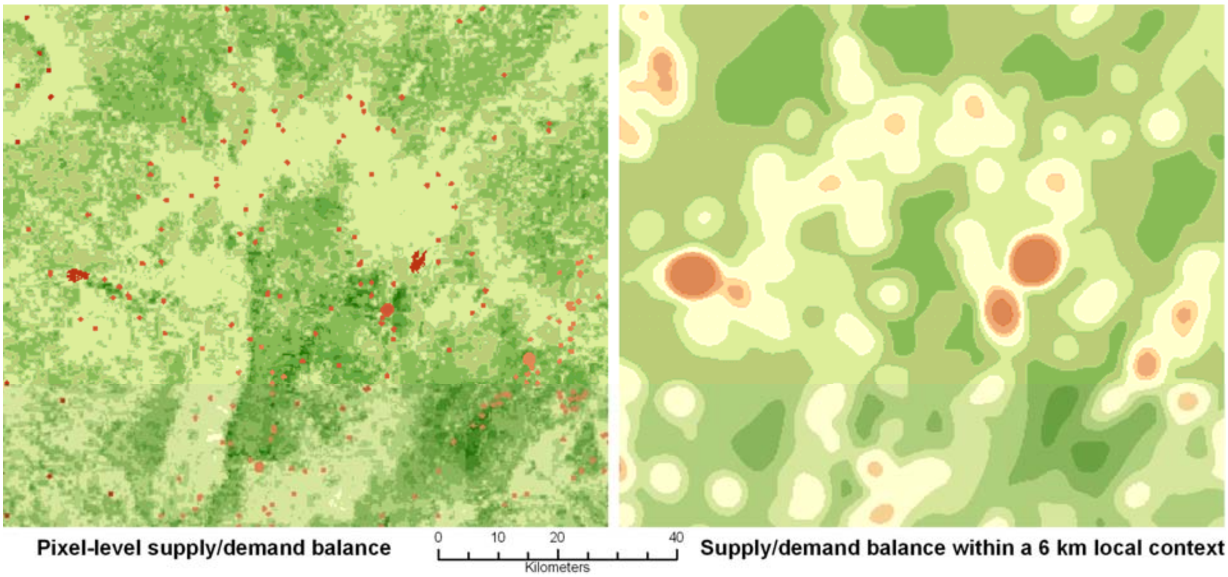
Sudan Institutional Capacity Programme: Food Security Information for Action (SIFSIA)

FAO OSRO/SUD/620/MUL

WISDOM Sudan

Spatial analysis of woodfuel supply and demand in Sudan based on WISDOM methodology and new land cover mapping



Activity carried out in the framework of the: Sudan Institutional Capacity Programme: Food Security Information for Action (SIFSIA) FAO OSRO/SUD/620/MUL

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Food and Agriculture Organization of the United Nations

Rome, March 2012

FOREWORD

The division of Sudan in two separate nations imposes new challenges and the need for new strategies concerning the management of natural resources in the new geopolitical context.

One of such challenges is the sustainable management of biomass resources, which are the prime source of energy for households and for small-scale industries and important sources of revenue as timber products. This is particularly serious and urgent in Sudan, due to the separation from the traditional woodfuel supply regions of the South.

The scope of applying the Woodfuel Integrated Supply/Demand Overview Mapping methodology to Sudan (WISDOM-Sudan) is to provide reliable knowledge on the sustainable production capacities and on the areas under high risk of degradation and to strengthen Sudan wood energy planning capacities, inter-sectoral and interdisciplinary decision making processes, strategic planning and policy formulation.

The WISDOM methodology is based on the analysis of the spatial distribution and the linkages of woodfuel supply and demand and it is designed to address issues of sustainability in wood energy planning.

The WISDOM methodology is applied to the 2012 Land-cover map produced by Land and Water Division (NRL) mapping unit of FAO and the Remote Sensing Authority (RSA) of Sudan using the latest Land Cover Classification System (LCCS) and using available information related to the sustainable productivity and consumption of woody biomass in Sudan.

This study reviews the country's capacity for self-sufficiency on woody biomass in the new geo-political context, revealing an overall national deficit ranging between 1.5 and 5.6 million m^3 of woody biomass. It provides geo-referenced information on the surplus areas, where sustainable production systems can be implemented and on the deficit areas, where protection measure must be put in place.

Among other aspects, this study highlight the important role of LPG in replacing charcoal and fuelwood in the recent past and hopefully in the coming future, and of imported woodfuels, maintaining and possibly increasing the flow originally coming from southern states.

The WISDOM analysis provides support for the definition of priority areas of intervention in a variety of aspects related to sustainable forest management and energy planning. The "Subsistence Energy" map, combining woodfuel balance with multi-dimensional poverty indicators is one example of decision-support product that permitted the identification of communities that suffer from concomitant conditions of serious woodfuel deficit and high poverty, which are causes of extreme vulnerability and of structural food insecurity problems.

The WISDOM analysis is implemented in the framework of the Sudan Institutional Capacity Program: Food Security Information for Action (FAO-SIFSIA) and the Food Security Technical Secretariat (FSTS-MoAI) in collaboration with the Sudan's Forests National Corporation (FNC).

The active participation of FNC to the study included the sharing of existing inventory and woodfuel consumption data, the collection of additional information and the technical knowledge offered at numerous meetings throughout the WISDOM development. Two training workshops were held at FNC HQ, one on the technical aspects of WISDOM Modules' development and a final one on the findings and policy implications. Both workshops saw the participation of 80-over participants representing all states and all concerned FNC HQ technical Units.

As stated by FNC Director at the joint SIFSIA-FNC cross-sectoral meeting held at the Ministry of Agriculture and Irrigation on 1st March 2012, this study will strongly contribute to the formulation of the 20-years energy master plan that FNC, the Ministry of Petroleum, the Ministry of Finance and other institutional stakeholders are in the process to formulate.

ABSTRACT

In the new geopolitical context of the Sudan, the need for new strategies concerning the management of natural resources and energy security are pressing and challenging issues. One of such challenges is the sustainable management of biomass resources, which are the prime source of energy for households and for small-scale industries. This is particularly serious and urgent in the new Sudan, due to the separation from the traditional woodfuel supply regions of the South.

In order to support strategic planning and policy formulation, the sustainable woody biomass supply potential and the consumption of woody biomass in the residential, commercial and industrial sectors are analyzed and mapped applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology.

The analysis integrates all available information related to the sustainable productivity and consumption of woody biomass in Sudan and is based on the new Land-cover map (release 2012) produced by Land and Water Division (NRL) mapping unit of FAO and the Remote Sensing Authority (RSA) of Sudan. The reference date of the study is 2011 and the spatial resolution of analysis is one hectare (raster cells of 100 m), while the minimum administrative level of analysis is the Administrative Unit (subdivision of Locality).

The study, that implied the creation of new maps of land cover, population distribution, accessibility, and others, helps to define deficit areas, where rural and peri-urban populations are likely to suffer severe shortages and/or where the available wood resources are likely to undergo unbearable pressure, and surplus areas, where the relative abundance of wood resources may support sustainable wood energy systems.

The analysis includes the estimation of supply/demand balance at the “local” level, based essentially on self-gathering of woodfuels within a limited accessible horizon, and at “commercial” level, based on the surplus resulting from the local balance and applying various minimum-resource availability thresholds. Balance results and accessibility factors are used in woodshed analysis, in order to define the areas under the influence of urban woodfuel demand and to estimate the probable fraction of Non Renewable Biomass (fNRB) of harvested woody biomass.

The study put forward critical planning elements at various geographic scales, from local level to aggregations of states with common characteristics, that help in the formulation of a comprehensive and cross-sectoral wood energy strategy for the Sudan. The study highlighting at the same time the aspects that need to be further investigated and the thematic elements to be added in order to better focus future interventions.

The study represents the starting point of a knowledge process supporting cross-sectoral planning for sustainable management, energy security and poverty alleviation, peace and resettlement action. The rich geo-statistical database provides excellent basis for additional thematic layers (farming systems, livestock and water, etc.) to support truly integrated and spatially-explicit development programmes, such as the Natural Resources Management for Food and Nutrition Security in Darfur promoted by TCE, FAO.

(Citation)

WISDOM Sudan. Spatial analysis of woodfuel supply and demand in Sudan based on WISDOM methodology and new land cover mapping

Prepared by Rudi Drigo

__ pages, _ boxes, __figures, __ tables.

Keywords:

Woodfuel supply/demand balance; woodfuel deficit; woodfuel surplus; fuelwood consumption; charcoal; wood energy; bioenergy; subsistence energy; land cover mapping; woody biomass; stock and productivity; GIS; spatial analysis; woodshed analysis; non-renewable biomass.

ACKNOWLEDGEMENTS

The analysis of the wood energy situation in Sudan was accomplished by FAO in the framework of the Sudan Instituitional Capacity Programme on Food Security Information for Action (SIFSIA N).

The work was conducted under the technical supervision of John Latham, Senior Land and Water Officer (Geospatial) and the GIS work has been supervised by Renato Cumani.

The activity was carried out under the coordination of Alemu Asfaw, CTA SIFSIA N, and in close collaboration with SIFSIA N staff.

The WISDOM analysis and training programme has been conducted by Rudi Drigo, International Consultant to TCE, with the assistance of Mohamed Osman El Hassan, National Woody Biomass Supply Consultant and Fatha el Aleem Mohie el Deen, National Woodfuel Demand Consultant.

The contribution and collaboration extended by the Forests National Corporation (FNC) through a large number of officials from Khartoum Headquarter and from State Units is gratefully acknowledged. A special thanks goes to the FNC team that participated to the Rapid Appraisal of non-household woodfuel consumption and to the GIS and Inventory units that contributed to the retrieval of the 1995 forest inventory information.

The contribution with LPG consumption data and advise provided by Mr Salah Eldin Ali Mohamed, Ministry of Petroleum, is acknowledged with thanks.

The friendly collaboration and sharing of information provided by Robin Bovey, Brendan Bramwhich, and Fabian Kreuzer of UNEP Khartoum is gratefully acknowledged.

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List of figures, boxes and tables

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ACRONYMS AND ABBREVIATIONS

ad	Air dry (biomass, usually measured in kg or tons, with approx. 12% moisture content)
AoI	Area of Interest
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
AU	Administrative Unit (subdivision of Locality)
BAU	Business-as-usual. Used to indicate current woodfuel demand conditions.
dbh	diameter at breast height
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Databases
FES	Fuel Efficient Stove (used also to define the scenario resulting from the introduction of fuel efficient stoves in rural and urban households)
FNC	Forests National Corporation
GIS	Geographical Information System
GLCN	Global Land Cover Network of FAO
HH	household(s) [in Tables]
IDP	Internally Displaced Population
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
LandScan	Worldwide population database compiled on a 30" × 30" latitude × longitude grid of the Oak Ridge National Laboratory (ORNL) Global Population Project
LC	Land Cover
LCCS	Land Cover Classification System
LPG	Liquefied Petroleum Gas
MAI	Mean Annual Increment
NFI	National Forest Inventory
NRB	Non Renewable Biomass. Used to indicate the fraction of the consumed (woody) biomass that is above the sustainable supply potential (or MAI).
NRL	Land and Water Division, Department of Natural Resources and Environment, FAO
OCHA	Office for the Coordination of Humanitarian Affairs of United Nations
od	Oven dry (biomass, usually measured in kg or tons, with 0% moisture content)(synonymous of Dry Matter DM)
Pixel	(from "picture element") The smallest unit of a raster map (syn. cell). In this study the pixel size corresponds to 10" × 10" latitude × longitude (approx 300 m) for the Rapid WISDOM Appraisal and to 100×100 m for the Detailed WISDOM Analysis.
RWA	Rapid WISDOM Appraisal
SIFSIA	Food Security Information for Action (Sudan Institutional Capacity Programme of FAO)
TOF	Trees Outside Forest (survey)
UBET	Unified Bioenergy Terminology
UNEP	United Nations Environment Programme
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping (methodology)

1. INTRODUCTION

The division of Sudan in two separate nations imposes new challenges and the need for new strategies concerning the management of natural resources in the new geopolitical context and the development of new planning tools.

One of such challenges is the sustainable management of biomass resource, which is the prime source of energy for households and for small-scale industries and is an important source of revenue as timber products. This is particularly serious and urgent in the new geopolitical context of the North Sudan, due to the separation from the traditional woodfuel supply regions of the South.

In addition to serving the subsistence energy needs, the rational management of the limited biomass resources of present-day Sudan, will serve to plan the woodfuel import regimes from neighboring countries, primarily from southern regions which have always been the main woodfuel supply sources.

The rational and sustainable management of the woody biomass resources of the North and their protection from excessive exploitation is now more important than ever, given the likely increase in demand. In turn, reliable knowledge on the sustainable production capacities and on the areas under high risk of deforestation and degradation due to marked deficit conditions will support the formulation of wise energy policy options and woodfuel import regimes.

1.1 SCOPE

Scope of this activity, carried out in the framework of the FAO-supported SIFSIA Project, was to strengthen Sudan wood energy planning capacities and to develop planning tools supporting inter-sectoral and interdisciplinary decision making processes, strategic planning and policy formulation.

In order to strengthen planning capacities, the activity aimed at establishing and/or reinforcing institutional partnership with contributors and main end users of the final product and awareness raising on the priorities of the wood energy sector, with special reference to the Forests National Corporation.

The objective of this activity was to (i) analyze the sustainable supply potential and the demand for woodfuels in new Sudan through the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) model, (ii) reveal the woody biomass production potential legally, environmentally and economically available for internal consumption for energy and other purposes, and (iii) discuss intervention priorities.

The WISDOM analysis carried out on Darfur in 2010[1] provided an example of the work to be done over the remaining part of the Country.

The analysis was intended as interdisciplinary and cross-sectoral, including forestry, energy, territorial and socio-economic components, as is typical for WISDOM analyses. Given the large variety of data sources and the limited resources available, the analysis was be based primarily on existing information. As in case of the WISDOM study on Darfur, the information produced by FNC over time provided fundamental references. Specifically, the FNC Forest Products Consumption Survey (1995) and the National Forest Inventory (1998) conducted with FAO assistance constituted the historical reference for both Demand and Supply Modules of the WISDOM analysis. The main efforts were dedicated to the update of these important historical references, in order to reflect the current supply and demand conditions, as done in case of Darfur.

[1] The final “WISDOM Darfur” publication is in press by FAO. Meanwhile, a summary paper on the methodology and results can be downloaded from: http://www.fao.org/fileadmin/user_upload/sifsia/docs/Darfur_WISDOM_Report_Jan2011.pdf

1.2.1 Main feature of the WISDOM method[2]

The methodological approach is based on the following three fundamental characteristics of wood energy systems:

Geographical specificity. The patterns of woodfuel production and consumption, and their associated social, economic and environmental impacts, are site specific (Mahapatra and Mitchell, 1999; FAO/RWEDP, 1997; FAO, 2003d).

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

User adaptability. Demand and supply patterns influence each other and tend to adapt to varying supply patterns and resource availability. This means that quantitative estimations 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).

In order to cope with the various dimensions of wood energy, the Wood Energy Programme of the FAO Forest Products Service has developed and implemented the **Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology**, a spatially-explicit planning tool for highlighting and determining woodfuel priority areas or woodfuel hot spots (FAO, 2003). WISDOM is the fruit of collaboration between FAO's Wood Energy Programme and the Institute of Ecology of the National University of Mexico. At national level, the WISDOM approach has been implemented in Mexico (FAO, 2005), Slovenia (FAO, 2004a), Senegal (FAO, 2004b), Castilla y Leon (Spain), Italy, Croatia, Central Africa Republic, Mozambique, Argentina, Rwanda and Peru and it's currently being implemented in Chad. At subregional level, WISDOM was implemented over the eastern and central Africa countries covered by the Africover Programme (FAO, 2005g) and over the countries of South East Asia (FAO, 2007).

WISDOM is meant to create a spatially-explicit knowledge base on supply and demand of woody (and non-woody) biomass for energy and thus to serve as a planning tool for highlighting and determining **priority areas** of intervention and to **focus planning options**. The result of the wall-to-wall supply/demand balance analysis is then used as starting point for the delineation of the necessary supply areas for existing or hypothetical consumption sites.

WISDOM features:

- **Geo-referenced data bases.** A core feature of the approach is the spatial base on which the data is framed. The analysis and presentation of results for all modules is done with the help of a Geographic Information System (GIS).

- **Minimum administrative and spatial units of analysis.** The spatial resolution is defined at the beginning of the study, on the basis of the desired level of detail (national study, regional study) and as constrained by the main parameters or proxy variables that will be used to "spatialize" the information. In most cases the basis for the definition of the administrative level of analysis is provided by the existing demographic data (i.e. census units), which represents the most detailed sub-national structure of a country. The spatial level of analysis (i.e. the size of the pixel in GIS raster data) is usually determined by the mapping detail of the available land use/land cover data.

- **Modular and open structure**. WISDOM consists of modules on demand, supply, integration and woodshed analysis. Each module requires different competencies and data sources and its contents is determined by the data available or, to a limited extent, by the data purposively collected to fill critical data gaps. Once the common spatial base of reporting is defined, each module is developed in total autonomy using existing information and analytical tools and is directed to the collection, harmonization, cross-referencing and geo-referencing of relevant existing information for the area of study.

[2] The description of the WISDOM method is largely taken from "Spatial bioenergy analysis : Ten-years experience with the WISDOM model" by Drigo et al. (in press).

- **Adaptable framework**. As mentioned previously, the information of relevance to wood energy comes from multiple sources, ranging from census data to local pilot studies or surveys, to projected estimates with unknown sources, and is often fragmented and poorly documented. Proxy variables may be used to "spatialize" discontinuous values. In synthesis, WISDOM tries to make all existing knowledge work for a better understanding of biomass consumption and supply patterns.

- **Comprehensive coverage of woody and non-woody biomass resources and demand from different users**. The analytical framework includes of all sources of biomass potentially available for energy (i.e. fuelwood and charcoal, crop residues, industrial residues, etc.) and all users categories (rural and urban residential; industrial; commercial and public).

The WISDOM methodology may be divided into two sequential stages of analysis:

1 - **WISDOM Base**. This stage includes the analysis over the entire territory of the study area.

2 - **Woodshed[3] analysis**. This second stage of the analysis uses the result of the WISDOM Base to delineate the sustainable supply zone of selected consumption sites. Depending on the scale and objectives of analysis, the selected sites could be urban centers, rural villages or existing/planned biomass plants.

The specific steps of analysis are summarized below while a graphic overview is shown in Figure 4.

<u>WISDOM Base</u>

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

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

<u>Woodshed analysis</u>

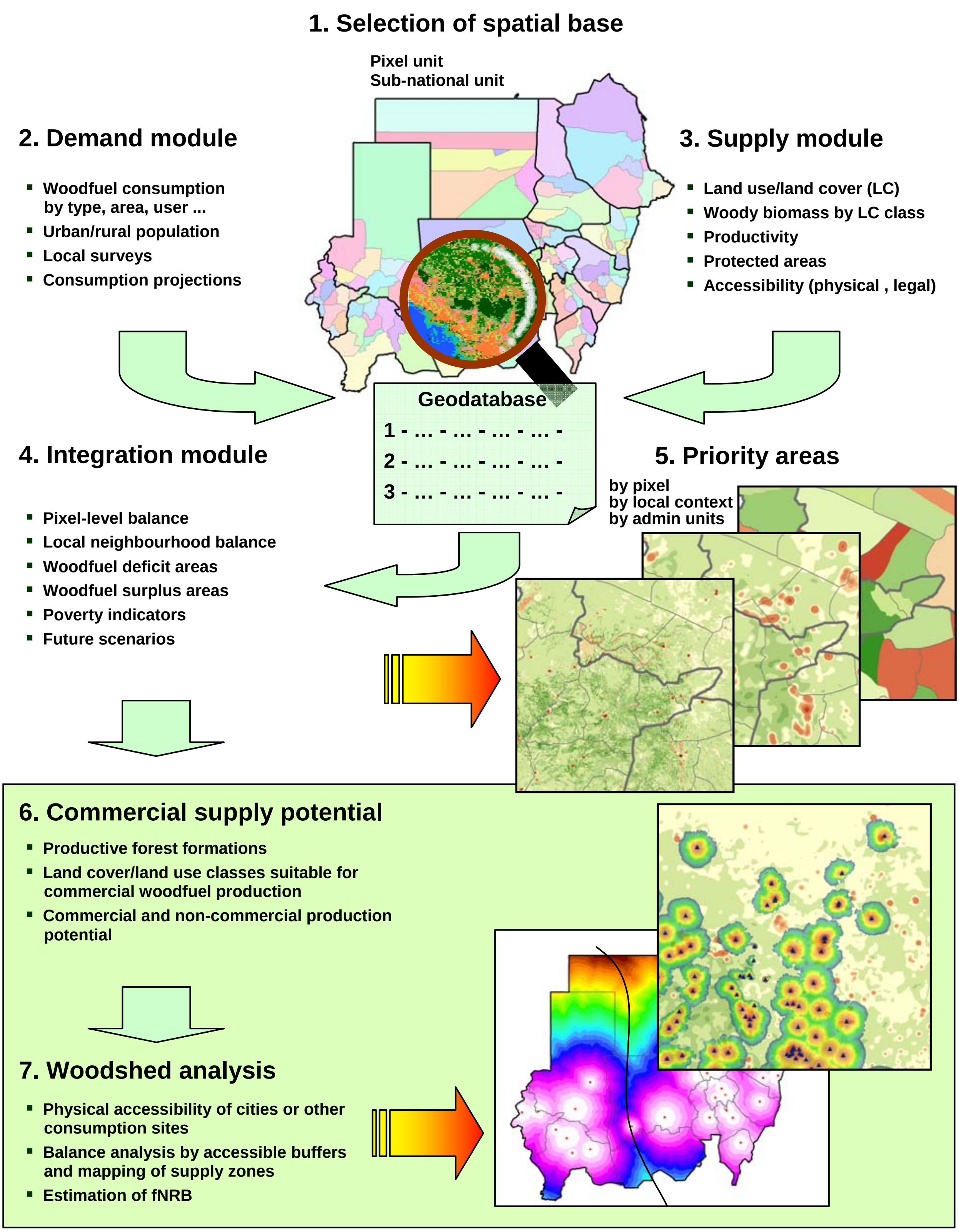
The analysis for the delineation of woodsheds, i.e. supply zones of specific consumption sites requires additional analytical steps that may be summarized as follows.

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

[3] The term "woodshed" is a neologism inspired by the familiar geographic concept of *water*shed. It is used to indicate the portion of the territory necessary to supply on a sustainable basis the woody biomass needed by a specific consumption site (existing or hypothetical).

FIGURE 1

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



2. WISDOM ANALYSIS

2.1 SELECTION OF SPATIAL BASE OF ANALYSIS

Mapping details:

Projection: Geographic, **GCS_WSG_1984,**

cell size DD **0.00089892031434099875**

For cost-distance analysis, that giver more consistent results with metric units, the Lambert Azimuthal Equal Area Projection was used (long 30.35 dd; lat 15.00 dd; datum WSG_1984)

Administrative units used for population mapping:

Vector ref. maps with attributes:

AU_pop08_reconciled01.shp

AU__Darfur.shp

The map of Localities (first subdivision of States) used as reference for the analysis is the version received in 2011 (North_loc.shp). A new version was provided on the 10th of February 2012 (SUDAN_SNSA_admin2_fixed2.shp) which presents minor differences in the shape of Locality Hamash Koreeb (Kassala) and of the adjacent Hayaa (Red Sea) and along the international border. The new administrative layout has been adopted in all maps shown in the document (Loc_feb12.shp; State_feb12.shp; Cty_feb12.shp. Due to time constraints the whole WISDOM analysis could not be re-run for the new layout and therefore the result statistics refer to the previous 2011 administrative layout. To be noted, however that the differences between the two maps are so small that the impact on the analysis is irrelevant.

Raster ref. maps with admin codes (original OR adjusted):

au_reconc_gc

auadjdar_gc

Land cover

Globcover v2.3 2009 (preliminary analysis)

LCCS database 2011 (final analysis , pending map release)

Reference years of WISDOM analysis

The reference years of the WISDOM analysis was determined by the reference years of the most important data layers. given the important changes introduced by the separation of South Sudan and the forthcoming 2011 Land Cover database, all efforts were made to assess the situation at year **2011**.

Concerning the Supply Module, the readily available land cover data, Globcover 2.3, describes the 2009 situation, while the new LCCS database will provide 2011 information (2010-2011 satellite data).

Concerning the Demand Module, the year of the last demographic census is 2008 as is the year of the map of human settlements. The analysis was done with two reference years: 2008, to reflect the consumption situation at census year and 2011, to reflect the situation after separation of Southern Sudan. For the estimation and mapping of woodfuel consumption in 2011, the urban and rural population growth rates were applied a well as the best available information on the migrations induced by the separation of South Sudan.

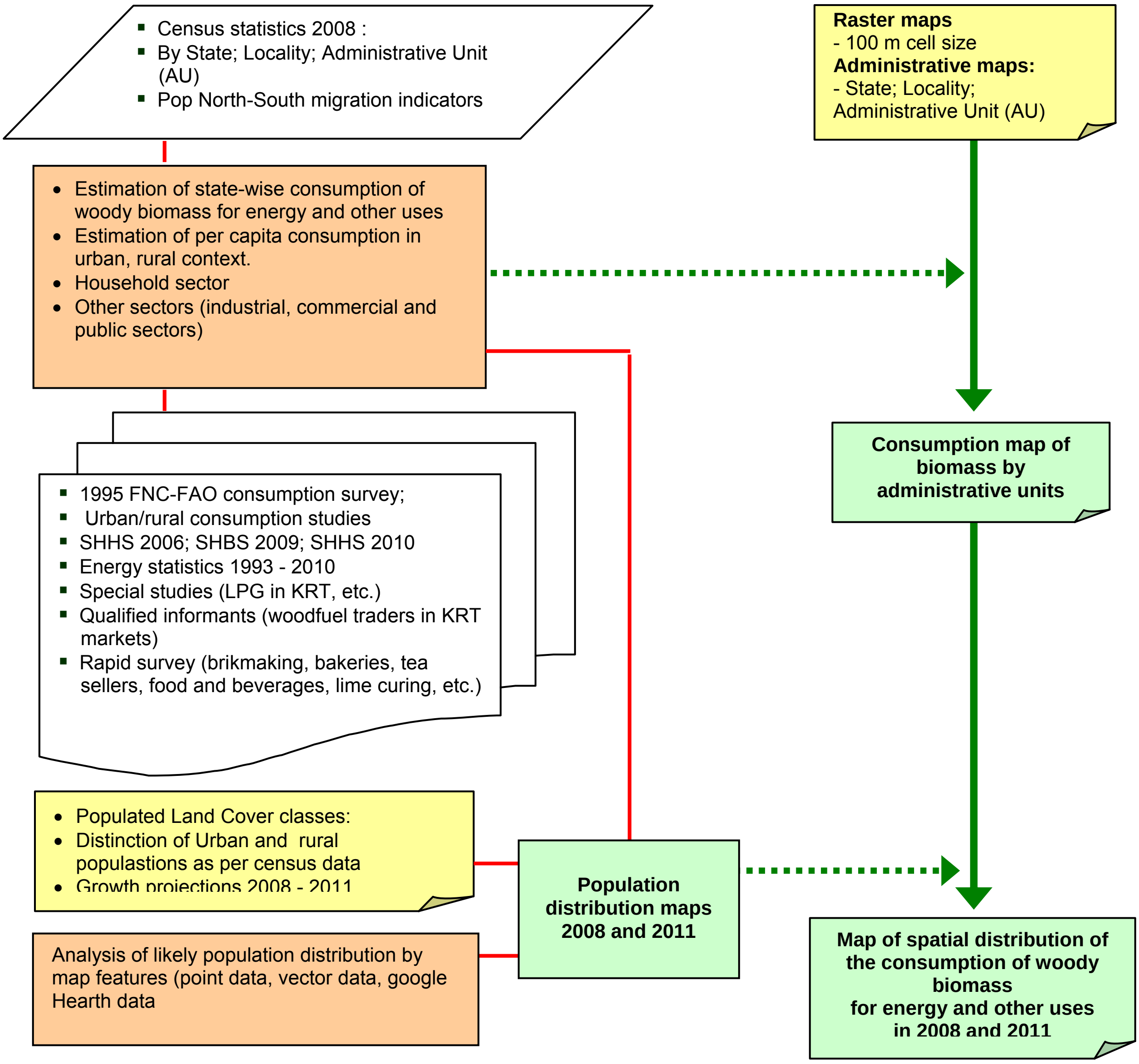
2.2 Demand Module

The goal of the Demand Module was to estimate the current consumption of woody biomass for energy in the various sectors and to represent as accurately as possible its spatial distribution. Given the absence of a recent and comprehensive reference, the specific objective, and main challenge, of the analysis was to review and update the woodfuel consumption values produced by the FNC/FAO survey of 1994, which is still today the most comprehensive analysis of wood products consumption in Sudan.

The main thematic layers and processing steps of the Demand Module are presented in the flowchart in Figure 2 and described in the following Sections.

FIGURE 2

Demand Module. Flowchart of main analytical phases. Input data: cartographic (yellow); statistical (white); estimated variables (orange); thematic map outputs (green).



2.2.1 Reference data

Household sector

The main references used for the estimation of the current consumption of woodfuels and LPG in the residential sectors include the following:

(i) The quantitative wood consumption estimates produced by FNC through the "Forest Products Consumption Survey in the Sudan" carried out in 1994 – 1995 in the framework of the FAO/FNC Forestry Development Project (GCP/SUD/047/NET), which provides the latest quantitative estimation.

(ii) Sudan Households Health Surveys (SHHS) of 2006 and 2010, each based on interviews of 15,000 households (1000 in each state).

(iii) Sudan Household Baseline Survey (SHBS) conducted in 2009 on interviews of 7,900 households (528 inn each state).

(iv) State-wise statistics of petroleum fuel types distribution, most notably of LPG, provided by the Ministry of Petroleum.

(v) Recent reports and studies on LPG consumption trends in Khartoum (Buchanan-Smith et al. 2009) and in Sudan (Hood, 2010) provided by UNEP.

The historical reference. The comprehensive wood products consumption study carried out in 1994-1995 by FNC is still nowadays the main quantitative reference on sector-wise and state-wise consumption of woody biomass. It is out of date, with respect to today's consumption patterns but it provides a solid reference and the main challenge has been to update its per capita consumption values on the basis of the recent source of information described below.

Nation-wide Household Surveys. The data collected by the Sudan Household Health Surveys (SHHS) of 2006 and 2010 and by the Sudan Household Baseline Survey (SHBS) of 2009 were processed in order to update the consumption values reported by the 1994 FNC study, which is the only source of quantitative consumption values, and to determine the current consumption pattern of fuelwood, charcoal and LPG.

The data processing was carried out by Siddig Mohammed Osman (SPSS software) on the original survey data that was available at SISFIA. The main parameter that could be extracted from these surveys is the fuel type used by rural and urban households. The relevant data was limited to the main fuel type used by the interviewed households. This information does not support quantitative estimates but provides useful reference on fuel saturation in the rural and urban areas of each state and documents the progressive substitution of charcoal and fuelwood by LPG in the urban areas of the most populous states. Survey results for 2006, 2009 and 2010 and estimated values for 2008 and 2011 are shown in Annex 1.

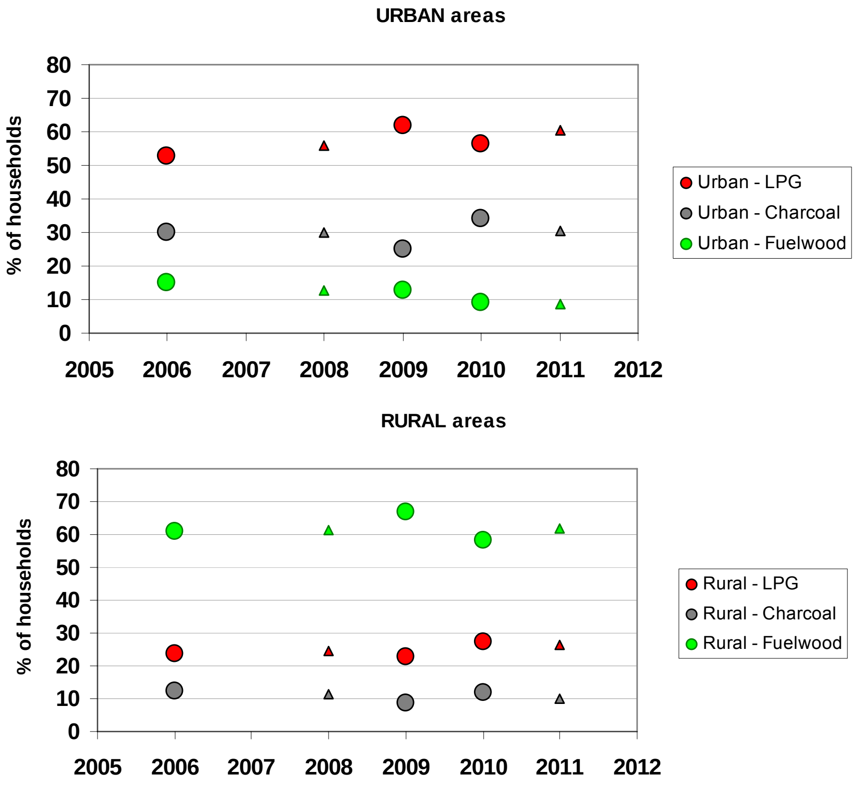
The nation-wide average values of saturation in urban and rural areas are shown in Figure 3. Although the time span covered by these surveys is relatively short (only 4 years), there is some evidence of the nation-wide increasing role of LPG in urban households and a decrease in the use of fuelwood.

At State level, the saturation of the various fuels and the changes observed among the surveys show great variations (see Annex 1). Figure 4 shows the geographic distribution of LPG saturation. The following may be observed:

- The use of LPG in Khartoum, River Nile, Northern and Gezira is probably close to saturation in urban areas and appears high also in rural areas.
- The use of LPG in Sinnar and White Nile is well established in urban as well as in rural areas.
- The use of LPG in Red Sea, Kassala, Gadarif, and North Kordofan is well established in urban areas but very limited in rural areas.
- The use of LPG of Blue Nile, South Kordofan and Darfur states is still very low or marginal in urban areas and totally absent in rural areas.

FIGURE 3

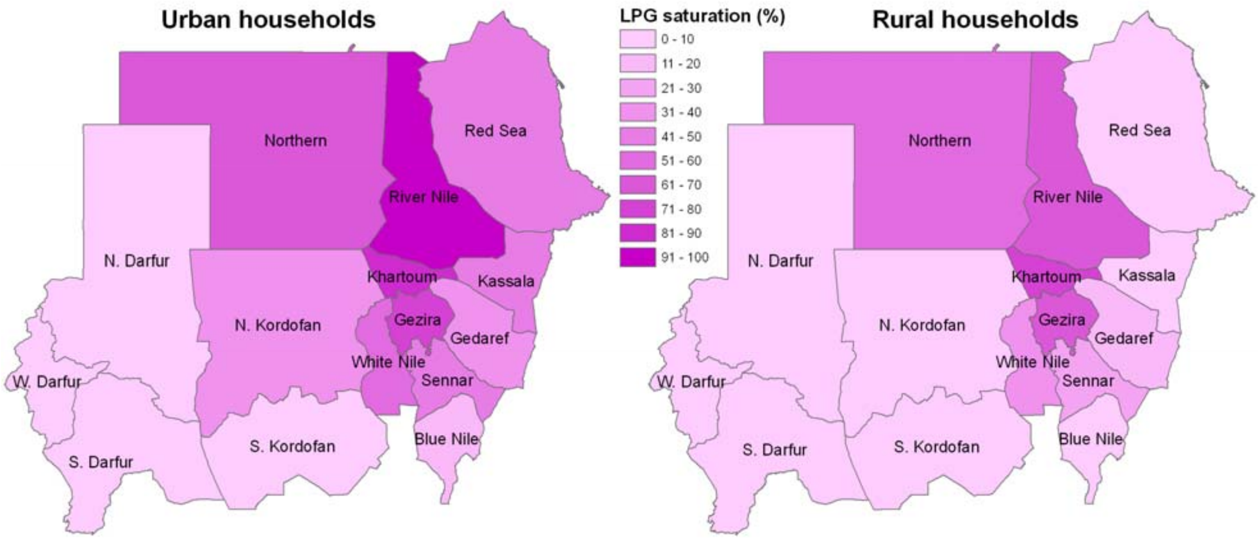
Percent of households using primarily LPG, Charcoal and Fuelwood in the urban and rural areas of Sudan.



Note: The larger data points for 2006, 2009 and 2010 refer to the survey results. The smaller data points are interpolations (2008) and extrapolations (2011) weighted on sample size.

