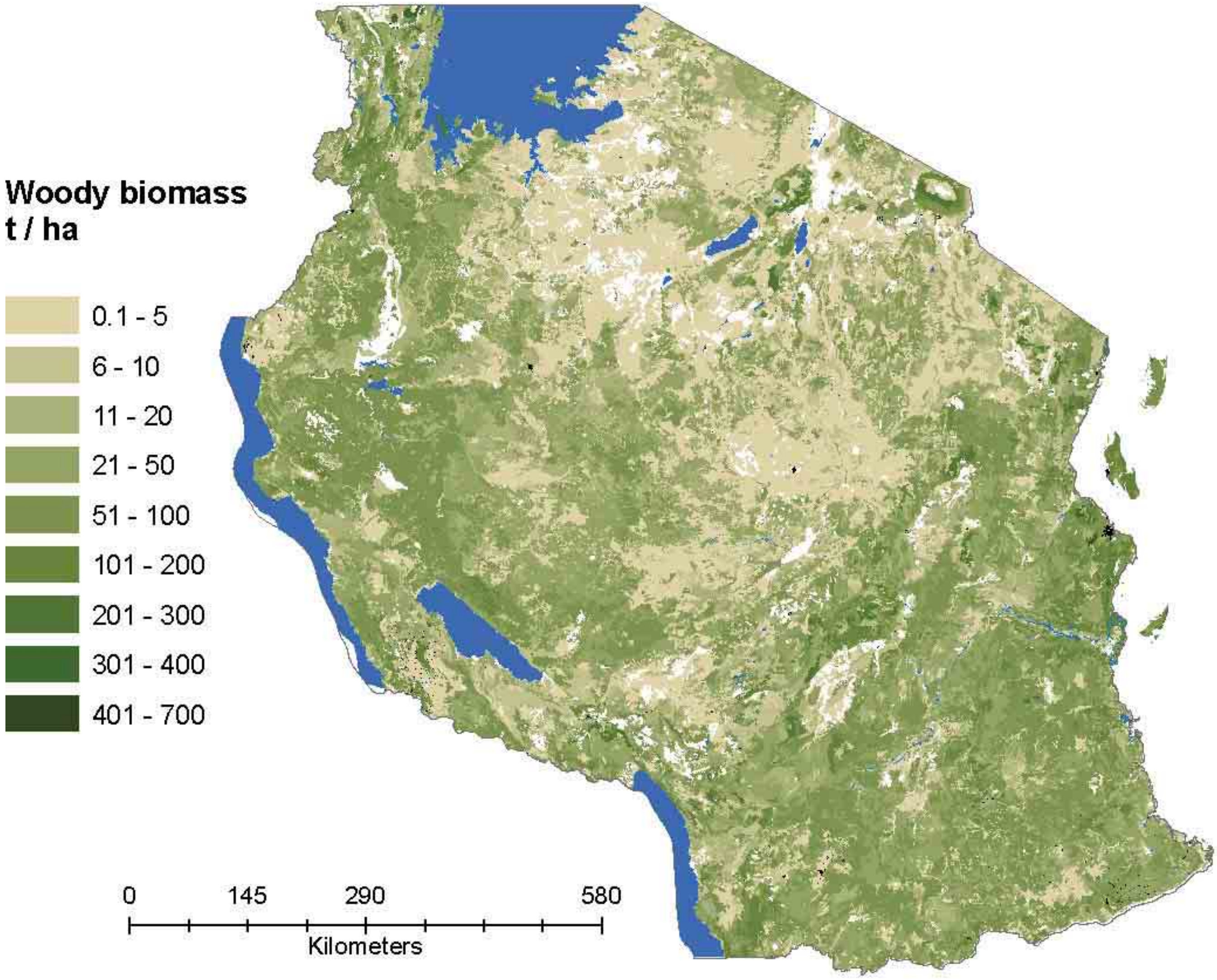
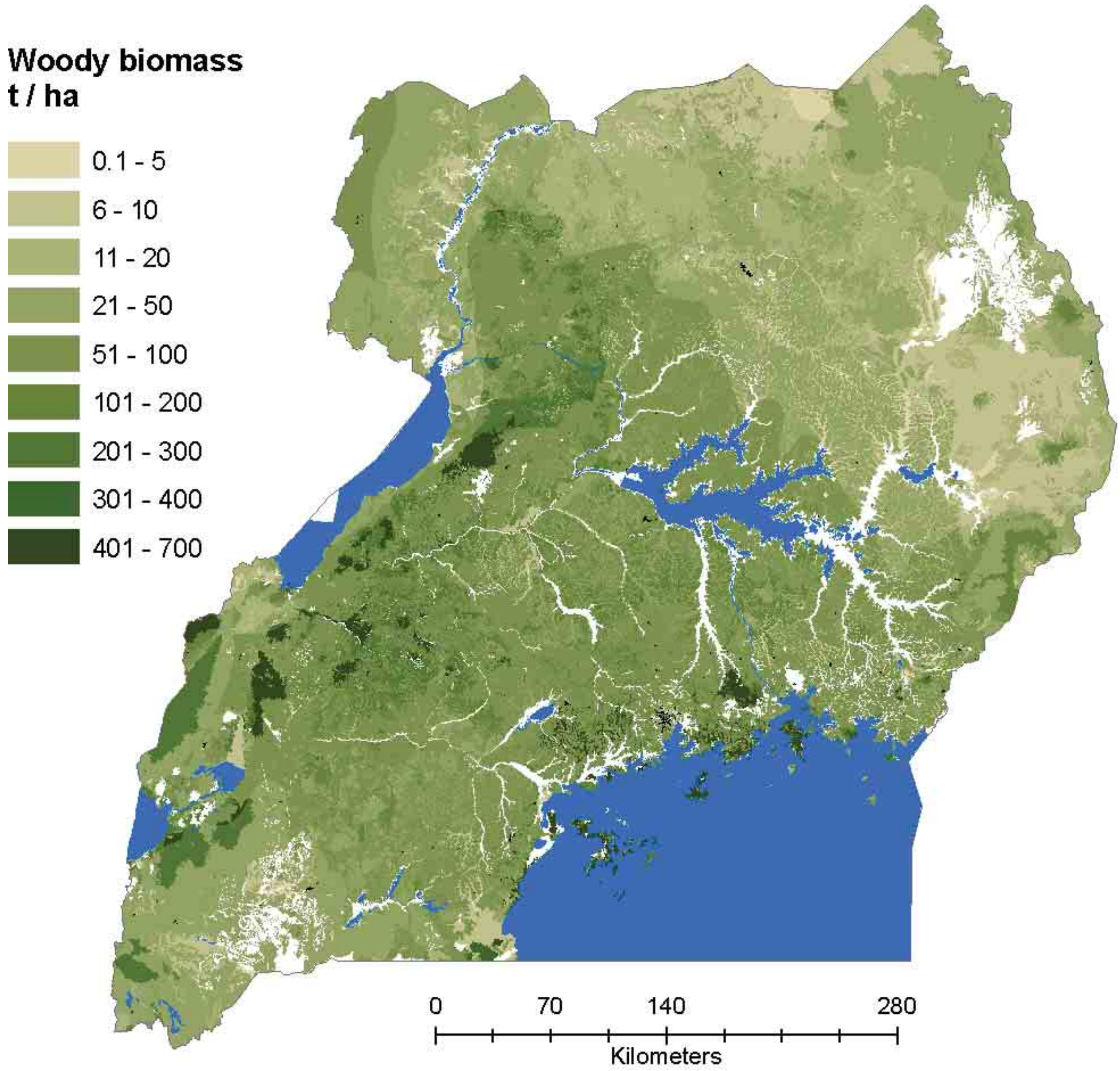


Figure 28: Uganda – Woody biomass density map

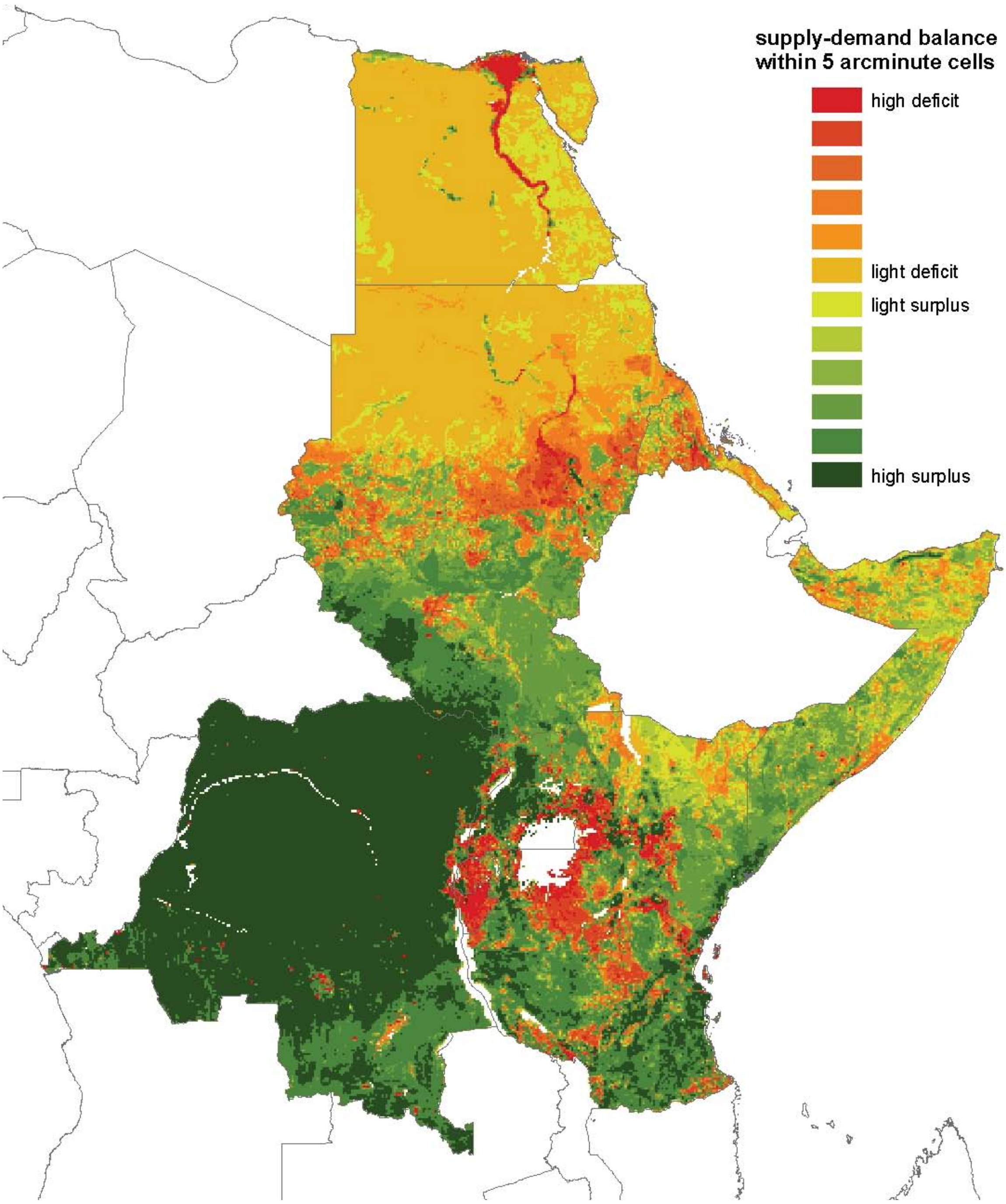


Integration module: Demand/supply balance

5 arc-minute data set (98 592 cells of approximately 9x9 km)

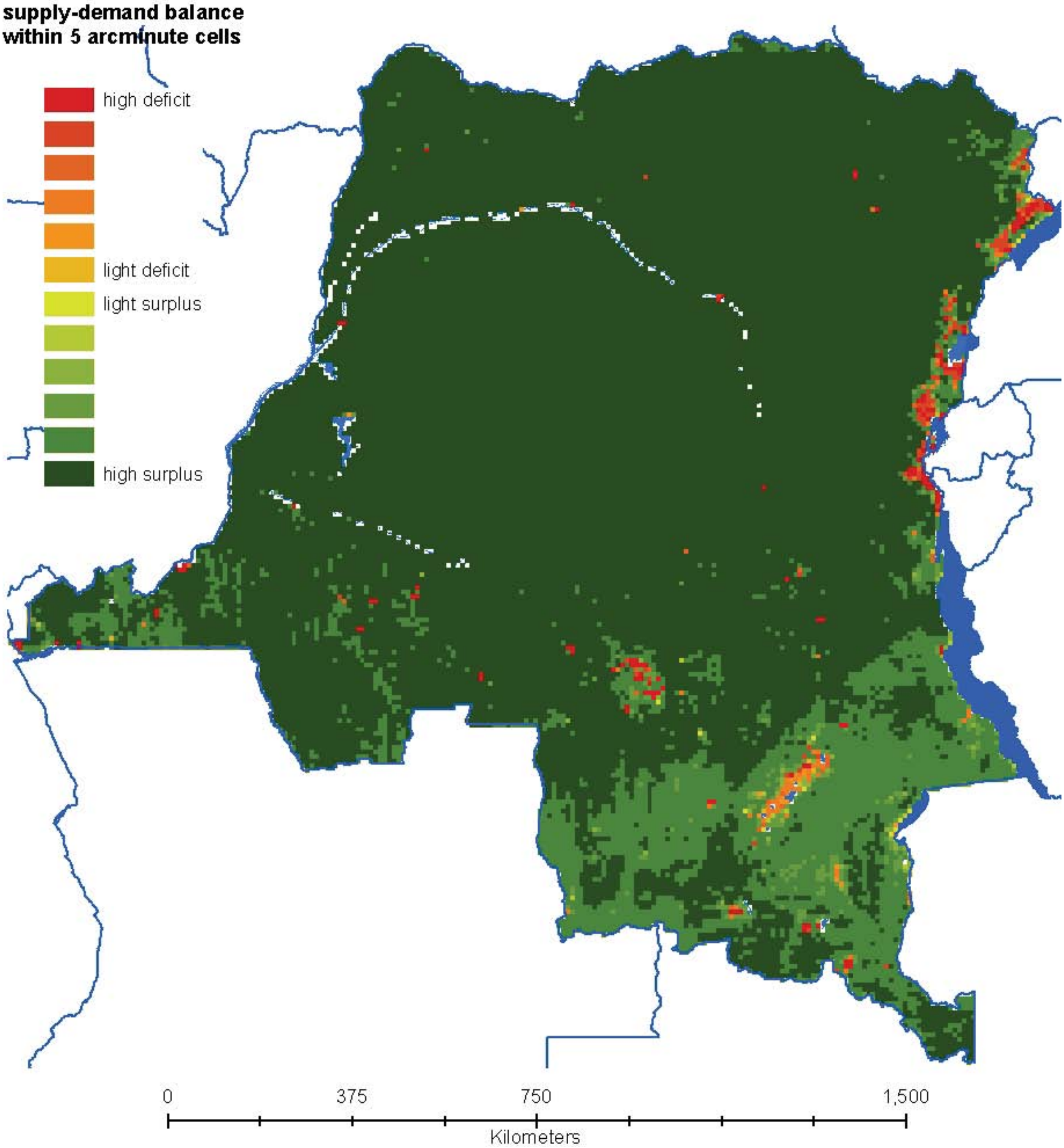
Regional data set

Figure 29: Regional map woodfuel supply-consumption balance categories.



