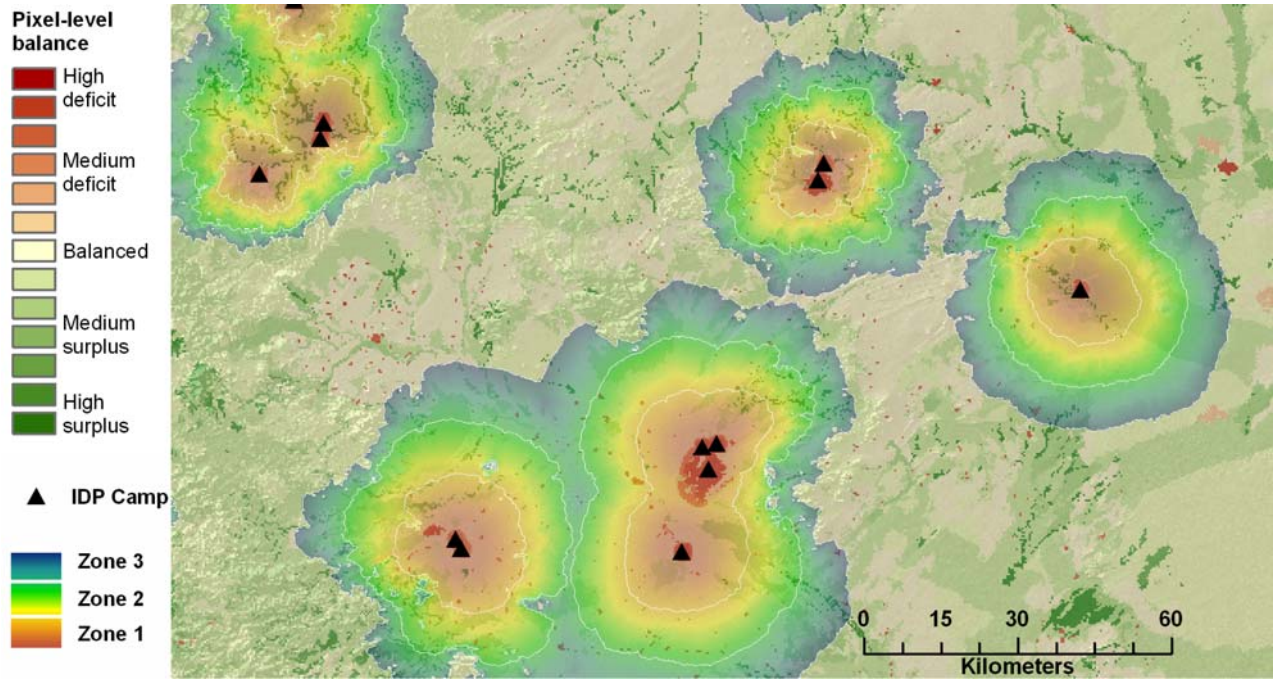
FAO-NRL Project - DARFUR OSRO/SUD/823/UEP

Sudan Institutional Capacity Programme: Food Security Information for Action (SIFSIA N) FAO OSRO/SUD/620/MUL

WISDOM Darfur

Land Cover mapping and WISDOM analysis for emergency and rehabilitation planning in Darfur

UPDATE 2011



Food and Agriculture Organization of the United Nations

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UPDATE 2011

Updated analysis based on the new Sudan Land-cover map produced by Land and Water Division (NRL) mapping unit of FAO and the Remote Sensing Authority (RSA) of Sudan (map release February 2012)

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Paola Codipietro

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Activity carried out in the framework of the FAO-NRL Project - DARFUR OSRO/SUD/823/UEP and the Sudan Institutional Capacity Programme: Food Security Information for Action (SIFSIA) FAO OSRO/SUD/620/MUL, with contributions from **Mohamed Osman El Hassan**, National Woody Biomass Supply Consultant, **Fath el Aleem Mohie el Deen**, National Woodfuel Demand Consultant, on WISDOM analysis, and from **Rossana Padeletti**, **Lorenzo Vita, Eldira Kollozaj, Ugo Leonardi, Daniela Mattina** and **Saverio Stoppioni** on photo interpretation and land cover mapping.

Food and Agriculture Organization of the United Nations

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FOREWORD

Since 2003, the conflict in Darfur caused innumerable deaths and the displacement into refugee camps of one third of its entire population, this whole sad process taking place in a fragile environment and further distressing the difficult equilibrium between man needs and available resources. At the very core of this precarious nexus sits the provision of woody biomass, for energy and other uses, from which depend the subsistence energy supply of many vulnerable populations, displaced and non, the sustainability of other essential sectors such as livestock and farming, and the overall environmental stability.

This study provides the policy makers, emergency and rehabilitation operators, project managers and technical personnel with a comprehensive and spatially-explicit view on the use and potential productivity of woody biomass in Darfur, with special attention to Internally Displaced Populations (IDP).

The analysis was based on the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM), a specialized system for examining the spatial distribution of woodfuel supply and demand and addressing issues of sustainability as key elements in wood energy planning. WISDOM has been designed by the Forestry Department of FAO and applied in a number of countries seeking to promote sustainable wood energy systems through careful management of wood resources. A previous regional-level WISDOM analysis conducted in 2004 covering ten East and Central African countries including Sudan has already supported Darfur policy formulation in spite of its coarse resolution.

This new WISDOM analysis presents a far higher spatial and thematic resolution and it is based on 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.

The WISDOM analysis uses a wide range of input data from a variety of sectors including population distribution and per capita consumption, mean annual increment and economic accessibility factors, among others. Due to the lack of recent and reliable data on some aspects, the present analysis uses some assumption and values attributions based on best judgment, with the scope of creating a comprehensive vision. These assumptions are clearly stated, highlighting the need for validation and recommending the filling of critical data gaps through new collection efforts.

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

It is inevitable, and well understood, that once lowered to project scale more information will be needed to guide operational action. Meanwhile this study provides an unprecedented basis to project developers and policy makers for defining the priority areas and the types of intervention as objectively as it is currently feasible.

The analysis benefited from the contribution of different institutions, national and international agencies and NGOs operating in the emergency sector and projects who shared maps, statistical data, reports and personal knowledge on the many facets of wood energy and of the Darfur socio-economic context. In this process, WISDOM improved the cross-sectoral dialogue among the numerous institutional stakeholders.

We hope that the work done and this publication will boost further analysis and, most important, will promote the establishment of institutional synergies for the formulation of sound wood energy strategies in the challenging context of peace-building, emergency management and rehabilitation programmes.

ABSTRACT

The sustainable woody biomass supply potential in Darfur, Sudan, and the consumption of woody biomass by Internally Displaced Populations and by rural and urban residents are analyzed and mapped applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology.

The study has been updated on the basis of 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). 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 and IDP camps 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 analysis results are used in woodshed analysis, in order to define and delimit the supply zone deemed necessary to supply woodfuels and woody biomass in a sustainable fashion to IDP camps, urban centers and rural villages. With reference to the current horizon of exploitation around IDP camps, the study reveals also the probable non-renewable fraction of the woody biomass currently used in the camps and the level of pressure exerted on wood resources.

The study put forward critical planning elements that help in the formulation of a comprehensive and cross-sectoral wood energy strategy for Darfur 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 peace and resettlement action, sustainable management and poverty alleviation. For this, more thematic layers must be combined to the ones already produced, such as farming systems, livestock and water, vulnerability and health factors, etc. benefiting from the data structure developed and the GIS analytical environment.

(Citation)

WISDOM Darfur. Land Cover mapping and WISDOM analysis for emergency and rehabilitation planning in Darfur. Update 2011

Prepared by Rudi Drigo and Paola Codipietro

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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; Internally Displaced Populations (IDP).

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The original analysis of the wood energy situation in Darfur was accomplished by FAO in collaboration and with the financial support of UNEP as part of the Timber and Energy Project (OSRO/SUD/823/UEP). The 2011 update was carried out in the framework of the Sudan Institutional Capacity Programme: Food Security Information for Action (SIFSIA N) , FAO OSRO/SUD/620/MUL.

The work was conducted under the technical supervision of John Latham, Senior Land and Water Officer (Geospatial) and has been assisted in the process through the close collaboration of Marc Abdala, Senior Emergency and Rehabilitation Coordinator for North Sudan and the operational support of SIFSIA N.

The land cover analysis has been supervised by Ms Paola Codipietro , consultant to NRL/GLCN programme) with the input of the interpreters Rossana Padeletti, Saverio Stoppioni and Lorenzo Vita in FAO HQ's Rome and at the Global Land Cover Topic Centre in Florence.

The 2011 update of the analysis was based on the Land-cover map over the whole of the Sudan produced by Land and Water Division (NRL) mapping unit of FAO and the Remote Sensing Authority (RSA) of Sudan and released in 2012. The GIS work has been supervised by Renato Cumani.

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

Given the cross-sectoral and multidisciplinary character of wood energy, the development of WISDOM Darfur would have been impossible without the contributions from many national institutions, international agencies, NGOs and individuals whose support is gratefully acknowledged. Among them, the authors wish to express their gratitude for the important contributions and the friendly collaboration to:

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Contents

List of boxes, figures and tables

ACRONYMS AND ABBREVIATIONS

ad	Air dry (biomass, usually measured in kg or t, 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
DLC	Darfur Land Commission
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)
FEWS NET	Famine Early Warning Systems Network
FNC	Forests National Corporation
FO	Forestry Department of FAO
GAA/WHH	Welthungerhilfe/German Agro Action
GIS	Geographical Information System
GLC2000	Global Land Cover Map 2000
GLCN	Global Land Cover Network of FAO
HAC	Humanitarian Aid Commission in Sudan
HH	household(s) [in Tables]
ICRC	International Committee of the Red Cross
NIDAA	Sudanes Development Call Organization
UNICEF-WASH	United Nations Children's Fund - Water, Sanitation and Hygiene
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 t, with 0% moisture content)
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
USAID	U.S. economic and humanitarian assistance
WFP	World Food Programme
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping (methodology)

SUMMARY

The scope of this study was to analyze the wood energy situation in Darfur with special reference to the Internally Displaced Populations (IDP) and to provide the basis for strategic wood energy planning in order to secure subsistence energy supply to vulnerable populations whilst reducing at the same time the unsustainable pressure on the resources of the region.

The analysis was based on the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology, developed by FAO in collaboration with the Institute of Ecology of the National University of Mexico and implemented in many countries worldwide. Fundamental features of WISDOM are spatial-explicit analysis 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).

The analytical approach included the following three distinct phases:

I. **Rapid WISDOM Appraisal (RWA)**: The demand for woodfuels and the potential sustainable supply was estimated and mapped on the basis of readily available geo-statistical data. The results of this preliminary analysis were used for the first cautious delineation of the territory needed for the sustainable woodfuel supply (woodshed).

II. **Land Cover Mapping and data collection within the preliminary woodshed zone**: Within the woodshed territory defined during the first phase, detailed land cover mapping was carried out[1] and up-to-date information on consumption patterns and supply potential was collected.

III. **Detailed WISDOM Darfur analysis**: the new geo-statistical data was used to refine the assessment and mapping supply/demand balance and the actual woodshed was revised accordingly.

Key products of the analysis include a new detailed land cover map and an "atlas" of thematic maps on the many aspects that compose the wood energy sector.

The wood-energy-related thematic layers produced include population distribution, woodfuel consumption, stock and productivity of woody biomass, their physical accessibility and, most relevant, several supply/demand balance scenarios and woodshed analyses specifically referred to IDP camps.

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 (or pixel) 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 local surplus as source of formal woodfuel production systems serving distant consumption sites.

This rich dataset provides a comprehensive and geographically discrete vision of the wood energy situation in Darfur, with specific reference to IDP Camps, revealing objective elements for priority zoning and strategic planning.

Key findings of the Detailed WISDOM Analysis

Demand for woody biomass

- The total annual consumption of woody biomass in 2011 according to the business-as-usual (BAU) consumption variant, all uses included, is estimated at 6.3 million m^3, or 3.7 million oven-dry tons

[1] The LCCS land cover mapping was subsequently extended to the whole Sudan. The analysis hereby presented refers to the Darfur portion of the new nation-wide land cover map released in February 2012.

- With 93 % of the total woody biomass use, the household sector is by far the most important demand sector. This value is higher in rural areas (98%) and lower in urban areas (77%), where industrial uses are concentrated. 86% of the household consumption goes to cooking and the rest to construction, maintenance and furniture. The cooking share is lower in rural areas (83%) and higher in urban areas (95%).
- The big building wave consequent to the influx of the international community, which boosted brick production to extreme levels, seems to have passed but the impact of this use sector remains serious. The present study assumes an annual fuelwood consumption of over 118,000 m^3, which is less than the wave peak but almost 5 times higher than pre-war situation.
- The consumption by the Institutional, commercial and industrial sectors (bricks included) is estimated at 453,000 m^3
- The dissemination of Fuel Efficient Stoves (FES), which is one of the ways to reduce the consumption of fuelwood and provide other benefits, has been done in IDP camps with good results but only marginally in rural and urban areas. It is estimated that a widespread and intensive stove programme in rural and urban areas ("FES" consumption variant) may reduce the total consumption by a maximum of 1.2 million m^3 (from 6.3 to 5.1 million m^3, or from 3.7 to 3 million oven-dry tons).
- LPG presently plays a marginal role as substitute of charcoal and fuelwood in Darfur and is likely to remain so for the near future, unless heavily promoted and subsidized.

Woody biomass supply potential

- The total stock of woody biomass in Darfur states is estimated at 99.8 million m^3, or 58.8 million oven-dry tons.
- The estimated Mean Annual Increment according to the medium productivity variant is 7.9 million m^3, or 4.6 million oven-dry tons.
- The physically accessible productivity is estimated at 7.4 million m^3, or 4.3 million oven-dry tons.