FIGURE 4

State-wise percent of households using primarily LPG in urban and rural areas

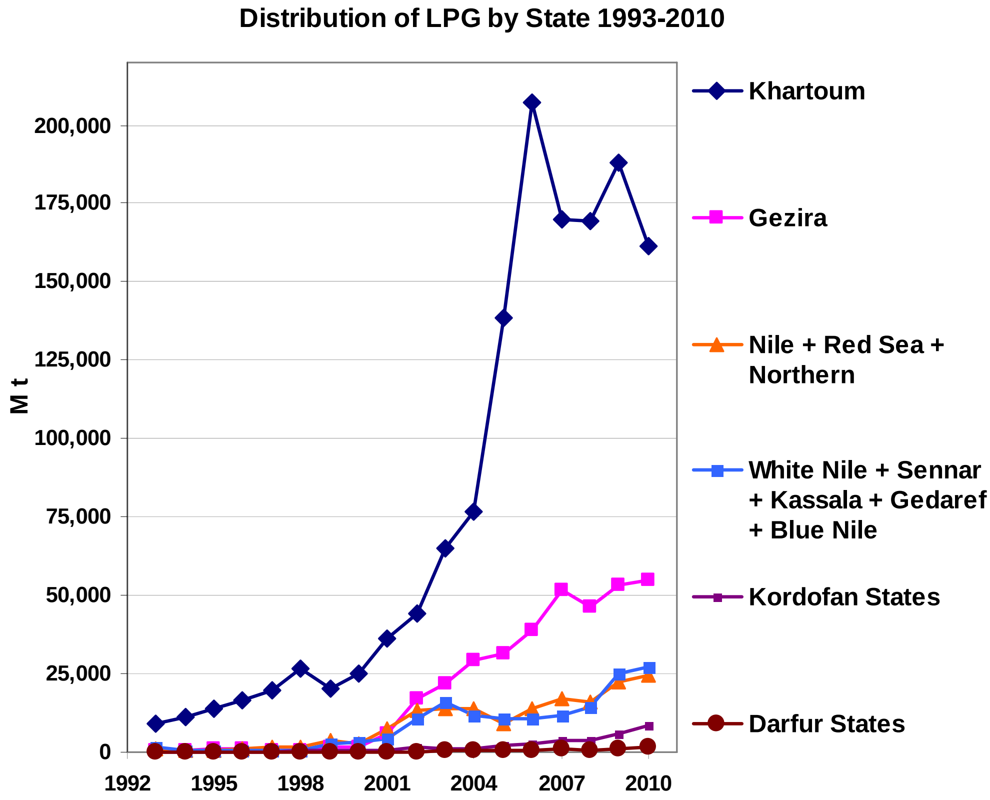


LPG distribution. Energy statistics provided by the Ministry of Petroleum also contributed to estimate the progressive penetration of LPG as household fuel in urban contexts. LPG is promoted by the Government and subsidized since many years (50 % of production costs), with the primary purpose of replacing charcoal consumption by urban households.

The graph in Figure 5 shows the rapid growth of LPG distribution in the States of North Sudan but also shows that such growth has taken place almost exclusively in the States of Khartoum, which absorbs, alone, almost 60% of the whole national production and Gezira (20%), followed at a distance by Nile and White Nile. LPG use in the remaining states is increasing but still rather negligible, primarily due to the high price applied in the peripheral states[4]. as a result of transport costs and sometimes due to undeveloped infrastructures (Hood A. H. 2010) .

FIGURE 5

Distribution of LPG in Sudan by State over the period 1993 – 2010.
Source: Min. of Petroleum, 2011.



Subsidized LPG is meant for the household sector only. In reality, however, a good fraction of the distribute LPG is use by small industries, bakeries, tea sellers and other commercial entities. This appears evident when looking at the gas distributed in Khartoum State, which could in principle satisfy the needs of as many as 1.2 million families (@ 1 cylinder/family/month), while the whole state has only 0.9 million families in total. It may as well be that there is a second distribution system that moves the cylinders in the neighboring states.

The consumption patterns of charcoal and fuelwood in Sudan's household, industrial and commercial sectors have changed considerably since the 1994 survey, especially in urban areas of the most populated States in Central Sudan. However, in the absence of recent consumption data, the quantitative estimation of current woodfuel consumption rates can only be approximate.

To be noted that, while the 1994 survey provided detailed quantitative results, all recent references are mainly qualitative, providing only indications on the current penetration of LPG and woodfuels, without evidence on the amounts of fuels actually consumed.

[4] A 12.5 kg cylinder of gas costs les than 15 SDG in Khartoum and over 30 SDG in Darfur capital cities.

The SHHS and SHBS surveys provided fuel saturation estimates (indication of the principal cooking fuel) without quantitative evaluations (and without information about the mix of fuels used). The 1994 survey did not produce a parameter directly comparable to saturation and therefore a direct trend line cannot be produced but the state-wise time series of LPG distribution allowed to assess the penetration of LPG in 1994 and thus, by difference, that of woodfuels.

The estimation of the woodfuel consumption in 2008 and 2011 was done with the purpose of matching population census data (2008) and of assessing the current situation. These estimates were based on 1994 per capita consumption rates, applying an adjustment factor derived from the state-wise woodfuels saturation values derived from SHHS and SHBS surveys.

Other sectors of consumption

In order to fill the lack of data on the consumption by other sectors, a rapid survey was designed and implemented by the National Woodfuel Demand Consultant with the participation of FNC staff. The rapid survey focused on the consumption of charcoal and fuelwood in the main commercial and industrial sectors in the urban area of Khartoum and Sinnar.

The results of the survey are summarized in the Report of the National Woodfuel Demand Consultant in Annex 4.

The survey provided clear indications on the changes in the consumption patterns, which were used to develop a set of corrective factors to be applied to the per capita consumption parameters of the 1994 FNC Survey. The sectors of use considered are listed below, with some elements about the adopted correction factors:

- **Tea and food sellers:** Factors reflecting the slight decrease in charcoal use in Khartoum and north states and assuming a stable use in south states.
- **Bakeries:** Factors combining reduced fuelwood use and increased number of bakeries
- **Brick making:** Factors reflecting reduced brick making in KRT & north states & increase in Darfur.
- **Lime curing:** Factors reflecting the use of charcoal fines in Khartoum and assuming the increase in Darfur and decrease in north states.
- **Vegetable oil production:** Factors reflecting the shift to other fuels in KRT and north states and assuming a stable use in south states.

2.2.3 Adopted consumption values

The set of state-wise corrective factors that were applied to the per capita consumption parameters of the 1994 FNC Survey in order to estimate woodfuel consumption in 2011 are presented in Table 1. .

The per capita consumption values applied to state-wise urban and rural population are presented in Table 2. These values are applied to the entire urban and rural population, including actual woodfuel user and non-users. The values reflect both changes in woodfuel saturation and changes in use efficiency. For instance, the dramatic reductions in the per capita consumption in the household sector that may be observed in several states are due primarily to the important reduction in the fraction of the households still using woodfuels.

TABLE 1

Factors applied to 1994 per capita consumption values, on account of the changes intervened in the use of woodfuels, in order to represent the 2011 situation.

		Factors applied on account of changes in fuel saturation		Factors applied on account of cooking efficiency		Factors used to distribute the consumption on rural and urban areas							
		Rural HH	Urban HH	Rural HH factor	Urban HH factor	Rural fraction of Commercial Sector consumption	Rural fraction of Institutional Sector consumption	Commercial	Institutional	Bakeries	Bricks	Lime curing	Veg. Oil
11	Northern	0.33	0.14	1	0.9	0.2	0.8	0.9	0.9	0.5	0.9	0.9	0
12	River Nile	0.32	0.11	1	0.9	0.2	0.8	0.9	0.9	0.5	0.9	0.9	0
21	Red Sea	1.00	0.75	1	0.9	0.2	0.8	0.9	0.9	0.5	0.9	0.9	0
22	Kassala	0.95	0.54	1	0.9	0.2	0.8	0.9	0.9	0.5	0.9	0.9	0
23	Gedaref	0.94	0.36	1	0.9	0.2	0.8	0.9	0.9	0.6	1	1	0
31	Khartoum	0.25	0.14	1	0.9	0.2	0.8	0.9	0.9	0.25	0.7	0.5	0
41	Gezira	0.29	0.39	1	0.9	0.2	0.8	0.9	0.9	0.6	1	1	0
42	White Nile	0.49	0.41	1	0.9	0.2	0.8	0.9	0.9	0.6	1	1	0
43	Sennar	0.80	0.52	1	0.9	0.2	0.8	0.9	0.9	0.6	1	1	0
44	Blue Nile	1.00	0.82	1	0.9	0.2	0.8	1	0.9	1	1	1	1
51	N. Kordofan	0.99	0.69	1	0.9	0.2	0.8	0.9	0.9	0.6	1	1	0.5
52	S. Kordofan	1.00	0.99	1	0.9	0.2	0.8	1	0.9	1	1	1	1
61	North D.	1.00	0.95	1	0.9	0.2	0.8	1	0.9	1	1.5	1.5	1
62	West D.	1.00	1.00	1	0.9	0.2	0.8	1	0.9	1	1.5	1.5	1
63	South D:	1.00	0.98	1	0.9	0.2	0.8	1	0.9	1	1.5	1.5	1

TABLE 2

Applied per capita consumption values and reference FNC 1995 values.

	FNC95 values			Applied values -2008			Applied values - 2011		
	General average	Rural	Urban	Rural	Urban	IDP Camps	Rural	Urban	IDP Camps
	Percapita consumption (m^3)								
	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
Northern	0.54	0.46	1.26	0.24	0.49		0.17	0.34	
River Nile	0.46	0.41	0.60	0.15	0.19		0.15	0.20	
Red Sea	0.54	0.41	0.67	0.38	0.39		0.40	0.46	
Kassala	0.67	0.53	0.93	0.49	0.62		0.50	0.59	
Gedaref	0.71	0.59	0.96	0.55	0.60		0.57	0.44	
Khartoum	0.76	0.74	0.76	0.25	0.25		0.23	0.23	
Gezira	0.64	0.53	1.10	0.18	0.39		0.18	0.48	
White Nile	0.57	0.47	0.77	0.29	0.42		0.27	0.43	
Sennar	0.83	0.76	1.03	0.58	0.74		0.62	0.70	
Blue Nile	1.03	1.03	1.02	1.03	0.88		1.03	0.83	
N. Kordofan	0.86	0.78	1.14	0.77	0.81		0.77	0.79	
S. Kordofan	0.64	0.59	0.78	0.59	0.70		0.59	0.70	
North Darfur	0.89	0.88	0.93	0.88	0.94	0.53	0.88	0.94	0.53
West Darfur	0.81	0.77	1.24	0.77	1.14	0.55	0.77	1.14	0.55
South Darfur	0.86	0.82	1.08	0.82	1.01	0.55	0.82	1.01	0.55

2.2.4 Mapping woodfuel consumption

Once the sectors of consumption are defined and quantified, the subsequent step is to distribute such consumption over the territory with the best possible approximation.

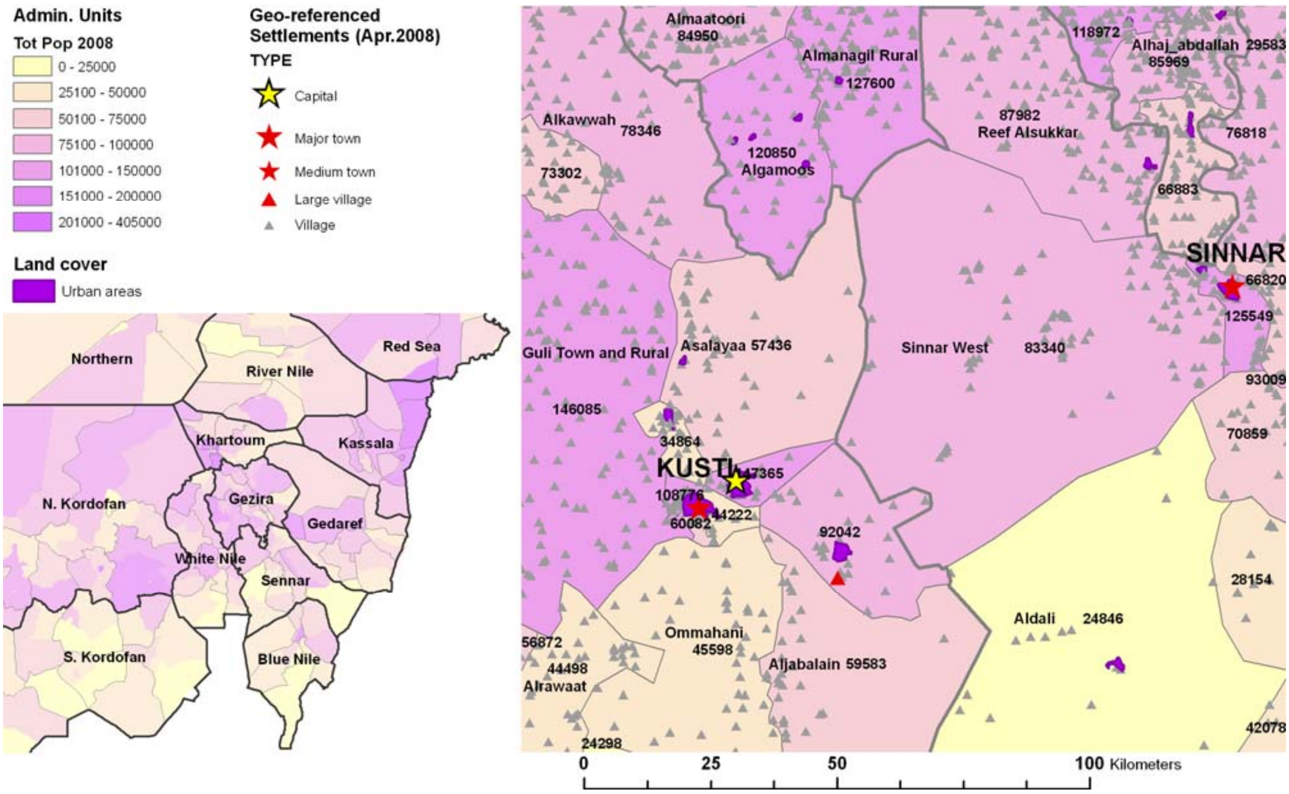
From a spatial distribution perspective, two major types of consumption patterns may be distinguished: diffuse patterns, typical of the residential consumption, and localized sites, typical of major industrial sites, biomass power plants, tea factories, etc. The first type is directly related to the distribution of the rural and urban population while for the second type the consumption is associated to specific locations through geographic coordinates (if available) or to known locations such as towns or sub-urban areas. Between these two extremes there are some types of consumptions, such as small industries, commercial and public users that are not ubiquitous but whose exact locations are not known. In these cases the distribution may be based on spatial proxies (elements of known spatial distribution that are directly or indirectly correlated to the type of consumption considered.

In case of Sudan, the household sector dominates woodfuel consumption, and mapping human population is the prerequisite to mapping the relative consumption. But other consumption sectors, such as commercial (tea sellers, bakeries, restaurants, etc.) and industrial (brick making and lime curing, blacksmithing etc.), are also more or less strongly related to population concentrations. For this, in absence of more precise data on the distribution of commercial and industrial users, urban population mapping will be used as spatial proxy for the mapping of the consumption in these sectors as well.

Urban and rural population mapping. Statistical and cartographic information relative to the distribution of the population at the level of Administrative Unit from Census 2008 was obtained from the Central Bureau of Statistics (CBS). Figure 6 shows the main cartographic layers used to map the distribution of the population.

FIGURE 6

Mapping population distribution. Example of administrative units, geo-referenced settlement points data and land cover.



Note: The detailed map on the right shows Administrative Unit name and the total population according to 2008 Census. The small features within the units were used to distribute census population, divided into rural and urban.

The population map produced for Darfur (WISDOM Darfur study) was maintained and complemented over the rest of the Sudan. As in case of Darfur, some discrepancies exist between the statistical and cartographic layers, which were resolved as best as possible through minimal values allocations to fill data gaps in order to assess and map woodfuel consumptions as reliably as possible. The information layers and procedures adopted for population mapping were the following:

Location of Urban population:

The mapping of urban population (as defined by 2008 census) required the hierarchical merging of the following cartographic layers:

1. New Land Cover map classes Urban
2. Africover classes Urban (5 group)
3. Capital and Towns point map (based on **Sudan_Settlements_Apr2008**).
4. geo-referencing of urban points reporting also urban population data for some locations, and points created using GoogleEarth to locate urban pop in AU with urban population but without urban centres
5. Selected populated points derived from **Sudan_Settlements_Apr2008** with help from **250k map catalogue** for the *probable* main urban centers.

Location of Rural and Nomad population:

The mapping of rural population (as defined by 2008 census) required the hierarchical merging of the following cartographic layers:

1. Map of villages **Sudan_Settlements_Apr2008** rasterized with varying buffers (in DD):

   From this map were excluded the larger towns used for urban population mapping. Resulting vector file: **N_Sud_settlem_Apr2008_buffer_2**; raster file: **settl08_buf2**
2. Map of villages **Settlements_Updated** rasterized with buffers (in DD) = 0.004 ; raster file: **sett_upd_buf**

The result of the analysis referring to 2008 population is shown in Figure 7.

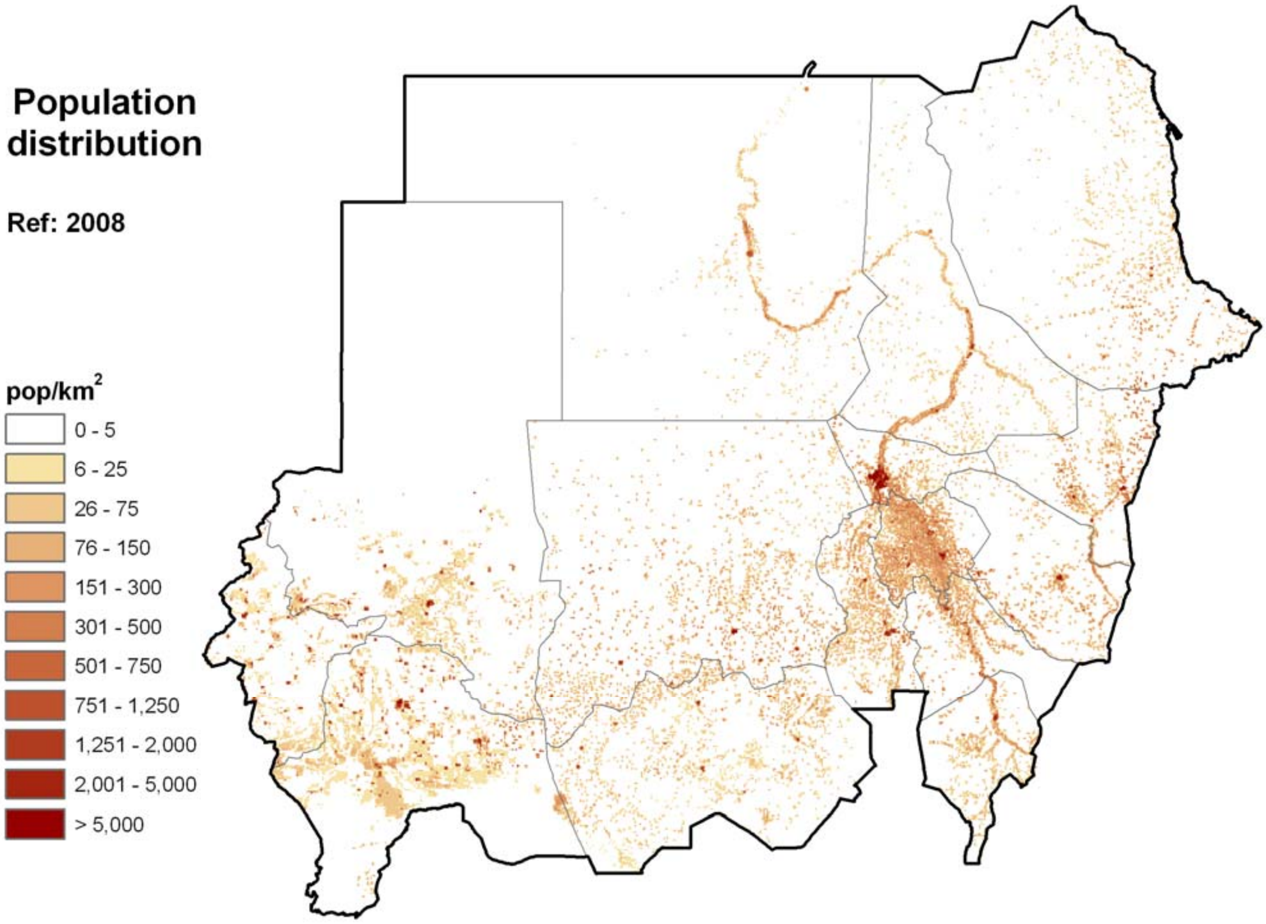
Population 2011

The approximate distribution of the population in 2011 was done on the basis of the 2008 map described above and the following elements:

- Growth rates of urban and rural population as defined by the World Statistics of the United Nations Statistics Division for the period 2005-2010. The annual growth rates applied are 4.3% and 0.7% for urban and rural populations, respectively.
- Information on the migrations associated to the North-South separation, provided by IOM Sudan (courtesy of Ms. Claire Bolt). Since 30th October 2010, when government-assisted return movements started, nearly 350,000 Southerners have returned to South Sudan from various States in Sudan. Provenences of the returnees was assumed proportional to their presence, which means 79 % from Khartoum State, 4% from Blue Nile, 3% from Darfur and the rest from the other states.

FIGURE 7

Population distribution Map of North Sudan. Ref. 2008



Note: The map merges urban and rural population layers. For Darfur areas reference is made to the map produced for WISDOM Darfur, which included IDP statistics.

2.3 SUPPLY MODULE

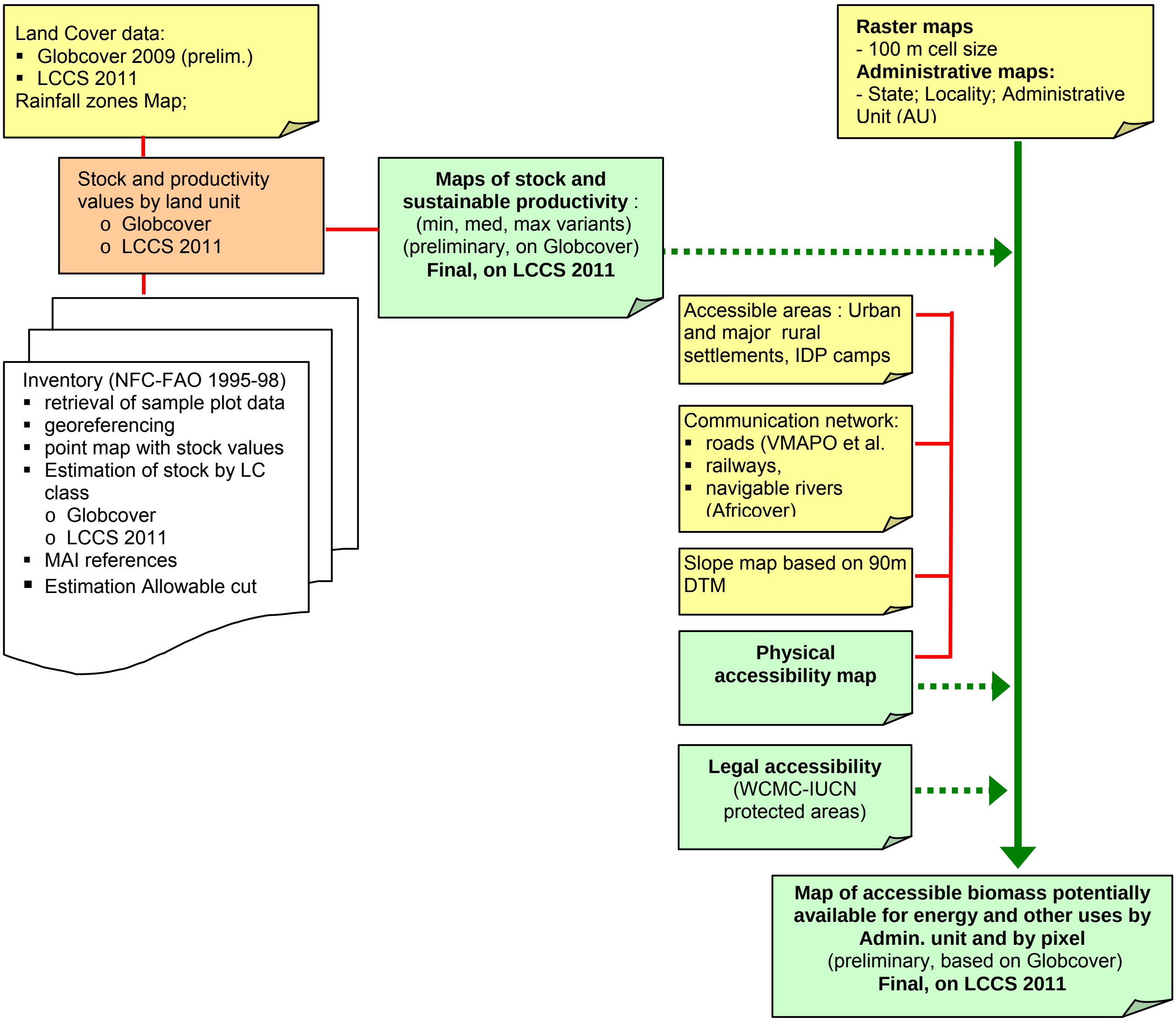
Scope of the WISDOM Supply Module is to produce a spatial representation of natural and man-made sources of woody biomass, their stocking and production potential. As for the Demand Module, which included non-energy uses of woody biomass, the Supply Module analysis includes woody biomass entirely, comprising the components that may serve other non-energy uses such as construction material and furniture making.

The estimation and mapping of the woodfuel supply potential is based on land cover information, describing the vegetation types and their location, and on field observations quantifying the stock and productivity of woody biomass, such as forest inventory data.

The flowchart in Figure 8 shows the source data and the main analytical steps of the Supply Module.

FIGURE 8

Flowchart of the main analytical elements of the Supply Module. Input data: cartographic (yellow); statistical (white); estimated variables (orange); thematic map outputs (green).



2.3.1 Cartographic layers

Given the straightforward relation between woody biomass sources and land use/land cover classes, the mapping of the potential sustainable supply is done on the basis of the land use/land cover map available and at the defined level of spatial and administrative detail.

The new Land Cover database for Sudan, based on FAO LCCS methodology depicting the situation in 2011 was used as main geo-referenced layer in the final development of the Supply Module. However, the new LCCS data, released in January 2012, was not available during the initial phase of analysis. In the absence of the new map and in order to support the progress of the WISDOM study, the Globcover Map 2009 was used as a temporary substitute for the LCCS data, for a preliminary analysis of the supply potential. Besides a set of preliminary supply estimates that permitted to proceed in the analytical process, the fact of completing the analysis on Globcover data provided interesting elements for a comparison with LCCS data and for the evaluation of Globcover constraints for the estimation of woody biomass resources.

2.3.1.1 Globcover 2009

Globcover 2009 (v.2.3) is a global land cover map with a spatial resolution of 10 arc-seconds (approximately 300 m at the Equator) and a classification system, for the Sudan area, based on 17 classes. Globcover is less detailed than the LCCS database but, in the absence of the new detailed map, it was considered appropriate for a preliminary analysis of the Supply Module.

Globcover data has been used in previous WISDOM analyses with encouraging results, considering its coarse resolution and global scale. Particularly relevant is the Rapid WISDOM Appraisal carried out on Darfur, where Globcover data was used to determine the size and shape of the study area (ref. WISDOM Darfur).

Tree Cover Percent (MODIS VCF)

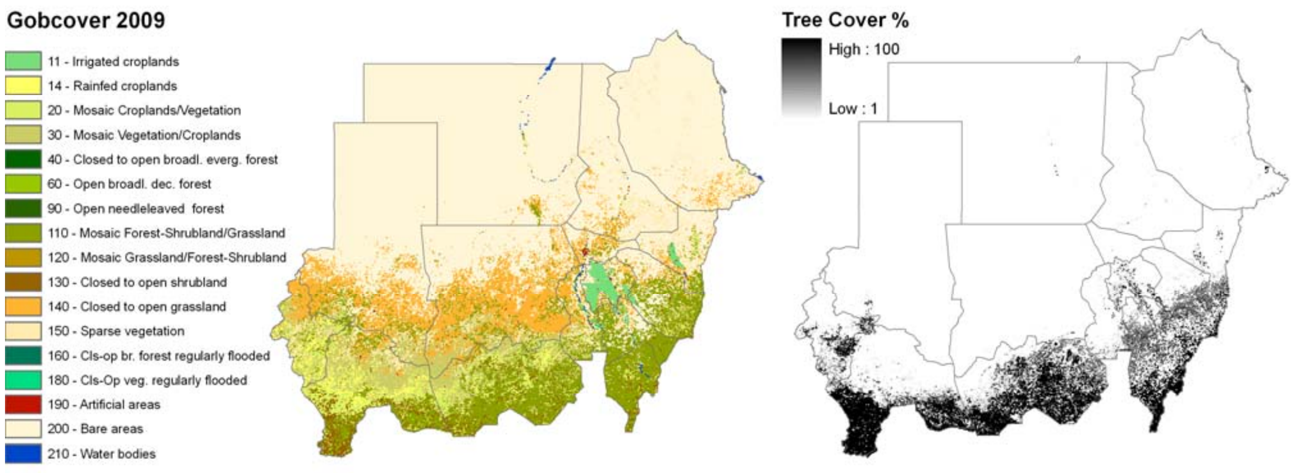
Once the average volume for each land unit (combination of land cover and rainfall) was estimated, the Tree Cover Map (Hansen et al., 2003) was used to spatially distribute the volume within each unit.

To be noted that the version currently available (v 003) still refer basically to the original 2000 data. A new version (v 004) is under preparation but not yet available.

Figure 9 presents the Globcover 2009 dataset as well as the map of the tree cover percent (Hansen et al., 2003), which were combined in the development of the preliminary Supply Module.

FIGURE 9

Cartographic layers used for the preliminary development of the Supply Module: Globcover 2009 and map of tree cover percent.



2.3.1.2 LCCS 2011

The new nation-wide mapping was conducted by the Land Cover Mapping of Sudan (FAO-GLCN), in parallel to the WISDOM analysis. The mapping followed the FAO-GLCN Land Cover Classification System (LCCS) (DiGregorio and Jansen, 2000) and may be intended as an update and upgrade of the 2001 Africover Map (Box 1).

BOX 1:

Land Cover Mapping of Sudan

The major steps of the compilation of the database include creation of an integrated imagery coverage, image processing and interpretation, validation of the interpretation. FAO/GLCN toolbox[1] is used to implement the methodology.

The GLCN mapping approach is a multifaceted procedure derived by the decadal experience in building up detailed national databases of natural resources. It can be considered a dynamic process that evolves and develops continuously in a constant balance of theoretical and technical aspects derived from the remote sensing and GIS technologies.

With a strong technical leadership from Natural Resources and Environment, Land and Water division of FAO (FAO-NRL), the project developed a strong national capacity for future Landcover update and similar initiatives. The land cover module, an important part of SIFSIA initiative, was implemented by NRL geospatial unit in collaboration with the GLCN group based in Florence (Italy). The Remote Sensing Authority (RSA), the Forests National Corporation (FNC) and the Ministry of Agriculture's Food Security Technical Secretariat (FSTS) are the major implementing partners.

More than 20 Government experts trained in practical use of FAO's Land Cover Classification System (LCCS); satellite image interpretation of SPOT and Landsat imagery through FAO's tool box for land cover mapping plus google-earth and field verification. Experts have already developed an LCCS legend and database for Sudan.

The production of the updated land cover database is an important task for the SIFSIA project. The current database, which heavily relies on high resolution images from 2010, updates the existing AFRICOVER database (dated 1999-2000). The database also uses a combination of other high and medium resolution satellite data and locally collected data (2006 – 2010).

The detailed legend used in the land cover interpretation includes 75 land cover classes, listed in Annex 1, that in the final map are combined to form as many as 690 class combinations.

The map in Figure 10 shows an overview of the final Land cover data. In the overview the land cover classes were aggregated according to 7 major land cover types. For mixed classes units the polygon is attributed to the first class.

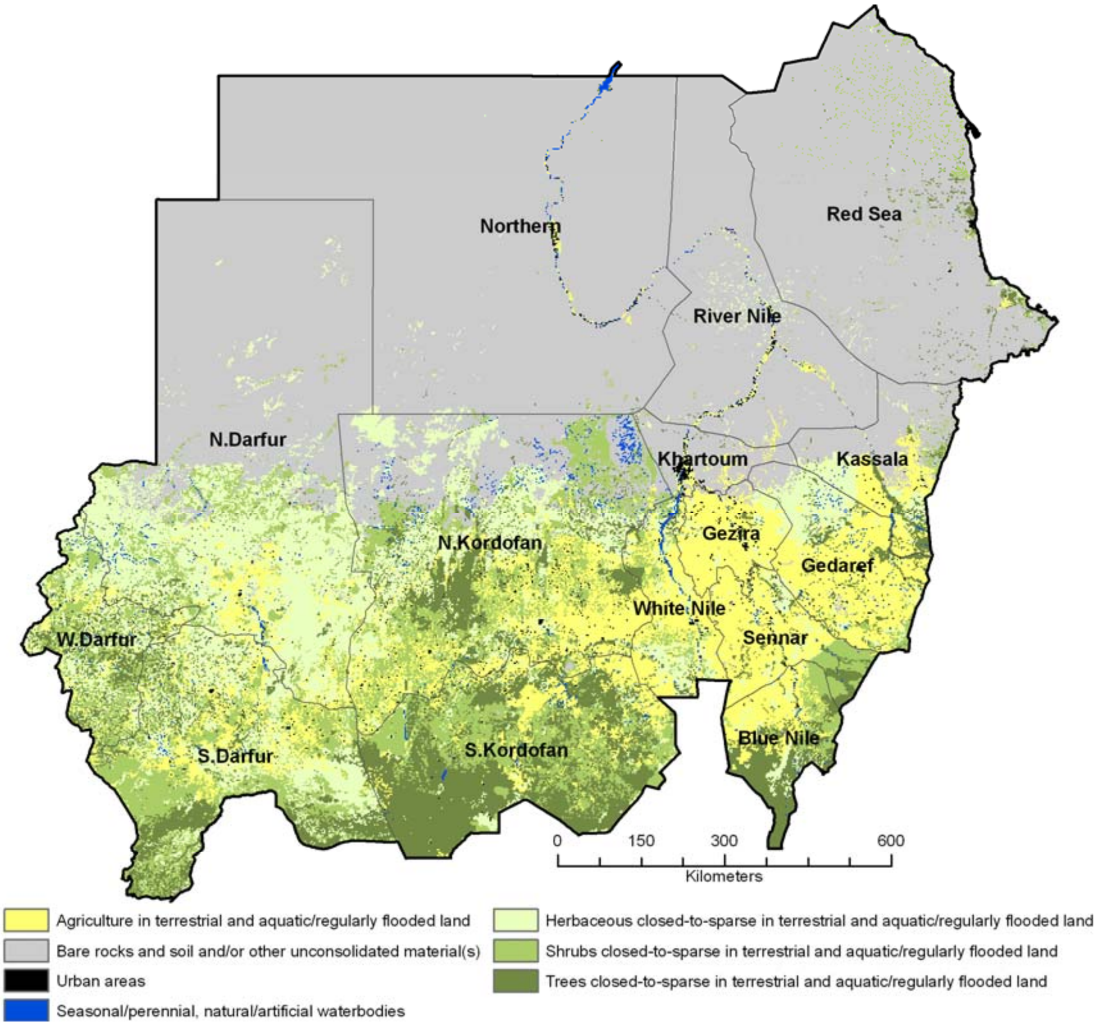
Bare areas cover over 52% of the country, dominating its northern half. Agricultural areas cover 12.6 % of the areas, with highest concentration in the eastern states. Natural vegetation classes cover about 1/3 of the country, with herbaceous, shrub and tree formations covering 13.4%, 10.7% and 9.4%, respectively.

The area calculation is subject to the following cartography rules and approximations:

- The polygons are labeled with a single class code if the main class covers more than 80% of the polygon area. This rate is valid for natural vegetation and does not apply to the agricultural areas where the minimum area covered within the polygon is 10-15% (in this cases the class 'isolated field is applied).
- For single class polygons the full area is attributed to the main code.
- In mixed class polygons 60% of the area is attributed to the first class and 40% to the second class of the mixed unit.

FIGURE 10

Land cover map of the Sudan based on LCCS methodology. Map overview displaying aggregated land cover classes



2.3.1.3 Rainfall zones

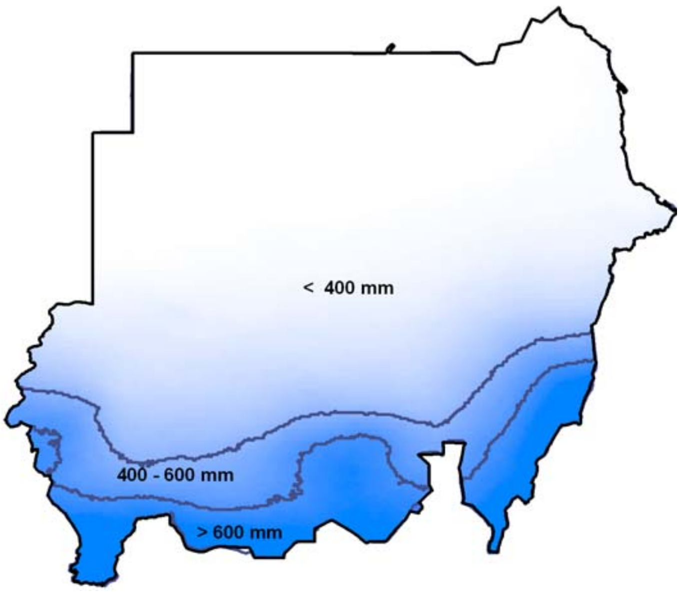
Given the dramatic rainfall gradient characterizing the Sudan, ranging from 0 mm in the north to 1,000 mm in the southernmost areas, rainfall data played an important role in the procedure applied for the estimation of woody biomass stocking.