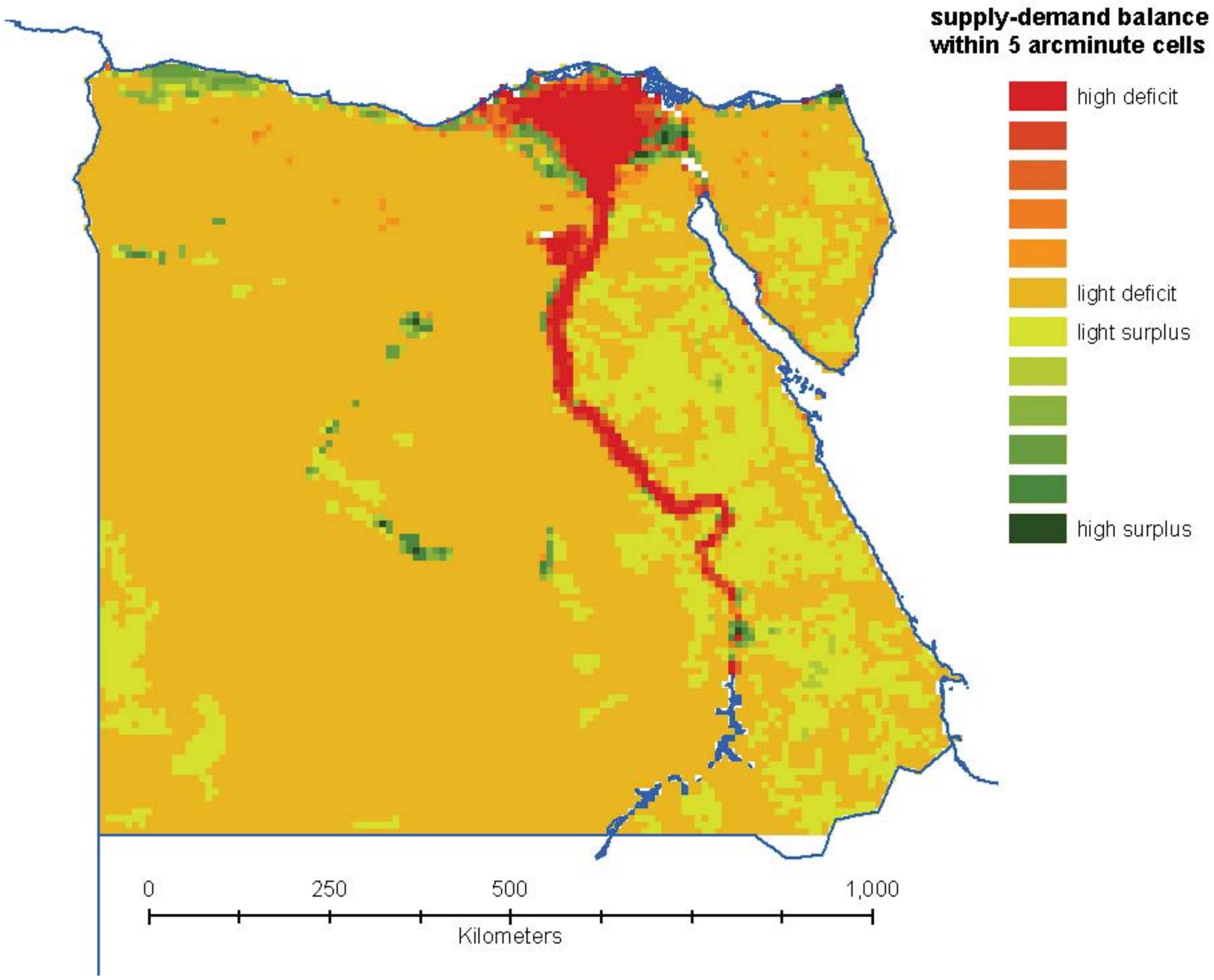
National data sets

Figure 30: Democratic Republic of Congo. Map of categories of woodfuel supply-consumption balance categories.



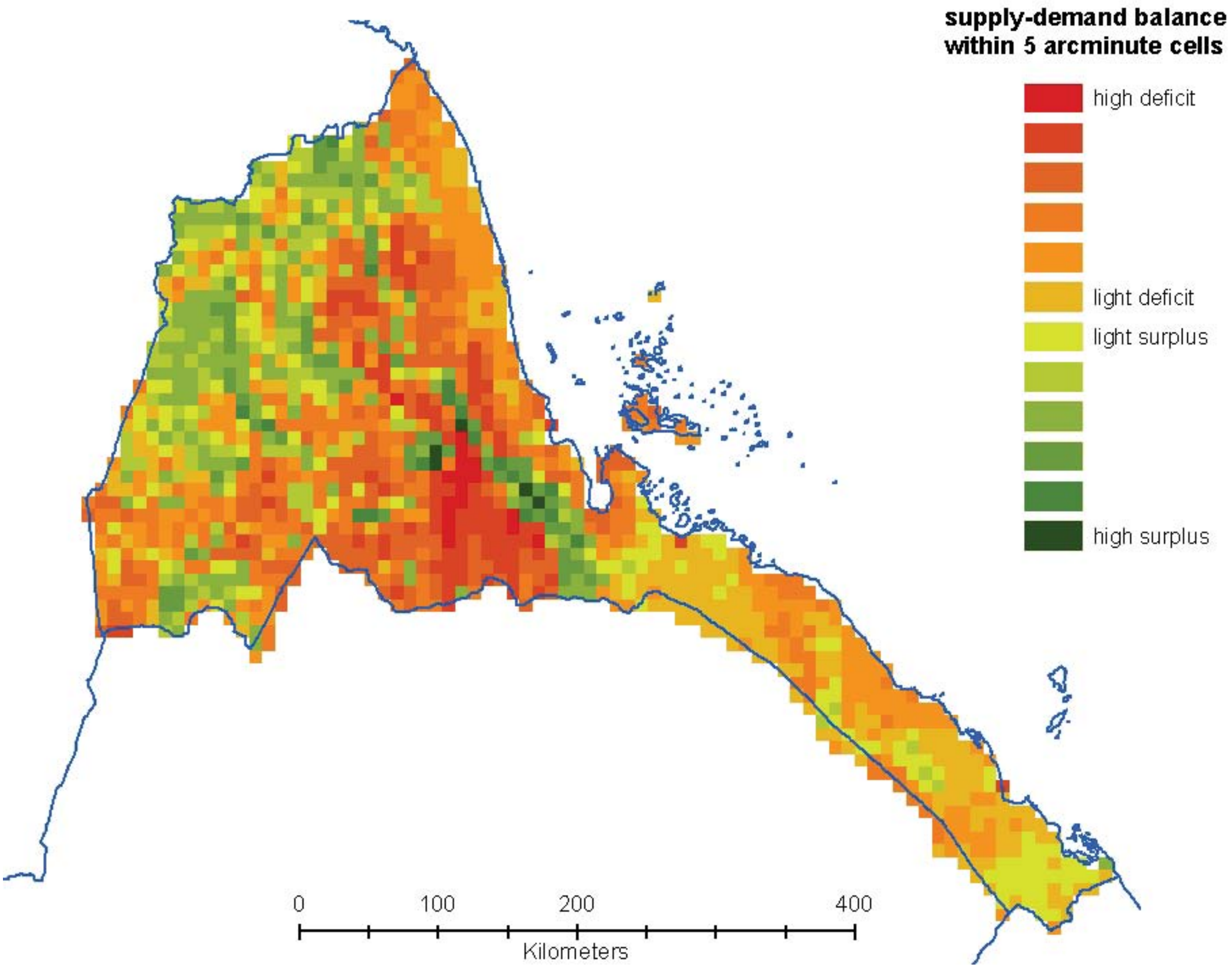
The list of the sub-national units of the Democratic Republic of Congo presenting marked deficit conditions are reported in Annex 4.

Figure 31: Egypt. Map of woodfuel supply-consumption balance categories.



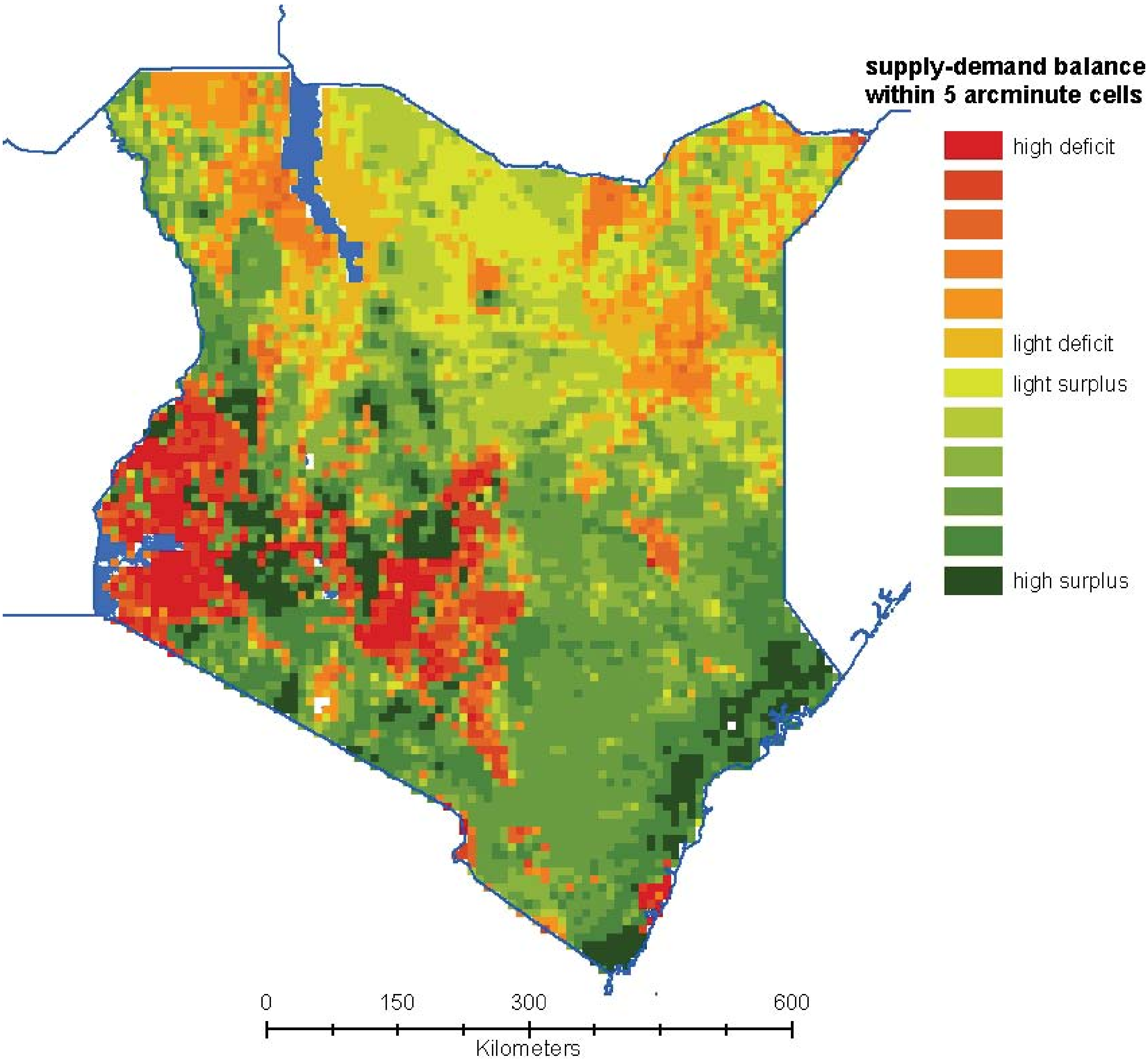
The list of the sub-national units of Egypt presenting marked deficit conditions are reported in Annex 4.

Figure 32: Eritrea. Map of woodfuel supply-consumption balance categories.



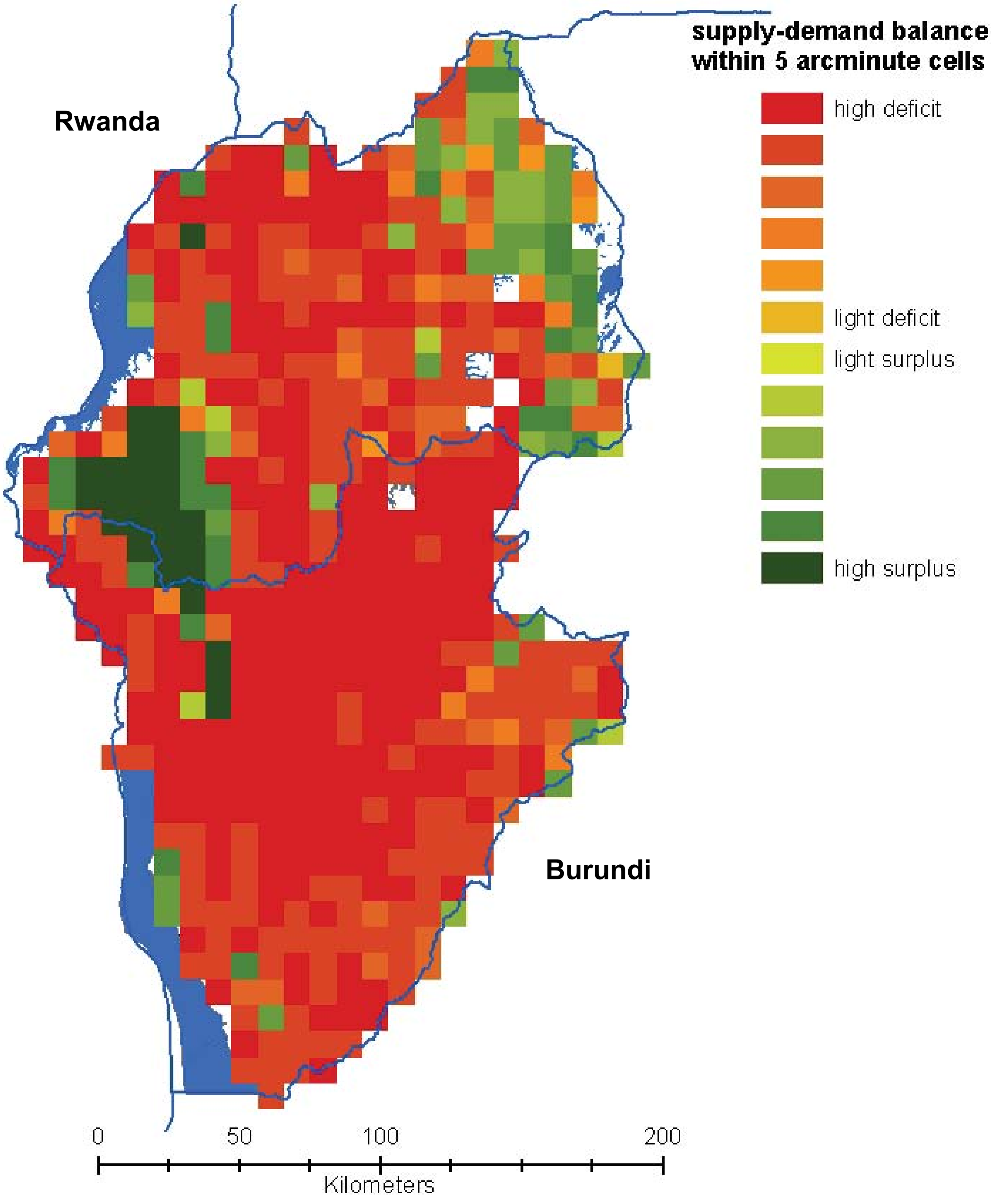
The list of the sub-national units of Eritrea presenting marked deficit conditions are reported in Annex 4.