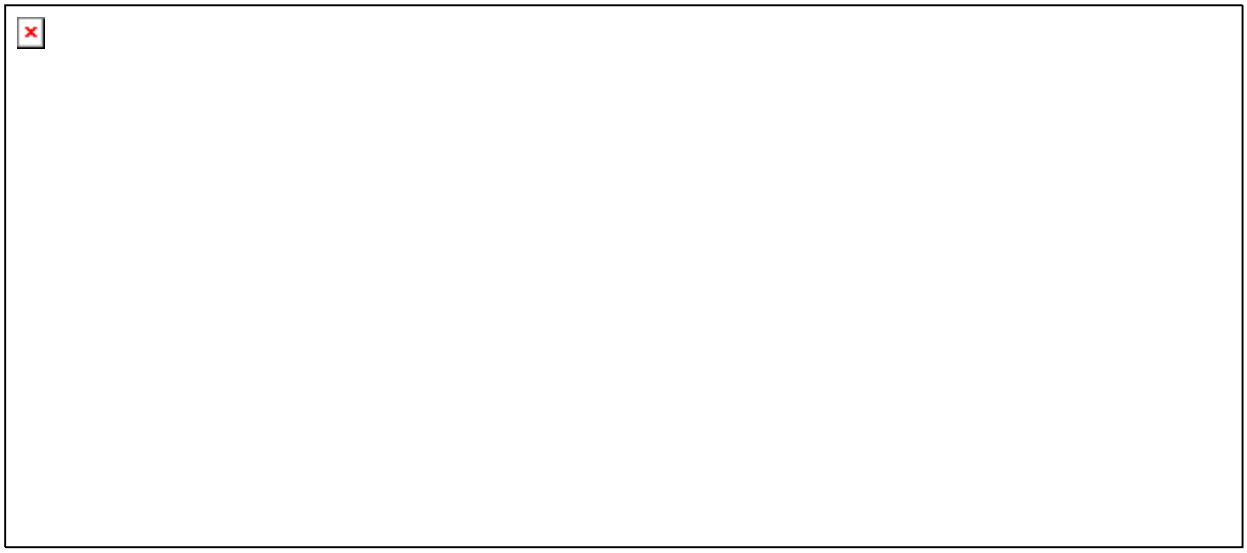
Supply/demand balance

- The supply/demand balance, assuming business-as-usual (BAU) demand and Medium accessible productivity, shows an overall surplus of 0.6 million oven-dry tons (1 mln m^3). Assuming the full impact of the FES consumption variant, the surplus rises to 1.3 million od tons (2.2 mln m^3). These results indicate that there is a theoretical sustainable potential but give no guarantee of economic sustainability (see below). Moreover, these summary results do not reflect the geographic distribution of deficit and surplus areas.
- Considering that the management and commercial exploitation of sparse resources may be uneconomical, balance analyses were carried out for "economically accessible" resources through the application of different minimum resource availability thresholds to local surpluses (see state-wise graph in Figure 1). The results for North Darfur show that, even with a low threshold of 100 kg $*ha^{-1}*yr^{-1}$ (corresponding to 1.5 od t or 2.55 m^3 per hectare on a 15-years rotation) the resources are insufficient to match the commercial demand. For South Darfur and West Darfur the positive balance may be achieved with a "medium" threshold of 150 $kg*ha^{-1}*yr^{-1}$ (2.25 od t or 3.8 m^3 per hectare on a 15-years rotation). The threshold of 200 kg/ha/yr (3 od t or 5 m^3 per hectare on a 15-years rotation) is definitely too high, as it shows negative balance in all states.
- Due to the deep deficit in North Darfur, Darfur as a whole shows a negative "commercial" balance even when the lowest threshold is applied, which is a clear indication that demand reduction and increase productivity must be strongly promoted.
- The main issue now is to define the limit set by commercial fuelwood and charcoal producers. If the thresholds mentioned above are profitable for local operators then the potential for sustainable wood energy system is confirmed. If, on the contrary, the minimum thresholds

defined by the operators will be higher, there will be need to integrate even more consistently the supply from other sources (other areas or new plantations, or woodfuel import from South Sudan and RCA) and/or reduce the demand through alternative fuels and FES programs.

FIGURE 1

Woodfuel supply/demand balance in Darfur States under various assumptions, including, from left: theoretical balance (Medium productivity vs. BAU and FES demand variants); "commercial" balances relative to minimum woody biomass surplus thresholds of 200, 150 and 100 od kg*ha^{-1}*year^{-1}.



Woodshed analysis

- Woodshed analysis revealed the extent of territory that must be managed for woodfuel production in order to meet the demand of IDP camps and other users, according to various supply and demand scenarios. When realistic productivity and demand assumptions are adopted, the woodshed expands to include the majority of Darfur territory, highlighting the difficulty of the situation and emphasizing that all users (urban, rural, IDP, industries, etc.) are equally competing for the resource and that the strategies must address them all.
- The analysis of supply/demand balance around IDP camps allowed to determine the Non Renewable Biomass (NRB) fraction associated to current supply systems and thus the associated risks of degradation and deforestation. The analysis was done considering distance from the camps of 12, 24 and 36 km (or equivalent efforts over rough terrain), the latter one being indicated as the limit of current supply zones. The results show that:
    - the situation is particularly serious in North Darfur, where the NRB fraction ranges between 95% at close distance and 79% when the maximum distance is considered;
    - relatively better appears the situation in West Darfur where NRB fraction is 70% at close distance but reduces to 0% for a horizon of 36 km;
    - South Darfur presents an intermediate situation, with an NRB fraction of 78% at close distance, reducing to 41% for an harvesting horizon of 36 km.

  The analysis can be carried out for specific locations, i.e. individual IDP camps, in order to assess environmental impacts and to target project action.

Main conclusions

In support to the formulation of a comprehensive wood energy strategy for Darfur, covering IDP Camps as well as other residential, industrial, commercial and institutional uses, the following

conclusions are of particular relevance:

Wood energy issues

- Darfur as a whole seems to have the theoretical potential, in terms of mean annual increment (MAI) of woody biomass, to match the current demand, but good part of the resources are too sparse to be economically accessible and the true balance is therefore clearly negative.
- Spontaneous and unplanned harvesting is impacting on the capital (stock) rather than on its interest rate (MAI), provoking degradation and depletion of natural resources.
- Converting the spontaneous harvesting into sustainable wood energy systems requires major efforts including:
    - intensive and locally tailored participatory management planning,
    - plantation establishment,
    - Fuel Efficient Stoves programmes in rural and urban areas.
- Providing alternative livelihood strategies for rural populations currently dedicated to fuelwood and charcoal production for sale at IDP camp sites are important and beneficial but assuming that this would reduce the pressure on wood resources is probably erroneous. If the demand remains, other would respond and reducing the exploitation in one areas would simply displace it over another area. More efficient would be to rationalize the supply/demand chain by promoting equitable and sustainable resource management, thus consolidating income sources wherever feasible.
- The margin between the demand and the growth potential is limited and the economic viability of sustainable commercial wood energy systems needs to be carefully evaluated. The results show an overall negative balance for Darfur as a whole even when applying low thresholds, primarily due to the deep deficit of North Darfur. Positive balance can be met in West and South Darfur only if formations with low productivity (and thus with limited attraction for private operators) are put under operational management.
- The values derived from the application of minimum resource availability thresholds, presented above, give us the context and constraints in which forest management planning must operate. The economic viability of sustainable production systems is evidently very limited, especially in North Darfur, and must be discussed and defined area by area with forest managers and local operators. Where the commercial balance remains negative, the supply strategies must be complemented by tree planting and the demand must be reduced by FES and fuel substitution programmes.
- From all above it is evident that strategy options must be locally tailored in order to be effective, and that the main contribution of the WISDOM tool is in supporting geo-referenced priority zoning under various policy items and assumptions.

Communication strategy

- The deep nexus between subsistence energy, livestock management, sustainable forestry and farming requires multi-sectoral strategies based on in a shared analytical context.
- The comprehensive and spatial-explicit vision of supply and demand is a basic pre-requisite to wood energy planning and strategy formulation at local and national levels and synergies among institutions and agencies for an integrated multi-sectoral approach are essential.
- In order to promote institutional awareness on the findings and on the planning support offered by WISDOM Darfur it is necessary to continue on the communication strategy aiming at state-level administrators and operators as well as to national institutions, agencies and donors community[2].

[2] A workhop 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.

WISDOM data

- Given the limits of existing data, the development of the WISDOM geostatistical database implied many assumptions and tentative value attributions. Competent critics are most welcome, especially if they can correct possible misinterpretation of existing data or if they can indicate new and more reliable references.

Weaknesses of approach/limitations

- WISDOM Darfur is still in its "prototype" version. It provides a comprehensive vision but a user-friendly interface for consultation, updating and maintenance has not yet been developed.
- The updated WISDOM Darfur presents the situation between 2010 and 2011. The vision provided by the current dataset is a "snapshot" that becomes out-of-date with the changing of the situation.
- Concerning the demand module, the main weaknesses are related to the reliability and completeness of demographic data, including regular resident and nomadic populations and IDP. The census subdivision and administrative maps show several inconsistencies and there is a poor correspondence between 2008 census statistics and IDP statistics for the same period, as it may be justified by the fluidity of the situation.
- Concerning the supply module, the main weakness is due to the absence of reliable data on the mean annual increment and on the sustainable and economically accessible productivity.
- Concerning the Integration module, other thematic layers can and should be added to the analysis in order to identify and delineate priority areas of intervention with cross-sectoral dimension. Most immediate thematic layers may include:
    - Water availability for population, livestock and farming.
    - Livestock presence and transhumance routes.
    - Poverty
    - Vulnerability
    - Access to services (health market schools, etc.)….

Main recommendations

The underlying recommendation to all following ones is that peace and security return to Darfur. Minimal security condition is a basic pre-requisite to most, if not all, recommended sustainable resource management actions.

Short term recommendations (< 2 years)

- 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:
    - Conduct more state-level workshops to discuss the results produced and the assumptions made, and define follow-up actions aiming at the appropriation of the WISDOM tool by state-level institutions and agencies
    - 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..
- The State-level SIFSIA Unit will be the "natural" data repository of WISDOM data. Along with the principle of data sharing and transparency, it is recommended to define an operational

data handling and storage policy. The institutional repository of the WISDOM dataset 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.
- 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 Darfur. 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.
- Complement the biomass component with other essential natural resources thematic layers such as water, farming systems and livestock, poverty and vulnerability, in order to allow integrated cross-sectoral analyses
- Define a programme of natural resource monitoring and management in support of conflict resolution
- Define priority areas of intervention in a cross-sectoral analytical context and prepare a folder of project proposals for donors' consideration, including:
    - FES projects in rural and urban areas, giving priority to the areas showing marked deficit conditions.
    - Agro-forestry projects
    - Establishment of short rotation forest plantations
    - Fuel substitution programs
    - …
- Design capacity building actions aiming at strengthening institutional planning capacities at national and state levels and the full appropriation of the WISDOM experience by the relevant national and state government entities.

Medium term recommendations (< 5 years)

- Undertake capacity building programs for national and state-level institutions on planning tools (i.e. WISDOM and related tools) and sustainable resource management.
- Undertake Fuel Efficient Stove programs in rural and urban areas, giving priority to the areas showing marked deficit conditions.
- Undertake new planting and agro-forestry programs in the areas surrounding IDP camps (hopefully abandoned) and urban areas which were degraded and deforested due to woodfuel overexploitation.
- Introduce/promote participatory sustainable forest management and woodfuel production practices as source of livelihood in connection to returnees and resettlement programs.
- Undertake detailed state-level forest inventories with the scope of assessing the stock and the productivity of biomass resources.
- In collaboration with State Land Commissions, collect and organize/digitize Forest Reserves information in order to clarify and/or define access rights and governance issues.
- Prepare cross-sectoral resource management master plan for the whole of Darfur including forestry, livestock and agriculture, energy and poverty reduction, and other relevant planning sectors.

Long term recommendations (> 5 years)

- Prepare local operational management plans in the framework of the comprehensive master plan and in synergy with local stakeholders.
- Implement participatory resource management programs aiming at the creation of rural woodfuel markets, wherever feasible.

1. INTRODUCTION

1.1 SCOPE

The scope of this project component was to analyze the wood energy situation in Darfur with special reference to the Internally Displaced Populations (IDP) and to provide the basis for strategic wood energy planning in order to secure subsistence energy supply to vulnerable populations whilst reducing at the same time the unsustainable pressure on the resources of the region.

Main questions to be answered are:

- What level of woodfuel demand can be satisfied through sustainable resource management?
- Where such management is possible and where not? Which part of the demand should be met by alternative fuels?
- What contribution can we expect from improved stoves and from new plantation programmes?

Five sites were preliminarily identified during project formulation, namely Mellit, Kutum, Al Fasher, Al Geneina and Nyala. These are zones with high presence of IDP Camps but they are not the only ones since many of such camps are distributed throughout the central region of Darfur States (see map of IDP camps in Figure 2 and photos in Figure 3), all facing similar subsistence energy shortages. Moreover, woodfuel supply is a common problem also for the population normally residing in the area.

FIGURE 2

Size and locations of IDP camps in Darfur States (in color selected sites)**.**

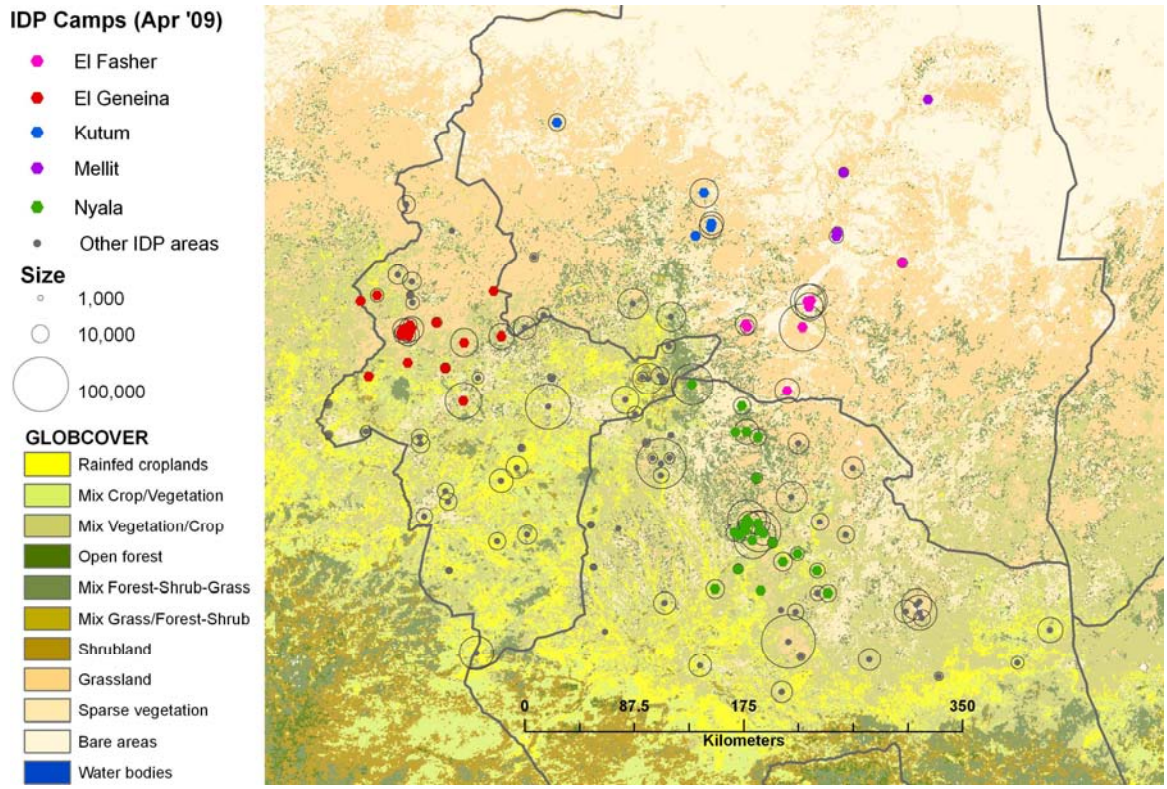


FIGURE 3

IDP camps seen from the air (source GoogleEarth). Nyala camps, among selected IDP sites and Girayda, an IDP Camp of 134,731 refugees not included among selected sites.