Similar to the approach followed for the Darfur study, three main rainfall categories were applied, as shown in Figure 11:

- Low rainfall zone: below 400 mm
- Medium rainfall zone: 400 – 600 mm
- High rainfall zone: above 600 mm

FIGURE 11

Average rainfall over the period 1990-2002



2.3.2 Forest inventory data

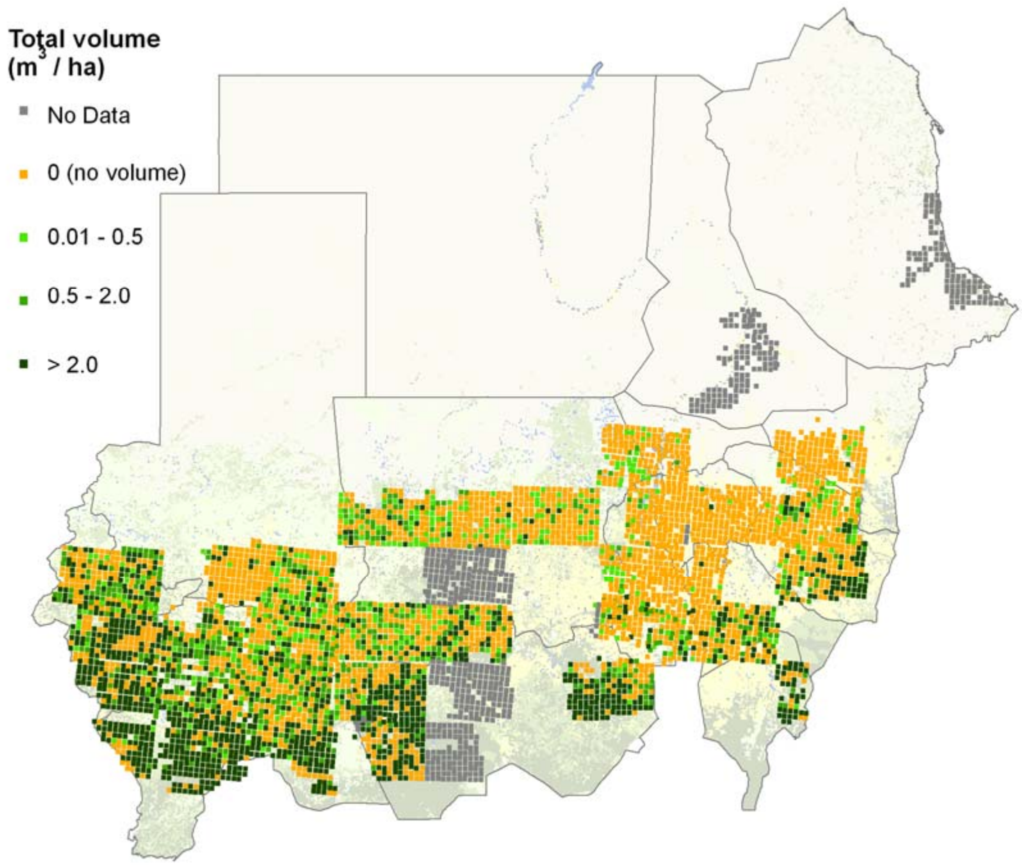
In the absence of a recent forest inventory, the main initial effort went to the retrieval of the field inventory data collected by FNC in 1995, to be used as forest stock reference for the areas where the land cover / vegetation type has not changed significantly. More specifically, the key task was to geo-reference the available summary plot data. The entire digital NFI dataset was lost in 1999 due to computer breakdown at FNC soon after the inventory but a copy of the summary results by plot was in use as field reference for Africover mapping of Sudan.

To assist in the WISDOM analysis, FNC organized and completed the entry of geographic coordinates of some 5000 sampling units from the original tally sheets.

The geo-referencing presented some problems concerning the coordinates (mostly errors in writing the long coordinates figure in the tally sheets) that were resolved as best as possible on the basis of the surrounding plots. The newly geo-referenced plots were linked to the plot summary results still available from the original 1998 data processing. The resulting plot data, shown in Figure 12, set was used in combination with land cover data to estimate the woody biomass stock of N Sudan.

FIGURE 12

Available geo-referenced sampling units with summary plot data from the 1995 National Forest Inventory



2.3.2 Stock and potential sustainable productivity

Woody biomass stock - Preliminary estimation based on Globcover 2009 data

The application of average stock values by land cover-rainfall classes derived from the field plot summaries of the 1995 inventory, which remain the only available field-based reference for the estimation of the stock of woody vegetation.

The first attempt to associate wood volumes and land cover-rainfall classes over the entire country produced a marked overestimation of the eastern states, when compared to inventory results. Such overestimate was probably due to unbalanced land cover classes. In order to reduce this distortion, the Sudan was divided into to zones (eastern states and western states) and average stock values were separately calculated. The results improved considerably, permitting a better fit with the inventory results. The state groupings applied and the results of this analysis are shown in Annex 2 Table A2.2 and Figure A2.1). The estimated biomass stock amounts to 85% of the stock estimated in 1995, which seems reasonable, considering the annual deforestation rate of Sudan and the degradation of remaining forest areas.

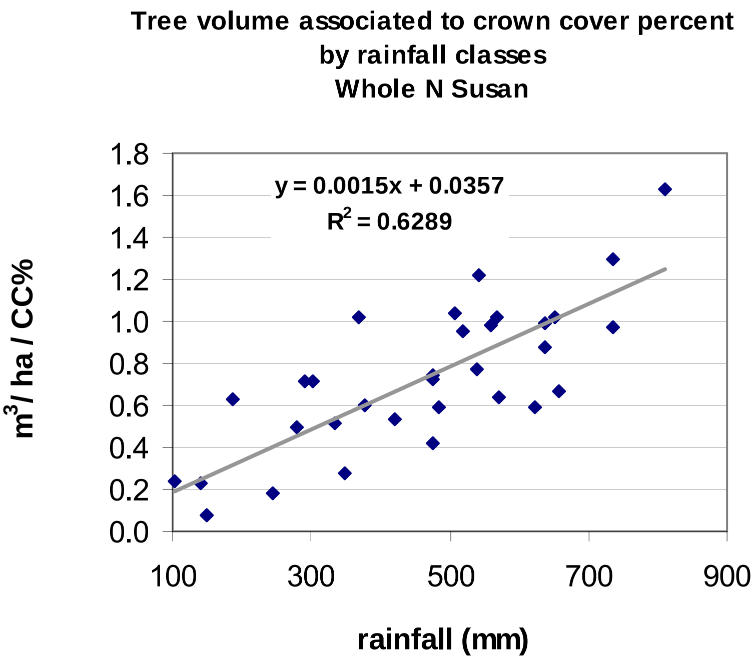
The map of woody biomass stock based on Globcover 2009 is shown in Figure 13 (bottom map).

Woody biomass stock - Final estimation based on LCCS 2011 data

The results of the 1995 NFI produced estimates of average wood volume of tree formations by geographic locations (map sheets) and by crown cover classes. Combining the geographic areas with rainfall classes permitted the estimation of the increase of tree volume corresponding to the increase of one percent in crown cover in the various ecological zones (Figure 13).

FIGURE 13

Relation between wood volumes, crown cover and rainfall



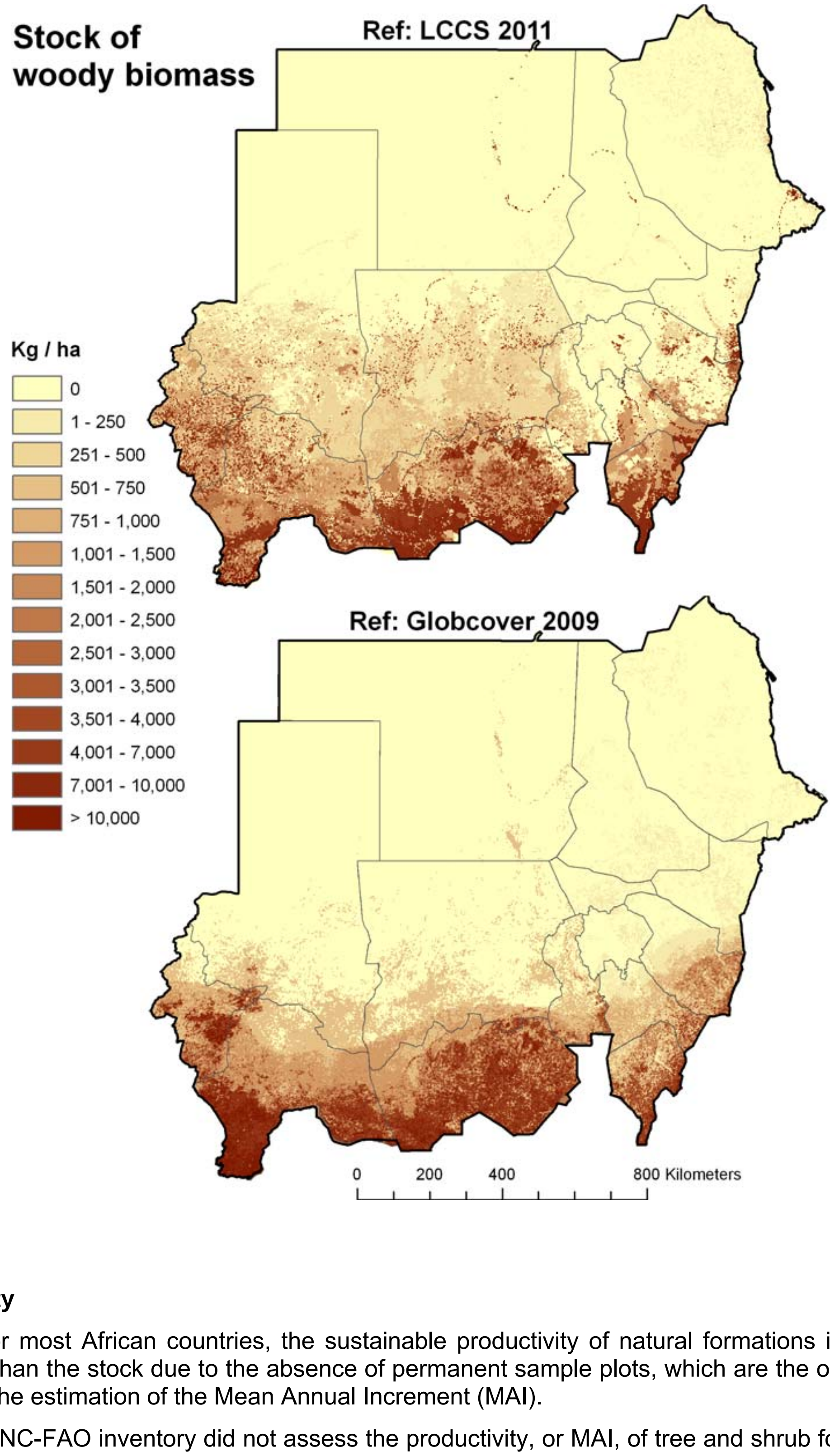
As already discussed in case of the WISDOM analysis for Darfur, the different approach applied in the NFI and in the LCCS mapping for the estimation of crown cover percent prevented the direct application of the NFI-based function to LCCS data: NFI crown cover was derived from the visual assessment of tree crown diameters from the ground, while the new LCCS implied the estimation of crown cover range values from satellite data.

Thus, once the relative relation between volume, crown cover and rainfall was established, the multiplier value was determined according to the relation between the volume estimated on the basis of the new land cover map and the volume measured in the NFI sample plots for the “unchanged” forest formations. The selected multiplier being the one that gave the best fit in the estimation of woody biomass stock between the two sources.

Woody biomass stock values associated to the land cover classes are reported in Annex 2, Table A2.3. The map of woody biomass stock based on LCCS 2011 is shown in Figure 13 (top map).

FIGURE 14

Stock of woody biomass. Estimates based on LCCS 2011 and on Globcover 2009.



Productivity

As usual for most African countries, the sustainable productivity of natural formations is a far less known parameter than the stock due to the absence of permanent sample plots, which are the only reliable sources of data for the estimation of the Mean Annual Increment (MAI).

The 1995 FNC-FAO inventory did not assess the productivity, or MAI, of tree and shrub formations. The only indication of productivity provided in the 1995 inventory report was a quantification of the allowable cut, estimated as 7 % of the stock.

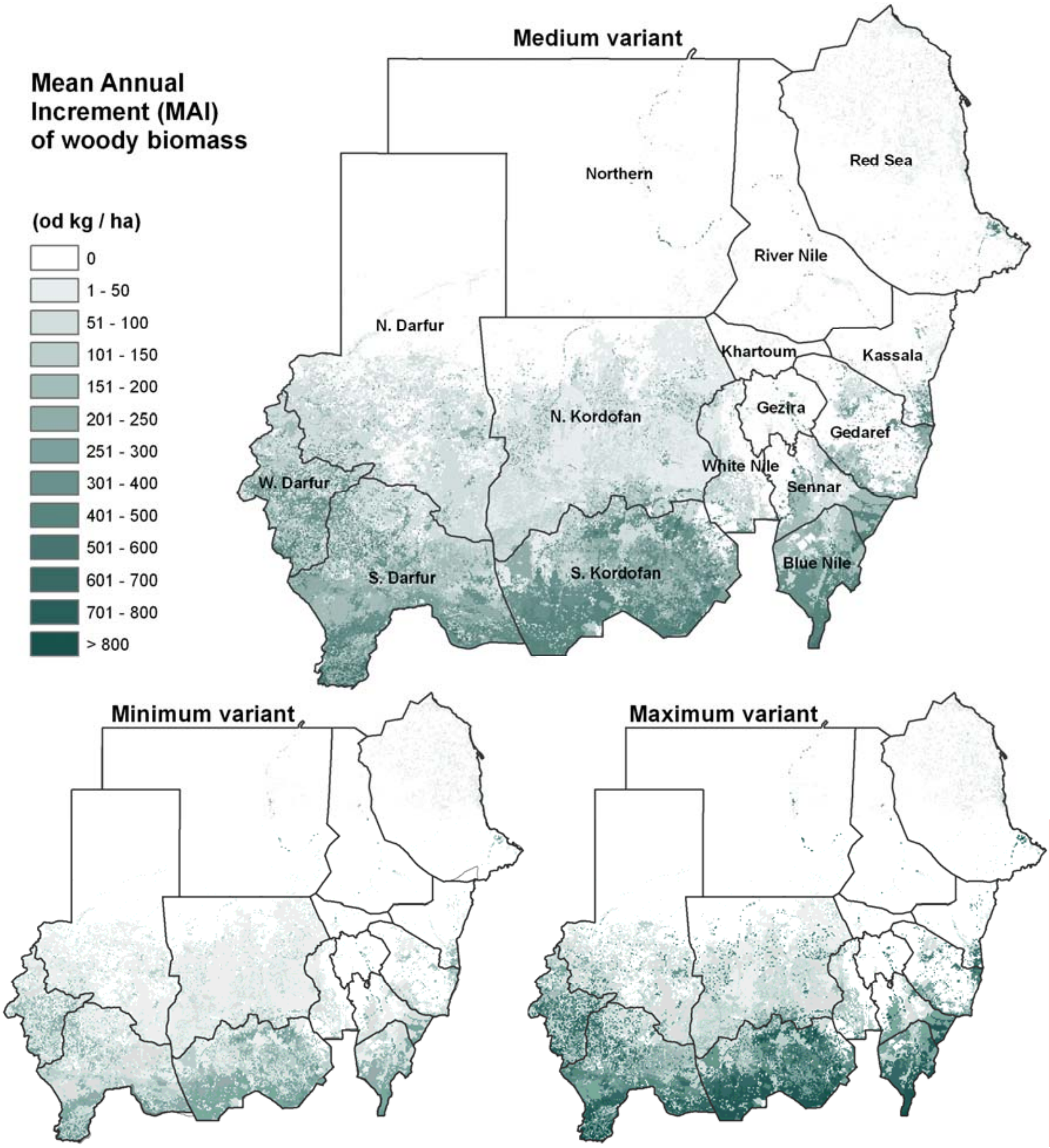
For the present study, in absence of local data, the estimation of the mean annual increment of natural woody formations was based on the equations relating stock and MAI (as % of stock) that were developed for the Supply Module of Global WISDOM analysis carried out by NRL and FO (Drigo, 2009 unpublished).

These equations, which were based on world-wide field observations reporting age of the stand along with biomass (or volume) data, provide tentative estimations of minimum, medium and maximum MAI values. It should be noted, however, that the density of the forests and woodlands of Sudan are very low and not well represented by the field observations of the global dataset. In particular, the percent MAI for the lowest stock values resulted too high. In order to maintain the MAI % values within reasonable range a fix productivity value was set to 15% for all formations with stock values below 1 ton / ha, thus assuming a minimum rotation period of 6 years.

According to the constrained medium variant equation, the general average MAI is estimated at 7.4% of the stock and the accessible productivity at 6.7%, which are in line with the value of allowable cut indicated by the 1995 NFI inventory report (7%). The estimated MAI of woody biomass according to the three variants are shown in Figure 15.

FIGURE 15

Mean Annual Increment /MAI) of woody biomass(Ref. Globcover 2009)



2.3.3 Accessibility

2.3.3.1 Legal accessibility

According to the 2010 edition of the WCMC-IUCN database of protected areas, there are only 3 internationally recognized protected areas in Sudan: The National Parks of Dinder (Southeast Sennar and Gedaref states) and of Elba (Northeast Red Sea) and the Managed Resource Protected Area of Wadi Al Alaqi (Northwest Red Sea).

The National Parks are IUCN Category II, while the Managed Resource Protected Area is IUCN Category VI. Accordingly, the accessibility of their resources through sustainable management are considered 0% for the first category and 75 for the second.

Statutory functions are also important in this respect and for this purpose it's necessary to delineate the geographic extent and management objectives of the gazetted Reserved Forests.

Digital maps are not yet available for the Reserved Forests, nor a definition of possible constraints to sustainable management. Consequently, Reserved Forests were not separately treated in the WISDOM analysis under the general assumption that their biomass resources should be available under sustainable resource management regimes. However, in view of future forest management planning, it is strongly recommended to digitize Reserved Forest as soon as possible.

2.3.3.2 Physical accessibility

The analysis of the physical accessibility of woody biomass resources was based on the map of roads and other communication routes, towns and rural settlements, and on the digital terrain model from which the map of slopes was derived. The accessibility of each cell of the raster map was calculated applying a cost-distance analysis. Figure 16 shows an example of the main cartographic elements used, which are described below:

Slope data were derived from the Digital Terrain Model (DTM) at 3 arc-second (approximately 90 m cells), merging the tiles covering the Sudan (N10E20; N20E20; N30E20).

The **road network** data available in Sudan has recently been updated for the Darfur sector but is very poor elsewhere. The global dataset Vector Map Level 0 (VMap0)[5] was selected as main reference for road network. VMap0, when compared to the digital road network data available in Sudan, appears far more detailed. For this it results that the accessibility derived from this source is more detailed than that developed on the locally available data.

Railway network data were extracted from the map Railroad__SIM__2005_.shp (source: IMWG data, 2010)

The specific map layers used for accessibility mapping are:

Vector data	derived raster data	Combined map for cost-distance
settlements_apr08_excl_villages.shp	major_set08	
	urb_select2	
vmapo_road_00	road_vmapo	**dist_0** (starting of cost-distance analysis
Railroad__SIM__2005_	rail_sim05	
Niles_Atbara_01	nile_atbara	
DTM at 3 arc-second		**slope_ns** (cost factor)

The raw cost-distance output was then segmented into percent accessibility classes expressing the fraction of the resource assumed accessible in each cell location. The range of percent values was defined on the basis of practical considerations and expert opinions. The final result, combining legal and physical accessibility is shown in Figure 17.

[5] The Vector Map Level 0 (VMap0), released by the National Imagery and Mapping Agency (NIMA) in 1997, is an updated and improved version of the Digital Chart of the World (DCW). The DCW is a vector base map of the world at a scale of 1:1,000,000, developed in 1992 by the Environmental Systems Research Institute, Inc. (ESRI) on commission for the US Defence Mapping Agency (DMA). Source: http://www.mapability.com/info/vmap0_download.html

FIGURE 16

Example of physical accessibility map. Left: location (Jebel Marra region). Middle: 90m Digital Terrain Model (hillshade view). Right: Accessibility map (white=most accessible; dark grey=least accessible), showing also road network, settlements and IDP Camps (red features).

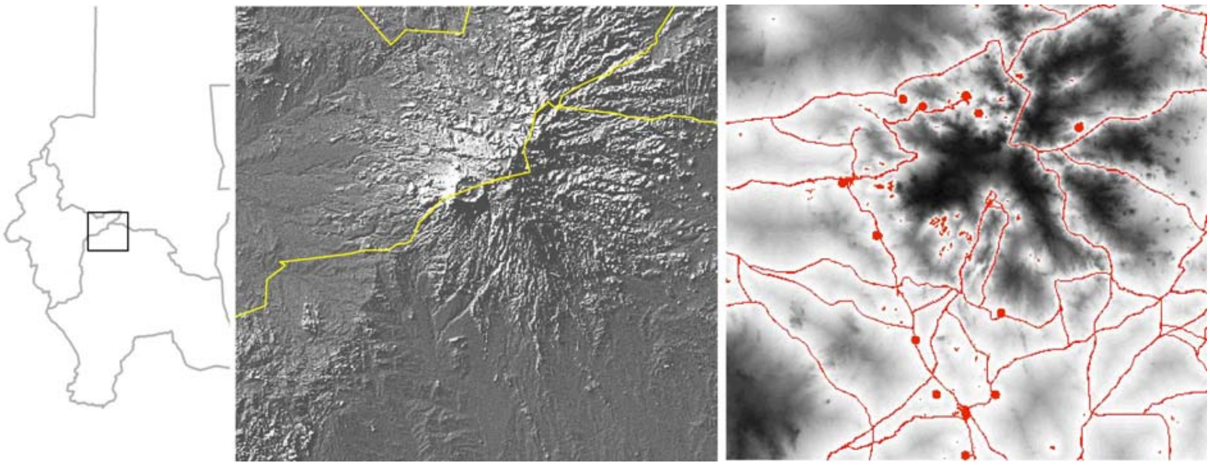
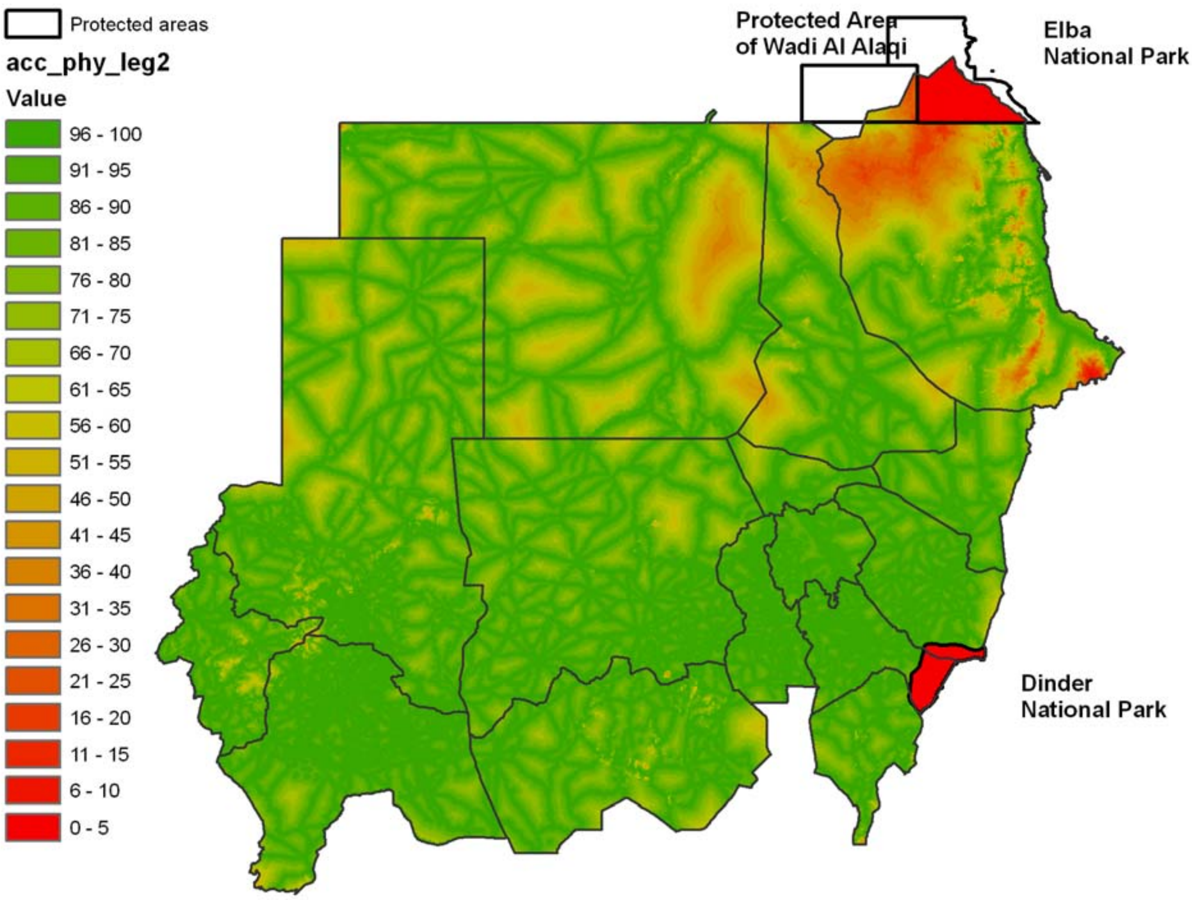


FIGURE 17

Accessibility map combining physical and legal components



2.3.3.3 Economic viability of woodfuel production

With a simplistic approach, the economic viability of woodfuel production was here limited to the definition of the threshold in the quantity of woody biomass that may be (sustainably) extracted by hectare, with or without a profit. Below such a threshold the available woody biomass may be considered accessible only for a local non-commercial context, largely represented by the self gathering of fuelwood for own consumption, but not to feed a formal woodfuel market of charcoal and fuelwood.

Such thresholds depends on local conditions, such as price of fuelwood and charcoal and level of demand and on the distance from the market place from the resources. A common reliable source of information in this case are the charcoal makers, who can tell what is the minimum amount of wood within a certain distance from the kiln to make the work profitable. This minimum quantity is then put in relation with the annual sustainable productivity and the rotation period estimated necessary for the land cover type to achieve such quantity. In absence of quantitative references, several thresholds were applied and the results reviewed (see Section 2.4.3: “Commercial” balance).

2.4 INTEGRATION MODULE

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

The first and most important result of the integration module is the balance between the accessible potential productivity and the total consumption of woody biomass for energy generation and other uses.

In order to describe the various planning dimensions of wood energy, the supply/demand balance analysis was carried out at the following three levels:

(i) Cell-level balance, which is the basis of all other balance analyses,

(ii) balance in a local context, few km around consumption sites, representing the informal self-supply horizon of rural and peri-urban households and,

(iii) balance based on the “commercial” fraction of the local surplus (resulting from the previous level) considered as source of commercial woodfuel production systems serving distant consumption sites.

2.4.1 Pixel-level balance

The supply/demand balance at the level of individual map pixel (or cell) is calculated by deducting the pixel-level consumption from the pixel-level available productivity. The calculation of the supply/demand balance by individual 1-hectare cell has an useful accounting function but it represents a somewhat virtual balance since individual pixels are usually either a production or a consumption site. An example of pixel-level balance is shown in Figure 18 (left-side map).

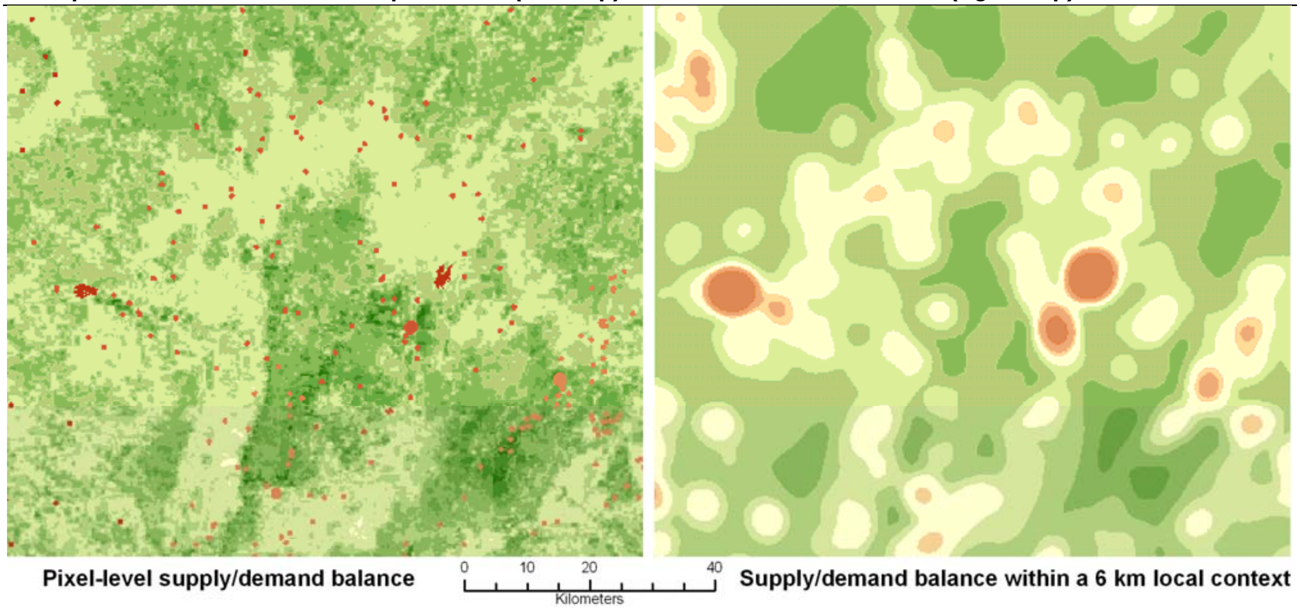
2.4.2 Local neighborhood balance

In order to achieve a realistic perception of the supply/demand balance it is necessary to combine the consumption and the supply potential within an area related to the real supply zone. In the case of rural and peri-urban households, the distance that household’s members are prepared to go to fetch fuelwood, on foot or by local transport means are good parameters to estimate the actual supply area.

In the context of Sudan, characterized by poor biomass resources, a relatively high household collection horizon of 6 km was applied. An example of the balance analysis in a 6 km local neighborhood is shown in Figure 18 (right-side map), along with a pixel-level analysis covering the same area. Comparing the local balance to the pixel-level balance it is interesting to see how the local context tends to render more visible the deficit areas, giving a more realistic perception of deficit and surplus zones

FIGURE 18

Example of balance calculated at pixel-level (left map) and on a 6-km local context (right map)



2.4.3 "Commercial" balance

The "commercial" balance is analyzed with the purpose of determining as realistically as possible the actual sustainable supply zone of major wood energy markets such as those of urban areas and IDP camps.

In the definition of the "commercial" balance the supply side to be considered is only the fraction of the surplus that may be regarded as available and suitable for market-oriented production systems, while the demand side to be considered is the deficit resulting from the local supply/demand balance. The commercial balance map is in fact an elaboration of the local balance map, maintaining unaltered all the cells that show a deficit condition as well as those with a surplus values above a certain threshold. The remaining cells, i.e. those with local balance values between 0 and the given surplus threshold, are considered non-influent and assigned a 0 value. This means accounting for deficit conditions but considering only the "commercial" share of local surplus, thus excluding the surplus resources that do not justify the investment required for their commercial exploitation.

In the absence of true value for the minimum economically viable threshold, that remains to be determined, an "explorative" analysis was done assuming various possible thresholds. Scope of the "explorative" analysis is that of assessing the impact of different minimum economically viable thresholds on the woody biomass realistically accessible and of identifying the target areas for productive sustainable forest management and the areas where protective measures and/or afforestation programmes would be more appropriate. Overall, the analysis provides basic elements on Sudan's self-reliance on woodfuel supply and on the magnitude of import and substitution policies.

Given the different supply and demand situations found in the 15 Sudan States and with reference to the analysis carried out for the Darfur region, the different minimum-surplus thresholds applied are 200, 150 and 100 od kg ha^{-1} $year^{-1}$.

2.4.4 Integration of poverty indicators

In order to strengthen the definition of priority areas of intervention and priority target communities, additional layers relative to the level of poverty and vulnerability were also analyzed in combination with supply/demand balance.

The best available sub-national indicators related to poverty were merged into a single layer in order to create a fairly consistent sub-national map, as summarized in Table 3 and shown in Figure 19 (SIFSIA, 2011). For this, the data from a variety of studies and surveys , listed below Table 3, were combined in order to provide a multi-dimensional definition of poverty and vulnerability of the populations in Sudan's states.

The combination of the map of supply/demand balance with that of poverty/vulnerability allowed stratification of the area as well as the population, reflecting the interaction of both factors, and enabled identification of priority areas and populations facing at the same time acute supply shortages and critical poverty conditions, as described in the Results Section.

TABLE 3

Multi-dimensional poverty ranking (SIFSIA – N, 2011) and poverty categories

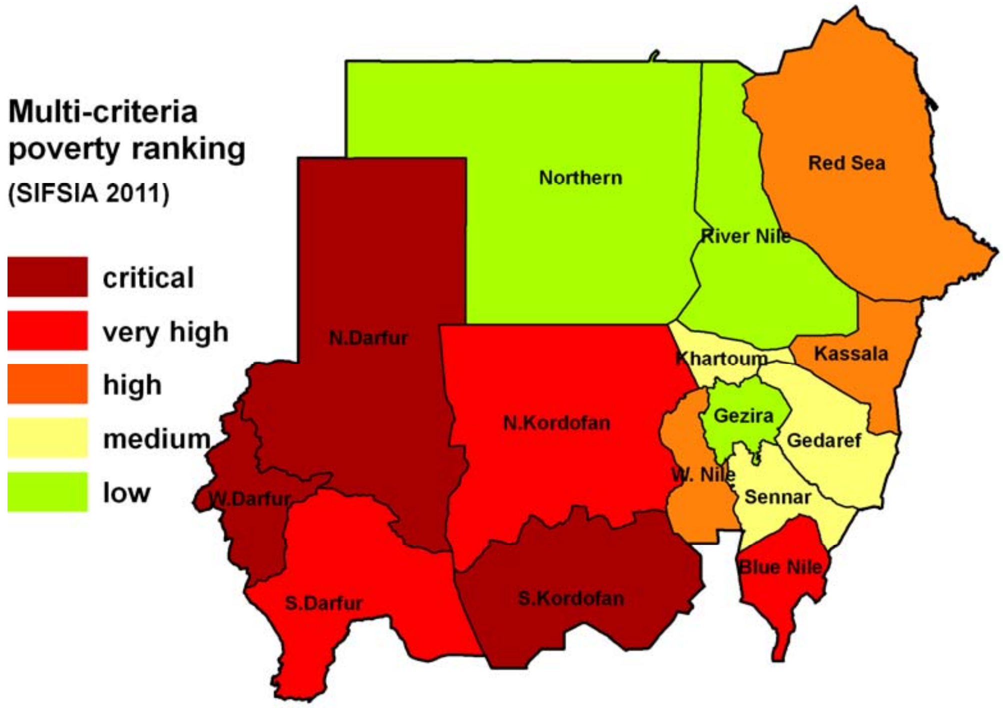
	MICS 2000 (% of poor)	FI Assnt (FAO) – Under-nourishment	Poverty Incidence	CFSAM (% of Popn Needing Assistance)	Human Poverty Index (IFAD - WB)	CFVSA (WFP) (% of Food Insecure)	Final ranking - Values	Poverty categories
	(1)	(2)	(3)	(4)	(5)	(6)		
Northern	20.4	16.0	36.2	0.0	23.2	1.0	**14**	**low**
River Nile	19.7	15.0	32.2	0.0	25.6	2.6	**14**	**low**
Red Sea	43.2	44.0	57.7	2.5	40.9	12.8	**7**	**high**
Kassala	50.3	30.0	36.3	3.5	44.7	10.8	**9**	**high**
Gadaref	60.1	22.0	50.1	0.0	44.4	9.2	**10**	**medium**
Khartoum	17.1	29.0	26.0	0.0	14.3	4.2	**12**	**medium**
Gazira	38.0	15.0	37.8	0.0	19.2	1.5	**13**	**low**
White Nile	44.4	41.0	55.5	17.3	35.0	9.8	**8**	**high**
Sinnar	48.4	29.0	44.1	0.0	33.9	5.8	**11**	**medium**
Blue Nile	50.7	24.0	56.5	16.5	49.4	14.2	**6**	**very high**
N. Kordofan	66.8	40.0	57.9	0.6	42.7	33.0	**5**	**very high**
S. Kordofan	54.7	27.0	60.0	33.2	52.0	31.9	**2**	**critical**
North Darfour	58.1	41.0	69.4	39.3	45.4	33.0	**1**	**critical**
West Darfour	67.1	20.0	55.6	21.6	57.7	40.2	**2**	**critical**
South Darfour	54.0	32.0	61.2	18.4	50.3	13.0	**4**	**very high**
Total	**47**	**61**	**47**	**100**	**39**	**15**		
Source years	2000	2009	2009	2011	2010	2006		

1. MICS - Multiple Indicators Cluster Survey, 2000, final report.
2. SHBS 2009 - Sudan Household Baseline Survey 2009 - Prevalence of Undernourishment - Food and Security Nutrition Assessment Report - Aug 2010.
3. Poverty in Northern Sudan - Estimates from the NBHS 2009 - CBS, Sept 2010.
4. Crop and Food Security Assessment Mission (CFSAM) to the 15 Northern States of Sudan- 2011 - Govt of Sudan and FAO/WFP in collaboration with partners, Jan 2011.
5. IFAD - WB - 2006 SHHS Survey - Poverty Assessment in Sudan Grant 961 - July 2010
6. CFVSA - WFP - Comprehensive Food Security and Vulnerability Analysis - Dec 2007 - Data collected in 2006

Source: SIFSIA - N, February 2011.

FIGURE 19

State-level poverty ranking based on SIFSIA multi-dimensional analysis



2.5 WEIGHTED WOODSHED ANALYSIS

Once the development of the WISDOM Base is complete for the whole area and the commercial balance maps are available, it is possible to outline the potential sustainable woodfuel/biomass supply zones of specific major consumption sites, such as Khartoum, other major cities and IDP Camps, keeping into account the consumption of surrounding urban and rural areas as well as the resources realistically available. These zones are termed “woodsheds” in analogy with the familiar geographical concept of *water*sheds (Drigo e Salbitano, 2008).

The woodshed of a given consumption site may be defined as the minimum area around the site in which the cumulative woodfuel balance between the deficit areas and the (commercial) surplus areas is non-negative.

When a single consumption site is considered, the woodshed is determined by the physical accessibility of the available surplus resources. However, when several consumption sites are considered at the same time, the woodshed is determined by the combined effect of both physical accessibility of available resources and of woodfuel demand exerted by each site considered. Therefore, the woodshed buffers around the selected cities are determined by the combination of two main factors:

(i) the physical accessibility of selected consumption sites, measured through cost-distance analysis starting from the selected cities, and using as cost factor the overall accessibility map (see Section 2.3.3.2);

(ii) the woodfuel deficit of the selected consumption sites (converted to continuous values through interpolation).