Figure 33: Kenya. Map of woodfuel supply-consumption balance categories



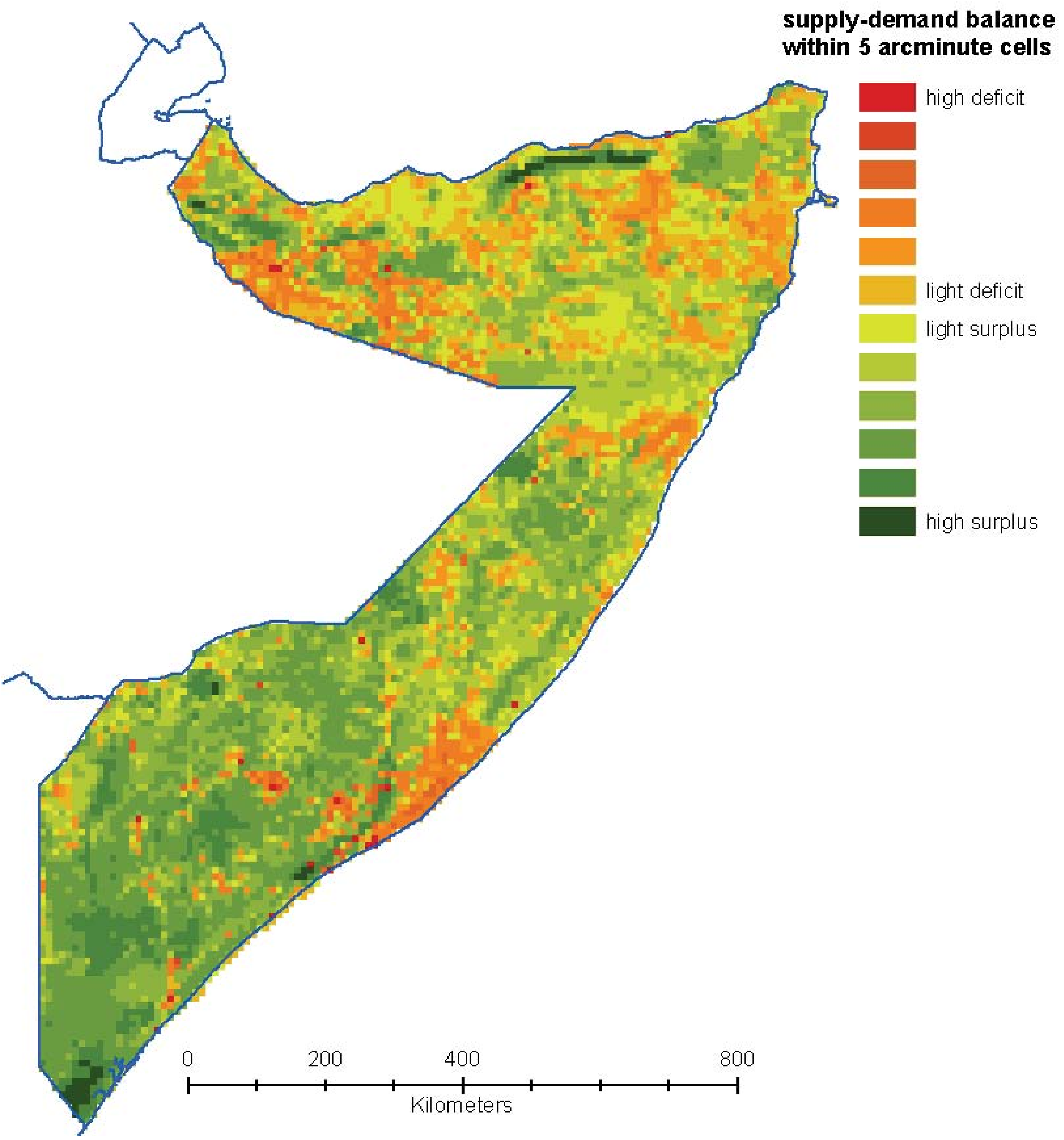
The list of the sub-national units of Kenya presenting marked deficit conditions are reported in Annex 4.

Figure 34: Rwanda and Burundi. Map of woodfuel supply-consumption balance categories



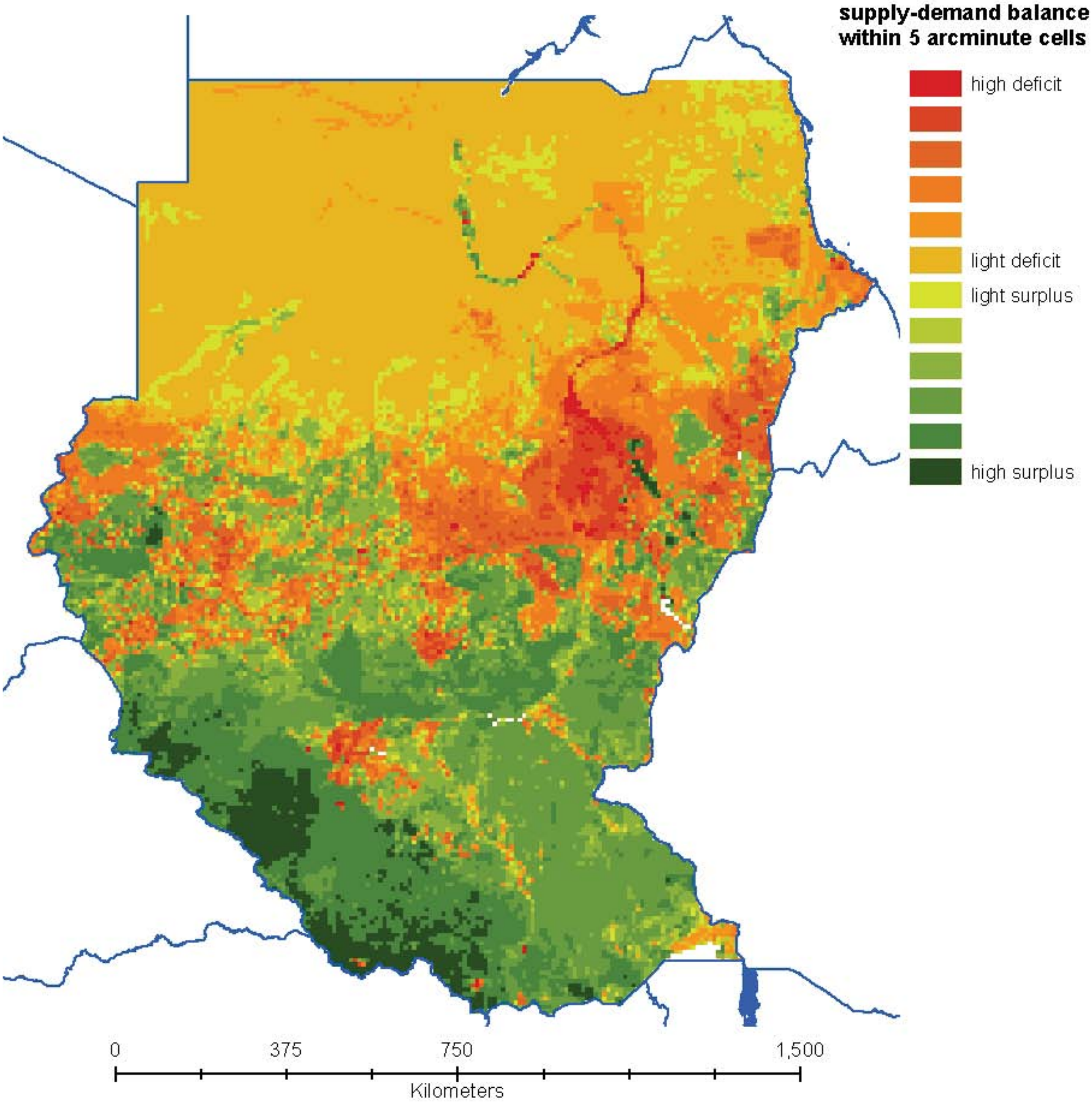
The list of the sub-national units of Rwanda and Burundi presenting marked deficit conditions are reported in Annex 4.

Figure 35: Somalia. Map of woodfuel supply-consumption balance categories.



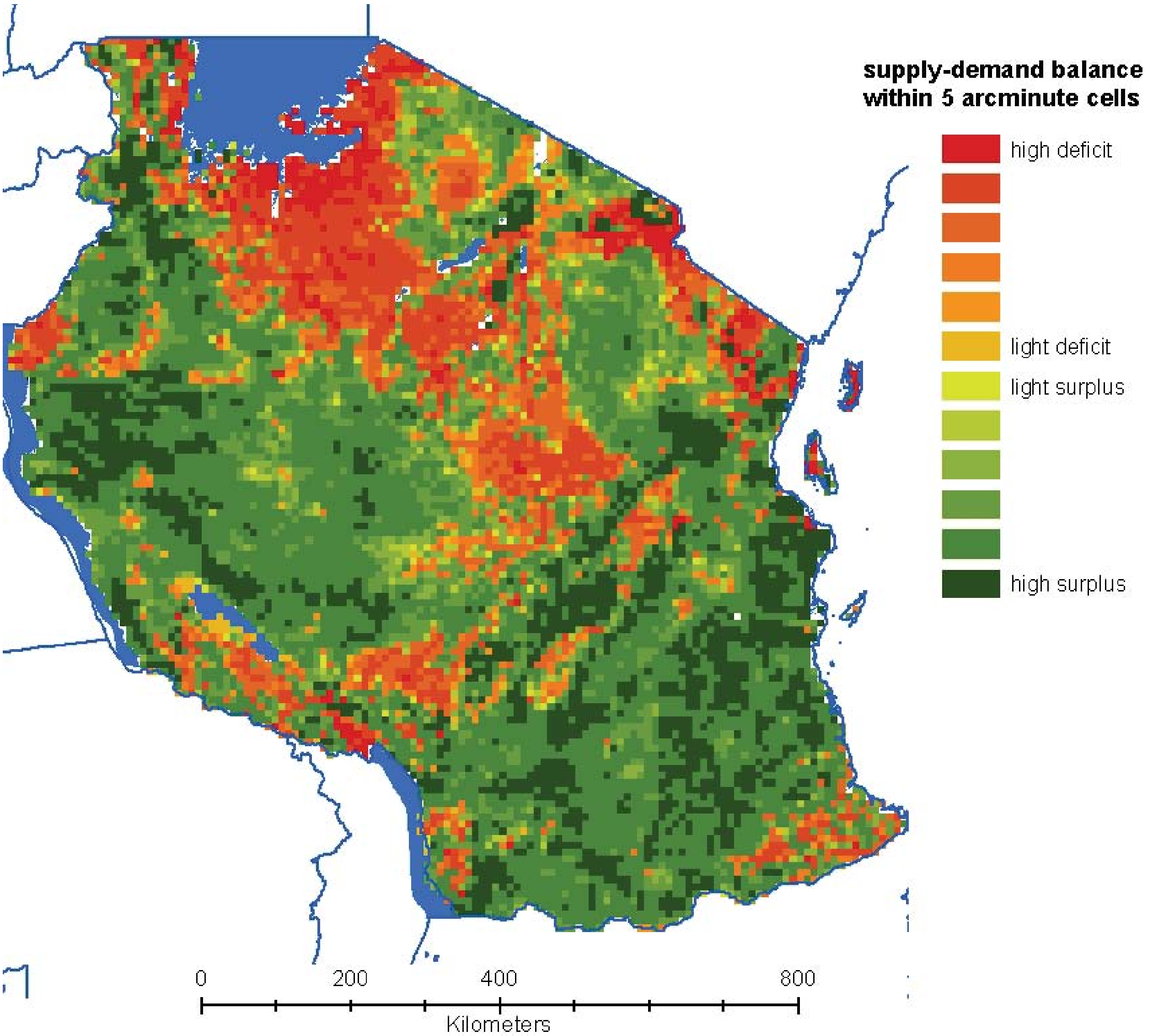
The list of the sub-national units of Somalia presenting marked deficit conditions are reported in Annex 4.

Figure 36: Sudan. Map of woodfuel supply-consumption balance categories.



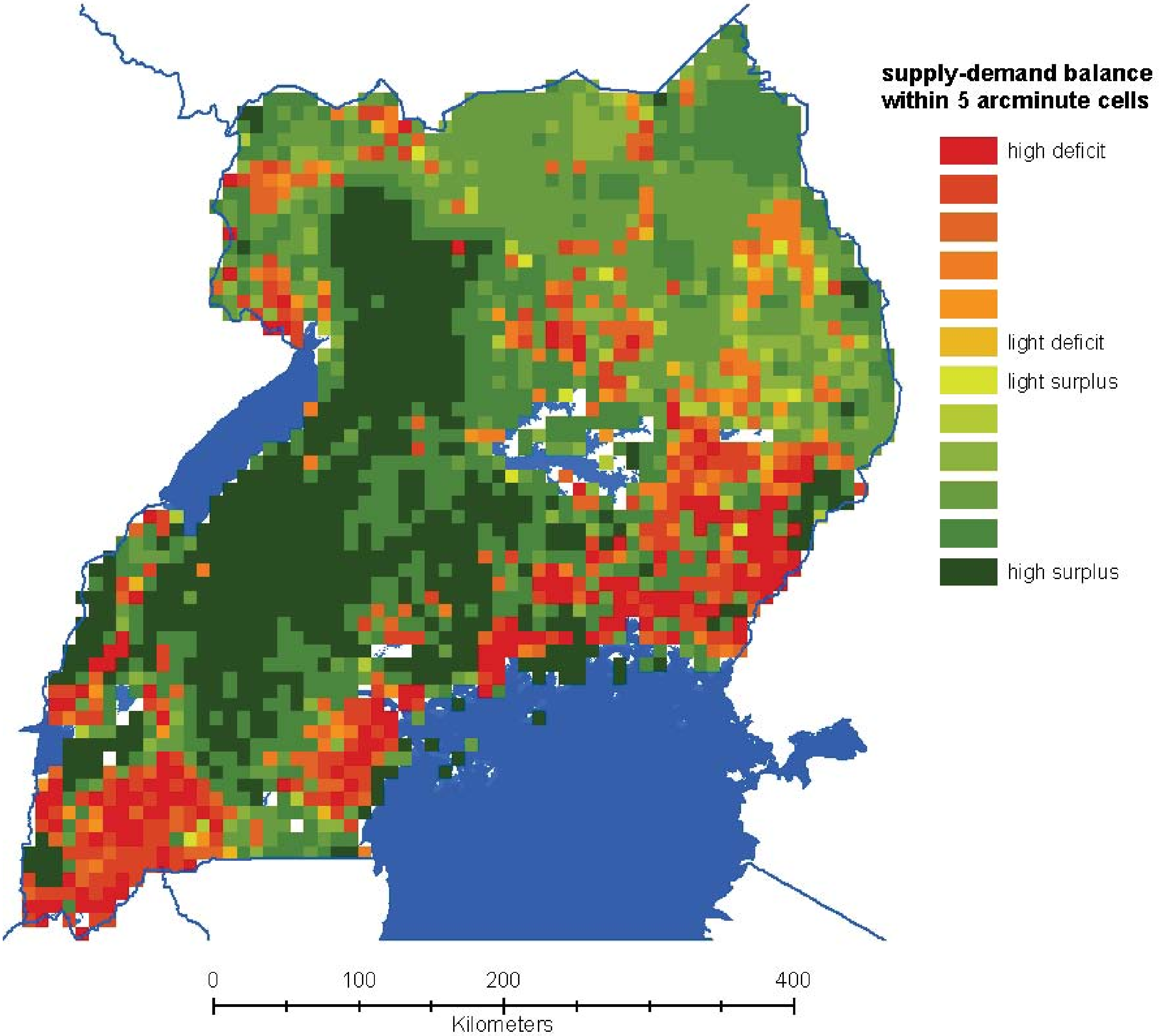
The list of the sub-national units of Sudan presenting marked deficit conditions are reported in Annex 4.

Figure 37: Tanzania. Map of woodfuel supply consumption balance.



The list of the sub-national units of Tanzania presenting marked deficit conditions are reported in Annex 4.