IDP Camp near Nyala. Eldookie GoogleEarth 2010

Refugee camp near Nyala

Refugee camp near Nyala

Portion of the Girayda IDP Camp in Buram, South Darfur, hosting 134,731 persons in April 2010

The demand for fuelwood and charcoal arising from selected IDP camps or from other camps or from resident populations cannot be considered/managed separately because they all compete for the same limited biomass sources. Either the solution for a sustainable supply can be achieved for all demand sectors or for none.

This means that the analysis must be comprehensive, considering all sectors of consumption (IDPs, resident users, commercial and industrial sectors) and all possible sources of woodfuels located in the Darfur area. The Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology was considered the most appropriate one to create a comprehensive knowledge base over Darfur biomass-energy situation, to verify if the sustainable supply and the current consumption within Darfur show a positive balance, what portion of the territory needs to be managed in order to produce the needed woody biomass, as well as other key elements for the formulation of a sound wood energy strategy.

1.2.1 Main feature of the WISDOM method[3]

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

[3] 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).

directed to the collection, harmonization, cross-referencing and geo-referencing of relevant existing information for the area of study.

- **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[4]:

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

2 - Woodshed[5] 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.

WISDOM Base

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

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

Woodshed analysis

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

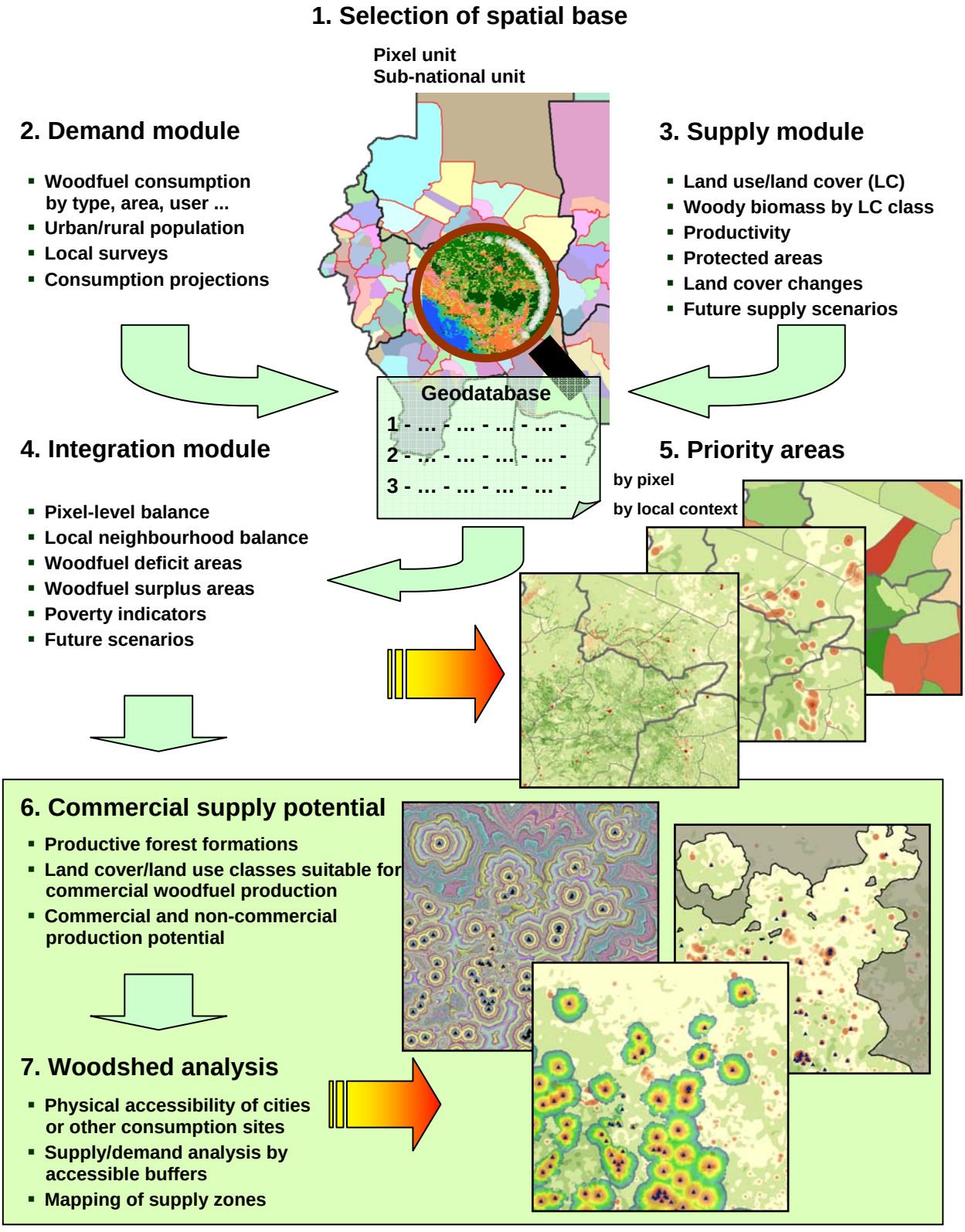
6. Mapping of potential "commercial" woodfuel supplies suitable for urban, peri-urban and rural markets.
7. Definition of woodshed, or potential sustainable supply zones, based on woodfuel production potentials and physical accessibility parameters.

[4] In the Darfur case, the WISDOM analysis was carried out twice: once for the rapid appraisal and once for the detailed analysis after land cover mapping and field data collection.

[5] 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 4

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



1.2 APPROACH

To assure good efficiency of analysis, detailed mapping and data collection was to be done only over the needed area, avoiding the inclusion of superfluous areas as well as the exclusion of important biomass sources necessary to achieve supply/demand balance.

For this, an iterative process was implemented, based on WISDOM methodology, including three distinct phases:

I. **Rapid WISDOM appraisal**: The demand for woodfuels and the potential sustainable supply is estimated and mapped on the basis of readily available geo-statistical data and "reasonable" assumptions. The results of this preliminary analysis are used for the first cautious delineation of the territory needed for the sustainable woodfuel supply (woodshed). Such woodshed zone represents the target area of the subsequent phases of the project.

II. **Mapping and data collection within the preliminary woodshed zone**: Within the woodshed territory defined during the first phase, detailed land cover mapping was carried out[6] and up-to-date information on consumption patterns and supply potential was collected.

III. **Detailed WISDOM Darfur analysis:** the new geo-statistical data is used to refine the assessment and mapping supply/demand balance and the actual woodshed is revised accordingly.

[6] The LCCS land cover mapping was subsequently extended to the whole Sudan. The analysis hereby presented refers to the Darfur portion of the new nation-wide land cover map released in February 2012.

2 PHASE I: RAPID WISDOM APPRAISAL (RWA)

Since the overarching scope of the wood energy component is to support strategic planning aiming at satisfying subsistence energy needs of IDP camps through sustainable wood energy systems and not to cover selected administrative units, the target territory varies with the quantity and spatial distribution of the demand and the quantity and spatial distribution of the sustainable supply potential.

The scope of the **rapid WISDOM appraisal** (RWA) was to achieve a preliminary definition and delineation of the territory concerned by project action. In practice, this preliminary analysis serves to define the Area of Interest (AoI) of detailed mapping, additional data collection and detailed WISDOM analysis.

In order to guarantee the complete coverage of the territory of interest, the rapid WISDOM appraisal was carried out over the Darfur and Kordofan States.

The administrative subdivision included States and Counties (or Localities).

The selected cell dimension of the raster maps generated, and thus the spatial resolution of analysis, is **10 arc-second**, at this latitude corresponds to approximately 300 m (9.3 ha pixels). The selected resolution and raster features of analysis was based on the global land cover map Globcover (v2.2), which is one of the main references used in the Supply Module.

2.1 RWA DEMAND MODULE

The analysis of demand was based on the following data sources:

- Demographic data from the 2008 census (by County)
- FAO global map of 2005 population distribution by 30 arc-second cells (FAO 2005 and subsequent update)
- Map of Internally Displaced Population (IDP) camps based on UN official figures from OCHA (source: points map Darfur_Affected_Population_Apr_1_2009_rev090709_wgs84.shp)
- Per capita consumption of woody biomass in Sudan States from the Forest Products Consumption Survey in the Sudan conduced by the Forests National Corporation with FAO assistance (GCP/SUD/047/NET)

The total population considered is that of the 2008 census by County, which includes the normal residents and the IDP.

Concerning the spatial distribution of this population within Counties, one statistical reference, i.e. the census data, and two spatial references were used: the FAO 2005 map and the map of IDP camps with associated number of refugees hosted (see left-side maps in Figure 5) . The resulting population distribution map shown in Figure 4 (right-side map) indicates the likely distribution of the 2008 population within the Counties on the basis of both the overall distribution of the FAO map and the distribution and size of IDP camps.

In the absence of more recent data, the consumption of woody biomass associated to the population was based on the results of the 1995 Forest Products Consumption Survey. The 1995 data refer to pre-war conditions and they are likely to overestimate IDP demand to some extent, but should still be representative of the residential populations. The values applied were conservative, intending that in these cases it is preferable to overestimates the demand rather than underestimate it.

Figure 6 shows the map of woody biomass consumption obtained by associating per capita consumption values (all uses combined) to the population distribution map.

FIGURE 5

Population distribution map. Top left map: FAO map of 2005 population distribution. Bottom left map: Map of Counties associated to 2008 Census and IDP camps. Right map: Map of the estimated distribution of 2008 population integrating the available spatial and statistical information.

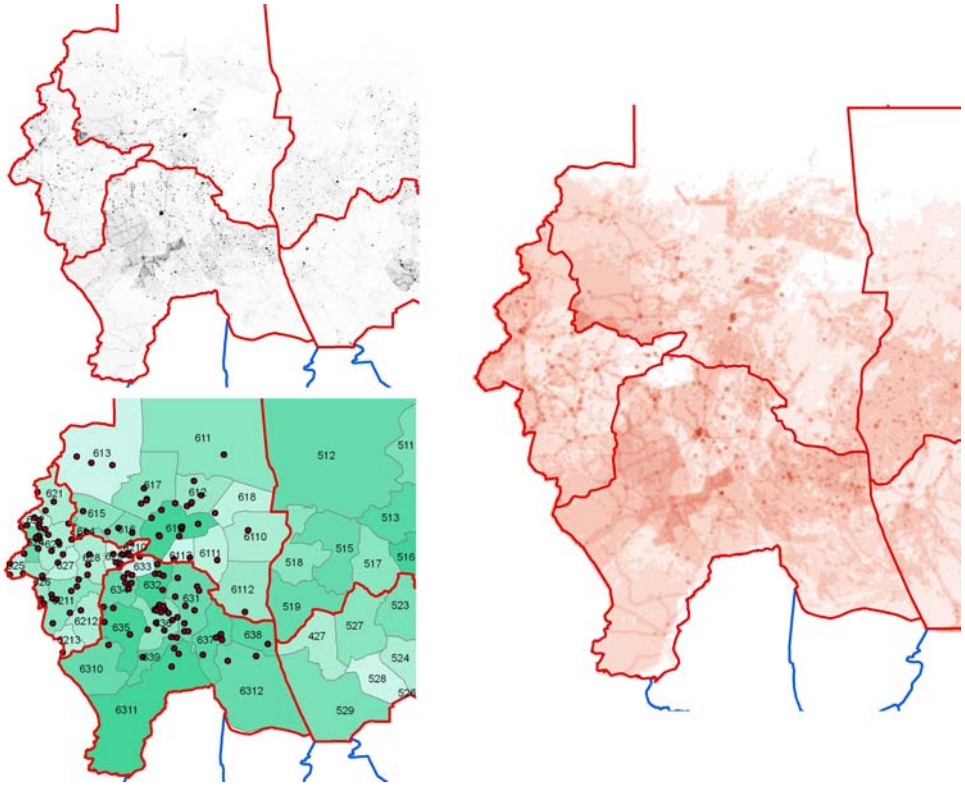
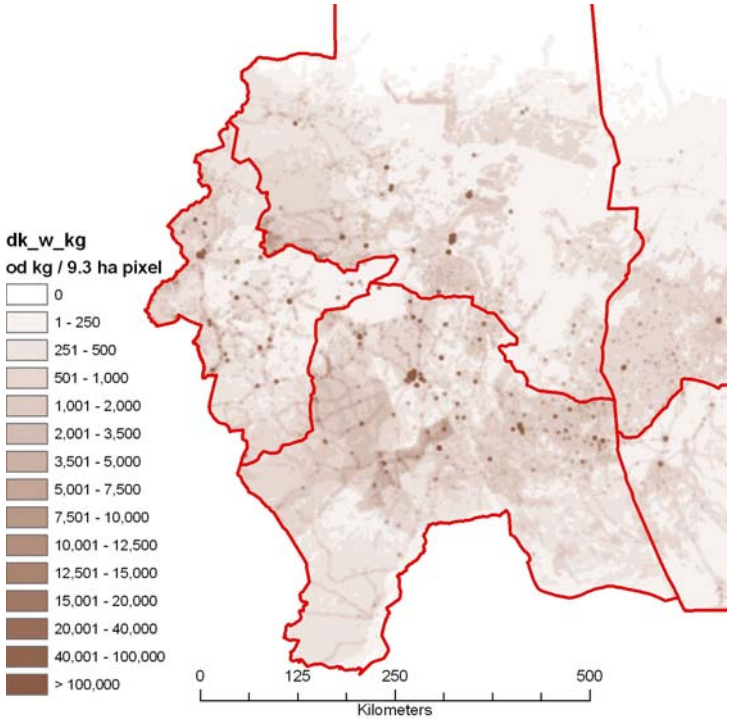


FIGURE 6

PRELIMINARY Woody biomass consumption map. Map obtained by associating per capita consumption values to the population distribution map