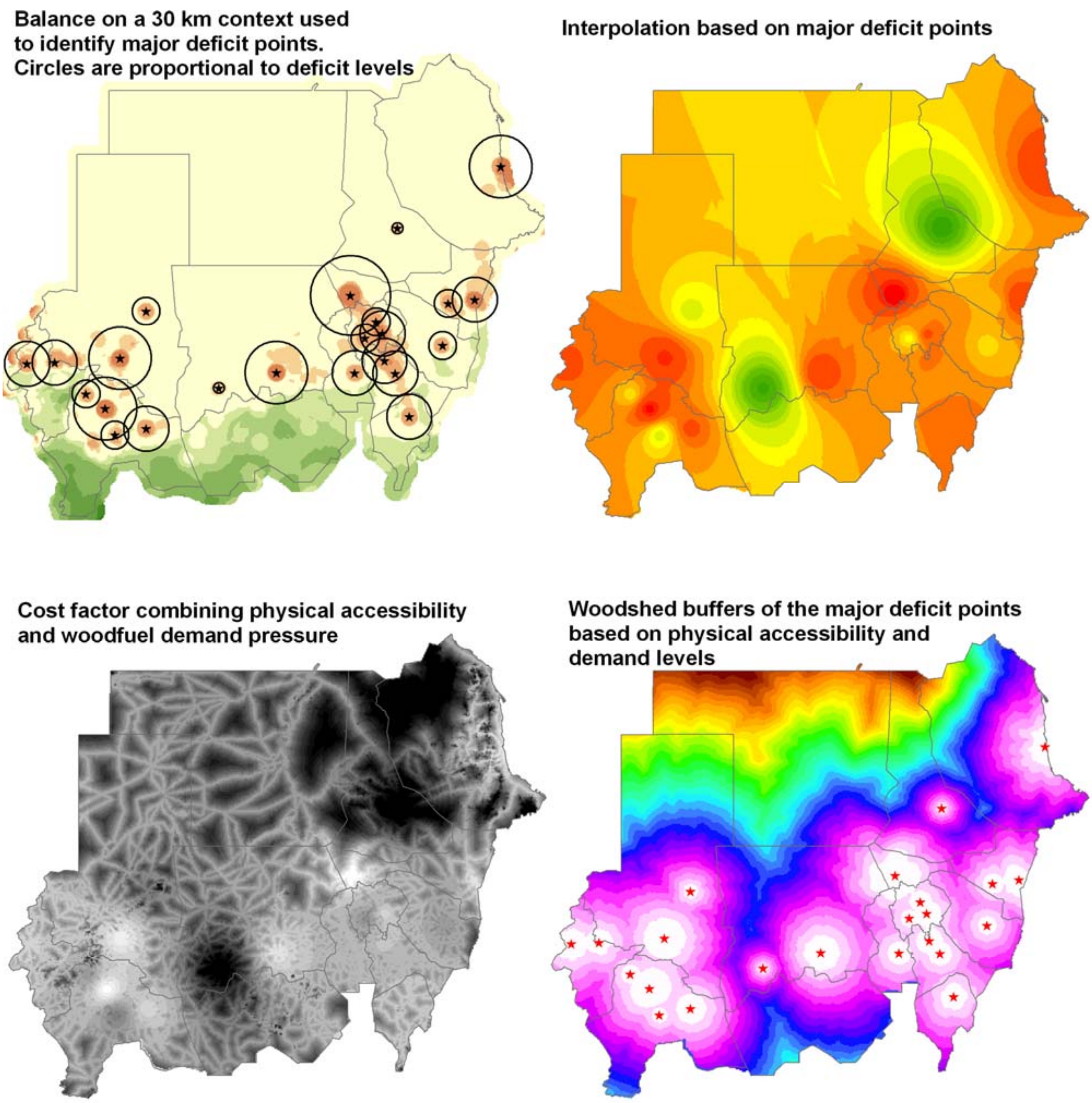
By means of this combined cost factor, the cities with higher demand (like Khartoum) “produce” wider woodshed buffers while the cities with lower demand “produce” narrower buffers, well representing the territory under urban influence/pressure. Figure 20 shows the maps that represent the main steps of weighted woodshed analysis. The first map (top-left) shows the supply/demand balance calculated on a radius of 30 km that was used to identify the major deficit sites. These site, converted into points, were then used to create the virtual “demand landscape” (top right map). The latter was then added to the physical accessibility map (see section 2.3.3.2 above) to create the bottom-left map combining both factors. The cost-distance analysis, starting from the major deficit points and using the combined factor map as cost layer, produced the bottom-right map that shows the “pressure” zones around such sites.

Once the “weighted” accessibility is produced, the procedure for the delineation of the actual woodshed of selected consumption sites is to calculate the supply/demand balance of each buffer (using the commercial balance) and to progressively expand the area buffer by buffer until the cumulative value of the commercial balance reaches a positive value, indicating that within such territory the supply potential (i.e. the commercial surplus) matches the demand.

To be noted, however, that the woodshed analysis tells what *should be* the harvesting area in order to guarantee the sustainable supply of the needed woody biomass, assuming the rational and sustainable resources management system. The woodshed analysis doesn’t tell what the *actual* harvesting area is, but it provides a revealing vision of the territory under urban influence and a clear target for forest management.

FIGURE 20

Weighted woodshed analysis. Phases of analysis.



2.6 ESTIMATION OF THE FRACTION OF NON RENEWABLE BIOMASS (FNRB)

Providing reliable and consistent fNRB estimates remains a major problem for CDM Projects because current approved methodologies do not include clear provisions for a standard calculation of fNRB. In general, performing a sound analysis to determine fNRB values is not trivial, requires high-level technical skills, and may add significant transaction costs to CDM projects.

One important consideration that influences the assessment approach is that the fNRB is location-specific, i.e., there are very large variations within countries and regions. National summary values based on statistical data cannot capture this fundamental aspect and may give misleading results. It is where, how and how much biomass is extracted that makes it renewable or not renewable. Providing spatial-explicit estimates of fNRB has the added value of helping focusing and priorizing project implementation to those areas within the country where the values are highest, and therefore maximizing both the global (largest mitigation per device) and the local (largest income from carbon sales) benefits.

Producing a single estimate of fNRB at aggregate geographical levels (such as a country) may fail to represent the true condition for an hypothetical project area as the impacts of fuelwood harvesting depend not on the overall balance between the fuelwood supply and consumption, but on the way consumption translates into harvesting practices (i.e., the type of management systems that are used to extract fuelwood) and the spatial patterns of these harvesting practices. For example if fuelwood extraction is concentrated in few forest spots where intensive clear-cutting w/o re-planting is conducted, the impact will be very different to a system where harvesting is more evenly distributed in the forest area.

Having completed the WISDOM analysis provides an excellent basis for a consistent estimation of the fNRB at national and sub-national levels. A new method to estimate the fraction of non-renewable biomass (fNRB) using the WISDOM model is here tested.

It should be emphasized that the accurate calculation of the fNRB for a specific location requires precise information on the areas from which the consumed biomass is extracted, their sustainable production capacity and on the existing management systems. Such knowledge is definitely unavailable on a systematic basis over the whole country and it's quite rare even at the local level.

However, the use of the WISDOM method efficiently supports the estimation of the expected fNRB for geographical regions, i.e. States and Localities, thanks to the systematic geo-referenced estimation of the consumption and of the sustainable productivity of woody biomass and its accessibility (physical, legal and economic).

To get to the expected fNRB at Locality level, a step-wise process of analysis is implemented:

Step 1: Estimation of the "**potential Renewable Biomass fraction**" (**pRBf**), i.e., the highest possible degree of renewability of a given biomass harvesting within a Locality.

Step 2: Estimation of the "**minimum fraction of Non-Renewable Biomass**" (**mfNRB**), which indicates the best possible situation, given the estimated level of harvesting and the supply potential, and assuming the rational management of biomass resources.

Step 3: Estimation of the **Sustainable Increment Exploitation Fraction** (**SIEF**). This parameter indicates how rationally the harvesting within a given area is carried out.

Step 4: Estimation of the "**expected Renewable Biomass fraction**" (**eRBf**), i.e., the likely degree of renewability of a given biomass harvesting within a particular territory assuming "current" management practices.

Step 5: Estimation of the "**expected fraction of Non-Renewable Biomass**" (**efNRB**), which indicates what the likely situation may be, given the estimated level of harvesting and the supply potential, and assuming current harvesting practices.

A detailed description of the fNRB assessment methodology is provided in Annex 4.

3.
RESULTS

The main result of the WISDOM analysis is the geo-statistical dataset. As summary of the main thematic elements, this section provides an overview of the most relevant maps produced in the modules and discusses the main findings. The spatial resolution of all maps corresponds to 100 m (cell of 1 hectare). State-wise statistics concerning demand, supply and balance at State levels are summarized in Tables 4 and, further below, Table 5. Detailed Locality-level results are presented in Annex 3.

3.1 DEMAND MODULE - ESTIMATED WOODY BIOMASS CONSUMPTION IN 2011

The total estimated consumption of woody biomass as fuelwood or as charcoal by sector of use and by State for the year 2011 is summarized in Table 4. The map of woody biomass consumption is shown in Figure 21.

Household consumption remains by far the main sector of use, covering almost 88% of the whole consumption (66% rural and 22% urban).

The consumption in the commercial and institutional sectors cover 3% and 2% of the total, respectively.

The industrial sector covers less than 7 % of the total, dominated by brickmaking, which covers 80% of the industrial use of woodfuels and 5.5% of the total national consumption.

FIGURE 21

Consumption of woody biomass in 2011 by Administrative Units.

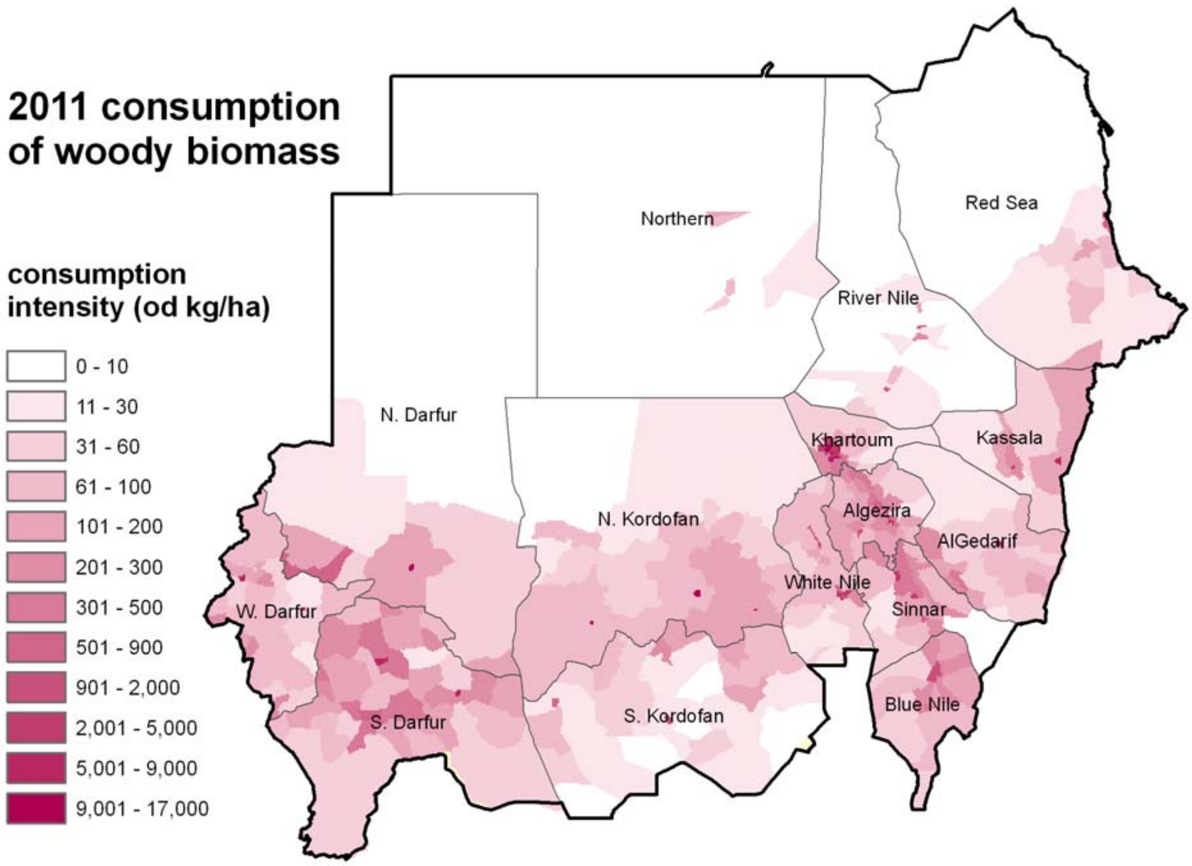


TABLE 4

Consumption of woody biomass in 2011 (in thousand oven-dry tons and cubic meters)

Values= '000 t od	Total consumption	Household Rural	Household Urban	Household IDP	Commercial (tea and food)	Institutional (Kalwas)	Industrial Total industrial	Bakeries	Brick	Lime curing	Vegetable oil	Others
Northern	**91.5**	**59.3**	**11.6**		**8.1**	**0.9**	**11.6**	5.7	5.9	0.0	0.0	0.0
River Nile	**120.3**	**68.6**	**14.1**		**10.6**	**2.7**	**24.2**	6.5	17.5	0.3	0.0	0.0
Red Sea	**377.4**	**190.9**	**132.8**		**12.3**	**9.9**	**31.5**	12.5	18.5	0.4	0.0	0.0
Kassala	**581.1**	**381.0**	**121.1**		**7.8**	**17.0**	**54.1**	4.9	32.8	16.5	0.0	0.0
Gedaref	**450.2**	**313.3**	**74.6**		**8.9**	**18.3**	**35.1**	8.7	25.5	0.9	0.0	0.0
Khartoum	**734.2**	**103.9**	**317.9**		**152.6**	**7.0**	**152.8**	34.0	116.5	1.0	0.0	1.3
Gezira	**559.8**	**309.0**	**133.5**		**37.5**	**7.5**	**72.3**	24.7	47.1	0.5	0.0	0.0
White Nile	**358.0**	**179.2**	**110.0**		**12.3**	**3.8**	**52.6**	14.3	37.4	0.9	0.0	0.0
Sennar	**507.2**	**371.7**	**64.5**		**2.9**	**2.7**	**65.5**	4.1	61.3	0.0	0.0	0.0
Blue Nile	**499.1**	**383.1**	**82.3**		**20.9**	**2.0**	**10.8**	3.1	7.7	0.0	0.0	0.0
N. Kordofan	**1,387.3**	**1,061.3**	**224.7**		**15.2**	**23.3**	**62.8**	9.5	41.0	0.0	12.2	0.0
S. Kordofan	**535.6**	**373.8**	**128.6**		**5.7**	**11.4**	**16.2**	9.4	4.8	0.0	2.0	0.0
North Darfur	**1,092.9**	**735.2**	**160.8**	**122.1**	**17.7**	**24.8**	**32.3**	10.1	20.8	0.0	1.2	0.2
West Darfur	**639.6**	**285.1**	**134.1**	**174.9**	**8.7**	**14.1**	**22.7**	4.7	17.0	0.0	1.0	0.0
South Darfur	**2,032.0**	**1,178.7**	**428.0**	**279.0**	**15.7**	**53.2**	**77.4**	23.9	32.0	1.0	20.4	0.1
Tot Sudan	**9,966.4**	**5,994.4**	**2,138.8**	**576.0**	**336.9**	**198.6**	**721.8**	176.0	485.9	21.5	36.8	1.6

Values= '000 m^3	Total consumption	Household Rural	Household Urban	Household IDP	Commercial (tea and food)	Institutional (Kalwas)	Industrial Total industrial	Bakeries	Brick	Lime curing	Vegetable oil	Others
Northern	**155.4**	**100.7**	**19.7**		**13.7**	**1.5**	**19.7**	9.7	10.0	0.0	0.0	0.0
River Nile	**204.2**	**116.5**	**24.0**		**18.0**	**4.6**	**41.1**	11.0	29.6	0.5	0.0	0.0
Red Sea	**640.8**	**324.2**	**225.5**		**20.9**	**16.8**	**53.4**	21.3	31.3	0.7	0.0	0.1
Kassala	**986.6**	**646.9**	**205.7**		**13.2**	**28.9**	**91.9**	8.3	55.6	28.0	0.0	0.0
Gedaref	**764.5**	**532.0**	**126.7**		**15.1**	**31.1**	**59.6**	14.7	43.3	1.5	0.0	0.0
Khartoum	**1,246.7**	**176.5**	**539.8**		**259.2**	**11.9**	**259.4**	57.6	197.8	1.8	0.0	2.1
Gezira	**950.5**	**524.6**	**226.7**		**63.6**	**12.7**	**122.8**	42.0	80.1	0.8	0.0	0.0
White Nile	**607.8**	**304.3**	**186.8**		**20.9**	**6.5**	**89.2**	24.2	63.6	1.5	0.0	0.0
Sennar	**861.2**	**631.1**	**109.5**		**5.0**	**4.5**	**111.2**	7.0	104.1	0.0	0.0	0.0
Blue Nile	**847.4**	**650.5**	**139.8**		**35.4**	**3.4**	**18.4**	5.2	13.2	0.0	0.0	0.0
N. Kordofan	**2,355.6**	**1,802.1**	**381.5**		**25.8**	**39.6**	**106.6**	16.2	69.7	0.0	20.7	0.0
S. Kordofan	**909.4**	**634.7**	**218.3**		**9.6**	**19.3**	**27.4**	15.9	8.2	0.0	3.3	0.0
North Darfur	**1,855.6**	**1,248.2**	**273.1**	**207**	**30.1**	**42.1**	**54.8**	17.2	35.3	0.0	2.0	0.4
West Darfur	**1,086.1**	**484.1**	**227.7**	**297**	**14.8**	**24.0**	**38.5**	8.0	28.8	0.0	1.7	0.0
South Darfur	**3,450.2**	**2,001.4**	**726.8**	**474**	**26.6**	**90.3**	**131.4**	40.6	54.4	1.7	34.7	0.1
Tot Sudan	**16,922.0**	**10,177.9**	**3,631.4**	**978**	**572.0**	**337.2**	**1,225.5**	298.8	825.0	36.6	62.4	2.7

3.1.1 Changing consumption patterns

The role of woodfuels in the energy mix of the Sudan has changed considerably in the last 15 years, since the last comprehensive consumptions survey . With reference to the information sources described above, we can see that the pattern of change in woodfuel consumption differs considerably from State to State, from rural to urban areas and from one consumption sector to the other.

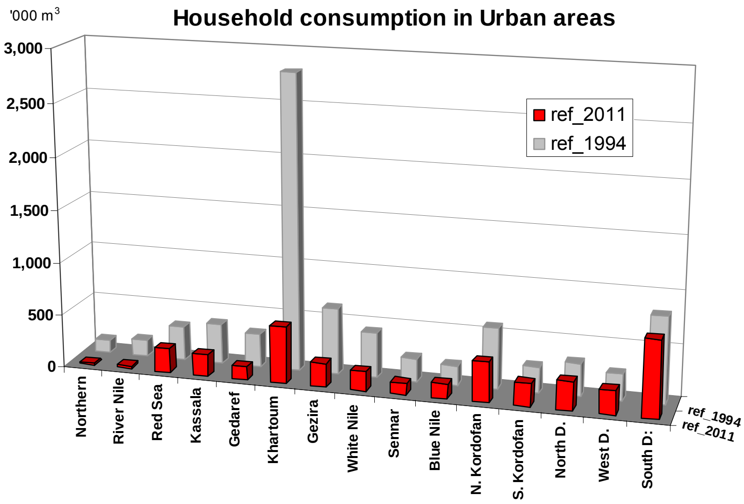
In order to visualize the entity of such changes and their locations, the graphs in Figures 22 to 24 show the new consumption estimates integrating old and new references (labeled "ref_2011") against a background displaying the consumption levels that may be expected in 2011 if no change had intervened in the consumption pattern since 1994 (labeled "ref_1994").

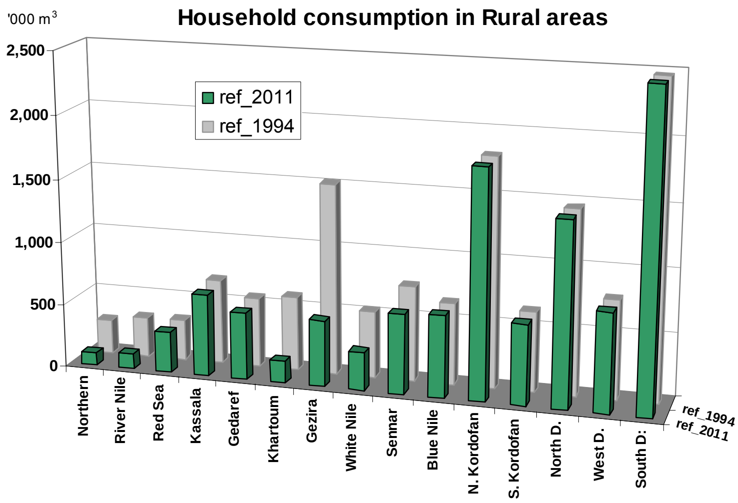
Overall, the total consumption in 2011, estimated at 16.9 million m^3 (9.97 million tons) is 28% less than the amount that could be expected for the same year if no change had intervened in consumption pattern, with a "saving" of some 6.7 million m^3.

The main element of change has been the substitution of charcoal and fuelwood by LPG, used for cooking by urban households and bakeries, and as main fuel by oil and soap factories. Most remarkable appear the reduced consumption in Khartoum and Gezira states in all contexts and use sectors. The other central and northern states show a significant reduction due mainly to the increasing use of LPG in urban and rural households. On the contrary, the southernmost states of Blue Nile, Kordofan and Darfur appear rather static in respect of woodfuel consumption pattern.

FIGURE 22

State-wise consumption of woody biomass in 2011 by the household sector in urban and rural areas .





Note: In the graphs above the new estimates based on recent references (ref_2011) are in color, while the grey values in the background represent the expected consumption levels <u>if no change had intervened</u> in the consumption pattern since the1994 survey (ref_1994).

FIGURE 23

State-wise consumption of woody biomass in 2011 by the commercial, industrial and institutional sectors.

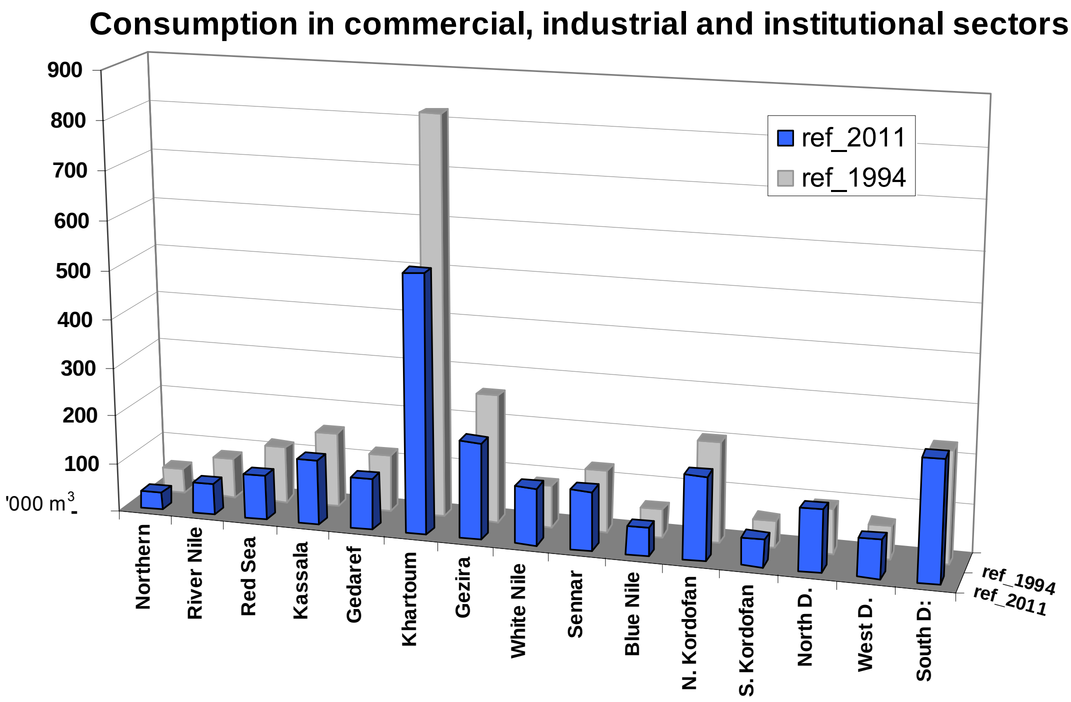
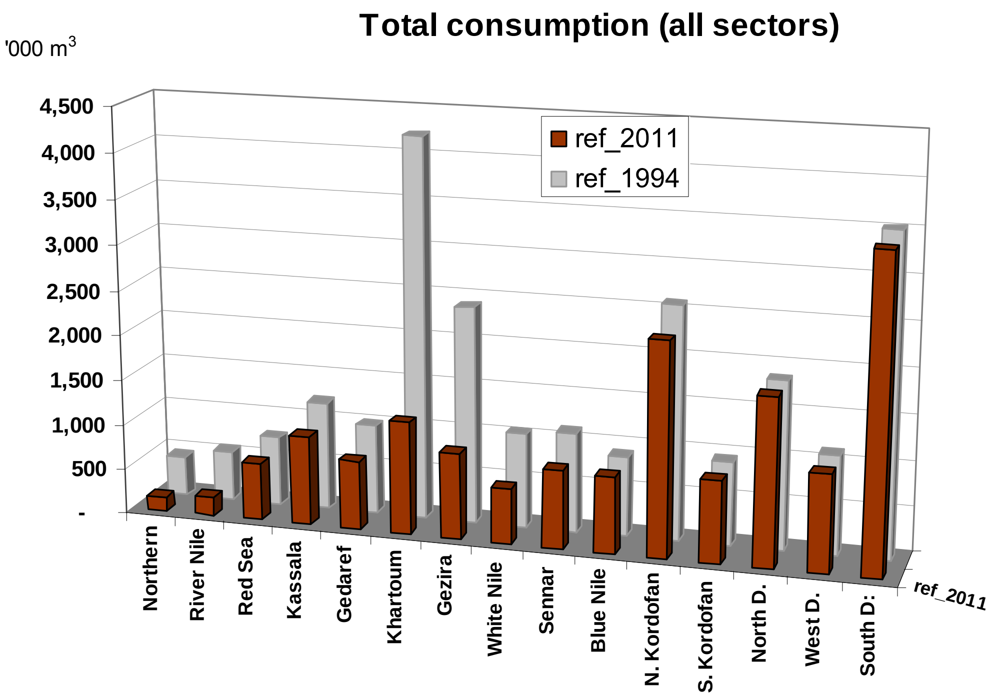


FIGURE 24

Total state-wise consumption of woody biomass in 2011 (all sectors).



Note: In the graphs above the new estimates based on recent references (ref_2011) are in color, while the grey values in the background represent the expected consumption levels if no change had intervened in the consumption pattern since the1994 survey (ref_1994).

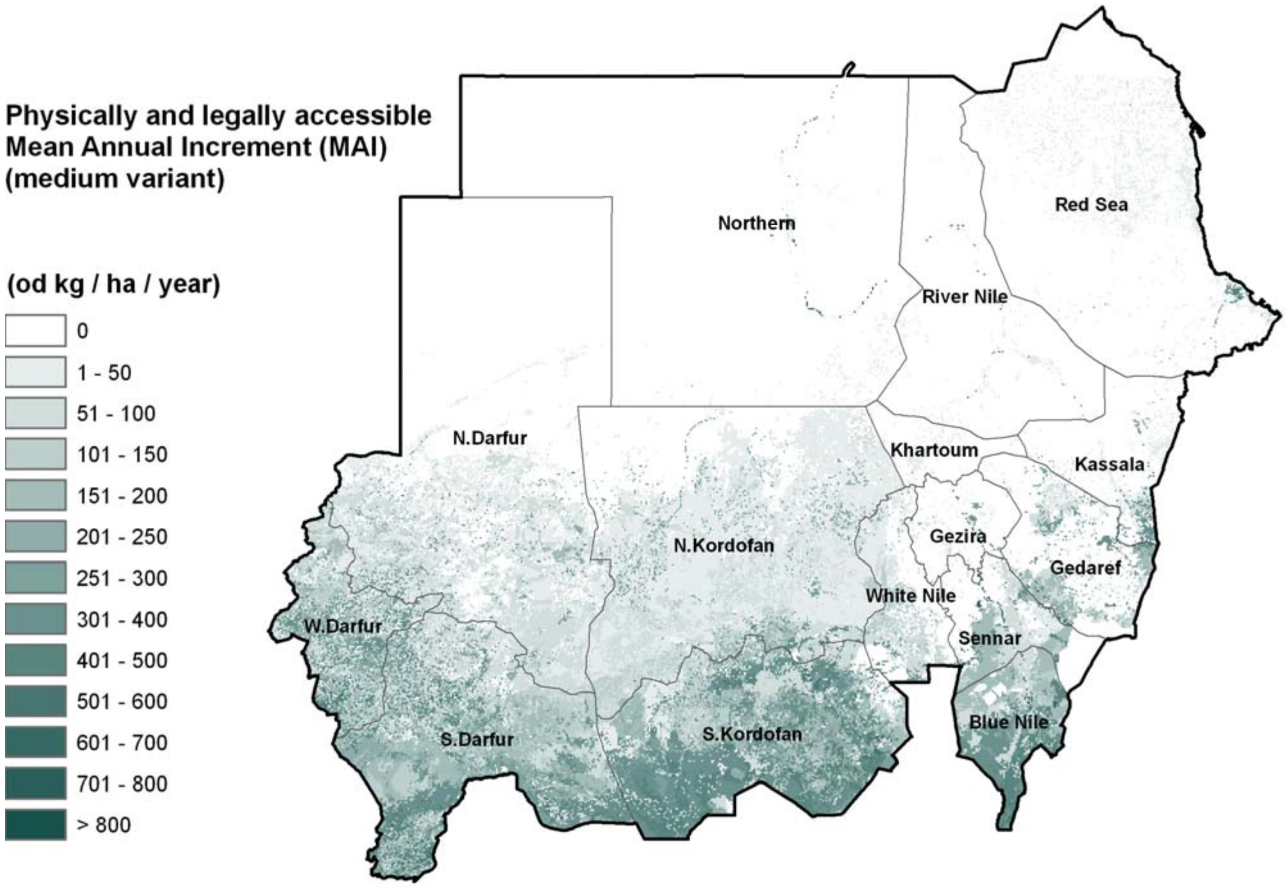
3.2 WOODY BIOMASS SUPPLY POTENTIAL (REF.: LCCS 2011)

The Mean Annual Increment (MAI) rates were calculated on the basis of generic functions relating MAI and stock. The MAI variant that appeared more realistic and that gave the best fit with the limited data available is the Medium MAI variant (see Figure 15 in Section 2.3.2). The physically and legally accessible fraction of the MAI of woody biomass, shown in Figure 25 for the medium variant, represents the maximum sustainable supply potential.

The state-wise statistics of Supply layers are reported in Table 5 further below, while the statistics relative to Localities are reported in Annex 3.

FIGURE 25

Physically and legally accessible Mean Annual Increment (MAI) of woody biomass – Medium variant. (Land cover ref.: LCCS 2011).



3.3 SUPPLY / DEMAND BALANCE

The analysis of supply/demand balance was carried out at three main levels: (i) at pixel level, combining the values of the corresponding pixels from the supply and demand maps, which is the basis of all other balance analyses, (ii) in a local context emulating the informal self-supply horizon of rural and peri-urban households, and, (iii) considering the "commercial" fraction of local surplus as source of formal and commercial woodfuel production systems serving woodfuel markets of distant consumption sites such as cities and IDP Camps.

3.3.1 Pixel-level balance (ref.: LCCS 2011)

In the pixel-level balance analysis the supply/demand balance was calculated for each individual 1-hectare pixel by subtracting the demand from the supply potential.

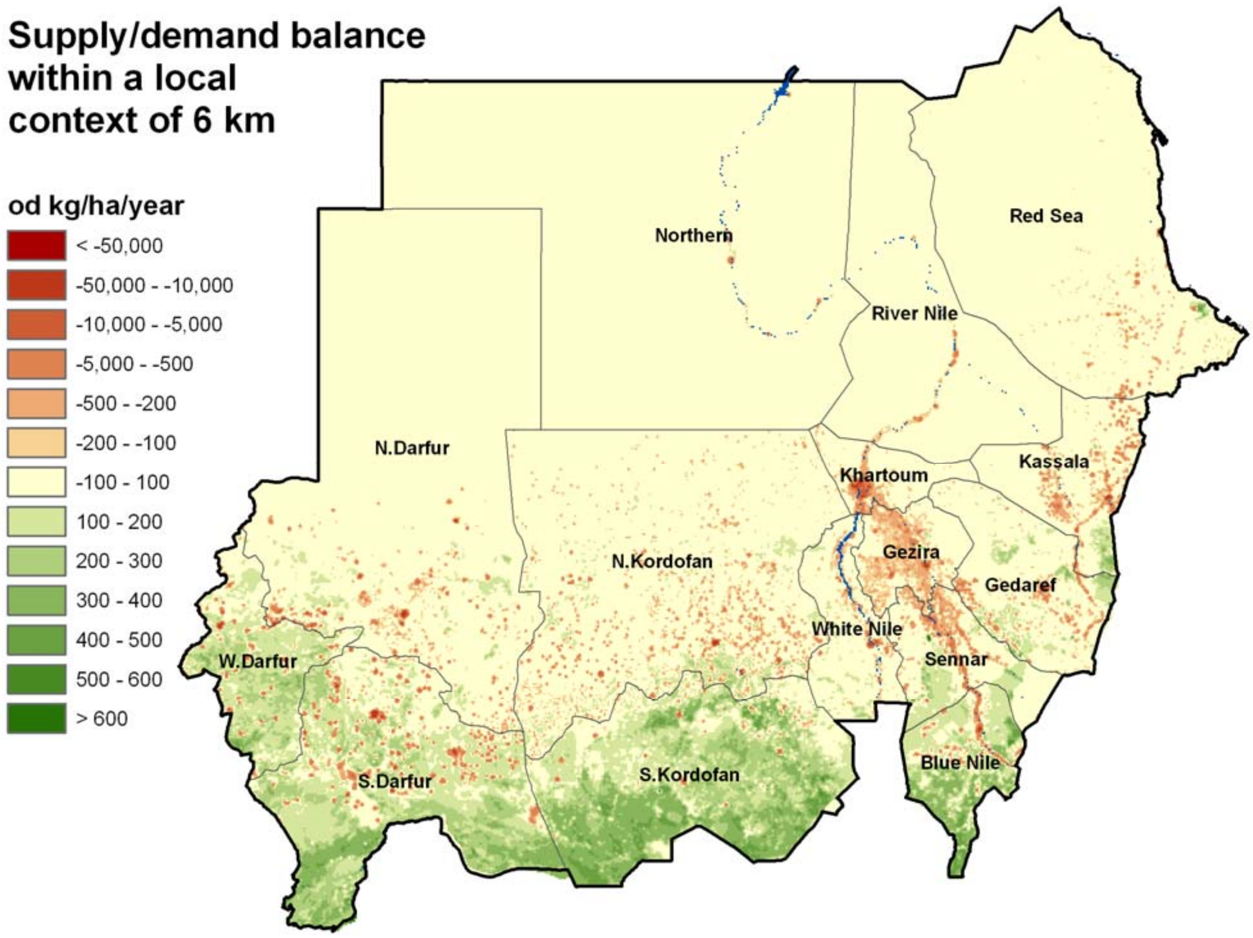
3.3.2 Balance in a local context and "commercial" balance (ref.: LCCS 2011)

The balance calculated on a local context of 6 km is shown in Figure 26. The local context tends to render more visible the deficit areas, giving a more realistic perception of deficit and surplus zones.

The state-wise statistics of local balance are reported in Table 5 below.

FIGURE 26

Supply/demand balance within a local context of 6 km. (ref.: LCCS 2011)



Local balance

The local balance, that considers the whole accessible sustainable production potential, shows an overall national surplus of 0.97 million tons (1.65 million m^3), but deficit conditions in all states of Sudan except for Blue Nile, South Kordofan, West Darfur and South Darfur, where the balance appears positive. The highest surplus is in South Kordofan while the highest deficit is in in Khartoum State, as it may be expected.

The local balance well represents rural areas, where supply sources and consumption sites are close by and the supply systems are informal, but fails to represent the supply/demand context of urban areas whose supply zones are usually far away and the supply chain are always commercial.

The local balances implies the rationale exploitation of the entire sustainable increment over the whole territory. This is obviously too optimistic concerning the management efficiency and also uneconomic, since it includes all formations, including the thinly sparse shrublands.

Commercial balance

The analysis of the "commercial" balance is based on the consideration that the management and commercial exploitation of sparse resources may be uneconomical. The supply resources considered in the analysis are the local surpluses resulting from the balance analyzed in a 6-km local context. In the absence of true "economically viable" thresholds, test analyses were carried out for different minimum resource availability thresholds. It should be emphasized that the thresholds applied are not true values but rather a range of values to be confronted to local operators and eventually replaced by valid thresholds. Scope of this preliminary analysis is to provide a first notion of the sustainable and economically accessible resources and to define the consequent challenges in terms of sustainable management, woodfuel import requirements and woodfuel substitution strategies.