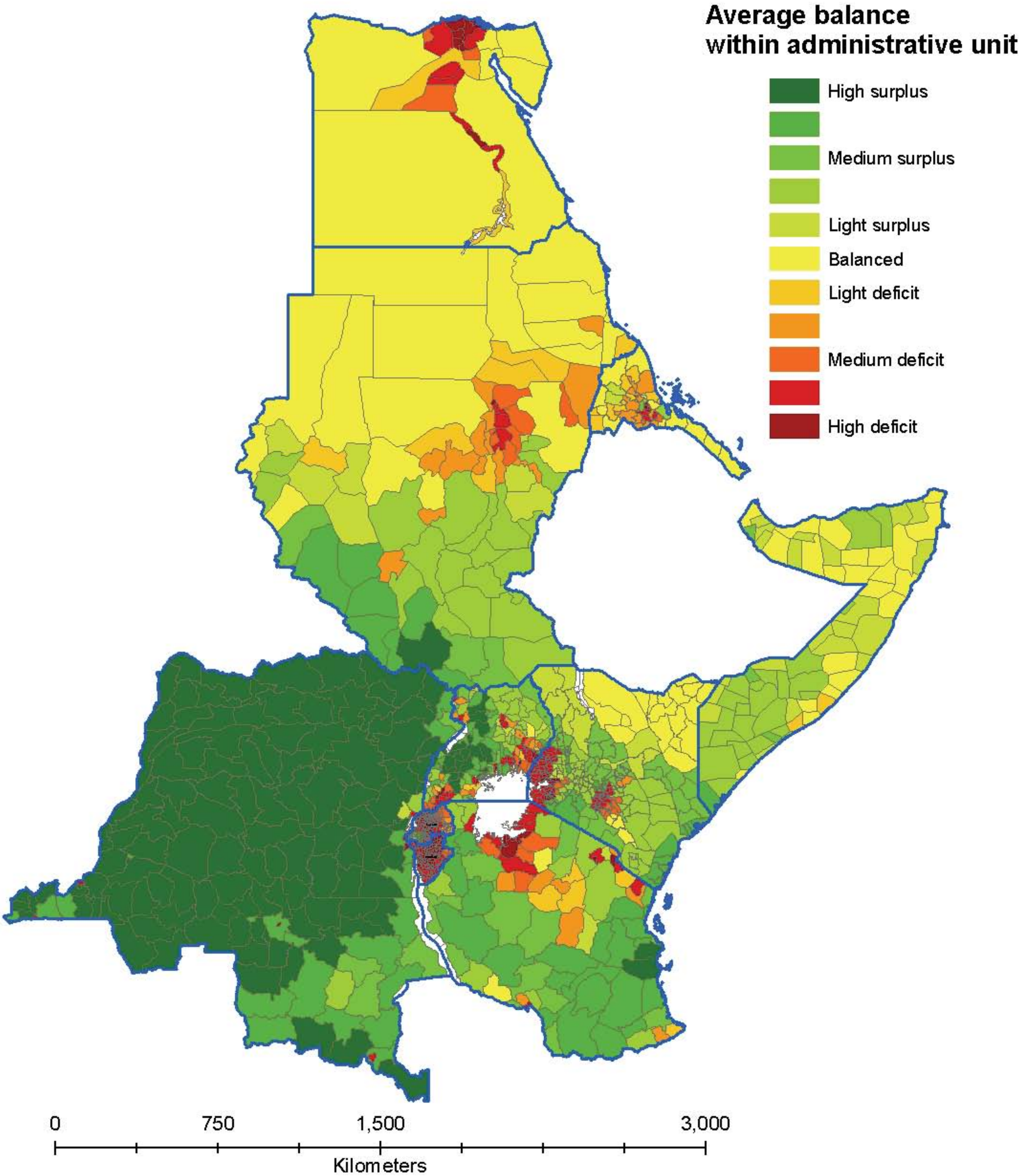
Figure 38: Uganda. Map of woodfuel supply consumption balance categories



The list of the sub-national units of Uganda presenting marked deficit conditions are reported in Annex 4.

Sub-national data set (1172 sub-national administrative units)

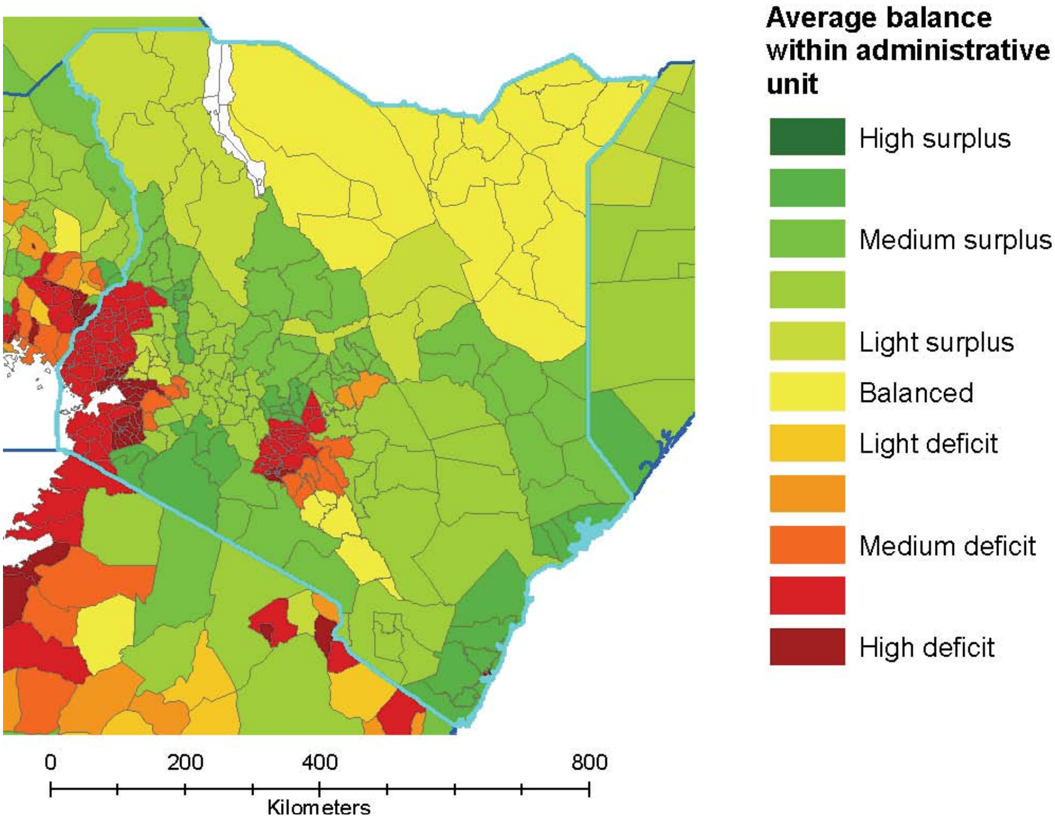
Figure 39: Regional map of average balance categories by sub-national administrative units derived from cell-level analysis.



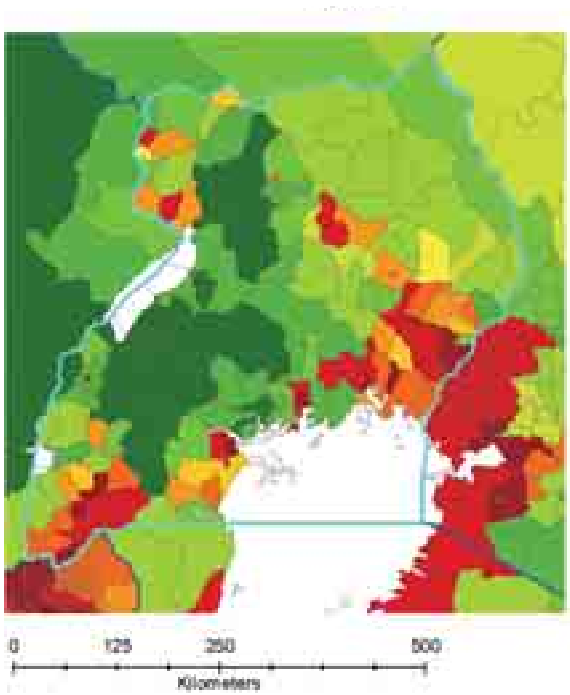
Annex 4 lists, for each country, the sub-national units presenting marked deficit conditions.

Figure 40: National maps of Kenya, Uganda, Rwanda and Burundi with average balance categories by sub-national administrative units.

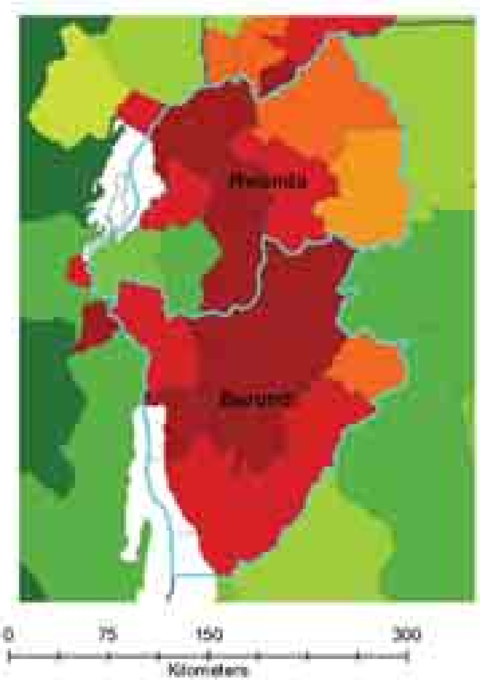
Kenya



Uganda



Rwanda and Burundi



PART 3: Findings

Relevance of wood energy

The present study confirmed the extreme relevance of wood energy in the eastern and central Africa sub-regions. In this context, it may be useful to recall that:

- in the ten countries covered by the present study the fraction of woodfuel production in total roundwood production at year 2000 ranged between 88 and 100 percent, with an average of 94 percent (FAOSTAT 2005, FAO) share;
- the contribution of woodfuels to total primary energy consumption in the countries of East Sahelian Africa, Central Africa and Tropical Southern Africa ranged from 75% to 86% (FAO 1999).

Level of analysis

The spatial resolution of biomass density maps produced in this study is very high, as it was based on national land cover maps developed at scales ranging between 1:100 000 and 1:200 000.

Concerning woodfuel demand and supply/demand balance, the analysis was done at 5 arc-minute grid cell level, which resulted in a geostatistical database composed by 98 592 units.

In addition, cell-level parameters were aggregated at sub-national level for a total of 1172 sub-national administrative units.

Scope of cell-level balance.

The thematic geostatistical layers produced in the study represent the beginning rather than the conclusion of an analytical process. They may, and hopefully will, support further level of analysis at both lower and higher geographical levels. At lower levels, i.e. national and sub-national, they can serve as basis of WISDOM analyses aimed at supporting and guiding energy and forestry policies. At higher levels, i.e. regional and global, they can contribute and provide qualified reference to regional and global wood energy mapping.

Wood energy systems, intended as the sequence of actions and elements that comprise the production, distribution and consumption of woodfuels, are complex and site-specific. They may, or may not, involve trade aspects; similarly, and to some extent consequently, woodfuels may be transported far from their production sites or they may be gathered and consumed locally; consumption patterns may change rapidly resulting from the availability of other fuels such as gas, kerosene, agricultural residues or cow dung in response to varying market conditions and/or levels of accessibility to wood resources..

Such fluid conditions cannot be predicted and modelled due to inadequate information on the driving variables and to the inherent complexity of the systems. It is therefore essential to understand the scope and limitations of the analysis carried out. In this respect, the following aspects should be highlighted:

- Reference data, such as the total woodfuel consumption for a given country and the urban/rural consumption ratios, are estimates rather than objective measurements. The estimation processes behind such estimates are poorly documented or, more often, totally unknown (Drigo 2005). This means that the consumption maps produced in this study are “best approximations” to be used for the definition of priority zoning rather than for quantitative calculations.
- The 5 arc-minute cells (9.2 x 9.2 km at the Equator; 8.2 x 8.9 km at 30° latitude) used as spatial reference for the integration of supply and demand parameters and balance calculation are meaningful only in case of locally constrained production/consumption patterns. The cell-level balance does not account for imported woodfuels that may, in fact, be transported from long distances, especially in case of charcoal. However, the 5 arc-minute cells are consistent with the gathering horizon of rural consumers that cannot afford marketed woodfuels or that live far from market centres.

Subsistence energy in a local supply/demand context

Subsistence energy may be defined as the amount of energy needed to guarantee basic needs (drinking water, heat) and nutrition (proper food preparation) in the household[11].

For many of the poor households in Africa subsistence energy is not guaranteed. For these households, which may be found in rural areas but also around urban centres, a deficit situation (demand higher than local supply capacity) has a direct impact the subsistence energy level necessary to cover essential uses.

Unlike other comparatively richer segments of the community that can afford to purchase fuelwood and charcoal at market prices, poor households depend strongly on locally accessible woody biomass for subsistence energy.

The effect of a deficit situation may lead to:

- a shift towards other fuels, that in case of poor people would inevitably mean agricultural residues and cow dung, with consequent impoverishment of soil nutrients and productivity;
- a diversion of part of the financial resources previously devoted to essential items as food and medicines towards the acquisition of commercial fuels, a household expense previously resolved by self-gathering;
- a lower energy input affecting the basic services that energy provides, such as boiling water cooking and heating, with negative impact on health and nutrition of poor rural and suburban households (Box 1);
- an unsustainable pressure on the accessible sources of woody biomass.

Box 1: Woodfuels and food security

Fuelwood scarcity, collection time and lack of alternative fuels can reduce the number of meals that are cooked in a day. Scarcity can also reduce the length of time food is cooked and this in turn can reduce the digestibility and hence the nutritional value of food particularly for children. Fuelwood shortages also restrict the processing of smoked dried and cooked foods which can cause consumption of less nutritious food with the respective consequences.

When supplies of woodfuel decline, people switch to other sources of fuel. In Bangladesh, India and Nepal, for instance, straw and cow dung are now being used for fuel instead of for feed and manure, thereby depriving the soil of natural fertilizers with the respective consequences for crop yields. In Nepal, freeing biomass and manure for use as a fertilizer could increase grain production by as much as 25 percent

The tight spatial relation that links poor households' needs for woody biomass to satisfy subsistence energy demand and wood resources justify the level of analysis of supply and demand at 5 arc-minute cell size, which is assumed represent an area that could be covered on foot to collect fuelwood. In fact, it may be assumed that within the approximately 9 x 9 km cell a randomly located consumer would have to cover a maximum of 4.5 km (some 2-3 on average, depending on the area wooded) to find woody biomass, which is in line with the distance covered on average by fuelwood gatherers in the region (Walther and Herlocker, 1983; McPeak, 2003).

Main deficit areas and affected populations

The percentages of rural populations living in the various balance categories are shown in Table 3. While it is obvious and expected that densely populated areas live under high deficit conditions, since the balance is calculated within the 5 minute cells, it is rather striking that over 41% of rural populations face marked deficit conditions (medium-high to high deficit). In absolute numbers this corresponds to some 59.2 million people living a marked deficit condition (26.6 million people in high deficit and 32.6 in medium-high deficit).

In countries like Burundi, Egypt and Rwanda virtually the entire population face deficit conditions.

[11] The term *subsistence energy* is used by the International Commission of Agricultural Engineering (CIGR) - Section IV: Rural Electricity and other Energy Sources (Ramdani, Kamaruddin, et al., CIGR).

Table 3: Rural populations living under different balance categories.

	percent of rural population (density below 2000 inh / km2)						
	High deficit	Medium – high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Burundi	76.9	19.1	0.8	0.1	0.4	1.3	1.4
Congo, D. R.	5.9	4.2	0.8	0.3	0.6	17.8	70.4
Egypt	71.4	18.5	2.0	2.7	1.2	3.7	0.4
Eritrea	5.5	54.1	16.0	13.3	5.1	5.4	0.7
Kenya	26.9	28.9	5.2	7.3	5.6	19.5	6.7
Rwanda	41.9	38.5	3.0	1.8	2.3	7.2	5.3
Somalia	1.1	4.5	12.9	32.1	23.2	25.6	0.6
Sudan	1.7	33.5	14.3	11.6	10.5	25.7	2.7
Tanzania	12.1	35.1	4.5	3.1	4.5	32.3	8.4
Uganda	21.8	24.5	3.6	2.5	3.7	28.7	15.3
Total rural pop.	**18.7**	**22.9**	**5.1**	**5.2**	**4.8**	**21.2**	**22.1**

The areas that present a more or less marked deficit in the local demand/supply balance covers 12.5 percent of the cumulative 10 countries' area. The occurrence and distribution of deficit areas within the countries is very heterogeneous, as shown in Table 4. There are countries literally dominated by deficit areas, such as Burundi and Rwanda, others that present important deficit areas, such as Eritrea, Tanzania, Uganda, Kenya and Sudan, and others that present minor deficit areas, such as Egypt, Somalia and D.R. Congo.

Table 4. Areas under different balance categories by country.