2.2 RWA SUPPLY MODULE

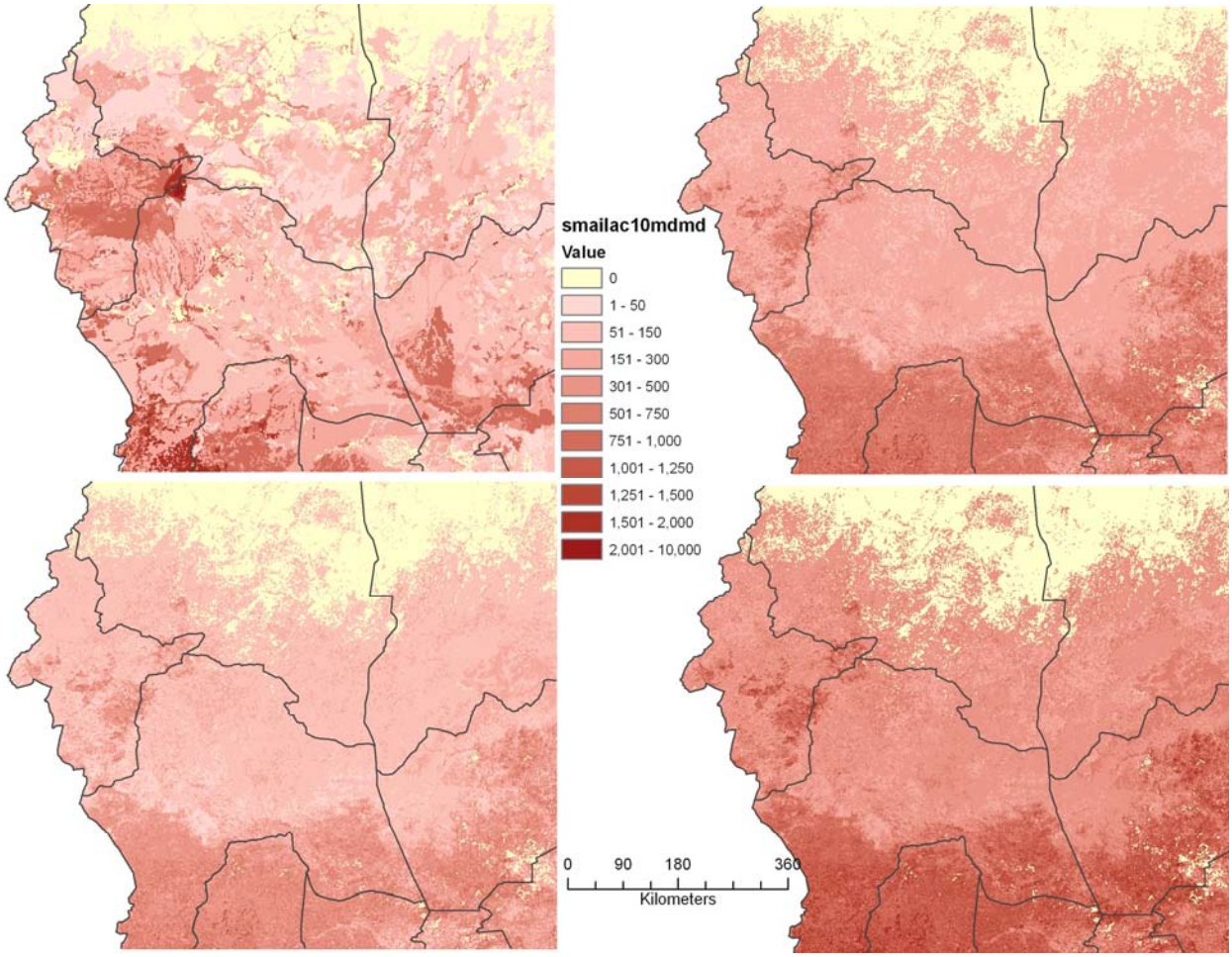
The preliminary estimation of woody biomass stock and sustainable productivity was based on supply module data from two main sources:

- The study "WISDOM East Africa – Spatial woodfuel production and consumption analysis" (Drigo, 2005), which was based on the Land Cover Classification System (LCCS 2) data produced in 2001 for Sudan in the framework of the FAO Programme Africover (Di Gregorio and Jansen, 2000).
- Preliminary results from the on-going study Global WISDOM (Drigo, 2009 unpublished report), which was based on Globcover data, version 2.2.

Figure 7 shows the woody biomass productivity in the region of interest derived from the East Africa study (top left map) as well as the three productivity levels estimated in the Global WISDOM analysis

FIGURE 7

Preliminary woody biomass productivity maps.



Top left and top right maps, showing the medium productivity values from the East Africa study and from the Global WISDOM study, respectively. Bottom left and bottom right maps, showing minimum and maximum productivity values, respectively, from the Global WISDOM study. The legend refers to the estimated mean annual increment in 10kg of oven-dry woody biomass by 9.3ha pixels.

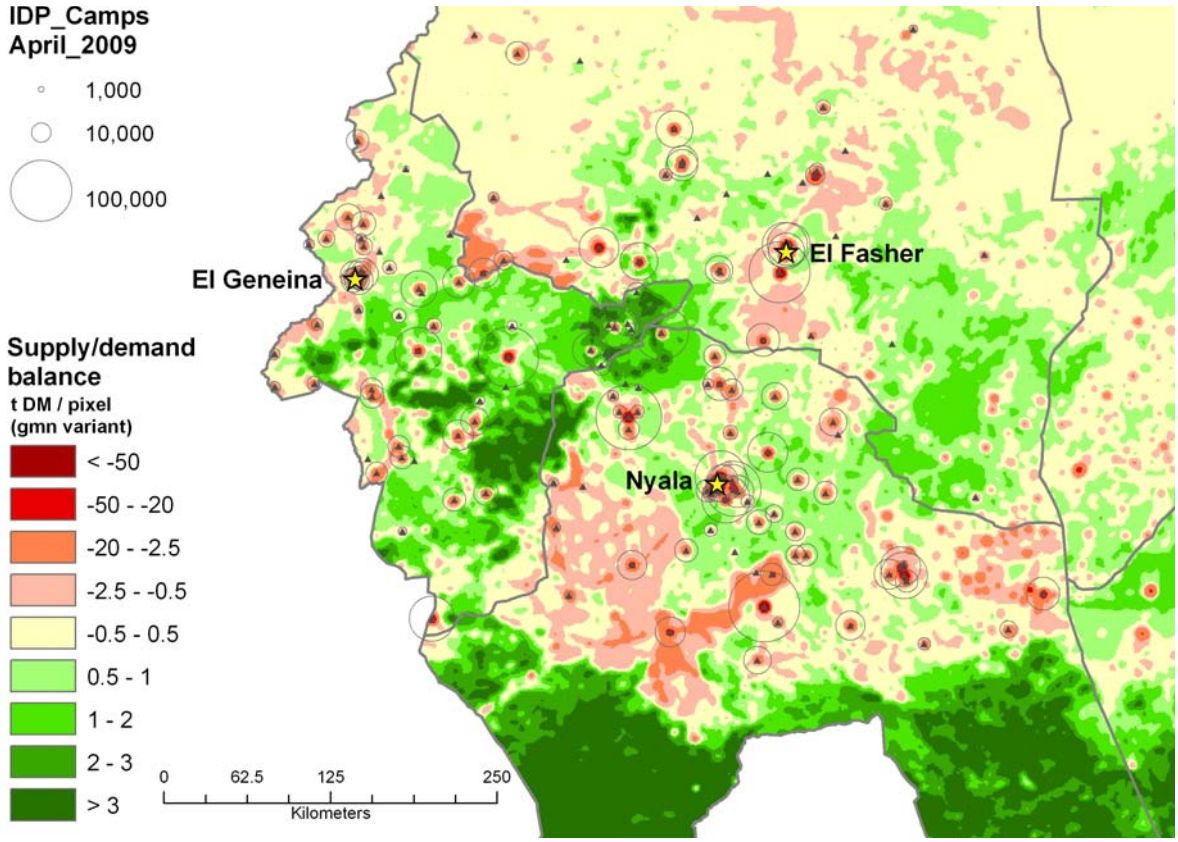
2.3 RWA INTEGRATION MODULE

The scope of the Integration Module was 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 or surplus according to estimated consumption levels and sustainable production potentials.

The result of the RWA integration module is the balance between the preliminarily estimated potential woody biomass productivity and consumption of woody biomass for energy generation and for other uses. Figure 8 shows the balance map based on minimum supply potential, which allowed a "conservative" estimation of balance conditions and subsequent woodshed analysis. In order to better visualize surplus and deficit areas, the map in Figure 8 shows the balance calculated in a local context of 3 km.

FIGURE 8

RWA Woody biomass supply/demand balance map. The map shows the local neighborhood balance assuming a 3-km supply/demand context (based on the minimum productivity values from the Global WISDOM study).



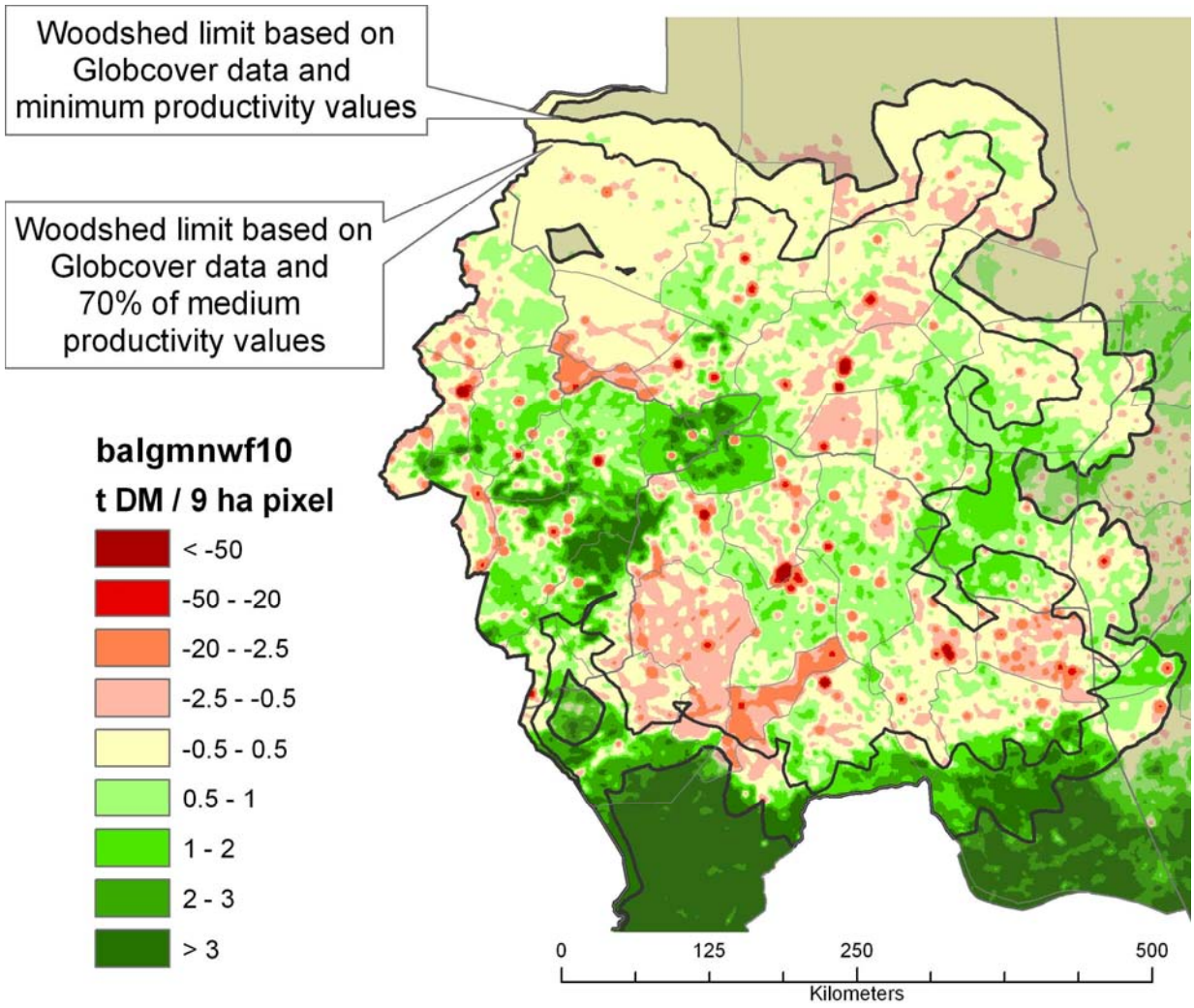
2.4 RWA WOODSHED ANALYSIS AND DEFINITION OF THE AREA OF INTEREST (AOI)

The preliminary definition of IDP camps' woodshed, or potential sustainable supply zones, was based on woodfuel production potentials and physical accessibility parameters.

In order to be certain to include a sufficient portion of the territory, the AoI was defined assuming reduced management intensities and lower increment values (Figure 8).

FIGURE 9

Woodshed zone of IDP camps of Darfur based on the estimated consumption and productivity reference values. The woodshed based on Globcover minimum productivity was used to define the AoI for land cover mapping and detailed WISDOM analysis.

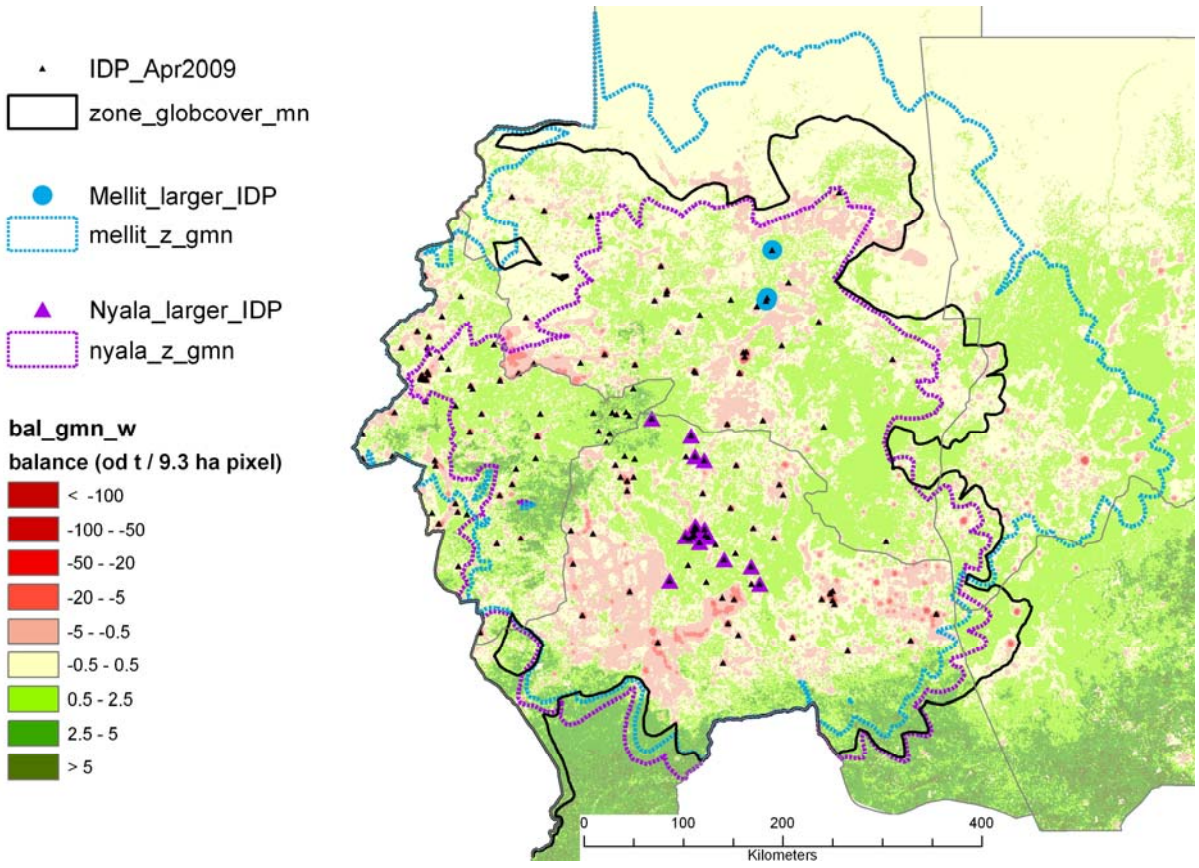


2.5 RWA CONCLUSIONS AND DEFINITION OF THE AOI

- The different references used to estimate the supply potential produce widely different resulting balance scenarios, which indicates the level of uncertainty inherent in the data (and the necessity to reduce such uncertainty, in future studies, through new land cover mapping and improved biomass data).
- The maximum productivity variant of the Global WISDOM appeared too "optimistic" and was not considered useful for the purpose of the rapid WISDOM appraisal, which produced a "conservative" delineation of the AoI of the project.
- All scenarios related to the preliminary analysis showed a positive balance within the Darfur region, which indicated the theoretical potential of satisfying subsistence energy needs (and other woody biomass demand sectors) if adequate resource management programmes are put in place (indication in good part confirmed by the Detailed WISDOM analysis, thus confirming the validity of the Rapid Appraisal approach).
- The extent of the estimated woodshed zone depended on the assumed productivity and consumption while its shape depended on the accessibility of the territory considered. Assuming conservative productivity levels, the sustainable supply zone (i.e. the area to be managed for woody biomass production), with almost 300,000 km^2, covers the entire central Darfur region.
- The extent of the woodshed changes relatively little with the site(s) selected for the analysis. It appears evident that no site is truly independent from the others concerning the supply zone. Figure 10 shows the woodshed based on the Globcover minimum productivity variant of Mellit IDP camps in North Darfur, of Nyala IDP camps in South Darfur as well as the one relative to all IDP camps. The sizes and shapes of these zones are similar, which indicates that there cannot be a resource management solution for one consumption site independently from all other sites.