The results, shown in Figure 27 and summarized at State level in Table 5[6], indicate the following:

- By applying a minimum availability threshold of 100 kg/ha/yr to the surplus remaining after local consumption (1.5 od t or 2.55 m^3 per hectare on a 15-years rotation), the "commercial" balance shows an overall deficit of 0.9 million od tons. With this threshold, four are the states that show a positive balance (South Kordofan, Blue Nile, West Darfur and South Darfur) and the possibility to export to other states. This indicates that, in principle, if all national wood resource that guarantee more than the set threshold are put under intensive management, the country's production could satisfy 91% of the national demand on a sustainable basis, while at least 9% should be imported or replaced by other fuels.
- By applying a minimum availability threshold of 150 kg/ha/yr (2.25 od t or 3.8 m3 per hectare on a 15-years rotation), the "commercial" balance shows an overall deficit of 1.97 million od tons. The states with positive balance are the same four but with maller surpluses. In this case, the country's production could (if intensively managed) satisfy 80% of its demand on a sustainable basis, while at least 20% should be imported or replaced by other fuels. .
- By applying a minimum availability threshold of 200 kg/ha/yr (3 od t or 5 m^3 per hectare on a 15-years rotation), the "commercial" balance so determined shows an overall deficit of 3.3 million od tons, with state-level values ranging between a deficit of 0.98 million tons in North Kordofan to a surplus of 2.1 million tons in South Kordofan. With this threshold, only two states (South Kordofan and Blue Nile) present a positive balance. In this case, the country's production could (if intensively managed) satisfy 67% of its demand on a sustainable basis, while at least 33% should be imported or replaced by other fuels.

Most important is now to verify the economic viability of the various situations with local operators and managers and to define the true "economically viable" minimum surplus values.

The gap between the theoretical thresholds defined above and the true economical thresholds (to be determined) will reveal the quantity of woody biomass that cannot be produced commercially and that must be produced from other sources (i.e. new plantations) or or imported, or that must be deducted from the demand through alternative fuels, FES programmes, etc.

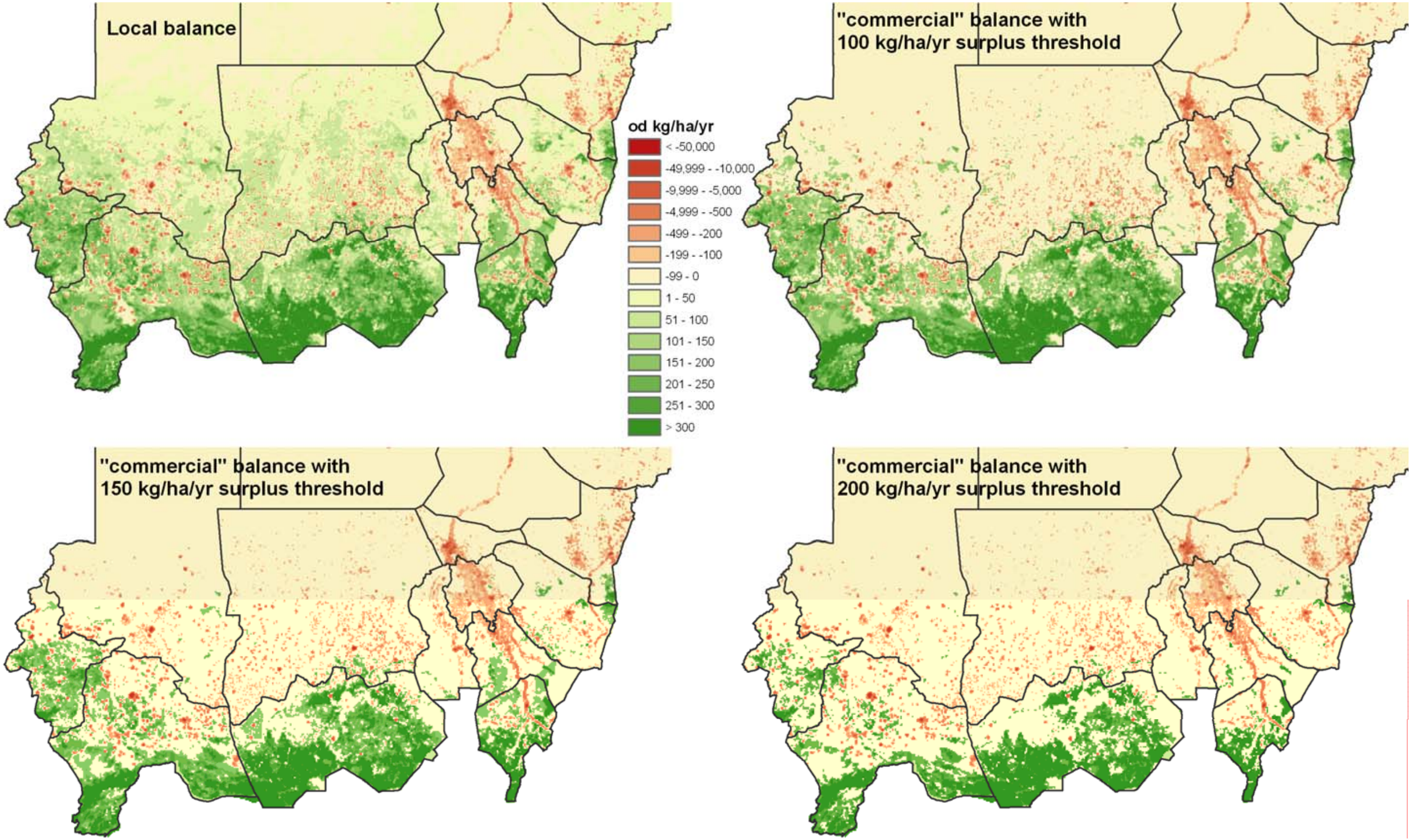
The commercial balance categories described above are based on the estimated sustainable surplus and on the assumption that the economic viable resources are rationally managed, which means that the accessible increment is exploited entirely. This is useful for defining the theoretical limits of sustainable forest management but is certainly not representative of today's situation. Today's exploitation is in good part unregulated and there are areas which are overexploited and area (much fewer, probably) which are underexploited.

In the perspective of future planning it is not realistic to assume that forest management may become so widespread and intense to mobilize the whole sustainable increment. It is therefore wiser to remain short of the whole sustainable growth when planning future forestry, energy and woodfuel import policies. But it is difficult to say what fraction of the accessible commercial surplus may be actually mobilized through sustainable forest management.

[6] To be noted that a positive balance at State level does not mean that the balances within its sub-national units are all positive. In fact, as shown in Annex 3, reporting sub-national statistics, several Localities present deficit conditions even when the overall state balance shows a surplus, and vive-versa.

FIGURE 27

Supply/demand balance within a local context (top–left map) and "commercial" balance maps applying surplus thresholds of100, 150 and 200 kg/ha/year. (ref.: LCCS 2011)



3.4 SUMMARY STATISTICS BY ADMINISTRATIVE UNITS (REF.: LCCS 2011)

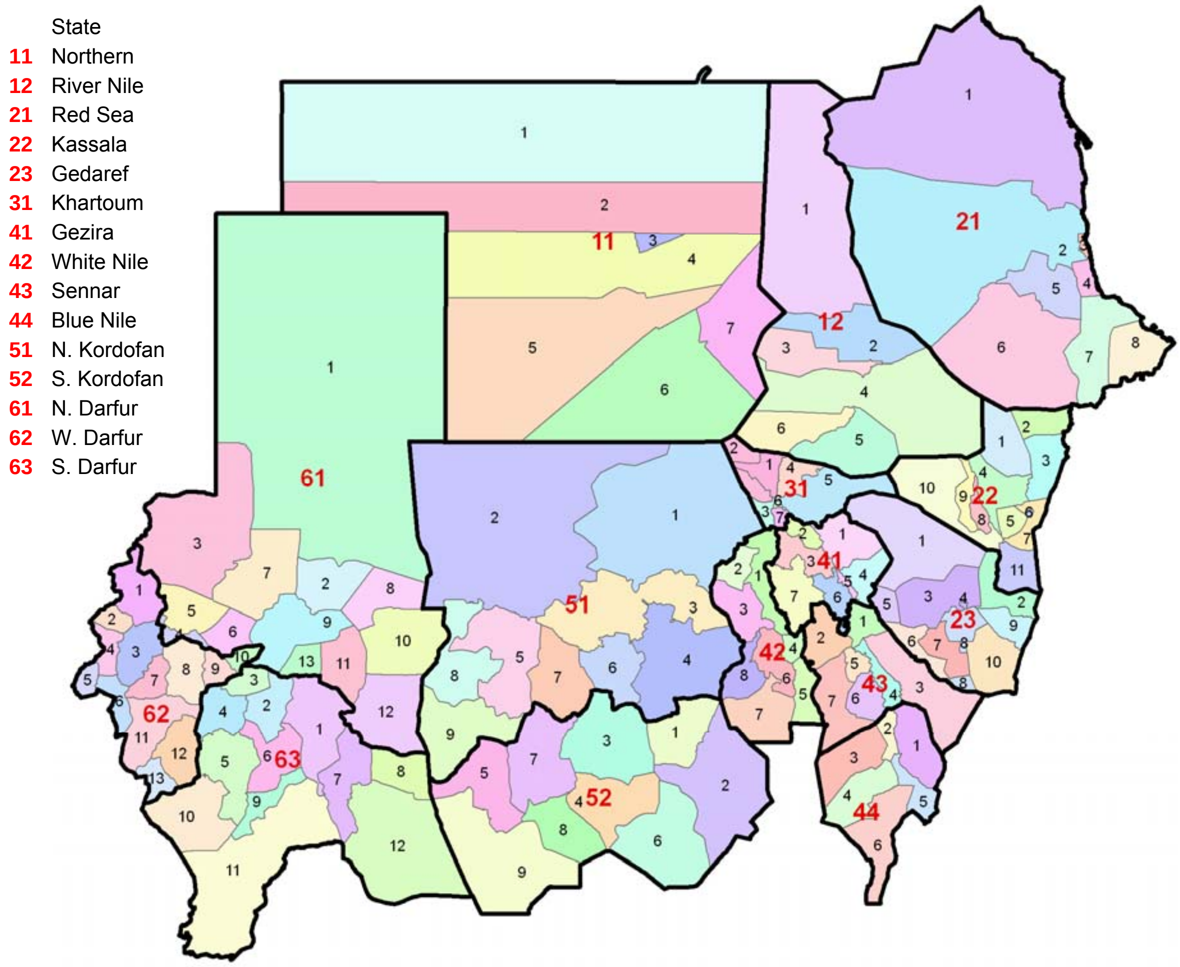
Once the pixel-level analysis is completed, the presentation of results by administrative units is just matter of aggregating the data to the desired level. Supply, demand and balance statistics can thus be computed and assigned, as attributes, to the administrative maps. The reporting level applied includes States and Localities, whose layout is shown in Figure 28.

Figure 29 shows the Locality level balance maps of local balance, based on whole accessible productivity, and “Commercial” balance based on surplus above 150 kg/ha/year.

The summary statistics resulting from the analysis concerning supply, demand and balance parameters are presented by State (Table 5) and by Locality (Annex 3),

FIGURE 28

Sudan States and Localities. (ref. layout 2012)



Note: Full Locality codes in Annex 3 include state codes (2 digits) and Locality code (2 digits).

FIGURE 29

Maps of supply/demand balance by Localities. Top map: Local balance based on whole accessible productivity. Bottom map: "Commercial" balance based on surplus above 150 kg/ha/year.

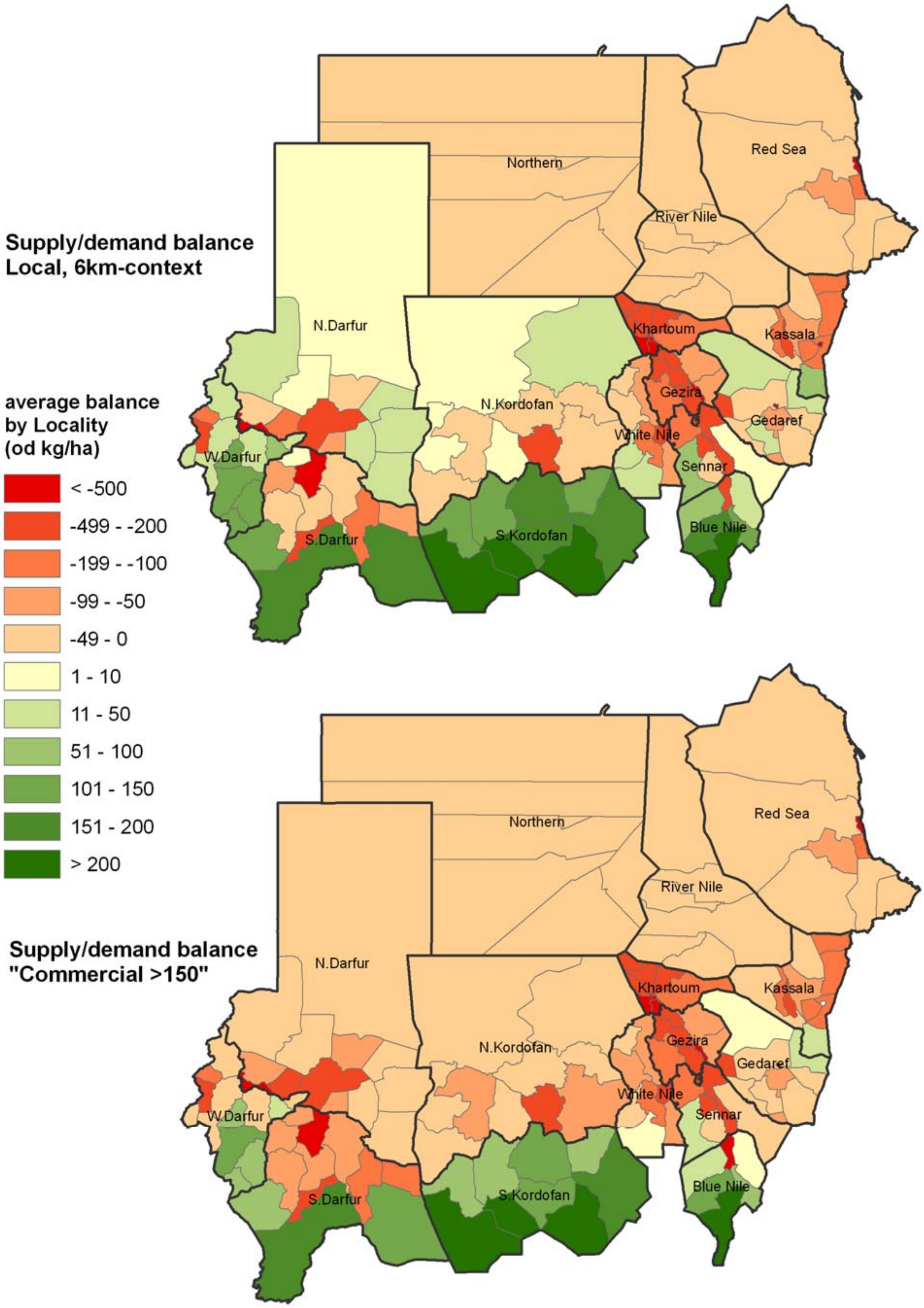


TABLE 5

State-wise summary of demand, supply and balance statistics "Commercial" balance values assume surplus thresholds of100, 150 and 200 kg/ha/year. (ref.: LCCS 2011)

State	Area	Demand 2008	Demand 2011*	Stock	Annual accessible supply potential	Local balance	Commercial balance "surplus>100"	Commercial balance "surplus>150"	Commercial balance "surplus>200"
	approx.km^2	'000 od t	'000 od t	'000 od t	'000 od t	'000 od t	'000 od t	'000 od t	'000 od t
Northern	388,964	**119**	**92**	**824**	**37**	**-54**	**-65**	**-66**	**-66**
River Nile	138,124	**110**	**120**	**451**	**20**	**-101**	**-107**	**-107**	**-107**
Red Sea	227,662	**337**	**392**	**903**	**63**	**-331**	**-359**	**-361**	**-364**
Kassala	54,030	**551**	**580**	**1,788**	**110**	**-469**	**-490**	**-502**	**-517**
Gedaref	62,048	**454**	**450**	**4,692**	**320**	**-128**	**-212**	**-258**	**-301**
Khartoum	22,159	**756**	**734**	**72**	**7**	**-726**	**-727**	**-727**	**-727**
Gezira	28,186	**489**	**559**	**701**	**36**	**-529**	**-532**	**-533**	**-534**
White Nile	38,688	**349**	**358**	**1,660**	**192**	**-171**	**-256**	**-275**	**-281**
Sennar	40,504	**470**	**507**	**6,008**	**278**	**-223**	**-269**	**-300**	**-382**
Blue Nile	39,984	**485**	**499**	**16,046**	**922**	**422**	**388**	**319**	**188**
N. Kordofan	248,693	**1,345**	**1,386**	**10,938**	**1,196**	**-189**	**-844**	**-941**	**-978**
S. Kordofan	143,348	**527**	**550**	**61,060**	**3,410**	**2,859**	**2,730**	**2,503**	**2,139**
North Darfur **	331,175	**1,051**	**1,090**	**6,699**	**749**	**-327**	**-830**	**-894**	**-917**
West Darfur **	54,861	**576**	**599**	**12,785**	**905**	**290**	**208**	**46**	**-180**
South Darfur **	142,285	**1,952**	**2,036**	**39,293**	**2,679**	**643**	**461**	**123**	**-263**
Tot Sudan	**1,960,713**	**9,570**	**9,954**	**163,920**	**10,926**	**967**	**-905**	**-1,974**	**-3,289**

Note: Units are oven-dry (od) woody biomass in thousand tons. 1 m^3 = 0.589 od tons. 1000 odt = 1698 m^3.

* Slight differences with Table 4 on 2011 consumption are due to mapping process.

** The differences between the supply and balance values of Darfur states and those produced by the 2010 WISDOM Darfur study are due to the different areas covered, to some changes in the land cover map, to the wider set of NFI sample data used as reference for biomass stock and to the constraints applied to the estimation of annual productivity.

3.5 WOODFUEL DEFICIT AND POVERTY

The integration of supply/demand balance with poverty-related indicators (shown in previous sections in Figures 29 and 19, respectively) permitted the stratification of the population of the Sudan into what we may call subsistence energy categories.

Table 6 shows the distribution of the population by woodfuel balance categories and poverty categories. The rural communities (second part of Table 6), that cannot afford commercial fuels and that depend primarily on the gathering of locally available wood resources for their daily needs are those that suffer most from a negative local balance and that are inevitably overexploiting the scarce resources locally accessible. The third part of the table quantifies the level of deficit estimated for each combination. These values are useful for the quantification of the deficit that need to be filled in and of the target communities that need to be assisted with priority through fuel efficient stove programmes and subsidized alternative fuels.

TABLE 6

Distribution of population (total and rural) and woodfuel situation by balance and poverty categories.

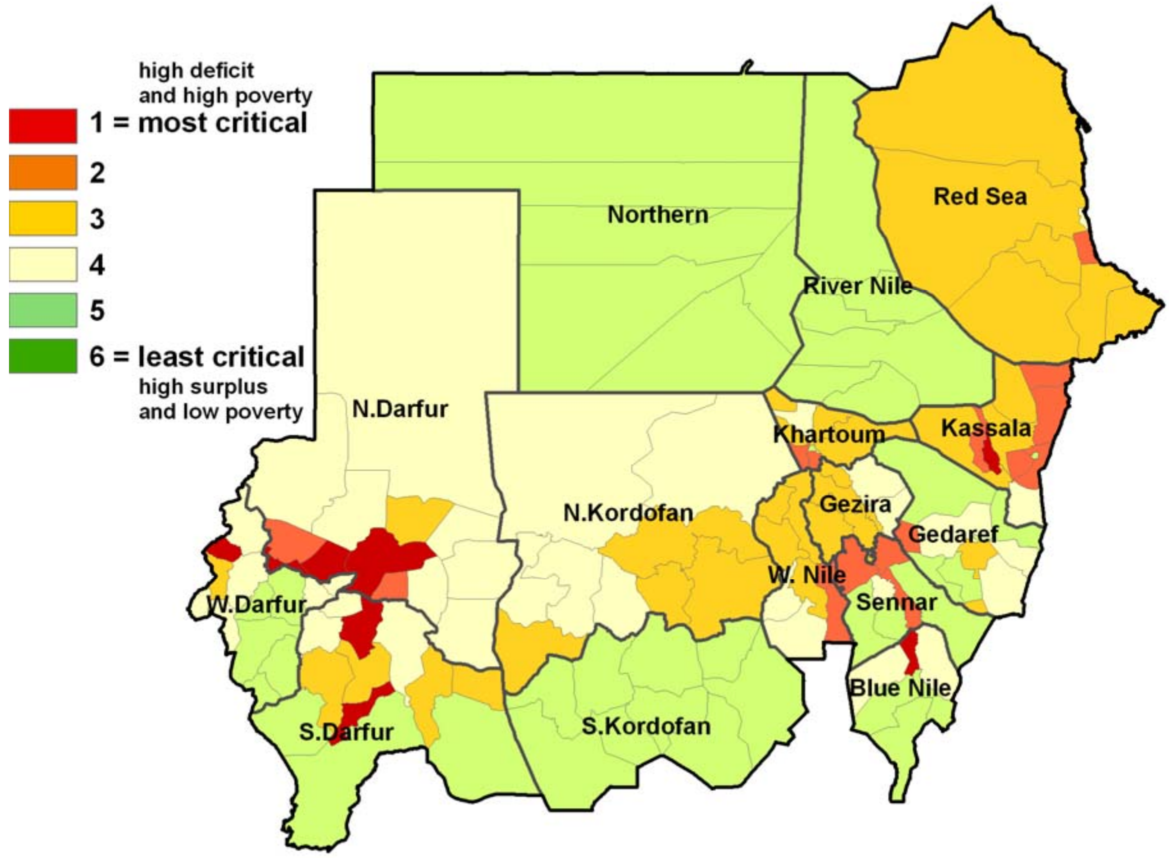
Total population 2011 ('000 inhabitants)	**Poverty categories**					
Woodfuel balance categories	critical	very high	high	medium	low	Total
Critical deficit	211	339	222	1,423	418	2,612
High deficit	919	852	784	1,072	2,590	6,217
Medium deficit	220	281	684	2,712	709	4,606
Light deficit	373	3,054	2,418	1,293	1,902	9,040
Light surplus	1,186	2,120	756	1,854	0	5,916
High surplus	1,949	1,269	313	0	0	3,531
Totale complessivo	4,857	7,915	5,178	8,354	5,619	31,922
Rural population 2011 ('000 inhabitants)	**Poverty categories**					
Woodfuel balance categories	critical	very high	high	medium	low	Total
Critical deficit	211	307	135	572	382	1,607
High deficit	630	346	784	541	2,020	4,321
Medium deficit	220	281	447	723	605	2,276
Light deficit	188	2,417	1,842	513	1,431	6,391
Light surplus	1,124	1,818	305	778	0	4,025
High surplus	1,563	1,197	0	0	0	2,760
Totale complessivo	3,936	6,367	3,513	3,127	4,437	21,380
Balance in rural areas (urban demand excluded) ('000 od t)	**Poverty categories**					
Woodfuel balance categories	critical	very high	high	medium	low	Total
Critical deficit	-95	-82	-38	-143	-40	-397
High deficit	-191	-87	-216	-127	-197	-816
Medium deficit	-52	-55	-65	-100	-49	-321
Light deficit	-15	-125	-228	-50	-78	-497
Light surplus	304	334	109	176	0	924
High surplus	3,355	1,768	2	0	0	5,125
Totale complessivo	3,306	1,753	-435	-243	-364	4,018

Note: See Figure 30 and Table 7 for color coding.

Further definition of the priority areas of intervention can be achieved by combining the two factors into a single “criticality” ranking, as shown in Figure 30 . Such ranking allows the identification of the communities that suffer from concomitant conditions of serious woodfuel deficit and high poverty, which are cause of extreme vulnerability. Results of this analysis, summarized in Table 7, showed that approximately 7.6% of the rural population of the Country, i.e. some 1.6 million people, live concomitant conditions of marked poverty (according to children’s nutritional status) and high woodfuel deficit (dark and light red areas in the map and table).

FIGURE 30

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



Woodfuel balance categories	Multi-criteria poverty categories: critical	very high	high	medium	low
Critical deficit	1	1	1	2	3
High deficit	1	1	2	2	3
Medium deficit	2	2	2	3	4
Light deficit	3	3	3	4	5
Light surplus	4	4	4	5	6
High surplus	5	5	5	6	6

TABLE 7

Population distribution by poverty and subsistence energy ranking, based on woodfuel balance and poverty categories

Poverty & subsistence energy ranking	balance in rural areas (urban demand excluded)	Rural population		Total population	
	'000 od t	('000)	%	('000)	%
1- most critical	-492	1,629	7.6	2,543	8.0
2	-657	2,846	13.3	4,464	14.0
3	-706	7,572	35.4	11,565	36.2
4	649	4,365	20.4	6,064	19.0
5	5,224	4,969	23.2	7,287	22.8
6- least critical	0	0	0.0	0	0.0
Total	4,018	21,380	100.0	31,922	100.0

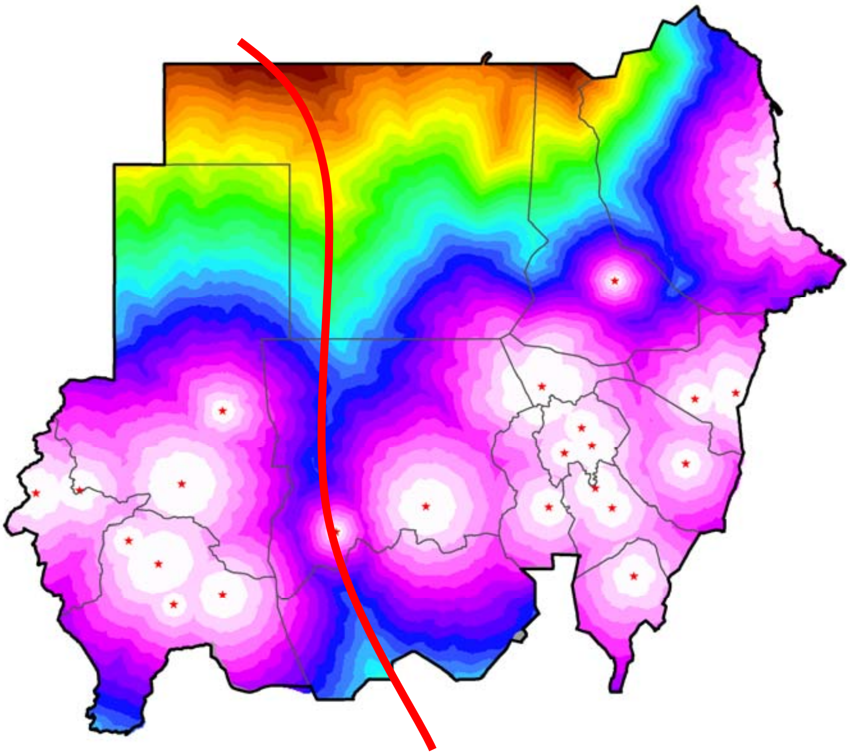
3.6 RESULTS OF WOODSHED ANALYSIS

Given that the commercial balances are all negative (with gap levels depending on the threshold assumed-, see Table 5), the sustainable supply zone of the country's major consumption sites is in principle bigger than the country itself. In such a situation, the conventional scope of woodshed analysis, which is that of defining the sustainable supply zone of the major consumption sites, has little purpose. It is simple: the supply zone must be the whole country, and is not sufficient; additional woodfuels import (and/or heavy demand reduction) remain necessary.

Nonetheless, woodshed analysis provides a coherent vision of the "pressure zones" determined by the accessibility of wood resource combined with the level of demand of the major urban areas, as shown in Figure 31. These pressure zones are clearly divided into two main areas of influence that divide the Country into two broad supply/demand systems: the western zone, grouping the Darfur states and part of the Kordofan states, and the central-eastern zone grouping all other states. This information has been useful in the estimation of the fraction of Non Renewable Biomass (fNRB), as described inn Annex 3.

FIGURE 31

Woodshed of major woodfuel demand sites



3.6.1 Supply zones pre- and post-separation

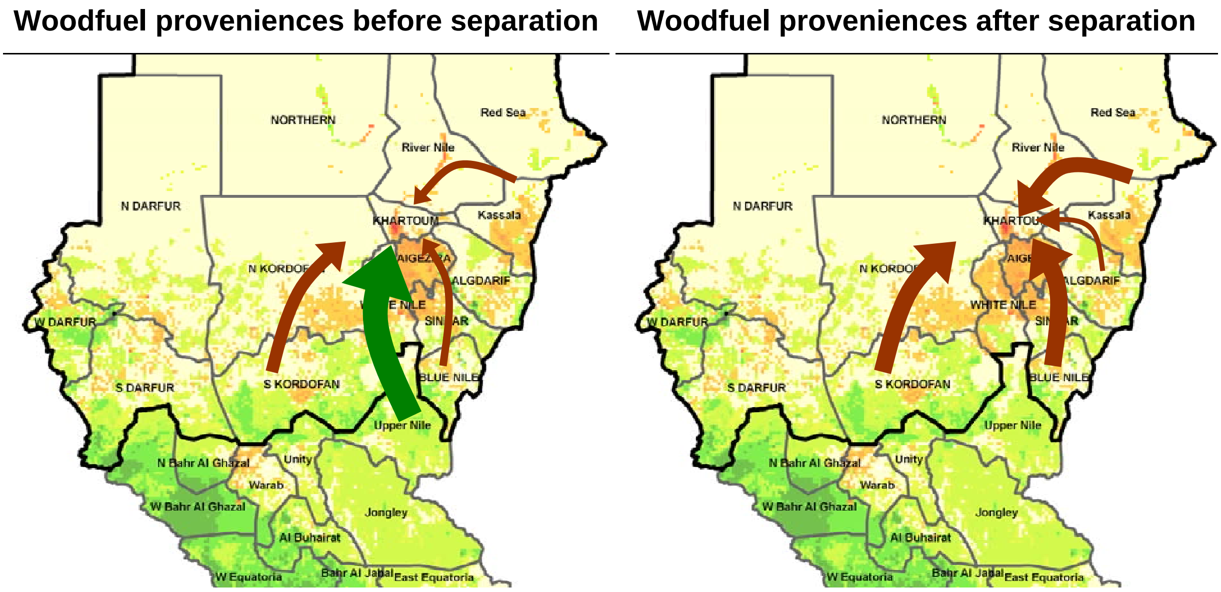
In order to evaluate the impact of the North-South separation on charcoal and fuelwood trade, several woodfuel traders in the major market areas of Khartoum and Omdurman were interviewed. Scope of the interviews was to define the production areas of charcoal and fuelwood before and after the separation.

The traders consistently stated that approximately 50% of the supply of charcoal and fuelwood (mainly dukhan wood) used to come from Upper Nile, now in Southern Sudan. The various provenances before and after the separation of North and South Sudan are presented in Figure 32.

The true impact of the North-South separation will depend on the borders permeability to woodfuels trade, overall import/export policies and their effect on commodities' prices. If borders will remain sealed, the consequence will be the doubling of the pressure on the meager forest resources of Sudan, primarily affecting South Kordofan and Blue Nile.

FIGURE 32

Main proveniences of woodfuel (charcoal and Dukhan, mainly) feeding Khartoum and Omdurman markets before and after separation.



3.7 ESTIMATED FRACTION OF NON RENEWABLE BIOMASS (FNRB)

The estimation of the fraction of Non Reneable Biomass (fNRB) is important in the context of climate-change mitigation initiatives such as the CDM, for the quantification of emission reductions induced by field projects and consequent carbon credits.

The analyis of the fNRB becomes particularly relevant in view of the dramatic change induced by North-South separation on the flow of woodfuels from Upper Nile and from other southern states (now completely halted). What is the cost of the woodfuel self-reliance in terms of carbon emission? and what would be the target of mitigation projects?

The accurate assessment of the fNRB requires detailed information on the supply areas an on the harvesting method. This information is not readily available and is very difficult to obtain.

The WISDOM model provides many elements useful to estimate the fNRB and the Sudan dataset was used to test a new methodology for fNRB assessment. The methodology includes the estimation the "minimum" fNRB (assuming that all resources are rationally managed) and the estimation of the "expectd" fNRB according to prevailing harvesting method. The estimation of the Minimum fNRB is based on the available WISDOM parameters of accessible supply and demand, while the "Expected" fNRB requires the assumption of values for additional parameters that define how rationally the resources are exploited. The analytical steps and assumptions made are described in Annex 4.

The minimum fNRB, estimated considering the sustainable and accessible production potential and assuming optimal resource management is estimated at 29.7 % of all consumed woody biomass. This is obviously optimistic, considering the spontaneous character of most part of the harvesting, but it's a useful reference value for planning targets.

The expectd fNRB, determined by current harvesting practices is very difficult to quantify with precision at this stage. However, based on reasonable assumptions (see Annex 4), a set of values were produced referring to the probable lower, medium and higher range of values, as reported in Table 8. The maps of Locality-level breakdown of fNRB values are shown in Figure 33.

By applying "reasonable assumptions", the expected fNRB at national level may range between 39% and 68%, with wide variability among the states. These values correspond to amount of carbon emissions ranging between 1.9 and 3.4 million tons (assuming C as 50% of dry biomass).

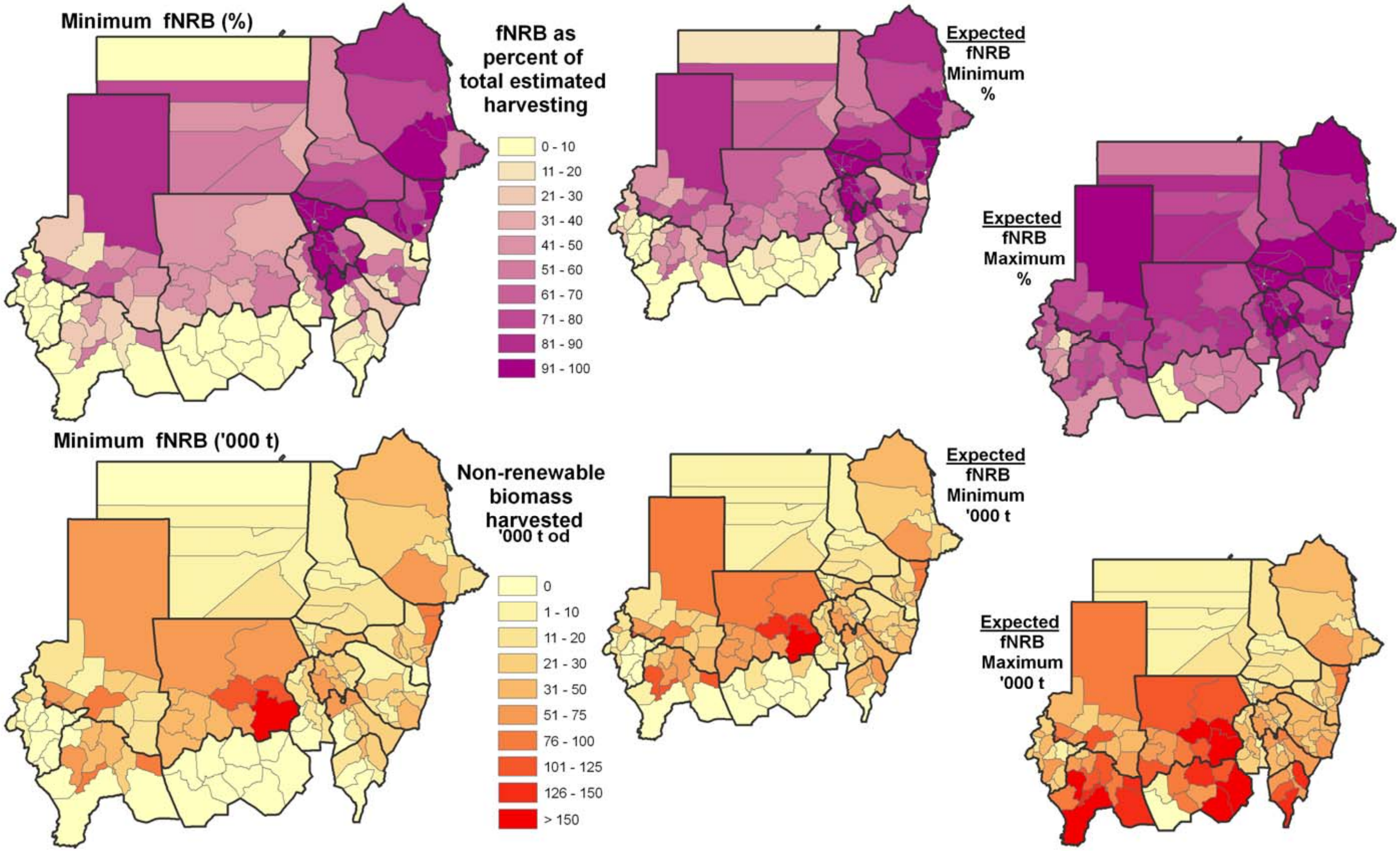
TABLE 8

Estimated fraction of Non-Reneable Biomass (fNRB) under optimal resource management (minimum fNRB) and estimated range of values under current situation (expected fNRB)

	Minimum fNRB		Expected fNRB (%)			Expected fNRB ('000 t)		
			Llower range	Medium range	Higher range	Llower range	Medium range	Higher range
State	**%**	**'000 od t**	**%**			**'000 od t**		
Northern	**46.7**	**32**	**56.4**	**64.9**	**74.6**	**38**	**44**	**50**
River Nile	**72.1**	**52**	**77.2**	**81.4**	**86.3**	**56**	**59**	**62**
Red Sea	**79.4**	**186**	**84.5**	**88.3**	**92.3**	**198**	**207**	**216**
Kassala	**80.6**	**342**	**84.8**	**88.7**	**92.8**	**360**	**376**	**394**
Gedaref	**41.1**	**180**	**56.4**	**67.7**	**79.2**	**246**	**295**	**346**
Khartoum	**93.8**	**93**	**94.8**	**95.4**	**96.3**	**94**	**95**	**96**
Gezira	**86.1**	**222**	**88.6**	**90.7**	**93.2**	**229**	**234**	**241**
White Nile	**32.8**	**80**	**45.7**	**58.8**	**72.3**	**112**	**144**	**177**
Sennar	**45.3**	**198**	**59.1**	**69.2**	**79.7**	**259**	**303**	**349**
Blue Nile	**9.3**	**79**	**25.7**	**45.5**	**65.8**	**220**	**390**	**563**
N. Kordofan	**42.8**	**604**	**56.5**	**67.8**	**79.1**	**798**	**956**	**1,116**
S. Kordofan	0.0	**0**	**2.1**	**20.0**	**44.0**	**40**	**377**	**833**
North Darfur	**56.6**	**499**	**67.2**	**75.7**	**84.2**	**593**	**668**	**743**
West Darfur	**5.3**	**34**	**13.5**	**27.5**	**51.6**	**86**	**177**	**332**
South Darfur	**18.0**	**358**	**28.1**	**40.5**	**64.7**	**561**	**807**	**1,291**
Tot Sudan	**29.7**	**2,961**	**39.1**	**51.6**	**68.4**	**3,890**	**5,132**	**6,809**

FIGURE 33

Fraction of Non-Reneable Biomass (fNRB) under optimal resource management (minimum fNRB) and range of expected values under current situation.