	Percent of countries' land area under different balance conditions						
	High deficit	Medium – high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Burundi	53.9	31.4	1.7	6.7	0.6	3.6	2.1
Congo, D. R.	0.6	0.5	0.3	2.2	0.2	15.0	81.3
Egypt	2.6	1.4	0.4	93.4	0.9	1.2	0.1
Eritrea	1.2	18.0	16.6	46.0	12.4	5.5	0.3
Kenya	3.9	7.1	5.1	33.4	13.4	31.6	5.4
Rwanda	26.7	31.8	4.3	10.5	5.6	14.4	6.7
Somalia	0.2	0.9	5.9	40.8	26.2	25.2	0.7
Sudan	0.4	7.3	8.5	46.3	9.2	24.9	3.4
Tanzania	2.9	16.3	4.1	10.1	5.2	46.6	14.9
Uganda	6.0	10.5	3.2	18.1	4.8	35.9	21.4
Aggregated totals	**1.6**	**5.6**	**4.3**	**34.0**	**6.7**	**22.0**	**25.8**

Note: The values represent percent of countries' land area by balance conditions as derived from the analysis of woodfuel consumption and potential sustainable supply within 5 arc-minute cells.

The most detailed spatial distribution of the various balance categories can be observed in Figure 29 (regional overview) and in Figures 30 to 38 (individual country maps) in the previous section.

Cell-values were also aggregated in order to identify the average balance conditions (always calculated at cell level) of sub-national administrative units. The results of this aggregation are shown in Figures 39 and 40 in the previous section. The sub national units presenting more pronounced deficit conditions are listed, for each country, in Annex 4.

National quantitative balances between the estimated total consumption and the fraction of the total national increment of woody biomass available for energy use (assumed at 94% in these countries) have little meaning because they hide important local variations but also because the reliability of quantitative estimates is rather limited.

Nonetheless, it is worth noting that countries such as Egypt, Burundi, Rwanda and Eritrea appear to consume an amount of woody biomass considerably higher than the estimated annual sustainable increment of their entire territories. This could be interpreted in several ways and, at least in part, it may be due to data inconsistencies (consumption figures may be overestimated and/or increment figures underestimated; import of woodfuels from neighbouring countries may be higher than recorded, as appears likely for Egypt).

It is however legitimate to believe that these pronounced deficit conditions may imply:

(i) the use of woodfuels derived from land clearings for conversions to agriculture and shifting cultivations that may temporarily release large amounts of wood and/or

(ii) a non sustainable pressure on more accessible natural formations with leading to forest degradation as is the case for Burundi, Rwanda and probably Eritrea.

(iii) a widespread shift to lower grade biomass fuels such as straw, residues and cow dung. These conditions pose a further burden on the environment, on agricultural productivity and on the poorest segments of the society who depend on these resources.

The research conducted in the last decade, including comprehensive field studies and projects have shown that woodfuel demand and supply patterns are very site specific (Leach & Mearns, 1988; Arnold *et al.*, 2003). Recognizing the site specificity of woodfuel use associated impacts has shifted the early thinking of a general fuelwood crisis to the understanding that critical areas vary from area to area (Arnold *et al.*, 2003; Mahapatra & Mitchell, 1999; RWEDP, 1997) and that there are mechanisms of adaptation that divert the pressure on wood resources, at least for larger surfaces.

Contribution to forestry and energy policy formulation

In spite the paramount relevance of wood energy in both forestry and energy sectors in all sub-Saharan countries, where woodfuels represent the main forest product as well as the main sources of energy, the role played by wood energy at high policy level remains marginal. One of the reasons frequently pointed out for such neglect is the absence of adequate information and the difficulty to frame this complex and site-specific issue in a coherent national context.

With respect to forestry and energy planning at national level, the information produced in this study still lacks details on physical and accessibility issues associated with wood resources as well as legal issues and other specific national policy aspects. Nonetheless, this information represents a first step in this direction and allows already segmenting the countries into zones characterized by different biomass stocking, consumption levels and local supply/demand balance conditions.

For forestry services, the definition of deficit and surplus areas helps in identifying priority zones where:

- woodfuel production may represent a viable forest management opportunity and a be a tool for sustainable rural development;
- exploitation goes far beyond the regenerating capacity of natural formations, calling for alternative solutions to be found in collaboration with energy and agriculture stakeholders and institutions.

For energy agencies, wood energy maps can support the formulation of policies and strategies. Promotion of modern wood and bio-energy systems or, conversely, subsidizing alternative fuels could be and implemented in synergy with forestry and agricultural sectors.

A new dimension to the process of mapping extreme poverty

As mentioned before the cell-level balance between the potential sustainable production of woody biomass and the consumption of woodfuels is meaningful mainly for the fraction of the consumers that depend on fuelwood gathering within accessible walking distance.

In view of its implication on poor households' subsistence energy supply, the definition of deficit and surplus areas within 5 arc minute cells acquires particular relevance in the context of mapping poverty and extreme poverty, a key item in the struggle to achieve Millennium Development Goal (MDG) 1 (eradicate extreme poverty and hunger) and MDG 7 (ensure environmental sustainability).

Many approaches exist to poverty mapping (Davis, 2003), all predominantly based on econometric approaches combining census and survey data and several spatial modelling methods working at household level (Lanjouw, 1998; Hentschel *et al*.,2000; Elbers *et al*., 2001; and Deichmann, 1999) or at community level (Bigman *et al*., 2000). However, a common characteristic to poverty mapping is that geographical components (location characteristics) and environmental data are not taken into account (Pertucci, Salvati and Seghieri, 2003).

Energy-related indicators are limited to access to electricity or other "conventional" energy sources for which formal statistics exist. From an energy perspective this inevitably leads to grouping all populations living outside the grids into a single category, while overlooking the access situation for "traditional" energy sources that strongly influence living conditions of poor households and the sustainability of the surrounding environment.

As pointed out by Pertucci *et al*., "Environmental degradation contributes to poverty through worsened health and by constraining the productivity of those resources on which the poor rely. Moreover, poverty restricts the poor to acting in ways that harm the environment. Poverty is often concentrated in environmentally fragile ecological zones where communities suffer from and contribute to different kinds of environmental degradation"

In combination with econometric data and in addition to other indicators relevant to poverty and food insecurity (Box 2), the deficit areas identified in the present study provide important indicators for the locations where poor households are likely to face serious difficulties in acquiring minimum subsistence energy levels and where the negative effects discussed above may occur. Specifically, the identification of woodfuel deficit areas may contribute directly and effectively to determining and qualifying vulnerability levels in both poverty and food security mapping

Box 2: Poverty and food insecurity indicators

Poverty categories:

Economic. These include monetary indicators of household well-being, particularly food and non-food consumption or expenditure and income. These measures are primarily used by economists, but many NGO and development agencies use a variety of consumption and income measures, including non-monetary proxies of household well-being such as ownership of productive assets or durables.

Social. These include other non-monetary indicators of household well-being such as quality and access to education, health, other basic services, nutrition and social capital. These measures are sometimes grouped into basic-needs or composite development indices by agencies such as UNDP.

Demographic. These indicators focus on the gender and age structure of households, as well as household size.

Vulnerability. These indicators focus on the level of household exposure to shocks that can affect poverty status, such as environmental endowment and hazard, physical insecurity, political change and the diversification and friskiness of alternative livelihood strategies.

Food-insecurity categories:

Direct measures of consumption. These indicators look at household or individual food intake, total and food expenditures and caloric acquisition.

Outcome indicators of nutritional status. These indicators focus on anthropometric and micronutrient indicators.

Vulnerability. This concept encompasses notions of access and availability, risk and uncertainty. Indicators include household access to assets, household size and composition, asset liquidity, crop and income diversification and food production at household level.

[From Davis, B. 2003. Choosing a method for poverty mapping.

PART 4: Follow up recommendations

Energy is an important factor towards achieving the Millennium Development Goals. Recording wood energy supply and consumption patterns is essential for development planning. It reveals areas where people rely on non-conventional energy sources, highlights poverty issues and illustrates environmental problems that may contribute to vulnerability.

The thematic geo-statistical layers produced with this WISDOM exercise and reported in this paper represent the beginning of an analytical process that will hopefully support a further level of analysis at national, sub-national levels. Further WISDOM analyses at these levels should be designed to support energy, forestry and development policies, while serving as a reference for regional and global wood energy mapping. To this end, it is important to improve the data gathering and statistics available to analysts and policy makers alike.

It is recommended that FAO and other national agencies:

1. Continue collecting reference data concerning both woodfuel consumption and woody biomass stocking and potential productivity. If an adequate set of field reference data can be gathered (main current constraint), it is recommended to stratify land cover data on a more detailed reference than the FAO Global Ecological Zone Map used in the present study. Notwithstanding the limitations posed by scarce field data on wood and biomass, a possible alternative could be the White Vegetation Map of Africa that provides a detailed description of a wide range of natural formations.
2. Widen and deepen the spatial analysis between supply and demand by introducing accessibility analysis based on physical (distance, slope) and legal (protected areas) factors.
3. Analyze the possible evolution of supply/demand scenarios using land cover change probabilities and demographic trends.

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Annexes

Annex 1. Definitions and conversion factors

Definitions of main terms:

Wood energy systems = all the (steps and /or) unit processes and operations involved for the production, preparation, transportation, marketing, trade and conversion of woodfuels into energy.

Woodfuels = all types of biofuels originating directly or indirectly from woody biomass.

This category includes fuelwood, charcoal and black liquor (the latter being not significant in the context of this study)

Fuelwood = woodfuel where the original composition of the wood is preserved

This category includes wood in the raw and also residues from wood processing industries (the latter being not significant in the context of this study)

Charcoal = solid residue derived from carbonization, distillation, pyrolysis and torrefaction of fuelwood.

[Unified Bioenergy Terminology, UBET, FAO 2004]

Basic parameters and conversion factors:

Wood – Net Calorific Value (30% mc, dry basis)	13.8	MJ/ kg
Charcoal - Net Calorific Value (5% mc, dry basis)	30.8	MJ/ kg
Charcoal/fuelwood	165	Kg charcoal/ CUM
Wood density	725	Kg/ CUM

Annex 2. Demand module. References on woodfuel consumption

Estimates of national consumption of fuelwood and charcoal according to various sources.

The highlighted values were selected as current best reference and used for the calculation of per capita consumption in the Demand Module.

Data extracted from the interactive Wood Energy Statistics (i-WESTAT FAO 2004).

Primary sources:	
ESMAP	Energy Sector Management Assistance Programme (joint World Bank-UNDP Programme)
FAOSTAT (2003)	Consumption estimates based on 2003 edition of FAOSTAT data.
GFPOS	Global Forest Products Outlook Study carried out by the Forestry Policy and Planning Division of FAO Forestry Department.
IEA	International Energy Agency
IEPE	Institut d'Economie et de Politique de l'Energie (Grenoble, France)
WETT99 Best estimates	Wood Energy Today for Tomorrow, 1999. Activity of the FAO Wood Energy Programme that analyzed wood energy information world-wide. Indicates values defined in that study as "best estimates"

Values in '000 m3 of fuelwood and wood for charcoal production

		Years	1995	1996	1997	1998	1999	2000
	Burundi							
	"Best" current reference							
Fw	The TCDC Country report, which was based on field surveys, appears as more reliable. The Faostat estimates, based on GFPOS regional model, estimates a lower consumption. The 2000 estimate was extrapolated from the 1998 TCDC report's estimate.							
Ch	Country report, which was based on field surveys and appears supported by all national sources (including official Faostat correspondents). The global GFPOS model, which is used as Faostat reference for FAO estimates gives far higher estimates. TCDC report estimates are also in line with Rwanda per capita estimates (including Faostat's) while GFPOS global model appears to overestimate charcoal consumption. The 2000 estimate was extrapolated from the 1998 TCDC report's estimate.							
Fw	Secondary source	Primary source						
	Two ref: Est. 90-93: Dir gén Energie, Min Energie Mines(MEM), Bilans énergétiques pour 1990,91 et 92. Est. 94-98: Dir Gén Eau et Forets	Country Report	7526	7758	7991	8231		**8437**
	FAO estimate	FAOSTAT (2003)	5418	5670	5813	5955		
	Official figure	FAOSTAT (2003)					4907	5056
	Household Fuelwood model: Regional; non-hh Fw model: Continental	GFPOS 1970-2030	5418	5670	5813	5955	6114	6277
	ENDA/IEPE year 1988	WETT99 Best estimate	4951	5403				
Ch	Two ref: Est. 90-93: Dir gén Energie, Min Energie Mines(MEM), Bilans énergétiques pour 1990,91 et 92. Est. 94-98: Dir Gén Eau et Forets	Country Report	294	304	314	325		**333**
	FAO estimate	FAOSTAT (2003)	1266	1353	1392	1435		
	Official figure	FAOSTAT (2003)					345	364
	Charcoal model: Global	GFPOS 1970-2030	1266	1353	1392	1435	1483	1533
	ENDA/IEPE year 1988	WETT99 Best estimate	337	349				

	Congo, Democratic Republic							
	"Best" current reference							
Fw	Extend WETT 99 using IEA estimates. However, Faostat 2003 could also be used as main reference because there seems to be a general convergence of estimates from IEA, WETT99 and the new Faostat (based on GFPOS regional model).							
Ch	Probably 25 Faostat 2003. There is a great difference between IEA data (reference of WETT 99 for 95, 96) and Faostat, based on GFPOS global model. This sets a far higher consumption than IEA after 1990 which may be justified in view of the 1990 ENDA/IEPE estimation.							
Fw	Secondary source		1995	1996	1997	1998	1999	2000
	FAO estimate	FAOSTAT (2003)	51488	52588	53485	54324	55267	**56228**
	Household Fuelwood model: Regional; non-hh Fw model: Continental	GFPOS 1970-2030	51488	52588	53486	54324	55267	56228
	Reference not available	WETT99 Best estimate	40614	46055	0	0	0	0
Ch	FAO estimate	FAOSTAT (2003)	7271	7555	7814	8081	8373	**8674**
	Charcoal model: Global	GFPOS 1970-2030	7271	7555	7814	8081	8373	8674
	Secretariat estimates based on 1991 data from African Energy Programme of the African Development Bank	IEA (2002)	1479	1521	1570	1624	1667	1715
	Reference not available	IEA nonOECD_99	1479	1521	1570	1624	1667	
	Reference not available	WETT99 Best estimate	1383	1555				
	Egypt							
	"Best" current reference							
Fw	Faostat estimates, based on the regional GFPOS model appear more reliable than WETT 99's.							
Ch	Faostat estimates, based on the global GFPOS model appear more reliable than WETT 99's.							
Fw	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
	FAO estimate	FAOSTAT (2003)	8592	8534	8607	8715	8752	**8906**
	Household Fuelwood model: Regional; non-hh Fw model: Continental	GFPOS 1970-2030	8539	8616	8687	8757	8831	8906
	Reference not available	WETT99 Best estimate	2157	2451				
Ch	FAO estimate	FAOSTAT (2003)	6879	6960	7035	7112	7193	7249
	Charcoal model: Global	GFPOS 1970-2030	6879	6960	7035	7112	7193	**7276**
	Reference not available	WETT99 Best estimate	55					

Eritrea

"Best" current reference

Fw The TCDC country report provides documented estimates which are higher than GFPOS model estimates. 2000 estimates was extrapolated using 1996 TCDC report's per capita consumption value.

Ch The Faostat estimates, based on the global GFPOS model fit well with the TCDC report's estimates of 1996. Faostat 2000 estimate is used as reference

	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
Fw	Interim Report, 1996: Strengthening The Department Of Energy, Comprehensive Energy Sector Studies, Eritrea (UNOPS Project ERI94)	Country Report		1840				**2088**
	FAO estimate	FAOSTAT (2003)	1142	1180	1227	1273	1320	1362
	Household Fuelwood model: National; non-hh Fw model: Continental	GFPOS 1970-2030	1142	1180	1222	1267	1314	1362
	Reference not available	WETT99 Best estimate	3249	3446				
Ch	Interim Report, 1996: Strengthening The Department Of Energy, Comprehensive Energy Sector Studies, Eritrea (UNOPS Project ERI94)	Country Report		712				
	FAO estimate	FAOSTAT (2003)	708	738	771	807	844	**889**
	Charcoal model: Global	GFPOS 1970-2030	708	738	771	807	844	882
	Direct Communication to the Secretariat from the Ministry of Energy and Mines, Eritrea.	IEA (2002)	691	733	758	448	461	473
	Reference not available	IEA nonOECD_99	691	733	758	448	461	
	Reference not available	WETT99 Best estimate	86	89				

Kenya

"Best" current reference

Fw It is difficult to judge the reliability of the two main sources: WETT99, based on (pre-1995) IEA data and Faostat based on the national GFPOS model. The IEA series (used by WETT99 as main reference) appears slightly higher and FAOSTAT (2002) slightly lower, based on GFPOS National model. Faostat was used as main reference, although its estimate may be lower than real.