FIGURE 10

Results of woodshed analysis starting from different sites.



The blue outline refers to the Mellit IDP camps. The purple outline refers to the Nyala IDP camps. The black outline refers to all IDP camps in the Darfur states

3 PHASE II: LAND COVER MAPPING

3.1 INTRODUCTION

To support the detailed and up-to-date analysis of woody biomass supply potential, a new land cover map of the AOI was prepared. The land cover mapping constitutes the basis for a reliable assessment of the supply potential and as focal area of a comprehensive wood energy strategy.

The land cover mapping was conducted in parallel to the WISDOM analysis, in synergy with the on-going Land Cover Mapping of Sudan (FAO-GLCN). The mapping follows 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.

3.2 PREPARATORY WORK

3.2.1 AOI Delineation

Initially, the priority mapping area was defined with reference to the administrative boundaries of the 5 Districts where the IDP camps mentioned in the project document are located: Al Fasher, Kutum, Mellit in Northern Darfur, Al Geneina in Western Darfur, Nyala in Southern Darfur. This initial definition was soon discarded since it excluded many IDP Camps in all States and included large areas in North Darfur that are not interested by IDP presence, as shown in Figure 11, left side map. The Area of Interest (AOI) was then re-defined on the basis of the results of the Rapid Wisdom Appraisal (Figure 11, right side map), which considered all IDP camps locations and the preliminary delineation of the woody biomass supply area, as described in the previous Section.

According with the RWA results, a final AOI was defined, and is shown in Figure 12 (left). The new area includes all the identified IDP and increases the study area up to 340.000 Km^2.

The change in the AOI increased the complexity of the land cover mapping extending the area (+ 13%) and including the areas characterized from a higher land cover fragmentation and complexity compared with the northern areas of Northern Darfur.

The irregular shape derived from the RWA area was extended to obtain a more regular boundary as shown in Figure 12 (left)

3.2.2 Satellite image acquisition

A set of Aster images (ASTER = Advanced Space borne Thermal Emission and Reflection Radiometer) with 15 m resolution was acquired for the study area.

The area covered by the Aster images is shown in Figure 12 (right). The majority of image dates range between 2005 and 2010. In few cases images acquired between 2000 and 2005 were acquired to fill minor areas that were not available in the archive for the last five-years period.

The object based segmentation and the interpretation were carried out on the Landsat imagery with the support of the Aster images, where available.

FIGURE 11

IDP camps location and AOI based on 5 Districts (left) and based on RWA results (right).

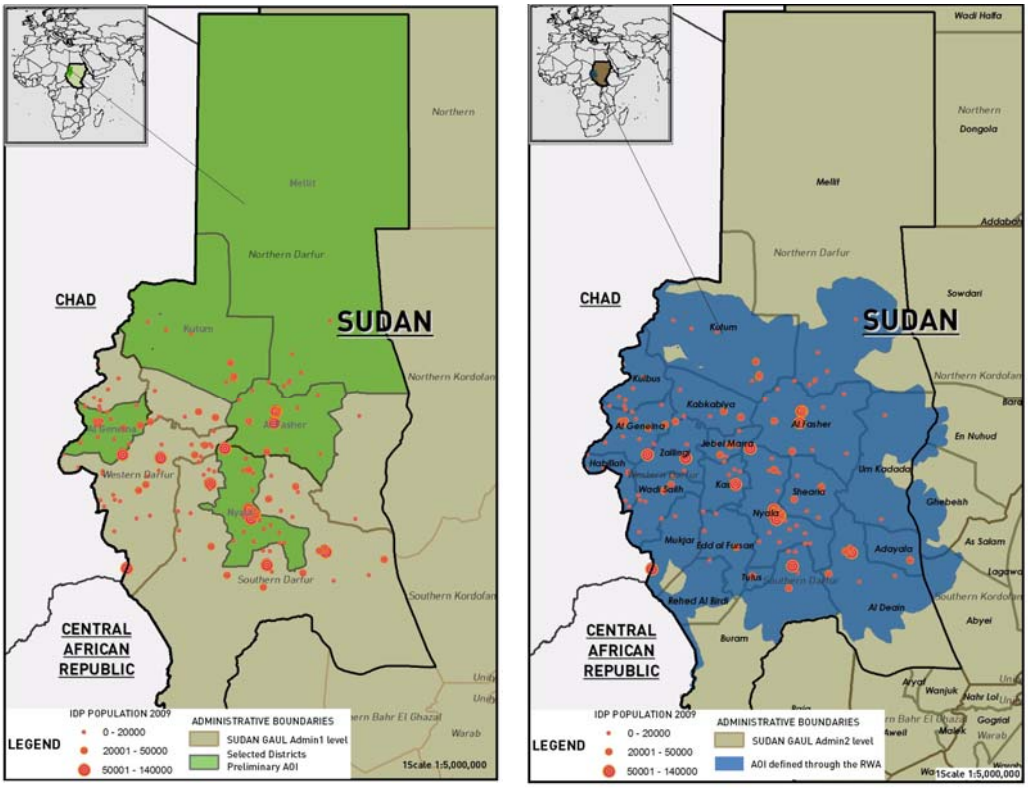
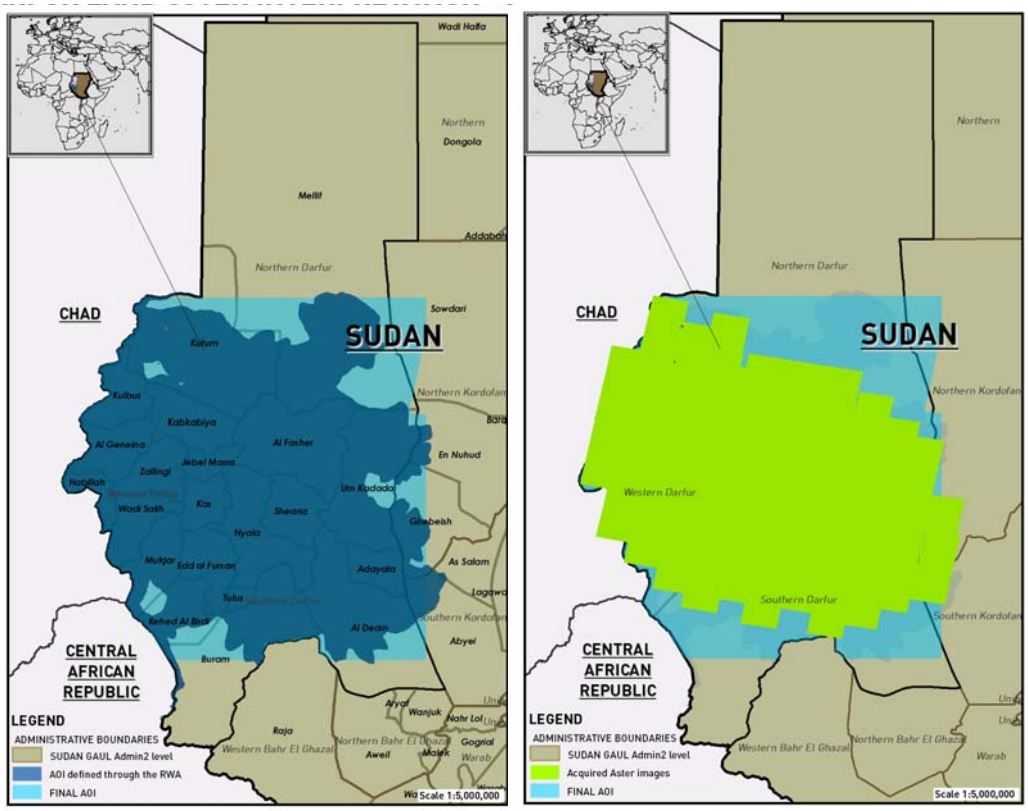


FIGURE 12

Final AOI as defined based on the results of the RWA (left) and acquired Aster images coverage (right).



3.2.3 Classification System and Legend

The land cover legend was built according with the LCCS (FAO Land Cover Classification System).

According with LCCS Method the classes belongs to 8 major land cover groups:

A11 – Cultivated and managed terrestrial areas

A12 – Natural or semi-natural terrestrial vegetation

A23 – Cultivated aquatic or regularly flooded areas

A24 – Natural or semi-natural aquatic vegetation

B15 – Artificial surfaces and associates areas

B16 – Bare areas

B27 – Artificial water bodies, snow and ice

B28 – Natural water bodies, snow and ice

The detailed legend used in the land cover interpretation is shown in Annex 1.

3.3 INTERPRETATION ACTIVITIES

The area to be interpreted, covering an area of approximately 340,000 Km^2, was divided into 45 subsets. The interpretation was carried out by 6 photointerpreters and each photointerpreter was assigned blocks of contiguous subsets for the photointepretation. The preliminary interpretation was completed in mid November, based on the Landsat images with the support of Aster images and referring to Google Earth high resolution images; where available.

The availability of Google Earth gives useful ancillary information although the high resolution images are not available for the whole area (see a in Figure 12). The use of multiple images can reduce the misinterpretation due to seasonality effects both in the agricultural areas where the visibility of fields can be reduced in the non cropping season and in natural vegetation areas characterized by deciduous species.

A review of the preliminary interpretation was carried after the fieldwork campaign to improve both the accuracy and consistency of the interpretation between different interpreters that were involved.

FIGURE 12

Sample of different resolution images available in Google Earth

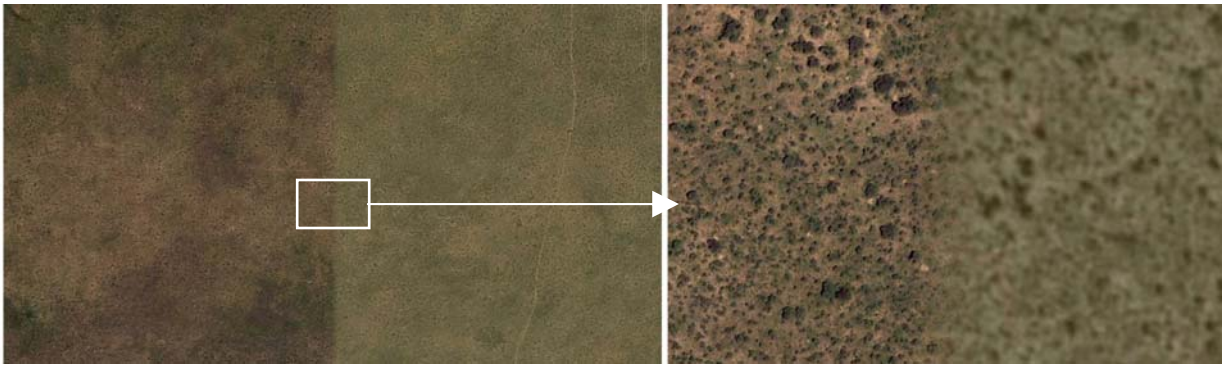
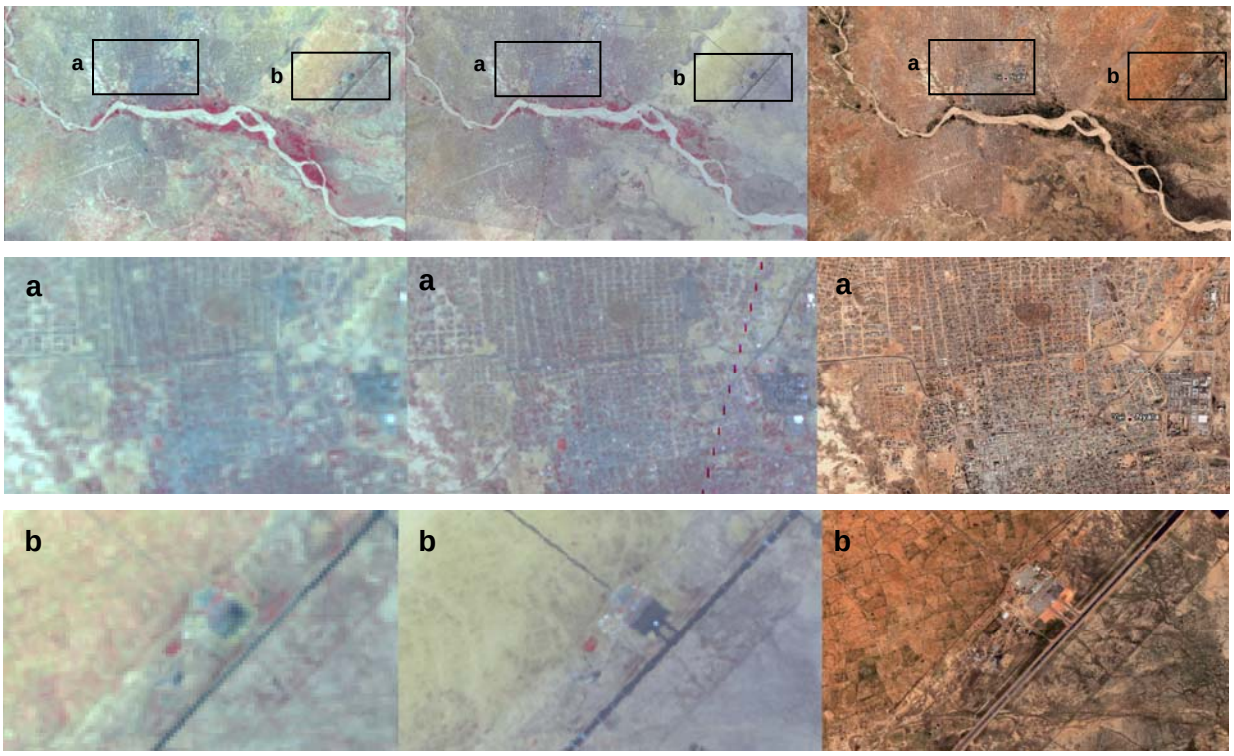


FIGURE 13

Different images/resolutions available



3.4 FIELD WORK ACTIVITIES

The field work objective was to collect information on the main vegetation parameters (vegetation layers, height, crown cover etc) in representative areas, as well as to clarify doubts on the land cover classification of specific areas. It is an essential component to support the interpretation activities and the map validation.