4. CONCLUSIONS AND RECOMMENDATIONS

4.1 FINDINGS AND CONCLUSIONS[7]

4.1.1 Main findings

Demand for woody biomass

The last comprehensive woodfuel use survey in Sudan was done in 1994 (FNC/FAO 1994). It should be emphasized that, for operational and locally-tailored wood energy planning, a nation-wide survey on woodfuel consumption is a fundamental requisite. Nevertheless, considerable knowledge was provided by forestry and energy institutions that was used for the present analysis, integrated by rapid appraisal data collected to fill critical data gaps. Such accreted knowledge supported the following main findings:

- The role of woodfuels in the energy mix of the Sudan has changed considerably since 1994. Overall, the total consumption in 2011, estimated at 16.9 million m^3, is 28% less than the amount that could be expected for the same year if no change had intervened in consumption pattern, with a "saving" of some 6.7 million m^3.
- The main element of change has been the rapid increment of LPG as a substitute to charcoal and fuelwood in urban households, bakeries, oil and soap factories. The most remarkable change appears in the reduced woodfuel consumption in Khartoum and Gezira states, where the estimated annual consumption, i.e. 0.73 and 0.56 million tons, respectively, is only 30% and 40% of the expected woodfuel consumption if no change had intervened.
- Its distribution, however, is unbalanced geographically and socially:
  - high in central states and marginal in peripheral states partly due to transport costs;
  - marginal in rural areas where there is more access and tendency to use fuelwood;
  - marginal in poorest segments of the society who cannot afford the cost of LPG
- In fact, the states with highest woodfuel consumption are South Darfur (2 million tons per year), North Kordofan (1.3 million tons) and North Darfur (1 million tons), which are the populous states where LPG distribution is still marginal.
- The success of LPG distribution in replacing charcoal and fuelwood gives a clear indication of what would be the impact of a drastic reduction of LPG availability. It is most probable that LPG users, in case of absence or excessive price increase, would revert to charcoal and fuelwood. In such case the increase in woodfuel demand would be immediate and proportional to the gap created by the missing LPG.

Woody biomass supply potential

Land cover data

- The preliminary analysis of supply was carried out on the basis of the global map Globcover 2009, while the final analysis was done on the basis of the new map Land Cover 2011. In

[7] Throughout the document the woody biomass consumption refers to the wood in its original status (i.e. fuelwood) or wood-equivalent in case of charcoal, applying a standard conversion factor of 216 kg of charcoal / m^3 of wood (FNC/FAO 1995). Whenever woody biomass is expressed in weight units (tons and kg) the values refer to the oven-dry (od) status, with 0 moisture content, unless otherwise specified.

addition to support given to the analysis, this dual process permitted to evaluate the suitability of Globcover for biomass mapping, when compared to the high resolution Land Cover 2011. In this respect, the main conclusions include:

- In the absence of detail local maps Globcover is a suitable reference for the areas characterized by higher vegetation densities and by higher biomass gradient among land cover types. Globcover shows evident limitations in representing low biomass formations, which are most common in Sudan, where large areas present extremely low annual rainfall.
- Globcover classes for the eastern states seem to be overestimating vegetation densities, when compared to the central and western states, probably due to unbalanced land cover classes. This produces an overestimation of the eastern states, when applied at once over the entire country.

- The new Sudan Land Cover Map (LCCS 2011) well represents the continuous gradient of low density vegetation types that characterize Sudan. To be noted, however, that the dataset is very heavy from a data handling perspective even if it's divided into state-wise datasets. A simplification of the database might be envisaged in order to facilitate users' access and processing.
- The plantation area according to forestry records (African Forest Forum, 2011) is far greater than the areas shown by the map. It is likely that, due to their low density, planted areas have been classified as natural formations. Acknowledging that the mapping of Sudan vegetation is extremely challenging due to the low crown cover of most formations, additional efforts should be put to map forest plantations as accurately as possible.

Stock and productivity data

The last forest inventory was carried out in 1995-1998, which covered 2/3 of the forest resources of today's Sudan. That inventory is still a useful reference for the estimation of woody biomass stock but it did not produce useful data on the annual productive potential. In this context, the estimation of the annual sustainable supply potential can only be approximate. In order to support operational and locally-tailored sustainable forest management it is necessary to conduct a nation-wide survey of woody biomass stock and productivity with reference to the new land cover map.

Supply potential

- The woody biomass stock estimated for the whole of Sudan is 164 million oven-dry tons (or 278 million m^3), which is approximately 15% less than the 1995 stock [8]..
- The total annual productivity of woody biomass (physically and legally accessible) is estimated at 10.9 million tons (18.5 million m^3), or 6.7% of the stock, which is in line with the value of allowable cut indicated by the 1995 NFI inventory report (7%).
- South Kordofan and South Darfur are the states with the highest supply potential, with 3.4 and 2.7 million tons (5.8 and 4.5 million m3), respectively.

Supply/demand balance and woodshed analysis

Local balance

The "local" balance shows an overall national surplus of 0.97 million tons (1.65 million m^3), but shows deficit conditions in all states of Sudan except for Blue Nile, South Kordofan, West Darfur and South

[8] The 1995 FNC/FAO inventory estimated a total stock of 166.5 million m^3 for the area covered by the survey, which was 65.5 % of the total forest areas. The current stock for the same area is estimated at 142.7 million m^3, i.e. 14.5% less than that of 1995, which seems reasonable on account of the deforestation and forest degradation processes that has most likely taken place over the past 15 years The annual rate of deforestation over the period 1995-2010 for the (Greater) Sudan was estimated at 0.8%, with a decreasing trend (African Forest Forum, 2011). No estimates are availableon forest degradation rate.

Darfur. The local balance, calculated within a 6-km horizon, represents well the rural context but cannot represent the urban context where supply chains are always commercial and the production sites are often far apart. Local balance is particularly suited for the analysis of subsistence energy status of rural populations and for the assessment of surplus amounts potentially available to feed commercial supply chains.

Commercial balance

Scope of “commercial” balance analysis is to indicate the quantity and the distribution of biomass resources potentially available, and suitable, for commercial woodfuels production. In the absence of true economic parameters relative to the minimum economically viable stock levels, a preliminary “sensitivity” analysis was done by applying three minimum surplus thresholds. The results show that:

- With a minimum surplus of 100 kg/ha/yr remaining after local consumption (that may produce 1.5 od t or 2.55 m^3 per hectare on a 15-years rotation), the “commercial” balance shows an overall deficit of 0.9 million od tons (1.5 million m^3). This indicates that, in principle, if all national wood resource that guarantee more than the set threshold are put under intensive management (see maps), the country’s production could satisfy 91% of the national demand on a sustainable basis, while at least 9% should be imported or replaced by other fuels.
- With a minimum surplus of 150 kg/ha/yr (2.25 od t or 3.8 m^3 per hectare on a 15-years rotation), the overall national deficit rises to 1.97 million od tons (3.3 million m^3). In this case, the country’s production could (again, if intensively managed) satisfy 80% of its demand on a sustainable basis, while at least 20% should be imported or replaced by other fuels. The productive areas are located in the southern part of West Darfur and South Darfur, the whole of South Kordofan and Blue Nile.
- With a minimum surplus of 200 kg/ha/yr (3 od t or 5 m^3 per hectare on a 15-years rotation), the national deficit rises to 3.3 million od tons (5.6 million m^3). With this threshold, only two states present a positive balance (South Kordofan and Blue Nile). In this case, the country’s production could satisfy 67% of its demand on a sustainable basis, while at least 33% should be imported or replaced by other fuels.

It is now necessary to verify the economic viability of the various situations with local operators and managers and to define the true “economically viable” resource potential. This will reveal the quantity of woody biomass that cannot be produced commercially and that must be produced from other sources (i.e. new plantations) or imported, or that must be deducted from the demand through alternative fuels, FES programmes, etc.

The role of imported woodfuels.

Prior to separation, it is estimated that some 50% of the charcoal and fuelwood sold in the main urban markets of Khartoum State were produced in Upper Nile or other southern states. If this fraction is applied to the consumption of urban households and to that of commercial and industrial sectors of the “low-forest” states of today’s central and eastern Sudan (Northern, River Nile, Red Sea, Kassala, Gedaref, Khartoum, Gezira, White Nile and Sennar), it may be estimated that the flow of woodfuels from southern states prior to separation was in the order of 0.9 million tons, or 1.5 million m3 (wood-equivalent).

Considering that the situation of Sudan’s forests and woodlands before the separation was far from sustainable even with such south born flow, it is clear that the future import quantities should be well above and probably in the order of 648,000 tons of charcoal (3 million m^3 wood equivalent).

Woodfuel import potentials.

South Sudan. There is no doubt that South Sudan remains the most obvious source of supply. According to the regional WISDOM analysis based on Africover data (Drigo, 2005) it appears that the South Sudan has an annual surplus potential of woody biomass (in excess of its own consumption) that could double, or even more, the whole consumption of the Sudan.

Ethiopia. According to the Ethiopia biomass survey of 2002, the zones along the border with Gedaref and Kassala presented a significant annual surplus of woody biomass in 2000 (Amhara Regional State, 2002; Tigray Regional State, Ethiopia. 2003). Such surplus was estimate to be approximately 1.5 million tons in North Gonder (Semen Gonder) of Amhara Region and approximately 0.2 million tons in Western and Nortwestern Tigray. It is likely that such surplus may be at least in part available for export to Sudan.

Central Africa Republic. According to the Rapid WISDOM Appraisal done over C.A.R. (FAO 2009), the provinces of Ouadda and Yalinga, in the Haute-Kotto, show a surplus potential of approximately 2.5 million tons, (or 4.2 million m^3). These resources could be, at least in part, available for export to South Darfur, although they are located at 300 to 500 km from the Am Dafok border point.

The above shows that the "technical" potential in neighboring countries is more than adequate to fill the sustainable production gap of the Sudan. The main problem is the economic accessibility of these supply sources and, most important, their political accessibility. One more issue that would greatly benefit from peace and stability along the southern borders of the Country.

Priority target areas and communities (subsistence energy issue)

The integration of supply/demand balance with poverty-related indicators permitted the stratification of the population of the Sudan into what we may call subsistence energy categories. This analysis permitted the identification of communities that suffer from concomitant conditions of serious woodfuel deficit and high poverty, which are causes of extreme vulnerability and of structural food insecurity problems.

The rural communities that cannot afford commercial fuels and that depend primarily on the gathering of locally available wood resources for their daily needs are those that suffer most from a negative local balance. The analysis permitted to quantify the deficit that need to be filled in and to identify the target communities that need to be assisted with priority through fuel efficient stove programmes and subsidized alternative fuels. Results of this analysis, showed that:

- 7.6% of the rural population of the Country, i.e. some 1.6 million people, live simultaneous conditions of extreme poverty and high to critical woodfuel deficit. Main locations are in the southwestern part of North Darfur and neighboring areas of South Darfur.
- Another 13.3 % (2.8 million) live marked poverty conditions and medium-high woodfuel deficit. This analysis clearly shows structural problems as poverty is related to many underlying causes, including energy consumption. Located mainly in North Darfur, northern Sennar and neighbor areas in White Nile and Gedaref, and central-eastern Kassala.

Fraction of Non Renewable Biomass

The WISDOM dataset was used to test a new methodology to estimate the fraction of Non Renewable Biomass (fNRB). The minimum fNRB, considering the sustainable and accessible production potential and assuming optimal resource management, is estimated at 29.7 % of all consumed woody biomass. This is obviously optimistic, given the spontaneous character of most part of the harvesting, but it's a useful reference value for planning purposes.

The true fNRB, determined by actual production areas and by current harvesting practices, is difficult to quantify with precision. By applying "reasonable assumptions", the expected fNRB at national level may range between 39% and 68%, with wide variability among the states. These values correspond to amount of carbon emission ranging between 1.9 and 3.4 million tons (assuming 50% of dry biomass).

4.1.2 Main conclusions

- The secession of Sudan magnified Sudan's energy security issues. Wood energy has always been a major issue in Sudan, being the only affordable energy for the majority of its people, especially in rural areas, and being the most important product of Sudan's forests and woodlands. The Sudan/South Sudan separation made this issue far more serious. For the Sudan, the separation and the current impasse on border traffic meant the disconnection with its traditional supply sources.

- Previous in-flow of woodfuels from southern regions is tentatively estimated at 1.5 mln m^3. The interruption of such flow further aggravates the unsustainable pressure on the limited resources of the Country
- This study reviews the country's capacity for self-sufficiency on woody biomass in the new geo-political context, based on the knowledge available in Sudan and shared by all institutions. WISDOM only provided the analytical context.
- WISDOM Sudan provides a comprehensive vision of the new situation with geo-referenced quantitative information supporting the formulation of sound policies and decision making.
- The true economic viability of sustainable commercial wood energy systems need to be carefully assessed.
- However, a preliminary evaluation of the economically accessible resources indicates that there is a large gap between the woody biomass that the country can presently produce on a sustainable basis and the current demand for woodfuels.
- Such gap[9] is in the order of 2 million tons, or 3.3 million m^3, which is approximately 1/5 of the current consumption. This is cause of a series of negative consequences, including: overexploitation of forest and woodlands, high carbon emission rates, increasing price of woodfuels and subsistence energy scarcity and increased vulnerability for the poorest segments of the population in deficit areas.
- All states show a marked deficit situation even under best-management scenario, except for South Kordofan, Blue Nile West and South Darfur

Regional characters and policy options

It is evident from the analysis conducted that there is no single-variable solution to the wood energy equation. The situation is so tight that the efforts aiming at sustainable wood energy must be oriented in all possible directions with clear territorial priorities and wide institutional synergies.

The geo-referenced results of the WISDOM analysis support the formulation of locally tailored strategies, down to Locality or even to IDP camp context. However, for broad policy orientation, the grouping of states by homogeneous wood energy features may help the definition of main policy options.

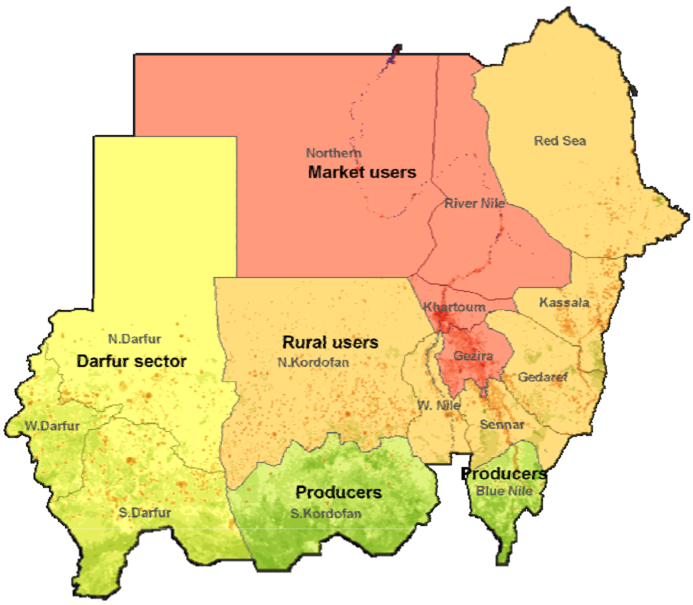
As shown in Figure 34, the states may be grouped into four categories, representing quite distinct supply and demand characteristics and requiring differing policy objectives:

The rationale for the regional grouping of states is summarized in Table 9. as follows:

Market users: These states (Northern, River Nile, Khartoum and Gezira) have marginal production capacities (unless massive irrigated plantations are established) and a decreasing demand

FIGURE 34

Grouping of states by homogeneous wood energy features



[9] Defining the true dimension of such gap requires the definition of the economic and environmental accessibility of open and sparse woodlands. Depending on the assumptions made, the gap ranges between 0.9 and 3.3 million tons (1.5 – 5.6 million m^3).

for woodfuels. They depend entirely on marketed fuels and the saturation of LPG is highest in both rural and urban areas. The woodfuel gap is estimated at 1.4 million tons or 2.4 million m^3. Main policy options for these states is to continue in the promotion of LPG and of renewable energy alternatives (hydro-electricity, solar, wind) and to secure imported charcoal. The main risk is a decrease of the LPG fraction due to dwindling availability or price increase would immediately turn into a steep increase in charcoal demand.

Rural users: These states (Red Sea, Kassala, Gedaref, White Nile, Sennar and N. Kordofan) have very high demand for woodfuels but limited supply potential represented in good part by sparse vegetation below market value. LPG penetration is significant in urban areas but still low in rural areas. The woodfuel gap is estimated at 2.6 million tons or 4.5 million m^3.The Main policy option for these states is to reduce the demand through stronger promotion of LPG and of renewable energy alternatives (hydro-electricity, solar, wind), dissemination of fuel-efficient stoves (FES) and to secure imported charcoal and fuelwood from "Producers" states, South Sudan and from Ethiopia. The biomass resources in these states are under high risk of degradation and the main management objectives should be protection, regeneration of depleted forest zones and plantations establishment.

Producers : These states (Blue Nile and S. Kordofan) have a relatively low demand and a high supply potential. The penetration of LPG is minimal in urban areas and non-existent in rural areas. The estimated commercial surplus is 2.8 million tons or 4.8 million m^3. The main policy option for these states is to strengthen the sustainable and participatory management of their forests for production purposes. From the demand side, FES dissemination programmes are recommended, in view of the health benefits more than to the reduced consumption.

Darfur sector : The Darfur states present different balance situations (negative in the North and positive in the West and South) but they are part of the same common context and somehow secluded from the rest of the Country. Both demand and supply potential are very high. LPG penetration is marginal in urban areas and non-existent in rural areas. The overall (commercial) balance shows a deficit of 0.7 million tons or 1.2 million m^3. The main policy options for these states are to strengthen the sustainable and participatory forest management in the South and West and to reduce the demand in the North (but also in urban areas of West and South) through strong promotion of LPG and of renewable energy alternatives (solar, wind), dissemination of fuel-efficient stoves (FES) and to secure imported charcoal and fuelwood from South Sudan and from C.A.R. The biomass resources in North Darfur (but also some areas of South and West) are under high risk of degradation and the main management objectives in these areas should be protection, regeneration of depleted forest zones and plantations establishment.

TABLE 9

Grouping of states by homogeneous wood energy features and main demand, supply and balance parameters.

	States	LPG penetration (hh sector)	Demand 2011	Accessible supply	Local balance	Commercial balance "surplus>150"
			'000 od t	'000 od t	'000 od t	'000 od t
Market users	Northern; River Nile; Khartoum; Gezira	Urb: 64-90 Rur: 68-76	1,505	100	-1,411	-1,433
Rural users	Red Sea; Kassala; Gedaref White Nile; Sennar; N. Kordofan	Urb: 30-63 Rur: 1-46	3,675	2,160	-1,511	-2,638
Producers	Blue Nile S. Kordofan	Urb: 4-21 Rur: 0.2-0.4	1,049	4,332	3,281	2,822
Darfur sector	N. Darfur; W. Darfur; S. Darfur	Urb: 2- 8 Rur: 0-0.1	3,726	4,333	606	-725
Sudan			**9,954**	**10,926**	**967**	**-1,974**

Institutional settings and wood energy planning capacities

The WISDOM analysis was implemented in the framework of the Sudan Institutional Capacity Program: Food Security Information for Action (FAO-SIFSIA) and the Food Security Technical Secretariat (FSTS-MoAI) in collaboration with the Sudan's Forests National Corporation (FNC).

The contribution of many institutions and agencies has been essential for the development of the study. Besides the new land cover map and limited additional data collection with direct SIFSIA assistance, the analysis is based on knowledge available in Sudan and shared by institutions and agencies. WISDOM only provided a coherent analytical context.

In particular, the collaboration and participation of FNC to the study has been strong throughout the development of WISDOM Sudan. FNC contribution included the sharing of existing inventory and woodfuel consumption data, the collection of additional information and the technical knowledge offered at numerous meetings. Two training workshops were held at FNC HQ, one on the technical aspects of WISDOM Modules' development and a final one on the findings and policy implications. Both workshops saw the participation of 80-over participants representing all FNC State Offices and all concerned technical Units of FNC HQ, as described in Annex 7.

As stated by FNC Director at the joint SIFSIA-FNC cross-sectoral meeting held at the Ministry of Agriculture and Irrigation on 1st March 2012, this study will strongly contribute to the formulation of the 20-years energy master plan that FNC, the Ministry of Petroleum, the Ministry of Finance and other institutional stakeholders are in the process to formulate.

The two WISDOM training workshops held at FNC permitted a thorough exchange on the WISDOM methodology in the Sudanese context. It should be emphasized, however that a full appropriation of the tool requires further training and capacity building on GIS and statistical data management, which are necessary for the maintenance and update of the geo-statistical database.

4.2 RECOMMENDATIONS

4.2.1 Sudan's wood energy

- All Sudan States must join efforts for a common Wood Energy Strategy (no separate solutions seem feasible) keeping in due consideration the variety of local conditions.
- An effective Strategy must address all sectors of use in all states: all compete for the same resource
- Major concerted and simultaneous efforts are needed, including :
  - Improving the sustainability of production (forest management, efficient charcoal making, new planting areas, promote agro-forestry, etc.).
  - Reducing the demand for woodfuels (FES programmes, promotion of affordable fuel alternatives, substitute clay bricks with Stabilized Soil Block (SSB) or cement bricks, poles with bamboo, etc.)
  - Maximize wood import potentials. Establishing as soon as possible a mutually beneficial woodfuel import/export policy with South Sudan and explore/develop import routes with Ethiopia and Central Africa Republic.

All actions must be pursued concurrently, but their positive effects come at different points in time.

Recommended actions effective in the <u>short/medium term</u> include:

- In the short term, importing of quantities of charcoal seems the most efficient measure to keep the pressure on internal resources within manageable limits. Import woodfuels from neighboring countries, mainly S.Sudan, which has traditionally been the main and major source of woodfuels
- Promotion of alternative energy sources (LPG, solar, wind). The promotion of LPG to urban households of all states may be relatively rapid, if financial resources are adequate to maintain subsidies and to guarantee distribution costs at a minimum. In this respect, seen the current unequal distribution of LPG among the states, it is recommended to review the subsidy system in order to include distribution cost and thus to benefit equally all potential consumers. It should be clear, however, that this action requires large amounts of LPG and that the current oil and LPG production crisis poses serious constraints to the viability of this solution.
- Brick making is the industrial activity that consumes large quantities of fuelwood. It is highly recommended, and urgent, to promote alternatives to clay bricks as building materials, such as SSB and cement bricks
- Undertake Fuel Efficient Stove programs in rural and urban areas, giving priority to the areas showing marked deficit conditions. The impact of FES programmes in rural and periurban areas may be more time demanding, although the benefits on health in this case go well beyond the simple reduction of fuelwood consumption.
- Define priority areas of intervention in a cross-sectoral analytical context and prepare a folder of project proposals for donors' consideration, as intended by the programme Natural Resources Management for Food and Nutrition Security in Darfur promoted by TCE, FAO.

Recommended actions effective in the <u>medium/long term</u> include:

- Participatory forest management is an absolute priority, as it aims at protecting the resource from current threats while assuring the continuity of the benefits to both producers and consumers. Sustainable woodfuel production practices should be pursued in connection to returnees and resettlement programs, where resources are adequate (WISDOM surplus areas), aiming at the creation of rural woodfuel markets as source of livelihood.

It is a major challenge, requiring considerable investments for a variety of actions, including:

- o conflicts resolutions in many areas and particularly in good part of the potentially productive areas;
- o definition of land tenure and access rights policies at local scale in all intervention areas;
- o local biomass inventories based on the new land cover data (in alternative to a new National Forest Inventory);
- o awareness raising (including cultural changes), participative planning and training of local operators; etc.

- Plantations and private woodlots establishment and agro-forestry programs to increment local self-sufficiency are highly recommended. New planting and agro-forestry programs should be undertake in the areas surrounding IDP camps (hopefully abandoned) and urban areas which were degraded and deforested due to woodfuel overexploitation.
- Prepare cross-sectoral resource management master plans including forestry, livestock and agriculture, energy and poverty reduction, and other relevant planning sectors. Local operational management plans should be prepared in the framework of the comprehensive master plan and in synergy with local stakeholders

In order to cope with this major challenge it is essential to reduce the current pressure on the resource as much as possible and as soon as possible through all actions aiming at reducing the demand.

Institutional synergies

There is a deep nexus among :

- o subsistence energy
- o Livelihood
- o sustainable forestry
- o livestock management and farming,

- … that cannot be dealt with separately but that call for cross-sectoral locally-tailored strategies in a shared analytical context.
- Synergies among institutions and agencies for an integrated cross-sectoral approach are strongly recommended. The priority areas of intervention must be defined in a shared analytical context and not in a sector-wise isolation. An excellent reference in this respect is the programme Natural Resources Management for Food and Nutrition Security in Darfur promoted by TCE, FAO. The same approach should be expanded to the whole of Sudan.

4.2.2 WISDOM model and wood energy planning

Wood energy knowledge base

- The development of WISDOM Sudan implied many assumptions and tentative value attributions that need validation on the basis of new reference data. In order to acquire reliable and up-to-date information, it is recommended to thoroughly update the National Forest Inventory and the Forest Products Consumption Survey.
- Concerning the Demand Module, data collection efforts must be concentrated with priority on the following aspects:
  - o Update consumption rates and trends in the residential and industrial sectors, with special attention to brick making.
  - o Monitor IDP returnees in order to keep track of the dynamics of woodfuel demand in

Darfur

- Ascertain the sources of the main woodfuel markets

- Concerning the Supply Module, data collection efforts must be concentrated with priority on the following aspects:
  - Assess productivity of tree and shrub formations by ecological zones (through permanent sample plots and rapid re-growth surveys on harvested sites)
  - Assess the economic accessibility of wood resources and the basic requirements of sustainable woodfuel production systems in the typical socio-economic and environmental contexts of Sudan. These parameters will be used to fine-tune the WISDOM analysis in order to determine the limits of the “management” option and to define with precision the target of alternative strategies aiming at reducing the demand and increasing the supply.
  - Identify and monitor the current woodfuel production areas (currently unrecorded)
  - Carry out a comprehensive land cover monitoring analysis in order to asses the rate of deforestation and forest degradation and reveal the cause-effect mechanisms. The analysis should be done with reference to the new Land Cover Map using additional multi-temporal satellite data and applying inter-dependent interpretation procedures (FAO 1997).
  - Assist FNC and State Land Commissions in the efforts of digitizing all Forest Reserves of Sudan in order to clarify and/or define access rights and governance issues and support planning.
- Concerning the Institutional capacities cross-sectoral synergies, it is recommended to:
  - Consolidate the dialogue between the Forests National Corporation and all other institutional stakeholders, including the Ministry of Energy, CBS, Physical Planning, Building Research, etc. Operational synergies are strongly recommended, especially in the design and execution of woodfuel demand surveys.
  - Collaborate with the Ministry of Trade on import of woodfuels from neighboring countries (Ethiopia, S. Sudan, CAR).

<u>Wood energy planning capacities</u>

- In order to improve the visibility and impact on planning and policy formulation, it is recommended to define and implement a communication strategy. Such strategy should include the following:
  - Prepare a summary publication on WISDOM Sudan for wide dissemination addressing policy makers.
  - Conduct state-level workshops to present main findings, discuss the assumptions made and define follow-up actions aiming at the appropriation of the WISDOM tool by state-level institutions and agencies
  - Promote cross-sectoral dialogue and the establishment of an inter-institutional / inter-agencies working group (WISDOM Team) at both technical and policy level through thematic workshops (starting from the individual and agencies already involved). Scope of such events will be promoting cross-sectoral policy formulation and project planning and sharing/strengthening the knowledge base for decision making
- SIFSIA is the repository of WISDOM geo-statistical data set. In order to assure efficient data sharing and transparency, it is recommended to define an operational data handling and storage policy. In order to do that, the SIFSIA Programme will need GIS and database management capacities and training vocation in order to facilitate capacity building along with data dissemination.
- In order to keep the WISDOM analysis “alive” and to make it effective for future planning, it is recommended to convert the current prototype into a structured information system including

protocols for update and maintenance and a user-friendly interface for consultation and querying by non-technical users.

- Design capacity building actions aiming at strengthening institutional planning capacities at national and state levels on planning tools and sustainable resource management and the full appropriation of the WISDOM experience by the relevant national and state government entities.
- In particular, it is recommended to support the strengthening FNC capacities on forest inventory and management, energy demand/supply studies and remote sensing/GIS technology at central and state levels.

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ANNEXES

ANNEX 1: PRIMARY FUEL USED FOR COOKING BY URBAN AND RURAL HOUSEHOLDS

TABLE A1.1

Primary fuel used for cooking by urban and rural households. Values from SHHS and SHBS surveys and estimates for 2008 (census year) and for 2011.

Urban	LPG					Charcoal					Fuelwood				
	SHHS 2006	SHBS 2009	SHHS 2010	Estim. weighted on sample size		SHHS 2006	SHBS 2009	SHHS 2010	Estim. weighted on sample size		SHHS 2006	SHBS 2009	SHHS 2010	Estim. weighted on sample size	
	2006	2009	2010	2008	2011	2006	2009	2010	2008	2011	2006	2009	2010	2008	2011
Northern	51.8	87.6	78.1	**68.7**	**87.8**	24.5	1.5	2.0	**11.8**	**0.9**	22.1	10.9	17.0	**17.9**	**10.8**
River Nile	90.9	86.6	91.9	**90.2**	**89.2**	3.5	4.2	3.9	**3.8**	**4.2**	4.0	9.2	3.1	**4.9**	**6.3**
Red Sea	52.4	45.4	30.7	**43.7**	**30.6**	42.5	51.2	63.5	**51.4**	**64.7**	2.2	2.3	5.2	**3.2**	**4.7**
Kassala	41.7	55.6	43.7	**45.6**	**51.3**	44.2	28.7	44.9	**40.9**	**35.9**	12.9	15.6	10.9	**12.9**	**12.9**
Gadarif	21.4	40.1	60.1	**38.3**	**63.8**	68.3	33.7	33.4	**48.9**	**19.9**	10.1	22.0	6.4	**11.7**	**14.0**
Khartoum	78.3	87.8	86.3	**83.1**	**88.4**	16.4	11.2	13.2	**14.2**	**10.6**	2.0	0.3	0.0	**1.0**	**1.0**
Gezira	82.4	82.0	60.5	**75.1**	**64.2**	15.4	14.7	38.1	**22.7**	**33.6**	1.2	3.3	0.2	**1.4**	**1.6**
White Nile	57.0	67.1	55.4	**58.8**	**61.4**	35.9	22.4	37.6	**33.3**	**29.4**	2.3	10.5	4.8	**5.0**	**9.1**
Sinnar	37.9	56.0	41.5	**43.3**	**50.8**	52.8	37.3	44.9	**46.6**	**37.1**	7.0	6.7	13.6	**9.1**	**12.1**
Blue Nile	8.4	18.6	17.5	**13.7**	**21.8**	61.0	48.1	68.7	**60.5**	**59.9**	30.2	33.3	13.6	**25.5**	**18.4**
N. Kordofan	29.3	40.9	27.7	**31.5**	**34.7**	53.9	46.2	60.5	**54.3**	**54.8**	15.7	12.9	10.7	**13.4**	**10.0**
S. Kordofan	3.0	3.1	4.4	**3.5**	**4.2**	53.8	42.7	65.1	**54.9**	**56.6**	41.1	53.3	28.3	**39.7**	**37.7**
North Darfur	4.3	7.4	6.8	**5.8**	**8.1**	30.9	26.0	47.6	**35.3**	**41.7**	64.1	66.6	43.8	**58.0**	**49.0**
West Darfur	0.0	0.0	2.1	**0.7**	**1.8**	16.1	27.9	32.4	**24.2**	**36.2**	79.9	72.1	60.3	**71.7**	**59.3**
South Darfur	4.8	5.4	6.9	**5.7**	**6.9**	52.8	64.7	68.9	**60.8**	**72.8**	42.3	29.9	24.2	**33.5**	**20.3**
Total Urban	52.8	61.6	56.2	**55.9**	**60.6**	29.8	25.2	34.0	**30.1**	**30.6**	15.2	12.6	8.9	**12.5**	**8.6**

Rural	2006	2009	2010	2008	2011	2006	2009	2010	2008	2011	2006	2009	2010	2008	2011
Northern	42.4	52.8	67.7	**53.1**	**68.7**	3.6	1.6	0.9	**2.2**	**1.0**	51.2	45.6	29.8	**42.9**	**30.3**
River Nile	71.0	66.9	69.4	**69.5**	**67.3**	2.3	1.7	1.6	**1.9**	**1.4**	25.4	31.2	25.4	**26.7**	**28.7**
Red Sea	3.2	0.0	2.4	**2.2**	**0.6**	21.1	37.1	42.1	**31.6**	**45.2**	59.2	60.1	55.4	**58.2**	**53.9**
Kassala	11.6	4.3	11.5	**9.9**	**7.4**	7.5	9.8	13.1	**9.9**	**13.4**	77.5	83.3	72.3	**77.2**	**76.6**
Gadarif	13.0	9.6	11.0	**11.6**	**9.4**	25.0	18.4	31.4	**25.6**	**26.5**	56.6	71.0	54.5	**59.2**	**63.1**
Khartoum	67.9	69.3	76.5	**71.0**	**75.7**	17.3	9.9	9.1	**12.9**	**6.3**	12.1	19.0	13.7	**14.2**	**17.4**
Gezira	69.1	59.0	75.7	**69.0**	**68.7**	17.8	15.5	10.9	**15.0**	**10.9**	9.7	22.4	9.7	**12.6**	**17.0**
White Nile	35.2	36.5	48.1	**39.7**	**46.5**	14.7	8.8	17.9	**14.4**	**13.9**	40.1	47.3	25.6	**37.0**	**32.4**
Sinnar	24.0	20.7	23.7	**23.1**	**21.9**	30.0	20.5	27.8	**27.1**	**22.7**	37.0	52.5	46.2	**43.6**	**53.5**
Blue Nile	0.1	0.2	0.1	**0.1**	**0.2**	18.4	13.2	15.9	**16.4**	**13.4**	81.0	86.4	82.5	**82.7**	**85.3**
N. Kordofan	2.1	1.1	6.4	**3.3**	**5.0**	7.6	0.9	16.0	**8.8**	**10.6**	89.2	96.9	76.9	**87.0**	**83.6**
S. Kordofan	0.2	0.0	0.6	**0.3**	**0.4**	10.0	4.9	14.4	**10.3**	**10.6**	88.7	95.1	84.3	**88.8**	**88.8**
North Darfur	0.3	0.0	0.3	**0.2**	**0.1**	1.4	0.4	3.3	**1.8**	**2.4**	96.3	99.6	95.3	**96.7**	**97.3**
West Darfur	3.0	0.0	0.0	**1.3**	**0.0**	1.8	1.3	1.6	**1.6**	**1.4**	88.1	98.3	89.1	**90.7**	**94.8**
South Darfur	0.3	0.0	0.0	**0.1**	**0.0**	5.8	1.6	1.2	**3.3**	**1.0**	93.7	98.4	98.8	**96.4**	**99.0**
Total Rural	23.5	22.7	27.4	**24.6**	**26.2**	12.1	8.7	11.9	**11.2**	**9.9**	61.0	66.7	58.3	**61.4**	**62.0**

Note: Percent of households using LPG, charcoal or fuelwood as primary cooking fuel. The sum of the fuels may not add to 100 due to the use of other fuels (i.e. electricity, biogas, kerosene, etc.).

ANNEX 2: LAND COVER CLASSES AND ASSOCIATED WOODY BIOMASS STOCK AND MAI

1- Globcover 2009

Global Land Cover Map GlobCover

GlobCover is an initiative of the ESA, which began in 2005 in partnership with the JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. The project GlobCover has developed a service capable of delivering global composite cover maps using data at 300m resolution MERIS sensor aboard the satellite ENVISAT.

GlobCover is the global map of land cover with higher resolution (300 meters) ever produced and independently validated. GlobCover composites are derived from pre-processing module of GlobCover, which includes a set of corrections (cloud detection, atmospheric correction, geolocation and re-mapping). The card is compatible with the GlobCover classification system "Land Cover Classification System (LCCS)" developed by the UN FAO. Currently, ESA offers a range of products covering two periods: December 2004 - June 2006 and January-December 2009.

For more information see Arino et al., 2007 and Bicheron et al. See GlobCover Portal: http://ionia1.esrin.esa.int/

Global map of tree density MODIS Tree Cover map

(Hansen et al., 2003)

The global map of the density of trees (MODIS Tree Cover map) at 500 m resolution is a product of the application of the algorithm Vegetation Continuous Fields (VCF) data from the sensor MODIS (Moderate Resolution Imaging Spectroradiometer).

VCF products are map layers representing proportional estimates global properties of the vegetation base. Base layers include percent cover of trees, herbaceous / shrub and bare ground. The methodology retains details VCF improving the representation of heterogeneous landscapes compared to other classification methods.