Ch Two main alternatives: the higher estimates of IEA (2002), selected by WETT99, and FAOSTAT (2002) much lower, based on GFPOS National model. It is difficult to judge which reference is more realistic. Given the convergence of national sources, the IEA 2000 estimate was used as main reference, although it may be higher than real.

	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
Fw	FAO estimate	FAOSTAT (2003)	15563	15668	15837	15727	15752	**15776**
	Household Fuelwood model: National; non-hh Fw model: Continental	GFPOS 1970-2030	15563	15668	15834	15727	15752	15776
	Other National years 1980-1989	WETT99 Best estimate	18146	19382				
Ch	FAO estimate	FAOSTAT (2003)	3303	3452	3565	3660	3769	3882
	Charcoal model: National	GFPOS 1970-2030	3303	3452	3565	3660	3769	3882
	Secretariat estimates based on 1991 data from African Energy Programme of the African Development Bank	IEA (2002)	8267	8406	8564	8770	8952	**9158**
	Other National years 1980-1989	WETT99 Best estimate	7806	8297				

Rwanda

"Best" current reference

Fw The official FAOSTAT figures appear extremely variable and inconsistent but the last track series of the GFPOS model seems to converge (with a possible overestimation) with the WETT 99 estimates. For this reason the GFPOS estimate for year 2000 was selected as reference.

Ch The official FAOSTAT figures appear more realistic than GFPOS model results. They are in line with other historical national references. The Faostat estimation for year 2000, based on official figures was selected as reference.

Fw	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
	Official figure	FAOSTAT (2003)	5148	5550	7100	6921	7209	4709
	Fuelwood model: FAOSTAT 3	GFPOS 1970-2030	5582	5569	6010	6474	7000	**7569**
	ENDA/IEPE 1988; Other National, 1991	WETT99 Best estimate	4566	5056				
Ch	Official figure	FAOSTAT (2003)				279	291	
	Repetition of last official figure	FAOSTAT (2003)						**291**
	Charcoal model: Global	GFPOS 1970-2030	988	1005	1091	1180	1281	1390
	ENDA/IEPE year 1988; Other National year 1991	WETT99 Best estimate	194	203				

Somalia

"Best" current reference

Fw The regional GFPOS model (Faostat reference) appears to overestimate fw consumption. Other references of late '80 indicate lower consumption rates. WETT99 was extrapolated to year 2000 using stable per capita rates and population statistics.

Ch The Faostat estimates (based on regional GFPOS model) appear higher than all other references nation-level estimates. Other references of late '80 indicate lower consumption rates. WETT99 was extrapolated to year 2000 using stable per capita rates and population statistics.

Fw	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
	FAO estimate	FAOSTAT (2003)	4447	4606	4799	4941	5109	5282
	Household Fuelwood model: Regional; non-hh Fw model: Continental	GFPOS 1970-2030	4447	4606	4799	4941	5109	5282
	Reference not available	WETT99 Best estimate	3568	3617	3706	3819	3947	**4083**
Ch	FAO estimate	FAOSTAT (2003)	3092	3253	3445	3593	3765	3742
	Charcoal model: Global	GFPOS 1970-2030	3092	3253	3445	3593	3765	3946
	ESMAP year 1984	WETT99 Best estimate	913	975	1019	1071	1129	**1192**

	Sudan							
	"Best" current reference							
Fw	The 2004 Report of the Ministry of Energy appeared most reliable and up-to date.							
Ch	The 2004 Report of the Ministry of Energy appeared most reliable and up-to date.							
Fw	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
	Forest products consumption survey (1994) carried out by FNC with support FA/Netherlands Project Forestry Development in Sudan.	Country Report	9008	9159	9482	9729		
	FAO estimate	FAOSTAT (2003)	12343	12300	12199	12188	12181	12175
	Household Fuelwood model: National; non-hh Fw model: Continental	GFPOS 1970-2030	12343	12300	12199	12188	12181	12175
	Reference not available	WETT99 Best estimate	7537	8036				
	Primary: Ministry of energy Report							**20808**
Ch	Forest products consumption survey (1994) carried out by FNC with support FA/Netherlands Project Forestry Development in Sudan.	Country Report	7666	7795	8070	8280		
	FAO estimate	FAOSTAT (2003)	3921	4023	4106	4234	4368	4503
	Charcoal model: Global	GFPOS 1970-2030	3921	4023	4106	4234	4368	4505
	Secretariat estimates based on 1990 data from Bhagavan, M.R., Editor, Energy Utilities and Institutions in Africa, AFREPREN,	IEA (2002)	14267	17442	17982	18533	13782	14618
	Reference not available	IEA nonOECD_99	14267	17442	17982	18545	18958	
	Reference not available	WETT99 Best estimate	13424	14315				
	Primary: Ministry of energy Report							**13477**
	Tanzania							
	"Best" current reference							
Fw	GFPOS estimates are far lower than WETT 99 and any other national reference. The 2000 consumption was estimated according to the trend indicated by all other sources (linear equation).							
Ch	Doubts between IEA (lower) and Faostat (higher). Faostat, based on national GFPOS model, was finally selected because its values fit better with per capita consumption database.							
Fw	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
	FAO estimate	FAOSTAT (2003)	14342	14294	14204	14012	13868	13728
	Household Fuelwood model: National; non-hh Fw model: Continental	GFPOS 1970-2030	14342	14294	14204	14012	13868	13728
	Other National year 1981	WETT99 Best estimate	39339	43629				
	estimated on linear trendline from non-FAO values from 1980 to 1996	Other National			38823	39161	39499	**39837**
Ch	FAO estimate	FAOSTAT (2003)	6093	6298	6494	6666	6860	**7059**
	Charcoal model: National	GFPOS 1970-2030	6093	6298	6494	6666	6860	7059
	National energy statistics until 2000	IEA (2002)	3103	3158	3218	3909	4739	5758
	Reference not available	IEA nonOECD_99	2855	2903	2958	3036	3109	
	Other National year 1990	WETT99 Best estimate	2494	3088				

	Uganda							
	"Best" current reference							
Fw	Uganda energy balance 2000							
Ch	Uganda energy balance 2000							
Fw	Secondary source	Primary source	1995	1996	1997	1998	1999	2000
	FAO estimate	FAOSTAT (2003)	28286	28639	28969	29214	29488	29767
	Household Fuelwood model: Regional; non-hh Fw model: Continental	GFPOS 1970-2030	28286	28639	28969	29214	29488	29767
	IEA19-IEA/AFREPREN Questionnaire Of Biomass Energy Statistics; 1997	Other National			23724			
	ESMAP 1980; Other National, 1997	WETT99 Best estimate	25179	24352	23724			
	http://www.energyandminerals.go.ug/NRG-Bal00.html	Uganda energy bal.2000						**21785**
Ch	FAO estimate	FAOSTAT (2003)	3896	3984	4076	4154	4238	4324
	Charcoal model: Global	GFPOS 1970-2030	3896	3984	4076	4154	4238	4324
	IEA19-IEA/AFREPREN Questionnaire Of Biomass Energy Statistics; 1997	Other National			2424			
	Reference not available	Other National						
	ESMAP year 1980; Other National years 1994, 97	WETT99 Best estimate	2605	2846	2424			
	http://www.energyandminerals.go.ug/NRG-Bal00.html	Uganda energy bal.2000						**2685**

Household fraction of total fuelwood and charcoal consumption

	Household fraction of total consumption		
	Fuelwood	Charcoal	Source
Kenya	0.85	0.94	Average of i-WESTAT sources
Eritrea	0.95	0.97	Average of i-WESTAT sources
Tanzania, United Rep.	0.84	0.98	Average of i-WESTAT sources
Sudan	0.71	0.89	Sudan Min. Energy /FNC 1999-2000.
Egypt	1.00	1.00	IEA et al for fuelwood. Guessed for charcoal
Uganda	0.78	1.00	Uganda Min. Energy. Energy balance 2000
Rwanda	0.86	0.98	Average of i-WESTAT sources
Burundi	0.99	0.97	Average of i-WESTAT sources
Somalia	0.99	0.92	Average of i-WESTAT sources
Congo, Dem. Rep.	0.80	1.00	Average of i-WESTAT sources

Distribution of non-household consumption

	Urban areas	Rural settlements	Rural sparse	Rural (general)
Congo D.R., Somalia, Sudan	0.5			0.5
Burundi, Egypt, Eritrea, Kenya, Rwanda, Tanzania, Uganda	0.5	0.3	0.2	

Summary table of total and per capita fuelwood and charcoal consumption and of map-adjusted values.

		Per capita woodfuel consumption (m^3 of fuelwood and wood for charcoal)								Total HH consumption ('000 m^3 of fuelwood and wood for charcoal)		Total NON-hh consumption		Best 2000 estimate of total national consumption	
		rural general		urban		rural sparse		rural settlement							
		fw rur	ch rur	fw urb	ch urb	fw rur-sparse	ch rur-sparse	fw rur-settlem	ch rur-settlem	fw	ch	fw	ch	Fw	Ch
Egypt	Based on UN pop stat. For 2000	0.167	0.088	0.08	0.134			0.12	0.111	8,906	7,276			8,906	7,276
	adjusted on map pop values	0.174	0.092	0.082	0.133	0.330	0.023	0.128	0.113						
	non_hh consumption														
	Tot per capita consumption	0.174	0.092	**0.082**	**0.133**	**0.330**	**0.023**	**0.128**	**0.113**						
Eritrea	Based on UN pop stat. For 2000	0.618	0.214	0.181	0.310			0.40	0.262	1,990	861	97.89	27.98	2,088	889
	adjusted on map pop values	0.630	0.218	0.183	0.312	0.678	0.208	0.406	0.265						
	non_hh consumption			0.0709	0.0203	0.0080	0.0023	0.0562	0.0161						
	Tot per capita consumption	0.630	0.218	**0.254**	**0.333**	**0.686**	**0.210**	**0.463**	**0.281**						
Kenya	Based on UN pop stat. For 2000	0.602	0.118	0.150	0.572			0.38	0.345	13,438	8,583	2,338	575	15,776	9,158
	adjusted on map pop values	0.621	0.122	0.146	0.554	0.664	0.084	0.384	0.338						
	non_hh consumption			0.103	0.025	0.029	0.007	0.246	0.060						
	Tot per capita consumption	0.621	0.122	**0.249**	**0.579**	**0.693**	**0.091**	**0.629**	**0.398**						
Uganda	Based on UN pop stat. For 2000	0.782	0.015	0.293	0.842			0.54	0.429	16,992	2,685	4792.6		21,785	2,685
	adjusted on map pop values	0.803	0.015	0.251	0.722	0.853		0.527	0.369						
	non_hh consumption			0.727		0.056		0.461							
	Tot per capita consumption	0.803	0.015	**0.978**	**0.722**	**0.909**		**0.988**	**0.369**						
Burundi	Based on UN pop stat. For 2000	1.462	0.009	0.008	0.483			0.74	0.246	8,346	323	91.10	9.83	8,437	333
	adjusted on map pop values	1.432	0.009	0.010	0.582	1.497		0.721	0.295						
	non_hh consumption			0.098	0.011	0.003	0.000	0.055	0.006						
	Tot per capita consumption	1.432	0.009	**0.108**	**0.592**	**1.501**		**0.776**	**0.301**						
Rwanda	Based on UN pop stat. For 2000	0.574	0.004	0.215	0.244			0.39	0.124	4,059	285	649.77	5.79	4,709	291
	adjusted on map pop values	0.528	0.004	0.519	0.589	0.529		0.523	0.296						
	non_hh consumption			0.746	0.007	0.021	0.000	0.176	0.002						
	Tot per capita consumption	0.528	0.004	**1.264**	**0.595**	**0.550**		**0.699**	**0.298**						

		Per capita woodfuel consumption (m^3 of fuelwood and wood for charcoal)				Total HH consumption ('000 m^3 of fuelwood and wood for charcoal)		Total NON-hh consumption		Best 2000 estimate of total national consumption	
		rural		urban							
		fw rur	ch rur	fw urb	ch urb	fw	ch	fw	ch	Fw	Ch
Sudan	Based on UN pop stat. For 2000	0.579	0.322	0.285	0.488	14,871	12,002	5936.8	1474.8	20,808	13,477
	adjusted on map pop values	0.584	0.324	0.281	0.482						
	non_hh consumption	0.149	0.037	0.258	0.064						
	Tot per capita consumption	**0.733**	**0.361**	**0.540**	**0.546**						
Somalia	Based on UN pop stat. For 2000	0.694	0.004	0.007	0.369	4,058	1,093	24.91	98.54	4,083	1,192
	adjusted on map pop values	0.650	0.003	0.009	0.494						
	non_hh consumption	0.002	0.008	0.006	0.023						
	Tot per capita consumption	**0.652**	**0.011**	**0.015**	**0.517**						
Tanzania	Based on UN pop stat. For 2000	1.274	0.046	0.315	0.518	33,594	6,905	6243	153.69	39,837	7,059
	adjusted on map pop values	1.164	0.042	0.496	0.815						
	non_hh consumption	0.121	0.003	0.438	0.011						
	Tot per capita consumption	**1.285**	**0.045**	**0.933**	**0.826**						
Congo, Dem. Republic	Based on UN pop stat. For 2000	1.034	0.006	0.685	0.576	45,094	8,668	11,134	6.84	56,228	8,674
	adjusted on map values	1.001	0.006	0.821	0.691						
	non_hh consumption	0.159	0.000	0.454	0.000						
	Tot per capita consumption	**1.161**	**0.006**	**1.275**	**0.691**						

Annex 3. Supply module. References on woody biomass stocking

Summary table of minimum, medium and maximum woody biomass values by life form, crown cover and ecological zone.