The methodology proposed for the field work was the standard FAO-Africover methodology.

Field data describes the reality on the ground and were collected to confirm or correct the preliminary photo-interpretation.

The areas where field samples were conducted were usually identified after the preliminary photo-interpretation was completed.

On the map, they were marked by a rectangular sampling quadrat representative of the polygon/land cover type to be checked.

Two main criteria were applied during the selection of the field samples areas:

- Criteria related to the photo-interpretation activity
    - o • the most frequent land cover types
    - o • areas in which there were doubts about the correctness of the interpretation
- Criteria related to logistic aspects
    - o • accessibility of the area
    - o • clustering of the field samples

For the Darfur AOI, at the end of the preliminary interpretation ca. 200 field work sites were selected within the AOI for the field work campaign. In November 2010, 2 teams (1 surveyor 1 driver) were hired to carry out the field survey.

Due to security reasons only a limited area could be surveyed, and within this area only some of the selected points were reached. Other points were recorded within the accessible area for a total number of 40 points.

Some pictures samples from the field survey are shown in Figure 14. The pictures are collected on the 4 cardinal directions N-E-S-W

As previously specified, there were security and accessibility limitations in reaching the defined field work areas. To compensate this problem, other points, not previously defined, were sampled to have additional data. The limited accessibility affected the number of land cover types that could be sampled and the representative nature of the sample for the area.

The fieldwork data highlighted an overestimate of natural vegetation cover in some areas that were identified as Shrub vegetation very open instead of sparse. These areas were revised accordingly.

3.5 LAND COVER MAP RESULTS

Preliminary mapping of the Area of Interest

The map in Figure 15 shows an overview of the final Land cover data covering the Area of Interest. In the overview the land cover classes were aggregated according to 8 major land cover types. For mixed classes units the polygon is attributed to the first class.

The distribution of the Land Cover classes is shown in the graph in Figure 16. The classes were aggregated according to the land cover type (Natural vegetation or Agriculture and within these groups according with the dominant layer Herbaceous, Shrub or Tree layer, and according to the crown cover density (Closed to Open 100-40%, Very Open 40-10%, Sparse 1-10%)

Natural vegetation covers the majority of the area and, within the natural vegetation class, the herbaceous cover has a widest distribution of all land cover classes.

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.

The new land cover represents an update of the Africover land cover map, and was reached through the interpretation of new imagery and thanks to additional functionality of the new FAO software and tools. However due to the time required for the interpretation of the full AOI (ca 340.000 Km2) and due to the postponed date of the field work campaign, only a limited time could be allocated to the final review of the interpretation after the field work. Furthermore, due to accessibility limitations, the number of samples collected in the field work campaign could not cover all the expected class types and also be considered representative for the area.

Final mapping of the Sudan

The Land and Water Division (NRL) mapping unit of FAO and the Remote Sensing Authority (RSA) of Sudan have subsequently extended Land Cover mapping to the whole Country. Figure _ shows the map released in February 2012. The new map has been used to complete the WISDOM analysis for the whole country.

The detailed legend used in the final 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 final country-level Land Cover map included some minor revisions of the first Darfur land cover and therefore the results presented hereafter are based on the updated Darfur portion of the national-level WISDOM analysis.

FIGURE 14

Examples of pictures samples from the field survey

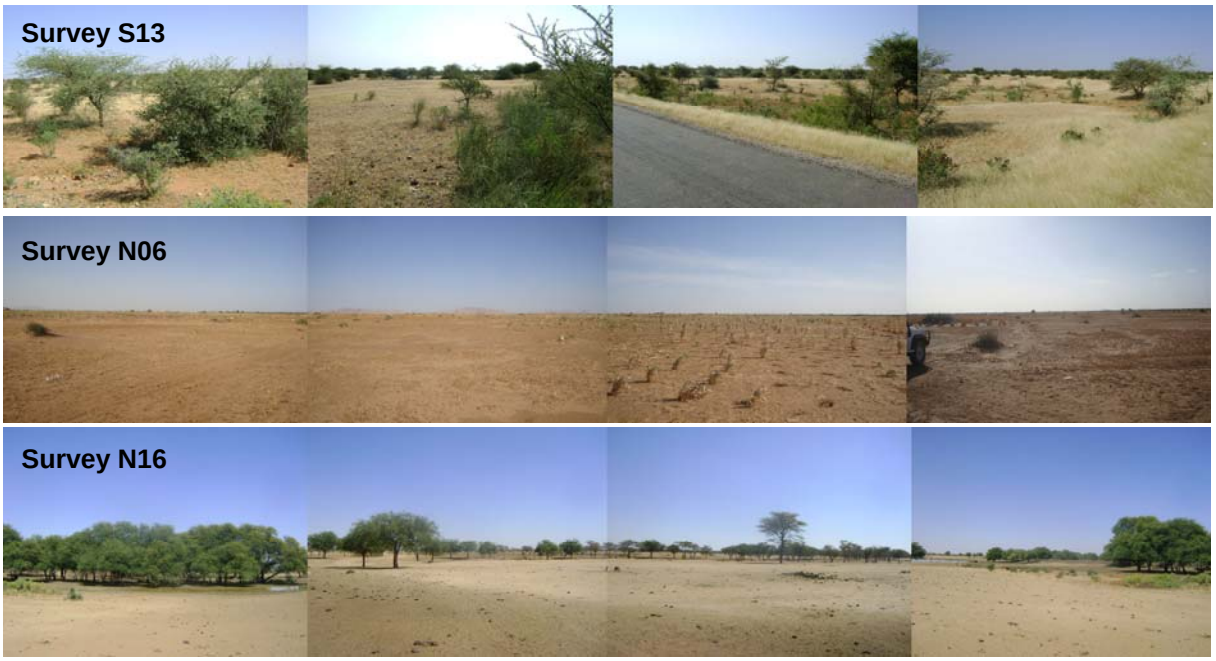


FIGURE 15

Preliminary land cover map of the AOI (NRL 2010). Map displaying aggregated land cover classes

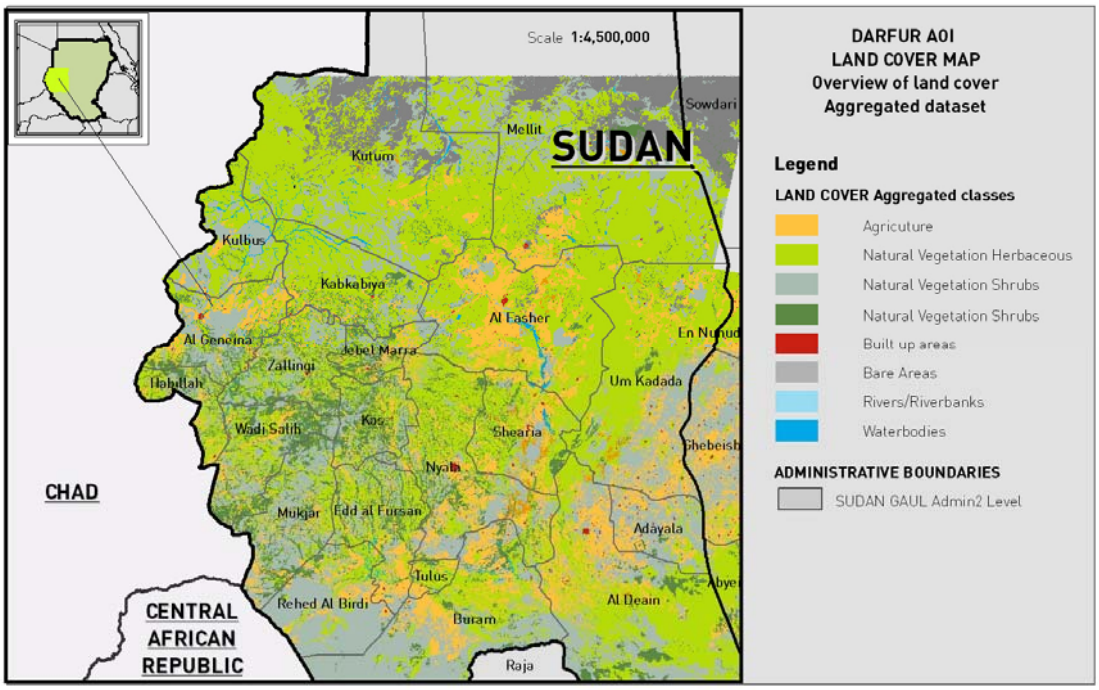


FIGURE 16

Distribution of the Land Cover classes (NRL 2010

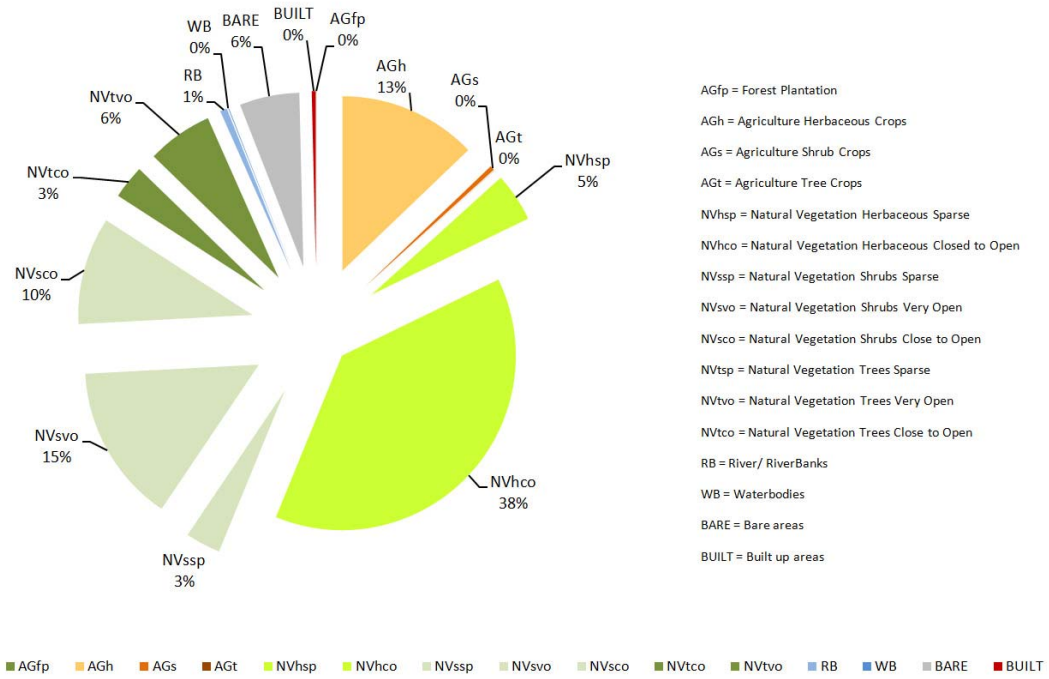
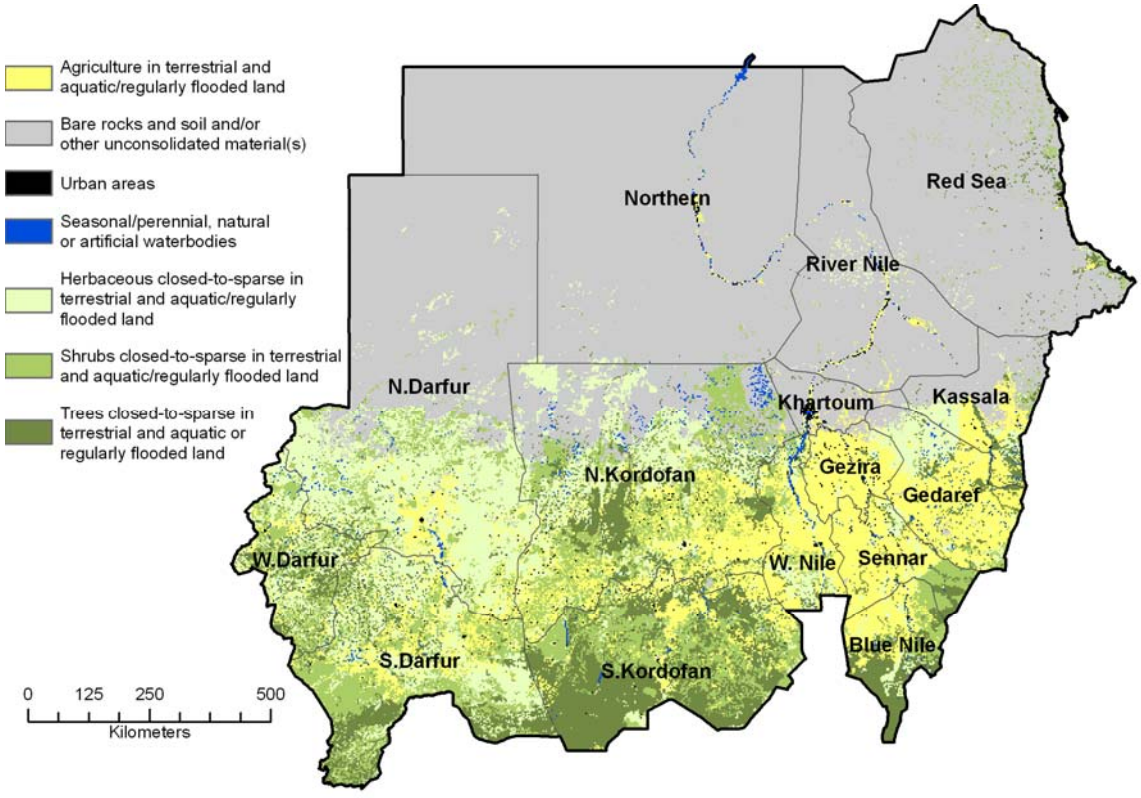


FIGURE _

Land cover map of the Sudan, completed in 2012. Map displaying aggregated land cover classes



4 PHASE III: DETAILED WISDOM ANALYSIS

In the Detailed WISDOM Analysis, all the assumptions made during the Rapid WISDOM Appraisal were reviewed on the basis of the new land cover data and more detailed local information.