TABLE A2.1

Globcover 2009 – original classes and class aggregations

GC_code	Globcover 2009 classes	Aggr. code	Aggregation	Ha
11	Irrigated croplands	1	crops	1,787,167
14	Rainfed croplands	1	crops	2,579,562
20	Mosaic Croplands/Vegetation	2	vegetation/crop	6,516,029
30	Mosaic Vegetation/Croplands	2	vegetation/crop	13,798,609
40	Closed to open broadleaved evergreen or semi-deciduous forest	3	natural vegetation	919
60	Open broadleaved deciduous forest	3	natural vegetation	249,522
90	Open needleleaved deciduous or evergreen forest	3	natural vegetation	165
110	Mosaic Forest-Shrubland/Grassland	3	natural vegetation	22,216,021
120	Mosaic Grassland/Forest-Shrubland	3	natural vegetation	1,515,835
130	Closed to open shrubland	3	natural vegetation	3,842,006
140	Closed to open grassland	4	grassland / bare land	20,450,619
150	Sparse vegetation	3	natural vegetation	8,640,618
160	Closed to open broadleaved forest regularly flooded (fresh-brackish water)	3	natural vegetation	9,353
180	Closed to open vegetation regularly flooded	3	natural vegetation	77,379
190	Artificial areas	4	grassland / bare land	247,594
200	Bare areas	4	grassland / bare land	113,782,285
210	Water bodies	5	water	358,941

TABLE A2.2

Globcover 2009 – Mean stock values by class aggregations

zst_gc09recl5r3_w_pl_stkkg.dbf)

Aggregation	Rainfall zone	Western states			Eastern states		
		Sampling units	MEAN stock (od t ha)	Applied stock values (od t/ha)	Sampling units	MEAN stock (od t ha)	Applied stock values (od t/ha)
1 crops	Low rainfall zone	13	0.6	**0.6**	142	0.0	**0.0**
	Medium rainfall zone	128	2.9	**2.9**	2	0.0	**0.0**
	High rainfall zone	56	4.9	**4.9**	1	1.6	**1.6**
2 veg/crop	Low rainfall zone	231	0.9	**0.9**	11	0.0	**0.0**
	Medium rainfall zone	756	2.4	**2.4**	13	0.3	**0.3**
	High rainfall zone	258	5.6	**5.6**	37	3.0	**3.0**
3 nat veg	Low rainfall zone	502	0.7	**0.7**	128	0.0	**0.0**
	Medium rainfall zone	300	1.7	**1.7**	185	0.5	**0.5**
	High rainfall zone	221	6.0	**6.0**	160	2.1	**2.1**
4 grass/bare	Low rainfall zone	1002	0.4	**0.0**	282	0.1	**0.0**
	Medium rainfall zone	103	1.2	**0.8**	126	0.5	**0.4**
	High rainfall zone	3	4.5	**1.0**	18	1.1	**1.0**
5 water	All Rainfall zones	6	0.0	**0.0**	2	0.0	**0.0**

FIGURE A2.1

Grouping of eastern and western states applied in the estimation of woody biomass stock on the basis of Globcover 2009.

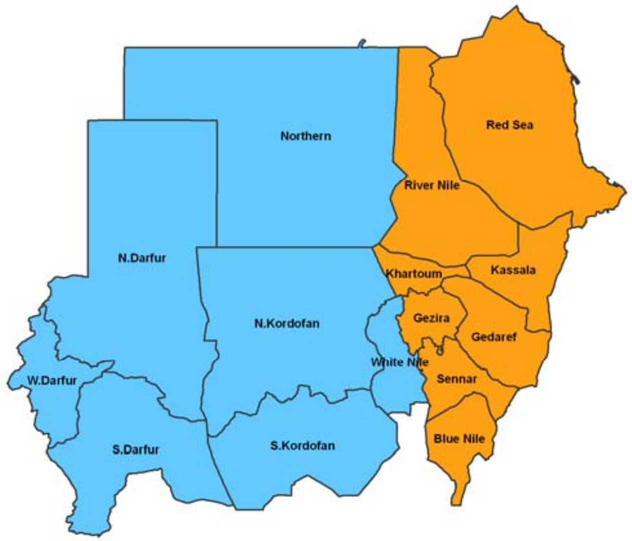

TABLE A2.3

LCCS 2011 – Mean stock and mean annual increment (MAI) values by class and by rainfall zone

A11 - Cultivated and managed terrestrial areas				Woody biomass stock (od t ha^{-1})			Medium MAI (od t ha^{-1}yr^{-1})		
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**Low rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**Low rainfall zone**
Rainfed Herbaceous Large (> 5 ha) Fields	1HL	11436-11341	101	-	-	-	-	-	-
Large Rainfed Herbaceous Crop(s) + Sparse Trees	1HL+2TS	11436-11341 + 20053	102	1.84	1.40	0.97	0.20	0.18	0.15
Permanently Cropped Area With Surface Irrigated Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop Sequentially)	1HLi	11239-11376	103	-	-	-	-	-	-
Large surface irrigated Herbaceous Crop(s) with Sugar Cane dominant crop	1HLiSC	10835-11968-S0915	106	-	-	-	-	-	-
Rainfed Herbaceous Medium (2-5 ha) Fields	1HM	11436-11971	107	-	-	-	-	-	-
Rainfed Herbaceous Medium (2-5 ha) Fields + Sparse Trees	1HM+2TS	11436-11971 + 20053	108	0.58	0.44	0.30	0.09	0.07	0.05
Permanently Cropped Area With Surface Irrigated Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop Sequentially)	1HMi	11239-12006	109	-	-	-	-	-	-
Rainfed Herbaceous Crop, Isolated Medium Fields	1HM-is	10263-11971	110	-	-	-	-	-	-
Rainfed Herbaceous Medium (2 - 4 ha) Scattered Isolated Fields with a layer of Natural Sparse (1-15%) Trees	1HM-is+2TS	10263-11971 + 20053	111	1.84	1.40	0.97	0.20	0.18	0.15
Rainfed Herbaceous Small (<2 Ha) Fields	1HS	11445	112	-	-	-	-	-	-
Rainfed Herbaceous Small (<2 ha) Fields with a layer of Natural Sparse (1-15%) Trees	1HS+2TS	11445 + 20053	113	1.84	1.40	0.97	0.20	0.18	0.15
Irrigated Herbaceous Small Fields (<2 Ha) wirth Additional Herbaceous Crops	1Hsi	11259-12635	114	-	-	-	-	-	-
Rainfed Herbaceous Crop, Isolated Small Fields	1Hs-is	10302	115	-	-	-	-	-	-
Rainfed Herbaceous Small Fields with Sparse Trees - Scattered Isolated fields	1HS-is+2TS	10302 + 20053	116	1.84	1.40	0.97	0.20	0.18	0.15
Post Flooding Cultivation Of Small Sized Field(s) Of Herbaceous Crop(s)	1Hs-Y	11446	117	-	-	-	-	-	-
Monoculture Of Continuous Large To Medium Sized Field(s) Of Rainfed Shrub Crop(s)	1SHMlm	10565	118	0.82	0.41	0.20	0.12	0.06	0.03
Rainfed Shrub Small (<2 ha) Sized Crop with Additional Herbaceous Crop	1SHs	11216-12626-W8	120	0.82	0.41	0.20	0.12	0.06	0.03
Rainfed Isolated (10-20%) Small (<2ha) Fields of Shrub Crop with Herbaceous Additional Crop	1SHs-is	10632-12626-W8	121	0.82	0.41	0.20	0.12	0.06	0.03
Large (>5 ha) Tree Plantation	1TPL	11182-11341-W7	122	32.86	25.07	17.29	0.86	0.75	0.62
Irrigated Tree Crop (1 add. Herbaceous Crop) - Small Fields	1TR3H57V	10547-12627-W8	124	20.06	20.06	20.06	0.67	0.67	0.67
Irrigated Tree Crop (No additional Crop) - Small Fields	1TRM	11343	125	20.06	20.06	20.06	0.67	0.67	0.67

A12 – Natural or semi-natural terrestrial vegetation				Woody biomass stock (od t ha^{-1})			Medium MAI (od t $ha^{-1}yr^{-1}$)		
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**
Closed to Open (100-15%) Herbaceous.	2HCO	21454	201	-	-	-			
Closed to Open (100 - 15 %) Herbaceous with Trees and Shrubs.	2HCOTS	21642	202	0.69	0.53	0.36	0.10	0.08	0.05
Sparse (1-15%) Herbaceous. Scattered herbaceous vegetation found in semi arid areas	2HR	20059	203	-	-	-			
Closed Shrubland (Thicket)	2SC	20018	204	3.80	2.90	2.00	0.29	0.26	0.21
Shrubs Closed (>70-60%) to open (65-20%) with sparse Trees (20-10%)	2SCO_ST	22638	205	4.49	3.42	2.36	0.32	0.28	0.23
Open General (65-15%) Shrubs.	2SOg	20022	206	1.84	1.40	0.97	0.20	0.18	0.15
Shrubs Open (70 - 40%)	2SOp	20022-1	207	2.42	1.84	1.27	0.23	0.20	0.17
Sparse (1-15%) Shrubs	2SR	20056	208	0.37	0.28	0.19	0.06	0.04	0.03
Very Open Shrubs (40 - 10 %)	2SVop	20022-3012	209	1.27	0.97	0.67	0.17	0.14	0.10
Closed (> 65 %) Trees with Closed to Open (>15 %) Shrubs.	2TCS	20278	210	21.62	16.50	11.37	0.70	0.61	0.51
Trees Open (65-40 %) with Closed to Open (> 15%) Shrubs.	2TO_Sco	20314-1	212	14.72	11.23	7.74	0.58	0.50	0.42
((70-60) - 40%) Open Trees with Sparse Shrubs	2TO_Ss	20324-1	213	9.57	7.30	5.03	0.46	0.41	0.34
Trees Open (65-15 %) with Closed to Open (> 15%) Shrubs	2TOS	20314	214	11.85	9.04	6.23	0.52	0.45	0.37
SPARSE TREES (Broadleaved Deciduous) WITH SPARSE HERBACEOUS (1-15%)	2TR	21384	215	0.58	0.44	0.30	0.09	0.07	0.05
Trees Very Open (40 - 10 %) with Closed to Open (> 15%) Shrubs	2TVO_Sco	20314-3012	216	8.97	6.85	4.72	0.45	0.39	0.33
Very open trees (broadleaved deciduous) with closed to open herbaceous and sparse shrubs	2TVO_Ss	20868-3012	217	6.69	5.11	3.52	0.39	0.34	0.28
Open Woody Fragmented Vegetation with Herbaceous Layer	2WOpfr	20309	218	0.35	0.26	0.18	0.05	0.04	0.03

A23 – Cultivated aquatic or regularly flooded areas				Woody biomass stock (od t ha^{-1})			Medium MAI (od t $ha^{-1}yr^{-1}$)		
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**
Large Sized Field(s) Of Graminoid Crops On Permanently Flooded Land	3HL	3605-1-S0308	301	-	-	-			

A24 – Natural or semi-natural aquatic vegetation				Woody biomass stock (od t ha^{-1})			Medium MAI (od t $ha^{-1}yr^{-1}$)		
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**
Closed Herbaceous (On Temporarily Flooded Land - Fresh Water)	4HCF	40056-R1	401	-	-	-	-	-	-
Closed Herbaceous (on permanently flooded land - Fresh Water)	4HCFF	42347-R1	402	-	-	-	-	-	-
Closed (> 65 %) Herbaceous Temporarily (2-4 months) Flooded with Emergents.	4HCTF	40383-R1	403	1.84	1.40	0.97	0.20	0.18	0.15

Open Herbaceous Vegetation With Emergents On Temporarily Flooded Land	4HOTF	40410	404	1.84	1.40	0.97	0.20	0.18	0.15
Closed to Open (100-40)% Shrubs With Herbaceous Temporarily (2-4 months) Flooded.	4SCHF	42057-60686	406	3.22	2.46	1.69	0.27	0.24	0.20
Closed to Open (100-40)% Shrubs With Herbaceous Permanently (> 4 months) Flooded.	4SCHFF	41971-60686	407	3.22	2.46	1.69	0.27	0.24	0.20
Tree closed On Temporarily Flooded Land	4TCF	40320	408	18.98	14.48	9.98	0.65	0.57	0.47
Closed trees on permanently flooded land	4TCHFF	40040	409	18.98	14.48	9.98	0.65	0.57	0.47
Trees Open (65-15%) Temporarily (2-4 months) Flooded.	4TOF	40047-1-R1	410	9.20	7.02	4.84	0.46	0.40	0.33
Trees Very open (40-15) On Temporarily Flooded Land	4TVOF	40047-287-R1	412	6.33	4.83	3.33	0.38	0.33	0.27
Open Woody Vegetation With Herbaceous Vegetation On Temporarily Flooded Land	4WPF6	40332-R1	413	5.52	4.21	2.90	0.35	0.31	0.26

B15 - Artificial surfaces and associates areas				**Woody biomass stock (od t ha^{-1})**			**Medium MAI (od t ha^{-1}yr^{-1})**		
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**
Airports	5A	5003-A21	501	-	-	-	-	-	-
Built Up Area(s) Oil fields	5OF	5001-A44Zp1(1)	502	-	-	-	-	-	-
Extraction Site	5Q	5004-2	503	-	-	-	-	-	-
Urban Areas (general)	5U	5003-9	504	0.82	0.41	0.20	0.12	0.06	0.03
Urban Areas - Rural Settlements	5UR	5003-9-A44Zp2	505	0.82	0.41	0.20	0.12	0.06	0.03

B16 – Bare areas				**Woody biomass stock (od t ha^{-1})**			**Medium MAI (od t ha^{-1}yr^{-1})**		
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**
Gravels, Stones and/Boulders	6G	6002-2	601	-	-	-	-	-	-
Loose and shifting sands	6L	6006	602	-	-	-	-	-	-
Longitudinal dunes	6LD3	6016	603	-	-	-	-	-	-
Dunes (undifferentiated)	6LD4	6009	604	-	-	-	-	-	-
Loose And Shifting Sands in Wady environment	6LW	6006-L16	606	-	-	-	-	-	-
Bare rock	6R	6002-1	607	-	-	-	-	-	-
Bare rock with a thin sand layer	6RL	6002-1(3)[Z8]	608	-	-	-	-	-	-
Bare soil	6S	6005	609	-	-	-	-	-	-
Sabkha - Bare Soil And/Or Unconsolidated Material(s) With Salt Flats	6SBL	6020-L17	610	-	-	-	-	-	-
Bare soil stony	6ST1	6005-6	611	-	-	-	-	-	-
Salt crusts	6SZ	6005(3)[Z2]	613	-	-	-	-	-	-

B27 – Artificial water bodies, snow and ice				Woody biomass stock (od t ha^{-1})				Medium MAI (od t ha^{-1}yr^{-1})	
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**
Dams	7WP	7002-5	701	-	-	-	-	-	-
Artificial Non-Perennial Waterbodies. (Hafeer)	7WPH	7003	702	-	-	-	-	-	-

B28 – Natural water bodies, snow and ice				Woody biomass stock (od t ha^{-1})				Medium MAI (od t ha^{-1}yr^{-1})	
Class User Name	**Map Code**	**LCCS Gis Code**	**WISDOM code**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**	**High rainfall zone**	**Medium rainfall zone**
Non-Perennial rivers (Surface Aspect: Sand)	8WFN1	8003-4	801	-	-	-	-	-	-
Non-Perennial rivers (Surface Aspect: Bare Soil)	8WFN2	8003-3	802	-	-	-	-	-	-
River	8WFP	8002-1-V1	803	-	-	-	-	-	-
Non-Perennial Natural Waterbodies (Standing) (Surface Aspect: Sand)	8WN1	8003-8	804	-	-	-	-	-	-
Inland water non-perennial with scattered vegetation	8WN1V	8003-19-U1	805	1.10	0.84	0.58	0.16	0.13	0.09
Lake shore	8WN2	8003-7	806	-	-	-	-	-	-
Natural Lakes	8WSP	8002-5-V1	807	-	-	-	-	-	-

ANNEX 3: SUMMARY OF DEMAND, SUPPLY AND BALANCE STATISTICS AT LOCALITY LEVEL

TABLE A3.1

Summary of demand, supply and balance statistics at Locality level. "Commercial" balance values assume surplus thresholds of100, 150 and 200 kg/ha/year. (ref.: LCCS 2011)

(see Figure 25 of main text for administrative layout)

	State / Locality	Demand 2008	Demand 2011*	Stock	Annual accessible supply potential	Local balance	Commercial balance "surplus>100"	Commercial balance "surplus>150"	Commercial balance "surplus>200"
		'000 od t	'000 od t	'000 od t	'000 od t	'000 od t	'000 od t	'000 od t	'000 od t
	Northern								
1101	Halfa	8	6	60	4	-2	-5	-5	-5
1102	Dalgo	6	5	15	1	-4	-4	-4	-4
1103	Alborgaig	14	10	83	4	-5	-5	-5	-5
1104	Dongla	31	24	115	5	-21	-22	-23	-23
1105	Algolid	11	9	101	4	-4	-5	-5	-5
1106	Aldabba	23	17	185	8	-9	-11	-12	-12
1107	Marawi	26	20	267	10	-10	-12	-12	-12
	Northern total	**119**	**92**	**824**	**37**	**-54**	**-65**	**-66**	**-66**
	River Nile								
1201	Ubu Hamad	12	12	211	7	-5	-8	-8	-8
1202	Berbar	15	16	104	4	-13	-14	-14	-14
1203	Atbara	16	18	8	1	-16	-17	-17	-17
1204	Eldamar	27	30	76	5	-26	-28	-28	-28
1205	Shendi	26	29	31	2	-26	-26	-26	-26
1206	Elmatamma	14	15	21	1	-15	-15	-15	-15
	River Nile total	**110**	**120**	**451**	**20**	**-101**	**-107**	**-107**	**-107**
	Red Sea								
2101	Halayib	38	41	210	16	-25	-37	-37	-37
2102	Alghanib	25	27	97	12	-17	-23	-23	-23
2103	Portsudan	97	126	14	2	-126	-127	-127	-127
2104	Sawaakin	19	23	2	0	-23	-23	-23	-23
2105	Sinkat	37	43	4	1	-43	-43	-43	-43
2106	Hayaa	64	69	40	3	-66	-68	-68	-68
2107	Toakar	39	44	407	23	-20	-24	-26	-28

2108	Aqeeg	18	19	129	8	-11	-14	-14	-15
	Red Sea total	**337**	**392**	**903**	**63**	**-331**	**-359**	**-361**	**-364**
	Kassala								
2201	Eldalta North	27	29	89	6	-23	-23	-24	-25
2202	Hamashkoreeb	74	77	16	1	-74	-75	-75	-75
2203	Talkook	79	83	60	5	-77	-79	-79	-79
2204	Aroma Rural	31	32	70	4	-33	-33	-33	-33
2205	Kassala West	23	24	23	2	-22	-22	-22	-22
2206	Kassala Town	109	116	56	2	-108	-108	-108	-108
2207	Kassala Rural	45	47	305	19	-34	-39	-42	-46
2208	New Halfa	67	71	8	1	-68	-68	-68	-68
2209	Nahr Atbara	39	41	3	0	-40	-40	-40	-40
2210	Khashm Elgirba	32	34	53	5	-29	-32	-32	-32
2211	Wad Alhilaio	26	27	1,105	65	38	30	22	11
	Kassala total	**551**	**580**	**1,788**	**110**	**-469**	**-490**	**-502**	**-517**
	Gedaref								
2301	Albutana	23	24	831	71	46	14	4	-4
2302	Alfashaqaa	40	41	973	59	18	15	11	-2
2303	Algadarif Central	36	38	342	28	-18	-33	-36	-38
2304	Algadarif Town	101	85	5	1	-76	-76	-76	-76
2305	Alfaow	58	60	22	3	-55	-55	-56	-56
2306	Alrraha	65	66	906	62	-3	-8	-17	-26
2307	Qalaannahaal	22	22	336	35	12	4	-5	-10
2308	Algallabat West (Kassab)	30	31	358	11	-21	-25	-27	-28
2309	Algooraishaa	27	29	332	20	-8	-14	-18	-21
2310	Alqalabat East	53	54	587	31	-23	-33	-39	-41
	Gedaref total	**454**	**450**	**4,692**	**320**	**-128**	**-212**	**-258**	**-301**
	Khartoum								
3101	Karari	102	99	4	0	-89	-89	-89	-89
3102	Ombaddaa	141	137	8	1	-125	-125	-125	-125
3103	Omdurmaan	74	71	6	1	-84	-84	-84	-84
3104	Bahri	87	85	25	2	-93	-93	-93	-93
3105	Shareq_Alneel	126	121	9	1	-118	-118	-118	-118
3106	Alkhartoum	91	89	7	1	-93	-93	-93	-93
3107	Jabal_awliya	135	131	13	1	-125	-125	-125	-125
	Khartoum total	**756**	**734**	**72**	**7**	**-726**	**-727**	**-727**	**-727**
	Gezira								

4101	Algazeera East	63	71	188	12	-59	-61	-61	-62
4102	Alkamleen	49	53	16	1	-53	-53	-53	-53
4103	Alhisaiheesa	81	92	84	4	-88	-88	-88	-88
4104	Um_alquraa	26	28	89	4	-26	-26	-26	-26
4105	Wad Madani Alkoobra	89	116	129	5	-96	-96	-96	-96
4106	South Algazeera	62	65	161	7	-79	-79	-79	-79
4107	Almanagil	119	134	33	4	-128	-129	-129	-129
	Gezira total	**489**	**559**	**701**	**36**	**-529**	**-532**	**-533**	**-534**
	White Nile								
4201	Algitaina	45	45	86	10	-40	-43	-43	-43
4202	Omramtaa	21	21	156	16	-3	-10	-12	-13
4203	Aldowaim	59	60	213	29	-30	-44	-46	-46
4204	Rabak	56	61	5	1	-59	-59	-59	-59
4205	Aljabalain	32	32	76	10	-21	-26	-26	-26
4206	Kosti	90	96	195	28	-71	-80	-81	-81
4207	Alssalam	18	17	601	56	38	13	3	-3
4208	Tandalti	27	27	328	43	14	-6	-10	-10
	White Nile total	**349**	**358**	**1,660**	**192**	**-171**	**-256**	**-275**	**-281**
	Sennar								
4301	Shareq Sinnar	78	85	204	13	-73	-74	-74	-74
4302	Sinnar	115	123	99	4	-112	-112	-113	-113
4303	Aldindir	69	75	3,490	84	7	-12	-22	-42
4304	Alsooki	75	81	317	22	-59	-67	-67	-67
4305	Sinja	61	66	404	25	-39	-40	-43	-48
4306	Abu-Hojar	47	51	502	50	-2	-10	-16	-37
4307	Aldali	25	27	992	81	55	47	34	-1
	Sennar total	**470**	**507**	**6,008**	**278**	**-223**	**-269**	**-300**	**-382**
	Blue Nile								
4401	Alrosairis	125	129	2,203	154	32	25	5	-32
4402	Aldammazeen	117	121	306	25	-96	-101	-104	-108
4403	Altadamon	47	48	1,214	109	61	51	30	-22
4404	Baaw	77	78	3,349	193	115	109	101	87
4405	Geesan	53	54	1,933	101	38	36	30	21
4406	Alkurmook	66	68	7,041	340	272	268	257	242
	Blue Nile total	**485**	**499**	**16,046**	**922**	**422**	**388**	**319**	**188**
	N. Kordofan								
5101	Jabrat_ elshiekh	106	108	1,941	188	80	-56	-70	-72

5102	Soadari	124	126	1,972	203	77	-87	-97	-98
5103	Baraa	165	168	1,093	140	-28	-101	-104	-104
5104	Omrowabaa	292	299	1,852	188	-109	-166	-189	-204
5105	Alnuhood	118	123	840	100	-21	-89	-97	-97
5106	Sheekan	255	271	889	90	-181	-201	-213	-226
5107	Abuzabad	82	84	779	87	2	-34	-43	-45
5108	Wadbandaa	71	72	682	81	8	-48	-54	-55
5109	Ghibaish	133	136	889	119	-18	-62	-74	-75
	N. Kordofan total	**1,345**	**1,386**	**10,938**	**1,196**	**-189**	**-844**	**-941**	**-978**
	S. Kordofan								
5201	Alrsahaad	82	85	3,825	207	122	107	92	74
5202	AbuJibaihaa	74	77	8,854	513	437	414	376	321
5203	Aldilanj	85	89	5,585	359	270	250	216	172
5204	Kadoogli	55	59	4,165	263	205	198	176	119
5205	Assalam	48	51	2,603	192	141	116	93	49
5206	Assalam	35	37	10,887	527	490	487	477	435
5207	Lagawah	61	62	2,663	221	159	136	73	23
5208	Kailak	15	15	5,296	268	253	250	244	229
5209	Abyei	72	75	17,182	859	782	772	755	717
	S. Kordofan total	**527**	**550**	**61,060**	**3,410**	**2,859**	**2,730**	**2,503**	**2,139**
	N. Darfur								
6101	Almalha	82	84	786	89	5	-76	-78	-80
6102	Milleet	70	74	341	36	-37	-59	-61	-61
6103	Eltina	36	36	982	115	78	-21	-31	-31
6104	Saraf-omra	107	110	150	15	-87	-89	-90	-90
6105	Alsiraif	78	80	505	52	-20	-49	-58	-60
6106	Kabkabiya	114	118	570	46	-73	-89	-100	-104
6107	Kotum	65	68	612	70	2	-53	-58	-58
6108	Alkoama	35	35	503	54	20	-13	-21	-29
6109	Alfashir	281	298	400	48	-251	-277	-279	-279
6110	Omkaddadah	45	47	645	72	25	-25	-30	-32
6111	Kalamando	36	37	356	44	8	-19	-21	-21
6112	Altowaisha - Alliayied	68	70	765	97	28	-30	-39	-42
6113	Dar Elsalam	35	35	83	11	-25	-29	-29	-29
	N. Darfur total	**1,051**	**1,090**	**6,699**	**749**	**-327**	**-830**	**-894**	**-917**
	W. Darfur								
6201	Koulbos	32	32	560	62	30	0	-16	-24

6202	Sirba	40	41	149	18	-20	-28	-31	-32
6203	Kirainik	60	61	1,115	95	30	19	-2	-23
6204	Alginaina	129	141	549	45	-97	-101	-110	-119
6205	Baidah	24	24	422	31	6	4	-3	-11
6206	Habeela	47	48	840	59	9	7	-2	-19
6207	Azoom	20	20	899	59	39	38	29	4
6208	Zalingay	56	59	1,405	101	30	24	-7	-34
6209	Nairtaty	25	25	648	43	17	15	7	-5
6210	Rokoro	9	9	198	17	7	0	-4	-6
6211	Wadi-Salih	72	74	3,218	191	121	118	99	52
6212	Wadi-Salih	33	33	1,840	120	87	81	63	22
6213	Omdukhon	30	31	941	63	32	30	24	13
	W. Darfur total	**576**	**599**	**12,785**	**905**	**290**	**208**	**46**	**-180**
	S. Darfur								
6301	Shiairyya	143	148	1,305	130	-18	-59	-83	-100
6302	Niyala	335	366	510	52	-307	-331	-338	-340
6303	Jabal-Marra East	25	26	321	28	0	-14	-19	-21
6304	Kass	136	142	1,551	106	-35	-39	-49	-72
6305	Id-Alfursaan	204	209	2,400	183	-27	-39	-68	-115
6306	Alssalam	133	135	1,779	135	-10	-19	-37	-62
6307	Aldiain	206	218	1,059	123	-97	-113	-162	-178
6308	Adeela	139	141	700	86	-55	-65	-94	-102
6309	Tolus	170	176	907	73	-101	-106	-114	-122
6310	Rihaid-Albirdi	103	106	2,737	240	134	123	81	17
6311	Booram	238	246	16,246	886	641	628	569	472
6312	Bahr-Alarab	120	123	9,778	637	517	494	438	361
	S. Darfur total	**1,952**	**2,036**	**39,293**	**2,679**	**643**	**461**	**123**	**-263**
	SUDAN total	**9,570**	**9,954**	**163,920**	**10,926**	**967**	**-905**	**-1,974**	**-3,289**

Note: Units are oven-dry (od) woody biomass in thousand tons. 1 m^3 = 0.589 od tons. 1000 odt = 1698 m^3.
* Slight differences with Table 4 on 2011 consumption are due to mapping process.
Note: The differences between the supply and balance values of Darfur states and those produced by the 2010 WISDOM Darfur study are due to the different areas covered, to some changes in the land cover map, to the wider set of NFI sample data used as reference for biomass stock and to the constraints applied to the estimation of annual productivity.

ANNEX 4. WOODFUEL DEMAND DATA & RAPID APPRAISAL OF NON-HOUSEHOLD CONSUMPTION

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Introduction

Great changes in the consumption patterns have taken place in the households, industrial and services sectors during the last decade due to the availability of petroleum fuels after oil resources exploitation and government's encouragement for the use of LPG. But there is no systematic record on the current consumption rates.

The available information on woodfuel consumption includes the 1994 Forest Products Consumption Survey, information produced by FNC over the years, national energy assessments carried out by the Ministry of Energy and other studies and surveys, such as the Sudan Household Health Surveys 2006 and 2010 and the Sudan Household Baseline Survey 2009 that provided useful references for an update of consumption patterns. A list of main documents reviewed is at the end of the present annex.

In order to update woodfuel consumption rates in the commercial and industrial sectors, a Rapid Assessment was carried out in some urban areas of Khartoum and Sennar, with the active participation of FNC staff..

In addition, in order to evaluate the effect of the separation of the South on the supply of major charcoal and fuelwood markets, visits were carried out to the Alazhari Market in Khartoum South and Abasseya Market in Omdurman during which retailers were interviewed to collect information about the sources of supply, prices, consumers categories.

The main findings of the review and of the Rapid Appraisal are summarized below. These results were used to update the state-wise consumption values produced by the 1994 Survey.

Wood Energy Demand

Till recently previous studies have only given the wood consumption in qualitative terms. Estimates of per capita consumption were unrealistic. The study of energy consumption in Sudan done by the National Energy Administration of the Ministry of Energy and Mining in 1982/1983 estimated the wood consumption as 44.8 % and charcoal as 26.0% of the total energy budget, The study did not give by consuming sectors or administrative units (provinces at that time).

Perhaps the most detailed comprehensive study was the Forest Products Consumption Survey of 1994.The study investigated the consumption by rural and urban households, industry, agriculture, establishment and services. Results were aggregated by state and national levels. For its comprehensiveness the Forest Products Consumption Survey results though more than fifteen years old are still useful as a base for estimating the present situation.

Five years later in 1999 the National Energy Administration undertook a national energy assessment which gave the energy consumption percentages at the state and national levels by sector i.e. households, electricity and water, mining and building, industries, services, transport and agriculture. It also gave the consumption by fuel type.

Other household health surveys carried by the Central Bureau of Sudan in 2009 and UNCEF and the Ministry of Health in 2006 and 2010 gave estimates of the rural and urban households' consumption of wood and petroleum fuels.

Since the exploitation of petroleum oil and rise in the petroleum refining capacity by the establishment of new refineries and increasing the production of the old one in Port Sudan a rapid change in energy consumption pattern has taken place with varying extent in all sectors.

The steep rise in LPG consumption over the period 1993 - 2010 is illustrated by the Figure 5 of

Section 2.2.1 "Reference data" of this report.

Household Consumption

In the Forest Products Consumption Survey of 1994 firewood constituted 84.8 % of the household consumption whereas the 1999 energy assessment estimated it as 59.33%. The household and Central Bureau of Statistics (CBS) surveys of 2006, 2009 and 2010 gave the consumption in terms of percentages of households using firewood and other fuels. It is evident from these surveys' results that the percentage of households using LPG is continuously increasing during the last decade. No mention was made of how much of woodfuel and other alternatives are consumed. These surveys did not give the quantities consumed as households can be using more than one type of fuel in unknown proportions.

It is also noticed that the percentage of households using fuelwood in the rural areas is higher than in the urban areas in all states and that the per capita consumption is higher in the states with more rainfall and richer forest resources except for Al Gezira State where other alternatives like agricultural residues are used.

Production of firewood in and outside the forest reserves according to FNC records is as shown below:

	Forest Reserves		Outside Forest Reserves	
	Firewood m^3	Charcoal (ton)	Firewood m^3	Charcoal (ton)
2004	57792	1597	185375	1063557
2005	92954	3878	227217	52272
2996	56894	5533	48345	19365828
2007	50006	751	149492	3742.655
2008	48191	18	546767	35255
2009	41887	50	210197	1804.745
2010	44918	135	231842	607507

Source: FNC annual reports

The firewood produced in the FNC forest reserves and that on which tax was collected, i.e. outside forest reserves, is supposed to be purchased in both urban and rural areas. This was 276760m^3 for the year 2010 as can be seen in the table above and is by far less than the 899553 m^3 purchased in rural areas of Sudan according to the estimate of the 1994 Forest Products Consumption Survey.

Considering the fact that firewood consumption by rural population is not expected to decrease but is more likely to increase because of population growth. These figures show that the FNC records cannot be solely relied upon in estimating the supply or demand for firewood.

Burnt Clay Bricks

Burnt clay bricks production in Sudan is continuously increasing. The Forest Products Consumption Survey of 1994 topic paper indicated that production of bricks in Northern Sudan was 2771 million bricks of which Khartoum State produced 1280 million bricks (46%). This increase in production by million bricks can be illustrated by the table below:

	1983	1994	Increase %
Khartoum	562	1280	128
Central states	520	1173	126
Eastern states	107	84	-22
Darfur	139	78	-44
Kordofan	105	65	-25
Northern	121	91	-38
Total	1554	2771	75

Source: Mohammed Hussein, 2004

The same source stated that the production of Khartoum was 1804 million bricks for the year 2004 with an increase of 41% of 1994 production. In 2009 it was reported that Khartoum State produced1.8 thousand millions bricks equivalent to 46% of the total production of 3.9 thousand millions for Sudan (Hussein, 2009). Future forecast for bricks production as stated in the topic paper of 1994 Consumption Survey is 37.3 thousand millions in 10 years i.e. 3.7 thousand millions/year consuming 3709.715 m^3 of firewood/year. This was further confirmed by the Sudanese Organization of Building and Construction Materials by stating that the production of bricks in Sudan was 3.9 thousand millions in June 2010. It has , however, been reported that the brick making industry in Khartoum is declining due to the use of building materials substitutes like cement blocks which is encouraged by the government and high price of firewood. This has been confirmed by the results of the rapid appraisal carried out in Khartoum State and Sinnar and Singa towns within the framework of this project showing that the present annual production of bricks in Khartoum is 1045275 thousands which is less than the 1994 production.

Consumption of firewood varies from one kiln owner to the other as some of them use compacted cow dung (garguf) which the kilns operators claim to have better burning than firewood.

The rapid appraisal showed that brick burning consumes annually 433m^3 in Khartoum and476m^3 in Sinnar.

Lime Curing

Lime curing kilns in Khartoum use charcoal fines only. The table below shows the consumption of fuelwood for lime burning by state in 1994 (Hood, 1994):

State	Fuelwood Consumed (m^3)	Number of Producers
Khartoum	1737.9	7
Geziera	408	3
White Nile	738	3
Red Sea	379.8	8
Kassala	18506.4	40
N. Kordofan	19.8	2
S. Kordofan	18	2
River Nile	300	5
S. Darfur	280	7
El Gedaref	648	3
Total	33035.9	80

Source: Hood (1994)

Vegetable Oil and Soap Industry:

Khartoum Province (State) oil and soap industry's consumption of fuelwood was 3690 m^3 in 1984 (Abdel Salam, 1985). The 1994 survey reported the presence of 152 and 127 of oil and soap factories respectively in Sudan consuming 48000 m^3 of firewood...In1994 57% of oil and soap factories were in Khartoum triangle (Khartoum North, Omdurman and Bagheir) 26% in the central states,12% in Port Sudan and 5% in Kordofan and Dar Fur (El Amin, 1994). The installed pressing capacities of oil factories is 2.8 million tons of oil seeds, 4 tons for cottage pressers and the soap making capacity is about 300000 tons/year. The current production of both oil and soap is 10% of the installed capacities. In 1994 the Khartoum factories used 90% furnace and in central Sudan a mixture of 27% firewood, 42% of ground nuts hulls and 31% of furnace was used.

At present all oil and soap factories in Khartoum and Sinnar have switched to petroleum fuel according to the factories' owners association and the industries chamber.

Bakeries:

There are two types of bakeries in Sudan the traditional type using firewood and the modern type using petroleum fuels and electricity. A survey study of the firewood consumed by bakeries in 1984 in Khartoum State gave an estimate of 66700 m^3 of fuelwood used by 645 traditional bakeries. Modern bakeries were then 120. Estimates given by the 1994 Forest Products Consumption Survey in tons of fuelwood is shown in the table below:

Region	Urban	Rural	Total
Northern	7520	8860	16380
Eastern	22690	17650	40340
Khartoum	80310	33960	114270
Central	24980	39180	64160
Kordofan	13150	9430	22580
Dar Fur	12960	6680	19640
Total	**161610**	**115760**	**277,370** (358,523 m^3)

Source: Abdel Salam, 1994, Assessment of Use Pattern and Forecasting of Demand of Fuelwood by Traditional Bakeries.

According to the Sudanese Association of Industries Chambers there are 6000 bakeries in Khartoum of which 1200 are modern and 4800 are traditional. The modern bakeries use diesel though most of them have switched to LPG because of its cheaper price and that the total number of bakeries in Sudan is estimated to be 17000. It is within the traditional bakeries that a big shift from using firewood to the use of LPG has occurred. The recent rapid appraisal has shown that only 5% of bakeries in the national capital are still using firewood, 15% use diesel and 80% use LPG. In sinnar 40% of bakeries use firewood while 60% use LPG. In Singa 38% of the bakeries use firewood while 62% use LPG. Consumption of firewood by bakeries in the national capital is estimated as 47791.5 m^3 per annum based on the appraisal sample. In Sinnar and Singa the bakeries consumption of firewood is 100 m^3 per year.

Tea, coffee and food making:

These activities started as an informal services sector in the national capital and other towns after the drought crisis in the mid eighties of the last century and increased in size afterwards as a consequence of the increased population displacement because of security disturbances in some parts of the country and high poverty levels. In 1994 the consumption was .

The number of citizens involved , mostly women, involved in these activities according to their associations and the official authorities are 10000 in the national capital, 500 in Sinnar and 300 in Singa town.