a) Natural formations

		Crown cover	Total closed	closed	closed to open	closed to very open	open	gen. open	very open	sparse	Sparse to very sparse	Very sparse
		Codes	cc	c	co	cvo	o	og	vo	s	svs	vs
		LCCS thresholds	1	>65 %	100 - 40%	100 - 15%	40 - 65%	15 - 65%	15 - 40%	15 - 4%	15 - 1%	4 - 1%
		midpnt	1	0.825	0.7	0.575	0.525	0.4	0.275	0.095	0.08	0.025
			Woody biomass (t / ha)									
Mountain System												
Tree		Min	159	131	111	91	84	64	44	15	13	4
	t	Mean	199	164	139	114	104	79	55	19	16	5
		Max	223	184	156	128	117	89	61	21	18	6
Woody		Min										
Note 1	w	Mean	74	61	52	43	39	30	20	7	6	2
		Max										
Shrub		Min	17	14	12	10	9	7	5	2	1	0
	s	Mean	30	25	21	17	16	12	8	3	2	1
		Max	43	35	30	24	22	17	12	4	3	1
Rain forest												
Tree		Min	240	198	168	138	126	96	66	23	19	6
	t	Mean	376	310	263	216	197	150	103	36	30	9
		Max	485	400	339	279	255	194	133	46	39	12
Woody		Min	55	45	39	32	29	22	15	5	4	1
	w	Mean	141	116	98	81	74	56	39	13	11	4
		Max	191	157	133	110	100	76	52	18	15	5
Shrub		Min										
Note 2	s	Mean	56	46	39	32	30	23	15	5	5	1
		Max										
Tropical moist deciduous forest												
Tree		Min	88	72	61	50	46	35	24	8	7	2
	t	Mean	137	113	96	79	72	55	38	13	11	3
		Max	152	126	107	88	80	61	42	14	12	4
Woody		Min										
Note 3	w	Mean	36	30	25	21	19	14	10	3	3	1
		Max										
Shrub		Min	17	14	12	10	9	7	5	2	1	0
Note 4	s	Mean	24	20	17	14	13	10	7	2	2	1
		Max	43	35	30	24	22	17	12	4	3	1
Tropical dry forest												
Tree		Min	63	52	44	36	33	25	17	6	5	2
Note 5	t	Mean	106	88	74	61	56	43	29	10	9	3
		Max	161	133	113	93	85	64	44	15	13	4
Woody		Min	13	11	9	8	7	5	4	1	1	0
	w	Mean	27	22	19	16	14	11	7	3	2	1
		Max	32	26	22	18	17	13	9	3	3	1
Shrub		Min	15	12	10	8	8	6	4	1	1	0
	s	Mean	18	15	13	10	10	7	5	2	1	0
		Max	22	18	15	13	11	9	6	2	2	1
Tropical shrub land												
Tree		Min	63	52	44	36	33	25	17	6	5	2
	t	Mean	106	88	74	61	56	43	29	10	9	3
		Max	161	133	113	93	85	64	44	15	13	4
Woody		Min										
	w	Mean	23	19	16	13	12	9	6	2	2	1
		Max	34	28	24	19	18	13	9	3	3	1
Shrub		Min	5	4	3	3	2	2	1	0	0	0
	s	Mean	8	7	6	5	4	3	2	1	1	0
		Max	24	20	17	14	12	9	7	2	2	1
Mangroves	m		150	124	105	86	79	60	41	14	12	4

b) Artificial formations

Land cover class	Code	Eco-zone	Woody biomass t / ha
Plantations rain fed	p	Mountain	99
	p	Rainforest	188
	p	Moist	68
	p	Dry	53
	p	Shrub land	53
Plantations irrigated	pir		188
Plantations - oil palm	oil		50
Orchards - Irrigated	orir		150
Orchards - Irrigated - papaya	pap		50
Orchards - Rain fed	orrain	Mountain	40
		Rainforest	75
		Moist	27
		Dry	21
		Shrub land	21
Cultivated shrub	cush		40
Cultivated shrub - tea	tea		40
Cultivated shrub - coffee	coffee		40
Cultivated shrub - pineapple	pinap		0
Cultivated shrub - banana	ban		0
Cultivated shrub - grape	grap		20
Cultivated herbaceous	cuh		0
Cultivated herbaceous - Maize	maize		0
Cultivated aquatic herbaceous - Rice	rice		0
Urban vegetated areas	urva	Mountain	40
		Rainforest	75
		Moist	27
		Dry	21
		Shrub land	21
No vegetation	nv		0

Notes
1. *Missing specific references, deducted from woody in rainforest adjusted on mountain tree biomass*
2. *Missing specific references, deducted from shrub in mountain adjusted on rainforest tree biomass*
3. *Missing specific references, deducted from woody in tropical dry adjusted on shrub in moist deciduous*
4. *Missing specific references, taken the average of mountain and dry areas*
5. *Missing specific references, based on shrub land values.*

Main references:

Mountain		% canopy	T/ha	Reference
Tree	Min	0.825	131	Kenya's Indigenous Forests. Status, Conservation and Management. IUCN Forest Conservation Programme. Peter Wass Editor
	Mean	0.825	164	Kenya's Indigenous Forests. Status, Conservation and Management. IUCN Forest Conservation Programme. Peter Wass Editor
	Max	0.825	184	Kenya's Indigenous Forests. Status, Conservation and Management. IUCN Forest Conservation Programme. Peter Wass Editor
Woody	Min			
	Mean			No specific reference available. Values deducted from woody in rainforest adjusted on mountain tree biomass
	Max			
Shrub	Min	0.575	10	FAO, Forest Resource Assessment 2005. Uganda data from P. Drichi
	Mean			Arithmetic mean
	Max	0.4	17	Kenya Forestry Master Plan - Main Report and Annex I, First Incomplete Draft (1992). Finnida - Menr
Rainforest				
Tree	Min	0.825	198	FAO, Forest Resource Assessment 2005. Uganda data from P. Drichi
	Mean	0.825	310	Brown S., 1997. Estimating biomass and biomass change of tropical forests. FAO Forestry Paper 134. (Mean value for Cameroon)
	Max	0.825	400	Brown S. Et al., 2004. Exploration of the carbon sequestration potential of classified forests in the Republic of Guinea - task 1 Report. Winrock International (original value 396 t/ha from “Guinee Forestiere”)
Woody	Min	0.575	31.7	FAO, Forest Resource Assessment 2005. Uganda data from P. Drichi
	Mean	0.4	56	Various authors, 2000. Carbon sequestration and trace gas emissions in slash-and-burn and alternative land uses in the humid tropic. ASB Climate Change Working Group, Final Report Phase II, Nairobi, Kenya
	Max	0.4	76	Various authors, 2000. Carbon sequestration and trace gas emissions in slash-and-burn and alternative land uses in the humid tropic. ASB Climate Change Working Group, Final Report Phase II, Nairobi, Kenya
Shrub	Min			
	Mean			No specific reference available. Values deducted from shrub in mountain adjusted on rainforest tree biomass
	Max			
Moist Deciduous				
Tree	Min	0.525	46	Walker S., Desanker P., 2002. The Effects of land use change on the belowground carbon stock of the Miombo woodlands. (http://lcluc.gsfc.nasa.gov/products)
	Mean	0.825	113	Kenya's Indigenous Forests. Status, Conservation and Management. IUCN Forest Conservation Programme. Peter Wass Editor
	Max	0.525	80	Walker S., Desanker P., 2002. The Effects of land use change on the belowground carbon stock of the Miombo woodlands. (http://lcluc.gsfc.nasa.gov/products)
Woody	Min			
	Mean			No specific reference available. Values deducted from woody in tropical dry adjusted on shrub in moist deciduous
	Max			
Shrub	Min	0.575	10	FAO, Forest Resource Assessment 2005. Uganda data from P. Drichi
	Mean			No specific reference available. Values assumed as average of shrub in Mountain and Dry forest
	Max	0.4	17	Kenya Forestry Master Plan - Main Report and Annex I, First Incomplete Draft (1992). Finnida - Menr

Dry forest				
Tree	Min			
	Mean			No specific reference available. Values considered equal to mean tree formations in Shrub land
	Max			
Woody	Min	0.275	3.6	Tourè A., Rasmussen K., Diallo O. & Diouf A., 2003. Actual and potential C stocks in the north-sudanian zone. A case study: the forests of Delby and Paniates in Senegal. Danish Journal of Geography, 103(1): 63-70, 2003
	Mean	0.275	7.5	The World Bank, 1986. Sudan forestry sector review. Report 5911-SU. (average of Upper Nile woodland)
	Max	0.275	8.8	Tourè A., Rasmussen K., Diallo O. & Diouf A., 2003. Actual and potential C stocks in the north-sudanian zone. A case study: the forests of Delby and Paniates in Senegal. Danish Journal of Geography, 103(1): 63-70, 2003
Shrub	Min	0.275	4	Woomer P., Tourè A., Sall M., 2003. Carbon stocks in Senegal's sahel transition zone. Presentation given at "The Dakar Workshop", Carbon sequestration, land cover monitoring and desertification in the Sahel, 11-13 March 2003. (http://edcintl.cr.usgs.gov/carbonseq/cd/SOCSOM_Synthesis/PODOR%20TALK%2003.ppt)
	Mean			Arithmetic mean
	Max	0.275	6	Woomer P., Tourè A., Sall M., 2003. Carbon stocks in Senegal's sahel transition zone. Presentation given at "The Dakar Workshop", Carbon sequestration, land cover monitoring and desertification in the Sahel, 11-13 March 2003. (http://edcintl.cr.usgs.gov/carbonseq/cd/SOCSOM_Synthesis/PODOR%20TALK%2003.ppt)
Shrub land				
Tree	Min	0.825	52	Pukkala T., 1993. Yield and management of the indigenous forests and fuelwood plantations of Bura. In: Laxèn J., Koskela J., Kuusipalo J., Otsamo A. (eds.) Proceeding of the Bura Fuelwood Project research seminar in Nairobi 9-10 March 1993. Univ.of Helsinky, Tropical Forestry Reports 9 : 87-96
	Mean	0.4	43	Average of 2 values from: Kenya Forestry Master Plan - Main Report and Annex I, First Incomplete Draft (1992). Finnida - Menr; Biomass assessment and fuelwood potential from woodlands in the western lowlands, from Ministry of Agriculture of Eritrea / FAO-TCP/ERI/6712 (1997): Support to Forestry and Wildlife Sub-Sector. Pre-investment study
	Max	0.825	133	Biomass assessment and fuelwood potential from woodlands in the western lowlands, from Ministry of Agriculture of Eritrea / FAO-TCP/ERI/6712 (1997): Support to Forestry and Wildlife Sub-Sector. Pre-investment study
Woody	Min			n.a.
	Mean	0.4	9	Pukkala T., 1993. Yield and management of the indigenous forests and fuelwood plantations of Bura. In: Laxèn J., Koskela J., Kuusipalo J., Otsamo A. (eds.) Proceeding of the Bura Fuelwood Project research seminar in Nairobi 9-10 March 1993. Univ.of Helsinky, Tropical Forestry Reports 9 : 87-96
	Max	0.095	3.2	Biomass assessment and fuelwood potential from woodlands in the western lowlands, from Ministry of Agriculture of Eritrea / FAO-TCP/ERI/6712 (1997): Support to Forestry and Wildlife Sub-Sector. Pre-investment study
Shrub	Min	0.4	2	Handbook of Forestry Sector statistics - Sudan. 1995 (GCP/SUD/047/NET)
	Mean	0.095	0.8	Pukkala T., 1993. Yield and management of the indigenous forests and fuelwood plantations of Bura. In: Laxèn J., Koskela J., Kuusipalo J., Otsamo A. (eds.) Proceeding of the Bura Fuelwood Project research seminar in Nairobi 9-10 March 1993. Univ.of Helsinky, Tropical Forestry Reports 9 : 87-96
	Max	0.575	13.6	Biomass assessment and fuelwood potential from woodlands in the western lowlands, from Ministry of Agriculture of Eritrea / FAO-TCP/ERI/6712 (1997): Support to Forestry and Wildlife Sub-Sector. Pre-investment study
Mangroves	Mean	0.7	105	J.G. Kairo, B. Kivyatu, N. Koedam, Application of Remote Sensing and GIS in the Management of Mangrove Forests Within and Adjacent to Kiunga Marine Protected Area, Lamu, Kenya, Environment, Development and Sustainability, Volume 4, Issue 2, Jun 2002, Pages 153 – 166. (145 mc/ha)
Oil palm plantation	Mean		50	Average of 2 values from: Thenkabail et al., Biomass estimations and carbon stock calculations in the oil palm plantations of African derived savannas using Ikonos data (http://www.isprs.org/commission1/proceedings/paper/00012.pdf); AAVV, 2000. Carbon sequestration and trace gas emissions in slash-and-burn and alternative land uses in the humid tropic. ASB Climate Change Working Group, Final Report Phase II, Nairobi, Kenya
Tea and Coffee cultivation	Mean		40	Tentative estimate.

Other references:

Country	Items	Reference
Volume and Biomass		
Sudan	Open and closed trees; mountain	Jenkin,R.N., W.J. Howard, P.Thomas, T.M.Abell,G.C.Deane, 1976. Interim report on forestry development prospects in the upper Kinyeti and Ngairigi basins, Imatong Central Forest Reserve, Sudan. Land Resources Division, Min. Of Overseas Development, UK.
Tanzania (and other SADC countries)	Several natural formations	Millington, A., and J. Towsend (eds) 1989. Tanzania Biomass assessment. Woody biomass in the SADC region. Earthscan Publication Ltd, London UK. Main references cited: D.B. Fanshawe 1967 - 72; A.C.R. Edmonds, 1976; Trapnell, 1953; Trapnell and Clothier, 1957, White , 1965.
Sudan	Several natural formations	Kazgail woody vegetation mapping and inventory report. February 1990.Sudan reforestation and anti-desertification project. Location: central Sudan; 12.25 N to 13.00 N - 29.57 E to 30.28 E. total area 289 000 ha.
Sudan	Several natural formations	GCP/RAF/354/EC. Country Report by Mr. Mohamed Ezeldeen Hussein, Coordinator of the National Forest Inventory Unit (FNC). Summary results from 1998 national forest inventory (carried out on 25% of the country)
Sudan	Several natural formations	The World Bank, 1986. Sudan forestry sector review. Report 5911-SU.
RDC		Christophe Musampa, personal communication. *Inventaire des forets claires du sud-katanga(SPIAF 1989).*
Somalia	Tree savannah volumes and Mean Annual Increment	Micski, Jozsef,1989. Estimation of forest resources and some consideration regarding forest management and plantations. Somalia tropical forestry action plan. ADB consultancy. Main references cited: Somalia rangelands survey 1979 - 1985
Kenya	Mean Annual Increment	Openshaw, K. (1982) applied an annual yield of woody biomass of 2.5 percent of the growing stock.
Somalia	Mean Annual Increment	Bowen et al (1987) estimates at 0.5 - 1.2 m3/yr/yr the recovery rate of the moderately degraded xerophilous woodland
Global	Mean Annual Increment	FAO, 1982. Fuelwood supply in developing countries. Forestry Paper 42:
Global	Forest plantations	Forest plantation resources, FAO data-sets 1980, 1990, 1995 AND 2000. By A. Del Lungo, FRA WP 14, FAO 2001.
Global	Forest plantations	Tropical Forest Plantation areas. 1995 Data Set, By D Pandey. FRA WP 18, FAO 2002.
Global	Biomass and conversion factors	Gaston G., Brown S:, Lorenzini M., Singh K., 1998. State and change in C pools in the forest of tropical Africa. Global Change Biology, 4: 97 - 114 (solo Abstract)
Global	Biomass and conversion factors	Brown, S., 1997. Estimating biomass and biomass change of tropical forests. Forestry Paper 134, FAO.