The spatial resolution was increased to 100 m cell size, each map pixel covering one hectare. Concerning administrative data, the level of analysis was increased to Administrative Units (subdivisions of Localities) as far as this was supported by the available data.

4.1 DEMAND MODULE

The main objective, and challenge, of the Demand Module was to produce the best possible assessment and mapping of current wood consumption pattern. The main thematic layers and processing steps of the Demand Module are presented in the flowchart in Figure 17 and described in the following Sections.

Primarily, the main challenge of the Demand Module has been the quantitative estimation of the changes in the consumption of woodfuels in Darfur that intervened since the last comprehensive wood consumption survey, which was conducted in pre-conflict era.

Main references:

(i) The quantitative wood consumption estimates produced by the "Forest Products Consumption Survey in the Sudan" (FNC/FAO GCP/SUD/047/NET, 1996), which provides the latest quantitative estimation referring to pre-conflict conditions.

(ii) Recent reports and studies on Darfur situation, among which the study "Destitution, distortion and deforestation - The impact of conflict on the timber and woodfuel trade in Darfur" (UNEP, November 2008), which provides a qualitative analysis of current conditions.

(iii) Recent review papers on the impact of Fuel Efficient Stoves (FES) programmes, such as ProAct 2008 and USAID, 2008.

Special attention was given to the fuelwood consumption for brick production, which was indicated in various reports as a particularly aggressive demand sector. The limited available evidence, mainly FNC reporting, shows that bricks production had its climax in 2006-2007 as side-effect of the influx of the international community into Darfur since the conflict begun, as shown in Table 1 . Although it is generally acknowledged that the statistics linked to taxation records produced by FNC capture only part of the true consumption, these seem to confirm the shared impression that the big construction wave has passed and that brick making is now back to "physiologic" levels linked to urbanization processes.

Figure 18 shows in graphic synthesis the prewar consumption estimated by the FNC-FAO survey, the "wave" reported by the taxation records and the annual consumption level assumed for the present study, which is estimated at 106,000 m^3 (4 times higher than pre-war conditions), on account of the increasing urban population and a higher fraction of brick houses.

The per capita household consumption for cooking in IDP Camps was based on the results produced by CHF International through a systematic informal survey of IDP households in Darfur to assess their FES program (USAID, 2007). In absence of new quantitative estimates for all other uses and sectors of consumption, these were estimated, tentatively, by applying "adjustment" factors to the FNC-FAO 1995 per capita consumption values.

FIGURE 17

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

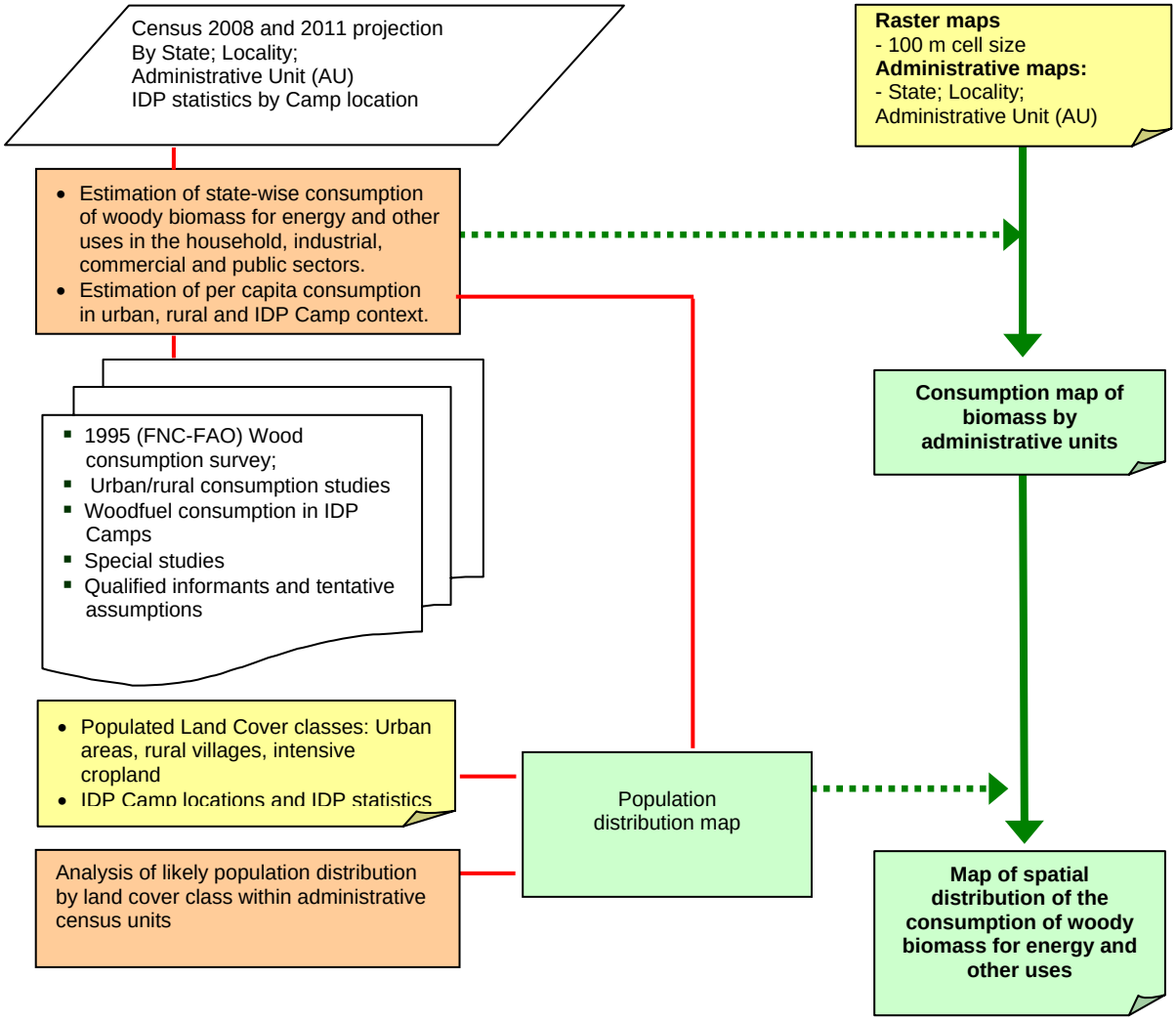


TABLE 1

Fuelwood consumed for production of bricks in Darfur, based on FNC reporting.

	North Darfur	South Darfur	West Darfur	Tot Darfurf.	Source:
	m^3	m^3	m^3	m^3	
1995				24,080	ref FNC/FAO 1995
2004	0	1,146	590	1,737	ref FNC from UNEP2008
2005	4,666	13,479	14,565	32,710	- do -
2006	376,928	145,712	4,094	526,733	ref: FNC reports 2006-2009
2007	332,804	63,000	61,071	456,875	- do -
2008	0	4,450	5,005	9,455	- do -
2009	583	0	4,014	4,598	- do -

FIGURE 18

Consumption of fuelwood for brick production in Darfur, showing pre-war consumption levels, the climax production due to the influx of the international community and the consumption level assumed for the present study.

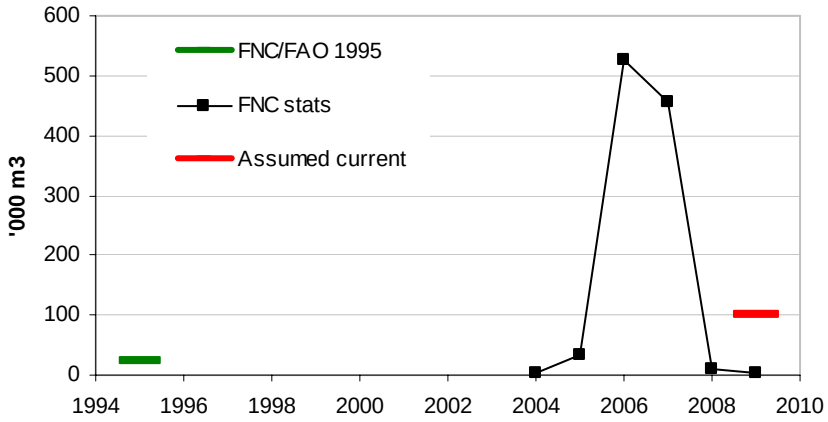


Table 2 shows the assumptions made and factors applied in the attempt of updating the per capita consumption rates with respect to the values estimated by the 1995 FNC-FAO survey. The table shows also the potential reduction resulting from intensive FES programs in rural and urban areas.

Table 3 presents the per capita consumption values adopted for both BAU and FES variants while Table 4 presents the breakdown of BAU consumption by sector of use and by rural, urban and IDP Camp contexts.

TABLE 2

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	Rural fraction of Institutional Sector
N. Darfur	**1.00**	**0.95**	**1**	**0.9**	**0.2**	**0.8**
W. Darfur.	**1.00**	**1.00**	**1**	**0.9**	**0.2**	**0.8**
S. Darfur:	**1.00**	**0.98**	**1**	**0.9**	**0.2**	**0.8**

	Commercial	Institutional	Bakeries	Bricks	Lime curing	Veg. Oil
N. Darfur	**1**	**0.9**	**1**	**1.5**	**1.5**	**1**
W. Darfur.	**1**	**0.9**	**1**	**1.5**	**1.5**	**1**
S. Darfur:	**1**	**0.9**	**1**	**1.5**	**1.5**	**1**

ASSUMPTIONS - FES variant

Assuming the impact of a strong Fuel Efficient Stove programme in urban and urban areas

Factors applied to household and Khalwas woodfuel consumption of BAU variant due to intensive FES programs in urban& rural areas

Rural	Urban	IDP Camps
0.7	**0.7**	**1**

So far, FES projects have been restricted to camps in government-controlled areas and, to date, there has been extremely limited coverage of rural and urban areas (ProAct. 2008).

TABLE 3

Applied per capita consumption values in the "business as usual" (BAU) and "fuel efficient stove" (FES) scenarios, and reference FNC 1995 values.

	FNC95 values			Applied values - BAU variant			Applied values - FES variant		
	General average	Rural	Urban	Rural	Urban	IDP Camps	Rural	Urban	IDP Camps
Percapita consumption (oven-dry kg)									
	od kg	od kg	od kg	od kg	od kg	od kg	od kg	od kg	od kg
North D.	522	516	547	521	526	311	386	472	311
West D.	478	451	728	444	665	323	338	570	323
South D:	509	484	636	487	577	323	365	506	323
Percapita consumption (m^3)									
	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
North D.	0.89	0.88	0.93	0.88	0.89	0.53	0.65	0.80	0.53
West D.	0.81	0.77	1.24	0.75	1.13	0.55	0.57	0.97	0.55
South D:	0.86	0.82	1.08	0.83	0.98	0.55	0.62	0.86	0.55

TABLE 4

Sector-wise consumption of woody biomass in 2011 (in thousand oven-dry tons and cubic meters)

Values=	**Total**	**Household**			**Commercial**	**Institutional**	**Industrial**					
'000 t od	**consumption**	Rural	Urban	IDP	(tea and food)	(Kalwas)	**Total industrial**	Bakeries	Brick	Lime curing	Vegetable oil	Others
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 Darfur	**3,764.5**	**2,199.0**	**722.9**	**576.0**	**42.1**	**92.1**	**132.4**	38.7	69.8	1	22.6	0.3

Values=	**Total**	**Household**			**Commercial**	**Institutional**	**Industrial**					
'000 m^3	**consumption**	Rural	Urban	IDP	(tea and food)	(Kalwas)	**Total industrial**	Bakeries	Brick	Lime curing	Vegetable oil	Others
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 Darfur	**6,391.9**	**3,733.7**	**1,227.6**	**978**	**71.5**	**156.4**	**224.7**	65.8	118.5	1.7	38.4	0.5

Another question requiring an answer concerned the role of LPG in Darfur as substitute to charcoal and fuelwood in urban and peri-urban areas. According to the statistics of the Ministry of Energy and Mining (now Ministry of Petroleum), the annual LPG distribution in Darfur States has been negligible up to 2003, climbing up abruptly to 550 tons in 2003 and stabilizing at around 700 tons between 2005 and 2008 (last year in statistics). The rapid increment of LPG consumption was probably induced by the influx of emergency operators in Darfur, similarly to the brick making boom in the same period. The quantity, however, is extremely small, serving less than 8,000 households altogether, and there is no clear evidence of a significant increasing trend. Therefore, the answer to the question above is that LPG, at present, plays a marginal role as household fuel substitute and that so will remain for the near future, unless it is heavily promoted and subsidized.

Population map

The mapping of Darfur's population distribution was carried out at a higher spatial resolution than for the RWA. Census data at the level of Administrative Unit, rather than Locality/County, was used as statistical reference and several maps features were used as spatial proxy, rather then the FAO 30 arc-second map of population distribution.

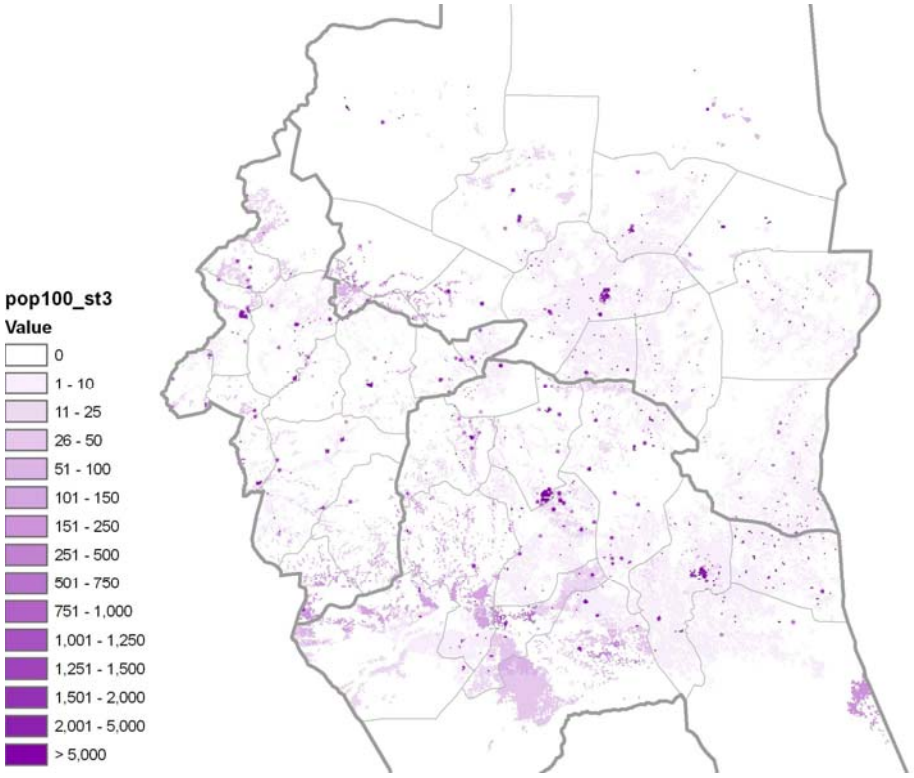
The population distribution map (Figure 19) was created integrating demographic statistics providing urban, rural and nomadic population by Administrative Units, administrative maps, the classes of the new land cover map defining urban areas and areas of intensive human activities (as probably populated areas).