The recent rapid appraisal showed that in the national capital that 85% of this number is engaged in tea and coffee making while 15% are engaged in food making. 7% of the coffee and tea makers use LPG and the remaining 93% use charcoal while 59% of the food makers use LPG and 41% use charcoal. In Sinnar and Singa the case is a little bit different in that all tea and coffee makers use charcoal and only 12% of the food makers use LPG. This might be attributed to the relatively cheap price of charcoal in Sinnar State. 1054166.7 and 13828104 kilograms of charcoal are consumed annually in the national capital and Sinnar respectively.

Procurement of Documents and Data

Documents procured and reviewed

1. Household energy consumption in Sudan, Ministry of Energy, 1983.
2. Forest Products Consumption Survey Final Report, FNC/FAO.1995.
3. Specific topic reports prepared for the Forest Products Consumption Survey. Of these the following were reviewed:
    - Consumption of wood in building in Sudan.
    - Wood Use in Brick making Industry in the Sudan.
    - Demand forecast for Wood in Clay Bricks Production in the Sudan.
    - Fuel wood Consumption in Khalwas (quranic schools) in the Sudan.
    - Firewood Consumption in the Vegetable Oil and Soap industries in the Sudan.
    - Assessment of Use Pattern and Forecasting of Demand of Fuelwood by Traditional Bakeries in the Sudan.
    - Woodfuel Consumption in the Lime Burning Industry in the Sudan.
4. Households Sector Energy Consumption Assessment, Ministry of Energy, 1999.
5. Household Health Survey, UNCEF, 2006 - 2010
6. Household Survey, Central Bureau of Statistics, 2009.
7. The Use of Liquefied Petroleum Gas (LPG) in Sudan, UNEP, June 2011.
8. Demand for Fuelwood and LPG - a Case Study of Khartoum in 2009, UNEP.
9. Increasing Pressure on Forest Products – Gap between Supply and Demand, 2010.
10. Review of Previous LPG Dissemination Initiatives
11. Survey of Clay Brick Kilns in Khartoum State, FNC (Khartoum), June 2004.
12. FNC annual reports 2004-2010.
13. A Comparative Study of the Economic and Environmental Effects of the Use of Liquefied Petroleum Gas and Firewood in Bricks Production in Um Rawaba and Al Rahad Localities, Shiekh El Din Amin Hussein M.Sc. Thesis (Arabic), 2009.
14. Consumption of Charcoal and Alternatives. A Case Study of the Industries in East Administrative Unit, Khartoum North Locality, Kawthar Mohammed Osman, M. Sc. Thesis (Arabic), 2011.
15. Clay Bricks Industry in the Sudan, a general look, Dr. Mohamed Hussein Hamid, Buildings Research Centre, University of Khartoum.
16. Petroleum fuels Statistics distribution by state 2003-2009, Energy Administration.
17. LPG Distribution by state, 2000-2008, Ministry of Petroleum and Mining.

ANNEX 5: fNRB ASSESSMENT METHODOLOGY BASED ON WISDOM

[Adapted from the methodology proposed to CDM SSWG by R. Drigo and O. Masera, 2011]

At the basis of the proposed methodology is that the fraction of non-renewable biomass is location-specific. National summary values based on statistical data cannot capture this fundamental aspect and may give misleading results. It is where, how and how much biomass is extracted that makes it renewable or not renewable, and national statistics cannot tell that, even if they are consistent and reliable (which is rare).

The accurate estimation of the fNRB for a specific location requires precise information on the areas from which the consumed biomass is extracted, their sustainable production capacity and on the existing management systems. Such knowledge is definitely unavailable on a systematic basis at aggregate level (i.e., countries) and it's quite rare even at the local level.

However, the use of the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) method may support the estimation of the expected fNRB values for geographical regions –countries, states, provinces-, thanks to the systematic geo-referenced estimation of the consumption and of the sustainable productivity of woody biomass and its accessibility (physical, legal and economic).

Fundamental features are the spatial-explicit analyses of (i) the demand for woody biomass for energy and other competing uses in all sectors of use, (ii) the supply potential from all direct and indirect sources (forests, woodlands, farmlands, industrial residues), (iii) the supply/demand balance in a local and informal fuelwood-gathering context and in a wider commercial context, and (iv) the outline of the sustainable supply zone of selected consumption sites (woodshed analysis).

WISDOM distinguishes two geographic contexts for supply/demand balance analysis, which are critical for an accurate fNRB estimation: "local" and "commercial" wood energy.

Local and Commercial wood energy contexts

Concerning the spatial relation between wood energy supply and demand, two distinct contexts may be observed:

- **Local supply/demand context**, which is typical of rural areas. The supply is based on fuelwood collection and/or charcoal production directly by the end users or by small temporary producers. The system is largely informal and the geographic horizon is limited to few kilometers from the consumption sites.
- **Commercial supply/demand context**, which includes urban demand and more or less distant supply zones. Fuelwood and charcoal are here market commodities that feed a chain of operators, such as producers, transporters, retailers and the supply zone can be at considerable distance from the consumption sites.

WISDOM can contribute to the analysis of both systems, which require different approaches. The Local context can be mapped with relative ease, while the Commercial one –linked to urban areas- is more complex to model. In fact, the estimation of the fNRB related to urban consumption requires knowledge about the location and extent of the actual woodfuels supply sources.

For analytical purposes, the following situations are distinguished:

- urban areas (as defined by census data)
- rural areas (with an horizon of 6 km around populated places),
- areas uninhabited or sparsely populated (all other areas).

Analytical steps

As noted, producing a single estimate of fNRB at aggregate geographical levels (such as a country) may fail to represent the true condition for an hypothetical project area as the impacts of fuelwood harvesting depend not on the overall balance between the fuelwood supply and consumption, but on the way consumption translates into harvesting practices (i.e., the type of management systems that are used to extract fuelwood) and the spatial patterns of these harvesting practices. For example if fuelwood extraction is concentrated in few forest spots where intensive clear-cutting w/o re-planting is conducted, the impact will be very different to a system where harvesting is more evenly distributed in the forest area.

To get to the expected fNRB at sub national level, a step-wise process of analysis is proposed.

Step 1: Estimation of the "**potential Renewable Biomass fraction**" (**pRBf**), i.e., the highest possible degree of renewability of a given biomass harvesting within a particular territory.

Step 2: Estimation of the "**minimum fraction of Non-Renewable Biomass**" (**mfNRB**). Based on the pRBF defined through the previous step, the mfNRB indicates the best possible situation of non-renewable use, given the estimated level of harvesting and the supply potential, and assuming the rational management of biomass resources.

Step 3: Estimation of the **Sustainable Increment Exploitation Fraction** (**SIEF**). This parameter indicates how rationally the harvesting within a given area is carried out or, more specifically, what fraction of the sustainable increment is actually exploited.

Step 4: Estimation of the "**expected Renewable Biomass fraction**" (**eRBf**), i.e., the likely degree of renewability of a given biomass harvesting within a particular territory assuming "current" management practices. This parameter is estimated by applying the SIEF to the pRBf.

Step 5: Estimation of the "**expected fraction of Non-Renewable Biomass**" (**efNRB**). Based on the eRBF defined through the previous step, the efNRB indicates what the likely situation may be, given the estimated level of harvesting and the supply potential, and assuming current management practices.

Step 1: Estimation of the "potential Renewable Biomass fraction" (pRBf)

Based on the geo-referenced WISDOM layers on supply and demand and further processing described below, the "*potential* Renewable Biomass fraction" (pRBf) is estimated as the highest possible degree of renewability of a given biomass harvesting within a particular territory. To do so we assume that the biomass resources are rationally exploited (i.e. the sustainable increment is the first to be exploited and, in case that the demand is higher than the sustainable supply, the sustainable increment of the area is exploited entirely).

The pRBf within a given territory can be formulated as follows:

(1) ***potential*** **Renewable Biomass fraction (pRBf)** (of a given administrative unit)**:**

(<sustainable supply potential> - <harvesting>) / <harvesting>

The <sustainable supply potential> can be estimated and mapped using available information while <harvesting> is rarely known. However, it can be assumed that within a country <harvesting> is equal to <consumption> [- import + export], which is a key parameter of the WISDOM model[10] that can also be estimated and mapped on the basis of available information.

Concerning the spatial relation between <harvesting> and <consumption>, the following two main aspects must be considered:

[10] In WISDOM, all woody biomass use is considered, including woodfuels as well as industrial wood products and construction material. Industrial roundwood production is usually deducted from the available wood energy supply potential while construction material used by rural households is added to the woodfuel consumption.

- In a local supply/demand context, typical of rural areas, there is a tight spatial relation between harvesting sites and consumption sites. It is reasonable to assume that within a sub-national unit the <harvesting> for rural consumption is equal to rural <consumption>.
- In a commercial supply/demand context typical of urban areas, the local spatial relation between harvesting sites and consumption sites is lost. As mentioned above, the supply zone of urban woodfuel markets may include production areas quite far from the cities. In such cases, assuming that the biomass supply of urban centers comes only from the unit where the cities are located would produce misleading results. In order to overcome this problem in absence of information on the actual supply areas, the harvesting relative to urban consumption for the major urban centers can be "distributed" over the biomass sources of the neighboring administrative units on the basis of urban woodshed analyses[11] and proportionally to their supply potential.

It should be noted that the pRBf value ranges between -1 and + ∞.

- Positive values indicate that the harvested biomass is less than the supply potential and the biomass extracted is potentially "renewable". The value shows the margin of surplus as the ratio between the supply potential and current harvesting level within the area under consideration.
- Negative values indicate that the harvesting is more than the sustainable supply potential and show the fraction of the consumption that cannot be met by the sustainable supply capacity of the area under consideration.

It's worth emphasizing that pRBf represents the best possible situation given the resources available within the study area, and not the actual situation, which depends on how rationally such resources are exploited.

Step 2: Estimation of the "minimum fraction of Non-Renewable Biomass" (mfNRB)

The "*minimum* fraction of Non-Renewable Biomass" (mfNRB) indicates the best possible situation, given the estimated level of harvesting and the sustainable supply potential of the area under consideration, and assuming the rational management of biomass resources. It is assumed that the harvesting is as sustainable as possible, which means using only the sustainable increment or, in case that the estimated harvesting is greater than the supply potential, using the sustainable increment entirely.

The minimum fraction of Non-Renewable Biomass (mfNRB) for a given area is derived from the pRBf, as follows:

(2) Minimum fNRB (mfNRB) = pRBf * (-1) * 100 (for negative values of pRBf)

= 0 (for positive values of pRBf)

Step 3: Estimation of the Sustainable Increment Exploitation Fraction (SIEF)

The pRBf and mfNRB assume rational harvesting practices, which may be quite different from those actually implemented in the field. For example, if the natural increment is neglected and the exploitation is entirely unsustainable, the true fNRB tends to 100% even in a biomass-rich area. On the opposite, if the entire sustainable increment is exploited before touching the forest capital, the true fNRB shows the lowest possible value, which corresponds to the value of mfNRB (formula 2).

The true Renewable Biomass fraction (RBf), and hence the true fNRB, depend on how rationally the production of fuelwood and charcoal is conducted. In other terms, they depend on what fraction of the

[11] The woodshed analysis serves to outline the sustainable supply zone of a city based on (i) the city's biomass demand and (ii) the distribution and accessibility of the biomass surplus suitable for commercial supply on the territory around the city. See Section 2.5 "Weighted woodshed analysis" . and Section 2.6.4 "Results of woodshed analysis".

territory non-sustainable harvesting is taking place or, ultimately, what fraction of the sustainable productivity is actually exploited.

If we know that the whole sustainable productivity of the area under consideration is exploited, the true RBf will be equal to pRBF and the true fNRB will be equal to mfNRB.

As the latter situation is very seldom the case, to get to the most likely or "expected" fNRB, without field evidence, one possibility is to use what we may call the Sustainable Increment Exploitation Fraction (SIEF), for a given area.

SIEF indicates how rational and efficient is the harvesting in the area concerned. SIEF is not telling how much of the increment is actually exploited but how rationally the exploitation is carried out. To be noted that *rational* does not mean *sustainable*; sustainable forest management is always rational, but rational exploitation is not always sustainable. For instance: a forest could be *rationally over*exploited when the harvesting is done over the entire forest with a rotation period that is too short; on the contrary, it is *not rational* if the *over*exploitation is done only over part of the forest.

SIEF value ranges, theoretically, between 0 (none of the sustainable increment is exploited, the exploitation is totally irrational) and 1 (the sustainable increment is exploited entirely before overexploitation takes place).

The Sudan context and some basic assumptions concerning the SIEF:

- Annual deforestation in Sudan is estimated, for the past decade, to be 0.8% of forest area (and slowly decreasing (African Forest Forum, 2011). This rate referred to Sudan prior to separation. Considering that an adequate import of woodfuels from South Sudan is not feasible given the closure of national borders, it may be assumed that the pressur on Sudan's wood resources will increase rapidly in order to match the missing flow from Upper Nile and other traditional southern supply sources (supplying as much as 50% of urban consumption). The deforestation rate may therefore increase or even double in the coming years.
- The annual consumption of woody biomas is estimated to be 6% of the stock. Tentatively it may be assumed that in the worst scenario, whereby all the harvesting is done against the stock leading to the permanent depletion of the forest, the annual deforestation rate would be in the order of 6%, which is much higher than the estimate deforestation rate even if we double the rate to 1.6%.
- The annual increment, and the allowable cut, is estimated around 7% of the stock and the rotation period is on average 15 years. This means that when the stock of the forest is cut entire and progressively, without a rotation system, 7% of the extracted biomass may be considered renewable and 93 % non renewable. If, on the opposite the clearfelling is done on a 15-years rotation system to allow for adequate regeneration the entire extracted biomass is renewable.
- Over a sizeable geographic region, extreme SIEF values of 0 and 1 are virtually impossible. Given the above the lowest SIEF value may be 0.07, representing the "renewable" fraction of a deforestation front, and the highest one may be set at 0.9, assuming a highly efficient sustainable forest management.
- Tentative SIEF value ranges :
  - In the local supply/demand context of rural areas the SIEF is relatively high, especially where the pressure from woodfuel users is high. For these areas SIEF value may range between 0.4 and 0.8, and a midpoint of 0.6 may be considered a first approximation.
  - For forest areas located in uninhabited or sparsely populated areas (USPA), whose exploitation serves primarily urban markets, the SIEF range is extremely variable but in general much lower than around rural settlements. For these areas SIEF value may range between 0.1 and 0.6, with a midpoint tentatively put at 0.35.
  - Only within urban areas, which are usually small, densely populated and with few biomass resources accessible for harvesting, a SIEF of 0.9 may be considered.

The SIEF values should be refined on the basis of field knowledge and adapted state by state. In this respect, it will be necessary to identify specific indicators that may guide in the definition of reliable SIEF values, such as, for instance, information on the status of forest management in the States of Sudan.

Step 4: Estimation of the "expected Renewable Biomass fraction" (eRBf)

In absence of direct field evidence on the harvesting methods actually applied in the field, the *expected* Renewable Biomass fraction (eRBf) is estimated by applying the SIEF to the potential Renewable Biomass Fraction (pRBf), as per formula (3):

(3) ***expected* Renewable Biomass fraction (eRBf)** (of a given administrative unit) **=**

(<USPA_supply*USPA_SIEF + rural_supply*rural_SIEF + urban_supply*urban_SIEF> - <harvesting>) / <harvesting>

In case of Sudan, the minimum, medium and maximum eRBf values were estimated applying the SIEF values indicated above (Step 3).

Step 5: Estimation of the "expected fraction of Non-Renewable Biomass" (efNRB)

Finally, the *expected* fraction of Non-Renewable Biomass (efNRB) for a given area is derived from the eRBf, as follows (formula 4):

(4)	**Expected fNRB (efNRB)**	**= eRBf * (-1) * 100**	**(for negative values of eRBf)**
		= 0	**(for positive values of eRBf)**

The results of the analysis are shown in Table 8, Section 2.6.6 "Estimated fraction of Non Renewable Biomass (fNRB)"

ANNEX 6: MAPS USED AND GENERATED FOR WISDOM NORTH SUDAN

See \WISDOM_N_Sudan\GIS\

Geographic coordinate system **GC WGS1984** with cell size of 0.000898920314340998875 DD (approx. 100m, cell =1 ha)

Selected projection (when metric units were require): Lambert Azimuthal Equal Area Projection (Central Meridian: 30.35.00; Latitude of Origin: 15.00.00).

N_Sudan filename	**format**	Description / processing
Cartographic base		
adj_pop_adm	r	Darfur's smallest administrative level for which the correspondence between Census 2008 statistics and administrative maps could be established (mostly AU units, but also aggregations of several AUs and Localities) = Raster of field "adjusted" in AU__Darfur.shp in UTM35N projection.
auadjdar_gc	r	Re-sampling of above (adj_pop_adm) to geographic projection
au_reconc_gc	r	Raster of above on
n_sud_adjau	r	Minimum administrative level of analysis (AU, mostly) covering the whole of North Sudan Merging of au_reconc_gc and auadjdar_gc
loc_feb12	**v**	New Locality layout with new national boundary
State_feb12	v	New states layout with new national boundary
Cty_feb12.shp	v	New national boundary
msk_feb12	r	New mask based on new national boundary
Demand Module		
		Population mapping
urb_place01	r	Urban areas clipped on AU with urban populations from census 2008 (value 1 ; background value 0)
		Rural and nomadic pop
rur_places01	r	Rural populate areas derived from land cover maps and buffered point maps of populated places, including portions of urban areas outside "Urban" AUs (value 1 ; background value 0) (NOT VALID FOR DARFUR AREA) = pop_places01 - urb_place01
		Population maps 2008 and 2011
pop08_tot2		Total pop 2008 = int((500 + (pop08_tot * p_08_adjfact)) / 1000)
p08_11grwfact		State-wise factor to calculate 2011 population on account of growth rates see sheet Pop_93_2008_2011 in Consumption values N Sudan 03.xls = reclass(n_s_states, recl_state_pop08_2011_grow_factor.txt)
pop11_tot2		Total pop 2011 = int((500 + (pop08_tot2 * p08_11grwfact)) / 1000)
		Woodfuel consumption
con08_2	r	**2008** Consumption of woody biomass in North Sudan (excluding WISDOM Darfur zone) (od kg / pixel) – for 2008 with all assumptions

		= (reclass(n_s_states, recl_states_conskg_W_assum_RUR_2008_1.txt) * rur08_2 / 100) + (reclass(n_s_states, **recl_states_conskg_W_assum_URB_2008_2.txt**) * urb08_0 / 100)
con11_2	r	**2011** Consumption of woody biomass in North Sudan (excluding WISDOM Darfur zone) (od kg / pixel) – for 2011 with all assumptions. Note: Population growth 2008-2011 and consumption trends are integrated into a single parameter applied to 2008 population maps. = (reclass(n_s_states, recl_states_conskg_W_assum_RUR_2011_mul2008.txt) * rur08_2 / 100) + (reclass(n_s_states, **recl_states_conskg_URB_2011_mul2008_2.txt**) * urb08_0 / 100)
darfcon08_kg	r	Resampling of con4_kg (Darfur demand 2008) to match N Sudan wgs data layers
darfcon11_kg	r	Darfur demand in 2011. Total consumption per 1-ha pixel – BAU variant (od kg / ha / year) Geographic projection Resampling of darcon11_utm to match N Sudan wgs data layers
con08_tot_2	r	**Total consumption in 2008** (whole North Sudan) (od kg / ha / year) = merge(darfcon08_kg, con08_2) * n_s_msk1
con11_tot_2	r	**Total consumption in 2011** (whole North Sudan) (od kg / ha / year) = merge(darfcon11_kg, con11_2) * n_s_msk1
Supply Module		
		NFI 1998 field plot data
pl_darf_m3ha		Darfur plots tentatively geo-referenced
nfi-georef_RD3.shp	v	Tentatively corrected geo-referencing of sample plots
nfi-georef_RD3_valid.shp	v	Tentatively corrected geo-referencing of sample plots with plot data, with or without trees and shrubs. (excluding Darfur)
msplot	r	Sample Plots in North Sudan
plot_valid.aux	r	Sample Plots in North Sudan with plot data, with or without trees and shrubs. (excluding Darfur)
plot_stkkg	r	Stock of woody biomass = reclass(plot_valid, recl_msplot_stkkgha.txt)
pl_stkkg	r	All plots, including Darfur. Stock of woody biomass (live and dead) in kg/ha (dry matter). = merge(plot_stkkg, pl_darf_stkkg)
		Land Cover
		Globcover ver 2.3 ref: 2009
gc2_3_ns	r	Resample of GLOBCOVER_L4_200901_200912_V2.3.tif to match WISDOM layers and clipped on n_s_msk0
rainf_int	r	Rainfall average 1990-2000 (from map taarimm1.img) resampled to match WISDOM layers
rainf_123	r	Rainfall (1=0-400; 2=400-600; 3=600-1195)
gc09_rain3	r	Combination of gc2_3_ns and rainf_123
		Tree cover map
tc1_nsf3		Tree cover map based on MERIS (cit.) resampled to 10 mm and smoothed (3 cells)
		Globcove class aggregated to 6 class groups
gc09recl5r3		= reclass(gc09_rain3, recl_gc09_rain3_gc09recl5r3.txt)
west2_1		Mask of western states (value 1)
east2_1		Mask of eastern states (value 1)
stk_adj1_w_e2		Stock of woody biomass in kg / ha, d.m. (also value / pixel) [floating point map ; 32 bit] Using 2 zones (west2 and east2) and adjustment 1 (see stk_&_mai_by_gc09_classes.xls) = merge((reclass(gc09recl5r3, recl_gc09recl5r3_w2_adj1_mult_tc1_nsf3.txt) * west2_1 *

		tc1_nsf3),(reclass(gc09recl5r3, recl_gc09recl5r3_e2_adj1_mult_tc1_nsf3.txt) * east2_1 * tc1_nsf3))
stk_we2int		Integer of stk_adj1_w_e2 = int(stk_adj1_w_e2 + 0.5)
		MAI maps (Globcover ver 2.3 ref: 2009)
		Note: In absence of local increment data, the MAI estimates are based on the functions based on global databases relating stock and MAI. The Sudan case has large areas with extremely low stocking that are outside the dataset originally used for function development. This tends to produce highest than real MAI% results for the lower stock categories. For this, the equations were applied only above a chosen stock threshold and a fix MAI% was assigned to the stock values below such threshold.
mai2md_int		Mean Annual Increment (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Medium variant. Floating point values [Calculation must be made on floating point map of stock] Stock threshold: 600; MAI% below Threshold: 20% = con(stk_adj1_w_e2 < 600, int(stk_adj1_w_e2 * 0.2 + 0.5), int(pow((stk_adj1_w_e2 / 1000), 0.5) * 150 + 0.5))
mai2mn_int		Mean Annual Increment (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Minimum variant. Floating point values [Calculation must be made on floating point map of stock] Stock threshold: 170; MAI% below Threshold: 15% = con(stk_adj1_w_e2 < 170, int(stk_adj1_w_e2 * 0.15 + 0.5), int(pow((stk_adj1_w_e2 / 1000), 0.6) * 70 + 0.5))
mai2mx_int		Mean Annual Increment (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Maximum variant. Floating point values [Calculation must be made on floating point map of stock] Stock threshold: 1000; MAI% below Threshold: 30% = con(stk_adj1_w_e2 < 1000, int(stk_adj1_w_e2 * 0.3 + 0.5), int(pow((stk_adj1_w_e2 / 1000), 0.42) * 300 + 0.5))

		Land Cover
		New LCCS ref: 2011
lccs_woody	r	Merge of all LCCS state maps reporting only woody classes. Raster version of “WISDOM_code” (numeric values associated to Map_Code and LCCS_code)
lccs_03	r	Merge of all state maps reporting all LCCS classes. Raster version of “WISDOM_code” (numeric values associated to Map_Code and LCCS_code)
lccs_aggr2	r	Aggregated LCCS classes = reclass(lccs_03, recl_numcode_agg1_num.txt) * msk_feb12
stkkg3	r	Map of woody biomass stock (preliminary dataset with some gaps) = merge(reclass(lccs_woody, recl_3_numcode_stkkgha_hr3.txt) * rainf_3, reclass(lccs_woody, recl_3_numcode_stkkgha_mr2.txt) * rainf_2, reclass(lccs_woody, recl_3_numcode_stkkgha_lr1.txt) * rainf_1)
stkkg3_2		Filling of missing cell values = stkkg3 + stk_we2int_x
stkkg3_3		clipping on msk_feb12 = stkkg3_2 * msk_feb12
stkkg3_fl		Float version necessary for subsequent processing = float(stkkg3)
msk_stk589kg		Mask of the land with stock >= to 589 kg/ha (1 m^3)
stkover589		Map of woody biomass stock above 589 od kg/ha (1 m^3) = stkkg3 * msk_stk589kg
mai3_mn		Mean Annual Increment (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Minimum variant. [Calculation must be made on floating point map of stock] Stock threshold: 240; MAI% below Threshold: 12.5% = con(stkkg3_fl < 240, int(stkkg3_fl * 0.125 + 0.5), int(pow((stkkg3_fl / 1000), 0.6) * 70 + 0.5))
mai3_md		Mean Annual Increment (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Medium variant. [Calculation must be made on floating point map of stock] Stock threshold: 1000; MAI% below Threshold: 15% = con(stkkg3_fl < 1000, int(stkkg3_fl * 0.15 + 0.5), int(pow((stkkg3_fl / 1000), 0.5) * 150 + 0.5))
mai3_mx		Mean Annual Increment (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Maximum variant. [Calculation must be made on floating point map of stock] Stock threshold: 2000; MAI% below Threshold: 20%

	= con(stkkg3_fl < 2000, int(stkkg3_fl * 0.2 + 0.5), int(pow((stkkg3_fl / 1000), 0.42) * 300 + 0.5))
mai3mdstk589	= mai3_md * msk_stk589kg

	Accessibility
n10_30e20	Merging of DEM tiles
ns_dem3as	Clipping of n10_30e20 on N Sudan
ns_dem100	Resampling of ns_dem3as to 100 m
Slope_ns	Slope map percent based on ns_dem100
dist0_ns	= merge(major_set08, urb_select2, road_vmapo, rail_sim05, nile_atbara)
dist00	Merging of Darfur and North Sudan communication layers = merge(dist0_1_darf, dist0_ns)
dist0_ns_darf	Starting feature of cost distance analysis
dist0_laz	Projection of dist0_ns_darf to Lambert Azimuthal Equal Area Projection (for cost-distance analysis)
slope_ns_laz	Projection of Slope_ns to Lambert Azimuthal Equal Area Projection (for cost-distance analysis)
slp_laz_0_1	Mask of 0-slope (value 1)
cd_laz2	Cost-distance analysis = costdistance(dist0_laz, (slope_ns_laz + slp_laz_0_1))
cd_laz2_i	Integer version = int(cd_laz2 + 0.5)
cd2_i_gc	Resampling of cd_laz2_i and geographic projection=
cd2_50_jenks	Segmentation of cd2_i_gc (classes based on 50 natural breaks-jenks)
acc2	Percent accessibility based on cd2_50_jenks see file cd2_access clases.xls = reclass(cd2_50_jenks, recl_cd2_50_jenks_acc2.txt)
acc2_fin	Filling of NoData cells on outer edges and clipping to n_s_msk1 = merge(acc2, int(acc2_tmp_f4) * n_s_msk1)
leg_acc_perc	Legal accessibility map (% accessible according to IUCN protection categories
acc_phy_leg	Accessibility (% accessible) based on physical and legal factors. = int(acc2_fin * leg_acc_perc / 100 + 0.5)
	Accessible MAI (Globcover ver 2.3 ref: 2009)
acgcmai2md	Accessible MAI (from Globcover09) – Medium variant. (kg / pixel, d.m. (also / ha) = int((50 + mai2md_int * acc_phy_leg) / 100)
acgcmai2md_x	Portions used to fill new admin layout

	Accessible MAI (LCCS ref: 2011)
acmai3md	Accessible MAI (fromLCCS2011) – Medium variant. (kg / pixel, d.m. (also / ha) – limited to LCCS map area = int((50 + mai3_md * acc_phy_leg) / 100)
	The administrative CBS map on which the WISDOM analysis was based differed slightly from the LCCS base map. In order to fill-in the missing portion, the stock and accessible MAI from the Globcover dataset was used.
lccs_msk0_1	mask map showing 0 value in the lccs-coverd area and value 1 for the portion outside lccs map.
stk_we2int_x	Stock based on Globcover data with values only in the portion NOT covered by lccs map. = int(stk_we2int * lccs_msk0_1)
stkkg3_2	Stock (fromLCCS2011) (kg / pixel, d.m. (also / ha) – extended to full CBS admin area (n_s_msk1) = stkkg3 + stk_we2int_x
stkkg3_3	Map clipped on new admin layout (msk_feb12) = stkkg3_2 * msk_feb12
acgcmai2md_x	Accessible MAI based on Globcover data with values only in the portion NOT covered by lccs map. = int(acgcmai2md * lccs_msk0_1)
acmai3md2	Accessible MAI (fromLCCS2011) – Medium variant. (kg / pixel, d.m. (also / ha) – extended to full CBS admin area (n_s_msk1) = acmai3md + acgcmai2md_x

acmai3md3	Map clipped on new admin layout (msk_feb12) = acmai3md2 * msk_feb12

Integration Module	

	Balance based on Globcover 09
bal3gc_md	Pixel-level balance – Medium variant (kg / pixel (ha), d.m.) = acgcmai2md – con11_tot_2
bal3gcmd6km	Local balance (context of 6 km) = focalmean(bal3gcmdf40, circle, 20) * n_s_msk1

	Commercial balance based on Globcover 09
c100b3gcmd6k	“Commercial” balance map assuming a minimum surplus threshold of 100 od kg/ha/year (1.5 od t or 2.55 m^3 per hectare on a 15-years rotation) = con(balgcmd_6km < 100, con(balgcmd_6km >= 0, 0, balgcmd_6km), balgcmd_6km)
c150b3gcmd6k	“Commercial” balance map assuming a minimum surplus threshold of 150 od kg/ha/year (2.25 od t or 3.8 m^3 per hectare on a 15-years rotation) = con(balgcmd_6km < 150, con(balgcmd_6km >= 0, 0, balgcmd_6km), balgcmd_6km)
c200b3gcmd6k	“Commercial” balance map assuming a minimum surplus threshold of 200 od kg/ha/year (3 od t or 5 m^3 per hectare on a 15-years rotation) = con(balgcmd_6km < 200, con(balgcmd_6km >= 0, 0, balgcmd_6km), balgcmd_6km)

	Balance based on LCCS2011
bal_md	Pixel-level balance – Medium variant (kg / pixel (ha), d.m.) = acmai3md2 – con11_tot_2
bal_md_3	Map clipped on new admin layout (msk_feb12) = **bal_md** * msk_feb12
bal_md6km	Local balance (context of 6 km) = focalmean(bal_mdf40, circle, 20) * n_s_msk1
bal_md6km_i	Integer of **bal_md6km**
bal_md6km_i 3	Map clipped on new admin layout (msk_feb12) = **bal_md6km_i** * msk_feb12

	Commercial balance based on LCCS2011
c100balmd6k	“Commercial” balance map assuming a minimum surplus threshold of 100 od kg/ha/year (1.5 od t or 2.55 m^3 per hectare on a 15-years rotation) = con(bal_md6km < 100, con(bal_md6km >= 0, 0, bal_md6km), bal_md6km)
c150balmd6k	“Commercial” balance map assuming a minimum surplus threshold of 150 od kg/ha/year (2.25 od t or 3.8 m^3 per hectare on a 15-years rotation) = con(bal_md6km < 150, con(bal_md6km >= 0, 0, bal_md6km), bal_md6km)
c200balmd6k	“Commercial” balance map assuming a minimum surplus threshold of 200 od kg/ha/year (3 od t or 5 m^3 per hectare on a 15-years rotation) = con(bal_md6km < 200, con(bal_md6km >= 0, 0, bal_md6km), bal_md6km)

Weighted Woodshed analysis	
	Selection of high consumption points for interpolation: 1. resampling of local balance (6km) to 10 x pixel size (1000 m pixel) 2. focalmean to identify major deficit areas (test circle 10 and 30 km) 3. create point map of main deficit areas and extract attribute = deficit (through “Extract Value to Point”) 4. Create inversed attribute values 5. Interpolate on inversed attributes to create the “inversed demand” cost component with a value range compatible to that of physical accessibility 6. Add physical accessibility and Inversed demand to create a combined cost factor 7. Run cost-distance from selected points based on combined cost factor
balgc_res_1km	resample of balgcmd_6km to 1km cell to facilitate processing
bal1kmpix_f30	Balance on a 30 km radius to define major deficit locations = focalmean, balgc_res_1km, circle, 30
Major_deficit_pnts	Point map of the major deficit areas

pnts_bal30km	Get deficit value for Major_deficit_pnts through "Extract Value to Point" In a separate attribute field convert the balance values into a range of positive values respecting the relation among the balance values: factor = int(lower balance value (lowest RASTERVALU) / balance value (RASTERVALU))
idw_fac30km	Run the interpolation model (Inverse Distance Weighting) on the factor values Idw pnts_bal30km factor c:\wisdom_n_sudan\GIS\w_woosdhed\Idw_fac30km C:\WISDOM_N_Sudan\GIS\balance_gc09\balgc_md 2 VARIABLE,12 #
idw_fac_1ha	Resampling to 1-ha pixel (float)
defi_fact	Integer of idw_fac_1ha clipped on N_S_msk1 int(idw_fac_1ha * n_s_msk1 + 0.5)
ph_acc_1_20	Reclass of physical accessibility acc2_fin into 20 classes from 1 (most accessible) to 20 (least accessible)
w_cost	Combined accessibility and deficit cost factor = int(defi_fact + ph_acc_1_20)
	Dist0 and slope maps were re-projected to metric units through Lambers Azimuthal Equal Area projection (ns_LAzEqA) : pnts_bal30km_laz; w_cost_laz
wcd_laz_1	Weighted cost distance (ns_LAzEqA) (pnts_bal30km_laz; w_cost_laz)
wcd_1	Weighted cost distance GC WGS84 Resampling of wcd_laz_1 to match cell size and projection
wcd_1clip	Weighted cost distance GC WGS84 Filling of NoData cells on outer edges and clipping to n_s_msk1 = merge(wcd_1, focalmean(wcd_1, circle, 2)) * n_s_msk1
wcd_396	Weighted cost distance buffer zones. = reclass of wcd_1clip into 396 equal interval classes

fNRB calculation

rur_6km00	RURAL areas of Sudan with 6km buffer resampled to 1 ha pixel
urb_6km	Urban areas of Sudan (excluded Darfur) with 6km buffer resampled to 1 ha pixel
d_urb_6km	Darfur urban areas with 6km buffer resampled to 1 ha pixel
urb_rur_un	Map showing urban, rural and uninhabited areas = int(merge(d_urb_6km, urb_6km, rur_6km00) * n_s_msk1)
loc_popzone	Map conbining Locality codes withurban, rural and uninhabited codes = int(loc_n_s * 100 + urb_rur_un)

ANNEX 7: WISDOM WORKSHOPS

Two full-day training workshops ON wisdom were held FNC Headquarter, Khartoum.

1. The first workshop, held on 21st September 2011, focused on the WISDOM methodology and on the technical aspects of the development of the Demand and Supply Modules.
2. The second workshop, held on 29th February 2012, reviewed the results of WISDOM Modules and focused on the findings and policy implications.

The workshops opening was done with auspices from the Director of the Forests National Corporation, Mr. Abdelazim, Mr. Alemu Asfaw, CTA SIFSIA, and Acting FAO Representative, and by Mr. Osman Omar Abdalla, Chief Technical Affairs, FNC.

The workshop was held by the team of SIFSIA Consultant responsible for the analysis: Rudi Drigo, International WISDOM Consultant, Fatha El Aleem Mohie el Deen, National Woodfuel Demand Consultant and Mohamd Osman El Hassan, National Woody Biomass Supply Consultant.

Each workshop had approximately 80 participants, including FNC Headquarters staff from technical units concerned with wood energy, management, inventory, GIS, etc. (over 60 participants) and delegates from most of FNC States Offices: Northern 1; Red Sea 2; Khartoum State 1; White Nile 2; Gezira 1; Gedaref 3; North Kordofan 3; South Kordofan 1; Blue Nile 2; FNC HQ 63.

In order to assure the appropriation of the WISDOM tool, the participants recommended that FNC should take the responsibility of:

- Updating the National Forest Inventory and Forest Products Consumption Survey to avail of reliable data for the application the WISDOM methodology and other planning purposes.
- Capacity building of FNC staff in the fields of Forest Inventory, Forest Management and, Remote Sensing and GIS to equip them for using the method.
- Awareness raising for decision makers to get their support to surveys and capacity building.

A separate workshop was held in El Fasher, North Darfur on 26th February 2012 to discuss the WISDOM findings on Darfur region with focus on IDP Camps. The 60 participants to the workshop included the FNC Directors and staff of North, West and South Darfur as well as delegates from UNEP, OCHA, UNAMID and several NGOs.

[TO BE UPDATED WITH LIST OF PARTICIPANTS OF 2ND FNC and DARFUR WORKSHOPS]

One last workshop was held at the Conference Hall of the Ministry of Agriculture and Irrigation on 1st March 2012, jointly organized by SIFSIA and FNC. The workshop was introduced by the Director of the Forests National Corporation, Mr. Abdelazim, by Mr. Alemu Asfaw, CTA SIFSIA, and was officially opened by the Ministry of Agriculture of the Khartoum State.

In the first session FNC made a presentation on “Increasing pressure on woody Forest Products - Gap Between Demand and Supply”.

In the second session SIFSIA presented the main findings, conclusions and recommendations of WISDOM Sudan[12].

The 120 participants to the workshop included delegates from the forestry, energy and agricultural sectors, from UN Agencies, Donors and NGOs.

[TO BE UPDATED WITH LIST OF PARTICIPANTS OF MoAI MEETING OF 1ST MARCH]

[12] The presentation made at the workshop may be downloaded from http://wisdomprojects.net/WISDOM_Sudan_Summary_Min_Agr_1_March_2012_ver04.zip [To be replaced by link to the PDF version at SIFSIA ftp website]