Annex 4. List of main deficit areas

Burundi

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit HDef	Medium –high deficit MHDef	Medium -low deficit MLDef	Balanced Bal	Medium-low surplus MLSur	Medium-high surplus MHSur	High surplus Hsur
Ngozi			0.97	0.03					
Muramviya			0.94	0.02					0.04
Karuzi			0.88	0.07	0.05				
Gitega			0.82	0.18					
Kayanza			0.85	0.08				0.01	0.07
Kirundo			0.75	0.18		0.07			
Muyinga			0.71	0.22	0.02	0.01	0.03	0.01	
Bujumbura			0.55	0.21		0.20		0.04	
Ruyigi			0.42	0.50	0.07		0.00	0.02	0.00
Bubanza			0.58	0.15			0.08	0.06	0.14
Bururi			0.29	0.43		0.19		0.09	
Rutana			0.24	0.73			0.02	0.01	0.00
Makamba			0.25	0.45		0.26		0.03	
Cibitoke			0.41	0.29	0.07			0.06	0.16
Cankuzo			0.09	0.68	0.05	0.01		0.16	

Democratic Republic of Congo

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit HDef	Medium –high deficit MHDef	Medium -low deficit MLDef	Balanced Bal	Medium-low surplus MLSur	Medium-high surplus MHSur	High surplus Hsur
Kivu	Sud-Kivu	Walungu	0.75	0.00		0.00		0.22	0.03
Kasai-Oriental	Mbuji-Mayi	Mbuji-Mayi	0.72				0.03	0.24	
Kivu	Bukavu	Bukavu	0.49	0.16		0.03		0.32	
Bas-Zaire	Matadi	Matadi	0.45					0.48	0.07
Shaba	Lubumbashi	Lubumbashi	0.37		0.15			0.48	
Kivu	Sud-Kivu	Idjwi	0.33	0.12		0.31		0.24	
Kivu	Nord-Kivu	Goma	0.29	0.01		0.09	0.13	0.48	0.00
Kinshasa	Kinshasa	Kinshasa Urban	0.44	0.13		0.21			0.21
Lake Kivu	N.A.	N.A.	0.06	0.17	0.00	0.73		0.03	0.01

Egypt

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit	Medium –high deficit	Medium -low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
			HDef	MHDef	MLDef	Bal	MLSur	MHSur	Hsur
Lower Egypt	Al Gharbiyah (Gharbia)	N.A.	1.00						
Lower Egypt	Al Minufiyah (Menoufia)	N.A.	0.97	0.03	0.00			0.00	
Lower Egypt	Al Qalyubiyah (Kalyoubia)	N.A.	0.91	0.07	0.02				
Lower Egypt	Al Daqahliyah (Dakahlia)	N.A.	0.72	0.12	0.01	0.08	0.04	0.03	
Lower Egypt	Dumyat (Damietta)	N.A.	0.61	0.02		0.31	0.00	0.06	
Upper Egypt	Suhaj	N.A.	0.52	0.22	0.03	0.22	0.00	0.00	
Lower Egypt	Kafr-El-Sheikh	N.A.	0.49	0.23	0.08	0.13	0.02	0.05	
Upper Egypt	Asyiut	N.A.	0.42	0.38	0.02	0.15	0.03		
Upper Egypt	Qina	N.A.	0.32	0.41	0.04	0.21	0.02	0.00	
Lower Egypt	Ash Sharqiyah (Sharkia)	N.A.	0.40	0.21	0.06	0.11	0.06	0.11	0.05
Upper Egypt	Beni Suwayf (Beni-Suef)	N.A.	0.24	0.10	0.04	0.59	0.02	0.02	
Upper Egypt	Al Fayyum (Fayoum)	N.A.	0.19	0.17	0.03	0.61			
Lower Egypt	Al Buhayrah (Behera)	N.A.	0.20	0.12	0.05	0.43	0.07	0.13	
Urban Governates	Al Qahirah (Cairo)	N.A.	0.17	0.05	0.06	0.72			
Urban Governates	Al Iskandariyah (Alex.)	N.A.	0.12	0.18	0.12	0.47	0.06	0.05	
Upper Egypt	Al Minya (Menia)	N.A.	0.11	0.05	0.00	0.82		0.02	

Eritrea

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit	Medium –high deficit	Medium -low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
			HDef	MHDef	MLDef	Bal	MLSur	MHSur	Hsur
Makelay	Asmara City	N.A.	1.00						
Makelay	Berikh	N.A.	0.60	0.01	0.24			0.14	0.01
Anseba	Keren	N.A.	0.56	0.12	0.32	0.00			
Makelay	Serejeka	N.A.	0.56	0.29				0.15	0.00
Makelay	Ghala Nefhi	N.A.	0.37	0.63					
Debub	Debarwa	N.A.	0.26	0.50	0.04	0.12	0.08		
Debub	Mendefera	N.A.	0.20	0.80					
Debub	Segheneyti	N.A.	0.22	0.46	0.00	0.05	0.11	0.15	0.00
Debub	Adi Keyh	N.A.	0.10	0.55			0.12	0.23	0.01
Debub	Kudo Bu`er	N.A.	0.01	0.89	0.09				

Kenya

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit HDef	Medium –high deficit MHDef	Medium-low deficit MLDef	Balanced Bal	Medium-low surplus MLSur	Medium-high surplus MHSur	High surplus Hsur
NYANZA	KISII	N.A.	0.96	0.02		0.02			
WESTERN	VIHIGA	N.A.	0.88	0.07				0.01	0.04
NYANZA	NYAMIRA	N.A.	0.67	0.33					
NAIROBI	NAIROBI	N.A.	0.63	0.36	0.01			0.01	
COAST	MOMBASA	N.A.	0.51	0.26	0.01	0.22			
NYANZA	KISUMU	N.A.	0.49	0.40		0.04		0.07	
WESTERN	KAKAMEGA	N.A.	0.53	0.31	0.01			0.08	0.07
CENTRAL	KIAMBU	N.A.	0.53	0.20	0.02	0.01	0.02	0.13	0.09
NYANZA	MIGORI	N.A.	0.36	0.51	0.03	0.09		0.01	
WESTERN	BUNGOMA	N.A.	0.48	0.29		0.01	0.04	0.03	0.16
CENTRAL	MURANGA	N.A.	0.44	0.20	0.03	0.07	0.03	0.10	0.13
WESTERN	BUSIA	N.A.	0.33	0.29	0.03	0.12		0.19	0.03
NYANZA	HOMA_BAY	N.A.	0.28	0.18	0.04	0.49	0.02		
NYANZA	SIAYA	N.A.	0.27	0.43	0.06	0.06	0.05	0.12	0.01
CENTRAL	KIRINYAGA	N.A.	0.45	0.21	0.06			0.08	0.20
RIFT VALLEY	TRANS-NZOIA	N.A.	0.29	0.48	0.01	0.01	0.02	0.06	0.12
RIFT VALLEY	KERICHO	N.A.	0.39	0.13			0.03	0.24	0.21
EASTERN	MACHAKOS	N.A.	0.10	0.58	0.09	0.07	0.03	0.12	0.01

Rwanda

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit HDef	Medium –high deficit MHDef	Medium -low deficit MLDef	Balanced Bal	Medium-low surplus MLSur	Medium-high surplus MHSur	High surplus Hsur
Ruhengeri			0.65	0.20	0.05			0.08	0.02
Gisenyi			0.56	0.30			0.01	0.08	0.05
Butare			0.48	0.46			0.05	0.01	
Gitarama			0.45	0.51	0.04				
Kigali			0.28	0.63	0.03	0.04		0.03	
Kibuye			0.24	0.46	0.01	0.16		0.10	0.04
Byumba			0.13	0.28	0.09	0.09	0.19	0.23	

Somalia

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit HDef	Medium –high deficit MHDef	Medium -low deficit MLDef	Balanced Bal	Medium-low surplus MLSur	Medium-high surplus MHSur	High surplus Hsur
Banaadir	Mogadisho	N.A.	0.48		0.50	0.02			
Sh. Hoose	Afgooye (Afgoi)	N.A.	0.04	0.09	0.13	0.25	0.24	0.24	
Sh. Dhexe	Cadale	N.A.		0.12	0.63	0.22	0.03		
W. Galbeed	Hargeysa	N.A.	0.01	0.04	0.33	0.38	0.12	0.11	
Sh. Dhexe	Aadan	N.A.		0.02	0.44	0.48	0.05	0.01	

Sudan

Subnational administrative level			Fraction of the administrative unit by balance category						
Level 1	Level 2	Level 3	**High deficit** HDef	**Medium –high deficit** MHDef	**Medium -low deficit** MLDef	**Balanced** Bal	**Medium-low surplus** MLSur	**Medium-high surplus** MHSur	**High surplus** Hsur
Khartoum	Khartoum	Khartoum North	0.99	0.01					
Central	El Gazira	El Kamlin	0.34	0.66					
Central	El Gazira	El Manaquil	0.23	0.77	0.00				
Khartoum	Khartoum	Khartoum	0.16	0.84					
Central	El Gazira	Hasaheisa	0.11	0.88	0.00				
Central	Blue Nile	Sennar	0.06	0.94	0.00				
Central	El Gazira	Ma tuq	0.04	0.96	0.00				
Central	El Gazira	Rufaa	0.14	0.68	0.01	0.01	0.01	0.07	0.08
Khartoum	Khartoum	Abu Deleiq	0.10	0.14	0.59	0.18			
Eastern	Kassala	Goz Regeb	0.03	0.77	0.07	0.11	0.02	0.01	
Central	El Gazira	Wad Medani	0.03	0.87	0.03		0.01	0.04	0.02
Central	Blue Nile	Es Suki		1.00				0.00	
Central	White Nile	Kawa	0.03	0.62	0.35				
Central	White Nile	El Dewiem		0.95	0.05	0.01			
Central	White Nile	El Geteina	0.03	0.58	0.35	0.04			
Central	White Nile	Rabak	0.08	0.26	0.48	0.03	0.00	0.15	
Kordufan	South. Kordofan	Kadugli	0.03	0.70	0.08	0.07	0.05	0.07	
Kordufan	North. Kordofan	El Obeid	0.02	0.58	0.31	0.09	0.00	0.00	
Kordufan	North. Kordofan	Umm Ruwaba		0.79	0.15	0.01	0.02	0.04	
Central	Blue Nile	El Garef	0.03	0.59	0.15	0.00	0.10	0.13	
Bahr el Ghazal	Bahr el Ghazal	Wun Rog	0.02	0.55	0.23	0.10	0.05	0.04	
Eastern	Kassala	Kassala	0.00	0.43	0.16	0.30	0.09	0.02	
Central	White Nile	Tendelti		0.68	0.03		0.03	0.26	
Eastern	Red Sea	Sinkat		0.34	0.63	0.03			
Khartoum	Khartoum	Omdurman	0.02	0.06	0.53	0.31	0.08		
Central	White Nile	Kosti		0.56	0.09	0.04	0.04	0.27	

Tanzania

Subnational administrative level — Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit HDef	Medium –high deficit MHDef	Medium -low deficit MLDef	Balanced Bal	Medium-low surplus MLSur	Medium-high surplus MHSur	High surplus Hsur
Mjini-Magharibi	Zansibar Town	N.A.	1.00						
Mjini-Magharibi	Zansibar West	N.A.	0.78	0.00		0.17		0.05	
Kilimanjaro	Moshi	N.A.	0.77	0.17	0.01	0.00			0.05
Mwanza	Ukerewe	N.A.	0.72	0.04		0.24			
Mwanza	Mwanza	N.A.	0.62	0.26		0.11			
Mwanza	Magu	N.A.	0.60	0.33		0.07			
Kaskazini-Pemba	Wete-Pemba	N.A.	0.60	0.19		0.21			
Kusini-Pemba	Chakechake	N.A.	0.63			0.16		0.21	
Kusini-Pemba	Mkoani	N.A.	0.60	0.08		0.25		0.07	
Arusha	Arusha	N.A.	0.61	0.10		0.20			0.09
Mwanza	Kwimba	N.A.	0.46	0.52		0.02			
Mwanza	Sengerema	N.A.	0.47	0.25		0.18		0.05	0.05
Mbeya	Kyela	N.A.	0.40	0.19	0.06	0.16	0.06	0.12	
Mara	Bunda	N.A.	0.35	0.55	0.00	0.09	0.01	0.00	
Arusha	Arumeru	N.A.	0.49	0.26		0.00		0.13	0.13
Kaskazini-Unguja	Zansibar North-Central	N.A.	0.39			0.42		0.19	
Tanga	Tanga	N.A.	0.36			0.64			
Kagera	Muleba	N.A.	0.34	0.30	0.03	0.09	0.01	0.24	0.00
Mara	Musoma	N.A.	0.277	0.60	0.02	0.09		0.02	
Kaskazini-Pemba	Micheweni-Pemba	N.A.	0.31	0.23		0.46			
Mara	Tarime	N.A.	0.26	0.63	0.03	0.04	0.02	0.01	
Tanga	Lushoto	N.A.	0.33	0.51	0.00	0.00	0.01	0.08	0.06
Shinyanga	Shinyanga	N.A.	0.14	0.84	0.01	0.00	0.00	0.00	
Kilimanjaro	Mwanga	N.A.	0.14	0.76	0.07	0.00	0.03		
Kusini Unguja	Zansibar Central	N.A.	0.23	0.20		0.27		0.29	0.01
Kaskazini-Unguja	Zansibar North	N.A.	0.21	0.22		0.25		0.32	
Mwanza	Geita	N.A.	0.18	0.55	0.06	0.08	0.01	0.09	0.03
Shinyanga	Maswa	N.A.	0.08	0.86	0.02	0.02	0.02		
Shinyanga	Bariadi	N.A.	0.09	0.60	0.09	0.03	0.11	0.09	
Tabora	Igunga	N.A.	0.05	0.76	0.05		0.04	0.10	

Uganda

Subnational administrative level | Fraction of the administrative unit by balance category

Level 1	Level 2	Level 3	High deficit HDef	Medium –high deficit MHDef	Medium-low deficit MLDef	Balanced Bal	Medium-low surplus MLSur	Medium-high surplus MHSur	High surplus Hsur
Mbale	Mbale Municipality	N.A.	1.00						
Jinja	Butembe	N.A.	0.91	0.09					
Kabale	Kabale Municipality	N.A.	0.89	0.11					
Lira	Lira Municipality	N.A.	0.91					0.09	
Kampala	Kampala City Council	N.A.	0.89	0.04	0.05				0.02
Soroti	Soroti Municipality	N.A.	0.87					0.13	
Mbale	Bungokho	N.A.	0.84	0.02				0.14	
Bushenyi	Kajara	N.A.	0.74	0.26	0.01				
Masaka	Kalungu	N.A.	0.74	0.21		0.04			
Bushenyi	Sheema	N.A.	0.68	0.32					
Tororo	Tororo	N.A.	0.67	0.33				0.00	
Kabale	Ndorwa	N.A.	0.59	0.26		0.15			
Tororo	Tororo Municipality	N.A.	0.55	0.45					
Pallisa	Butebo	N.A.	0.57	0.13		0.22		0.08	
Kabarole	Fort Portal Municipality	N.A.	0.55	0.22				0.23	
Iganga	Bugweri	N.A.	0.57	0.03				0.40	
Mbale	Bubulo	N.A.	0.67	0.15		0.00			0.18
Mpigi	Entebbe Municipality	N.A.	0.53	0.04		0.00		0.43	
Masaka	Masaka Municipality	N.A.	0.41	0.59					
Jinja	Kagoma	N.A.	0.50	0.00				0.50	
Kabale	Rukiga	N.A.	0.38	0.60	0.02	0.00			
Pallisa	Kibuku	N.A.	0.44	0.08	0.01			0.47	
Mukono	Ntenjeru	N.A.	0.38	0.33	0.11		0.02	0.16	
Mbarara	Rwampara	N.A.	0.31	0.65		0.01		0.03	
Mbarara	Ruhaama	N.A.	0.30	0.58		0.05		0.07	
Tororo	Kisoko (West Budama)	N.A.	0.34	0.47				0.15	0.03
Masaka	Bukomansimbi	N.A.	0.27	0.56	0.09	0.04		0.03	
Tororo	Bunyole	N.A.	0.31	0.36	0.06	0.00		0.27	
Iganga	Luuka	N.A.	0.36	0.12	0.04		0.06	0.40	0.02
Pallisa	Budaka	N.A.	0.30	0.26	0.09	0.19		0.17	
Kumi	Ngora	N.A.	0.23	0.63	0.14				
Arua	Maracha	N.A.	0.25	0.45		0.00	0.18	0.12	
Mukono	Nakifuma	N.A.	0.48	0.16			0.00	0.16	0.20
Mbarara	Isingiro	N.A.	0.21	0.52		0.17	0.07	0.03	
Pallisa	Pallisa	N.A.	0.21	0.43	0.30	0.01		0.05	
Bushenyi	Rushenyi	N.A.	0.17	0.83	0.01	0.00			
Kamuli	Buzaaya	N.A.	0.27	0.21	0.00			0.52	
Mpigi	Kyadondo	N.A.	0.42	0.13		0.04		0.24	0.17
Nebbi	Padyere	N.A.	0.20	0.47	0.04	0.00	0.15	0.13	
Mbarara	Mbarara Municipality	N.A.	0.14	0.86					
Lira	Erute	N.A.	0.21	0.29	0.16		0.02	0.32	
Rukungiri	Rubabo	N.A.	0.14	0.62	0.21			0.03	
Rakai	Kyotera	N.A.	0.23	0.51		0.06	0.00	0.12	0.09
Kabale	Rubanda	N.A.	0.27	0.41		0.01		0.19	0.12
Kisoro	Bufumbira	N.A.	0.33	0.45		0.00		0.01	0.21
Mbarara	Kashari	N.A.	0.25	0.32				0.34	0.09
Gulu	Gulu Municipality	N.A.	0.47					0.23	0.30
Iganga	Kigulu	N.A.	0.29	0.19				0.39	0.12
Kumi	Kumi	N.A.	0.10	0.52	0.09	0.25	0.01	0.02	
Iganga	Bunya	N.A.	0.27	0.17		0.16		0.28	0.12
Tororo	Samia-Bugwe	N.A.	0.25	0.31	0.11	0.06		0.12	0.15
Kapchorwa	Tingey	N.A.	0.39	0.15	0.00	0.08		0.10	0.28
Iganga	Bukooli	N.A.	0.19	0.30	0.05	0.08		0.31	0.07