In view of the high relevance of the geographic distribution and consistency of IDP camps for the present analysis, the available map of IDP camps locations and associated statistics were integrated in the population mapping procedure, in spite of the poor consistency with the demographic data.

In the context of the WISDOM analysis over Sudan the consumption was projected to 2011 applying 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.

FIGURE 19

Population distribution map (reference years: 2008). Values indicate persons*(km^2)$^{-1}$



Given the limited consistency among the datasets (i.e. the demographic data breakdown is not consistent with the administrative map; inconsistencies between IDP statistics and demographic data; etc.) the population map resulting from this process should be considered as a reasonable approximation useful for the present analysis, rather than an accurate population distribution map.

4.2 SUPPLY MODULE

The WISDOM Supply module aims at a spatial representation of natural and man-made woodfuel sources, their stocking and production capacities. In this case, given that the Demand module considers wood consumption for energy (fuelwood and charcoal) as well as for other uses (construction material, maintenance and furniture), the Supply module analysis includes woody biomass entirely, comprising non-energy uses.

Figure 20 presents a flowchart with an overview of the main analytical elements needed to complete the Supply Module. The flowchart shows the input data, cartographic and statistical, the main derived parameters and the thematic maps produced throughout the process.

Forests and woodlands are the primary sources of woody biomass, as result of forest management and felling concessions and, most commonly, of uncontrolled exploitation, or as by-product of land use conversion processes such as farming expansion.

However, woodfuels are not produced or harvested exclusively from forests and woodlands; rather, they are obtained from **all land cover/land use types** in which there is growth of woody biomass, e.g. agro-forestry and farmland trees.

4.2.1 Land Cover and rainfall

Given the ecological settings of Darfur, the estimation and mapping of woody biomass resources is particularly challenging due to the low density of forest and woodland formations that characterize this region, not to mention the trees and shrubs scattered over rangelands and farmlands.

On the positive side, it should be noted that the LCCS mapping approach (see Chapter 3) is particularly suitable to this challenging task, thanks to the adoption of classifiers that provide an estimation of crown density of tree, shrub and grass layers for each land cover class. The land cover classes created for Sudan on the basis of these classifiers are 75 (see Annex1), which give origin to the almost 690 unique class combinations that form the final land cover dataset. This large number of land cover classes (and class combinations) is well suited to describe the continuous vegetation gradient of Darfur landscape and thus to assess and map its biomass resources.

The new land cover map formed the basis of the assessment of supply potential and contributed to other analytical steps, such as the development of the population map, as described in the previous section.

Another layer used in the analysis of supply potential is the map of rainfall, which characterizes the north-south gradient that influences most the stock and productivity of the vegetation. Land cover “complexity” and rainfall are shown in Figure 21.

4.2.2 Stock and potential sustainable productivity

In the absence of recent biomass inventories, the estimation of woody biomass in forests and woodlands is based on volume data from previous forest inventories. In the present case the main supporting elements in the estimation of woody biomass stock have been the 1995 National Forest Inventory (NFI) carried out by FNC with FAO support. The distribution of field sample is shown in Figure 22.

The results of the 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 23).

FIGURE 20

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

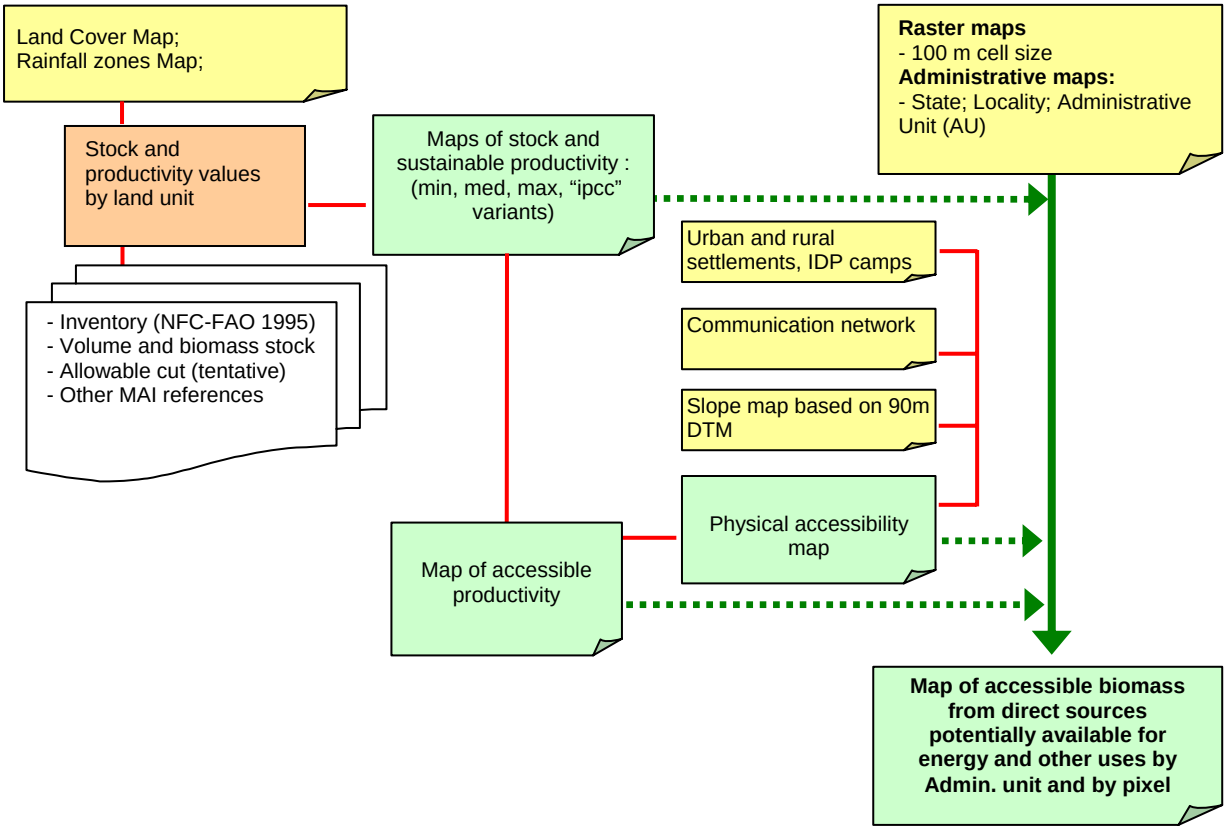


FIGURE 21

Rainfall zones shown on 2011 Land cover map.

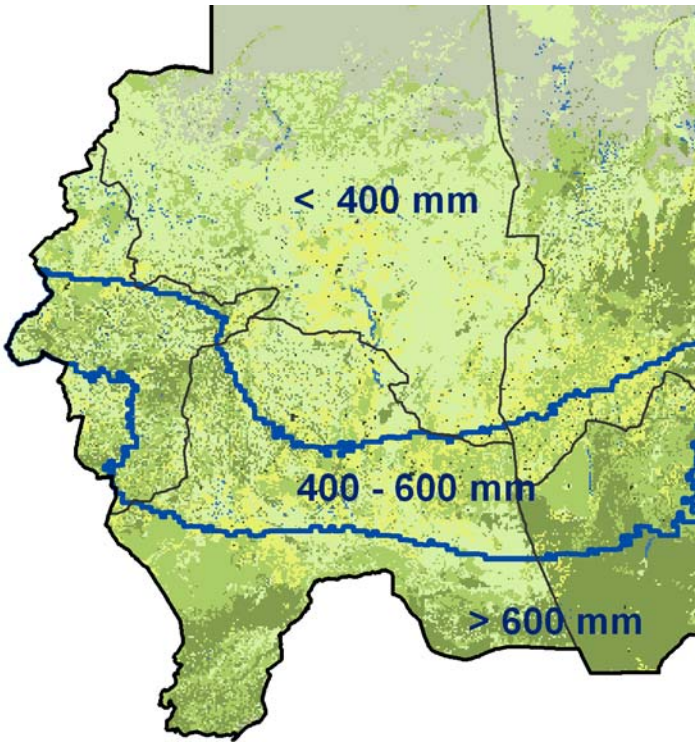


FIGURE 22_

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

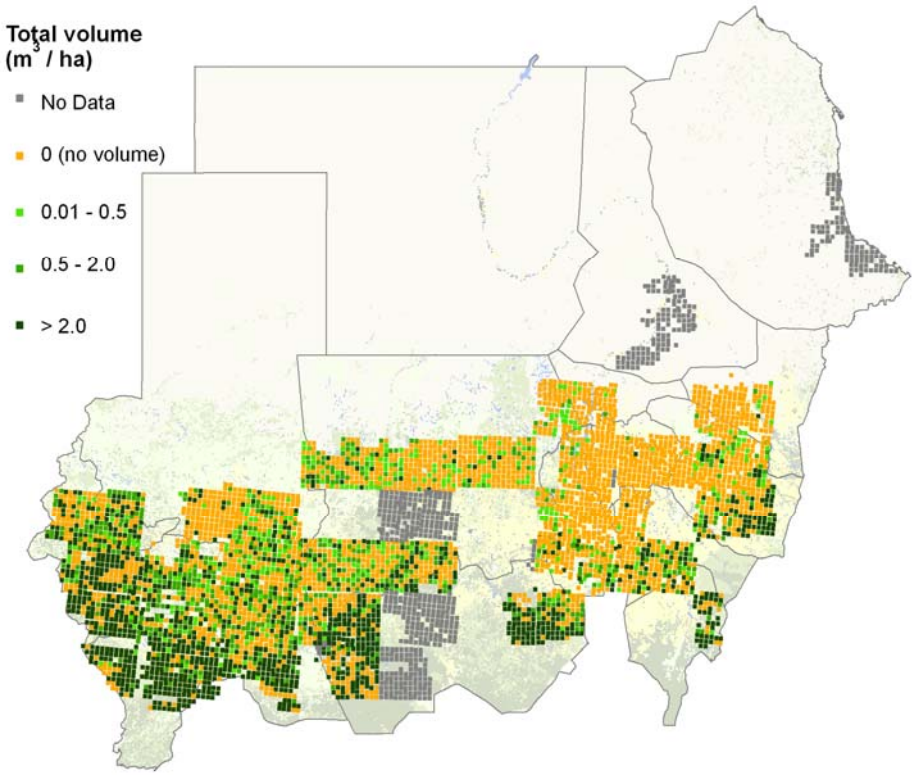
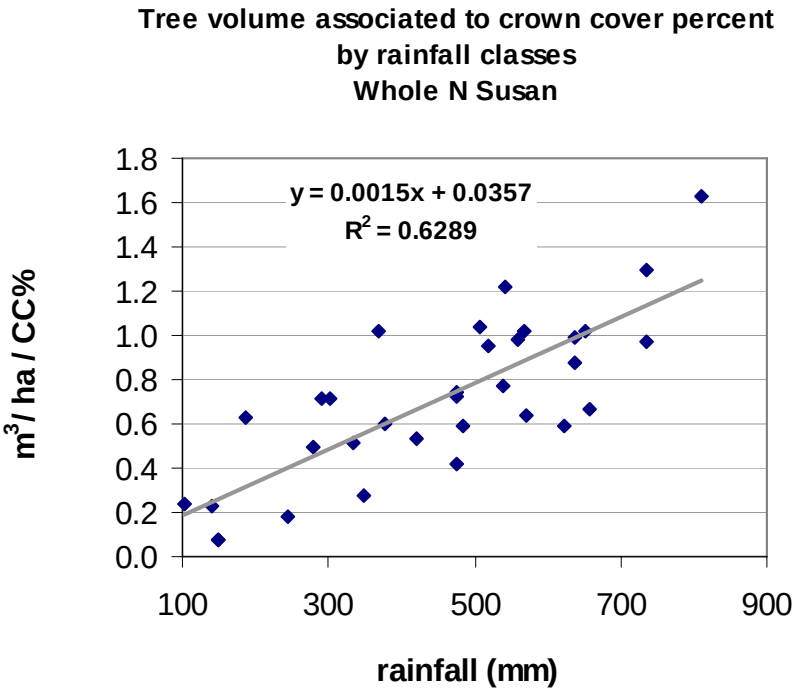


FIGURE 22

Tree volume associated to crown cover percent by rainfall class from NFI results.



Unfortunately, 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 1.

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.

4.2.3 Accessibility

4.2.3.1 Legal accessibility

According to the 2009 edition of the WCMC-IUCN database of protected areas, there are no internationally known protected areas in Darfur.

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. The list of Reserved Forests in Darfur States are listed in Annex 2.

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.

4.2.3.2 Physical accessibility

The analysis of the physical accessibility of woody biomass resources was based on the map of roads and other communication routes 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.

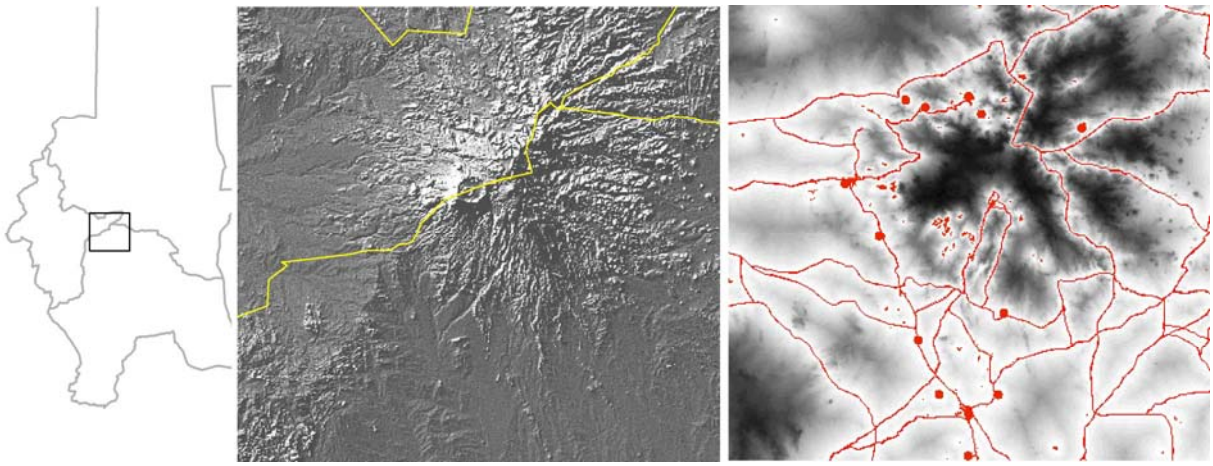
This analysis was based on the following data layers (see Figure 23) :

- Map of road network provided by OCHA Sudan: ;
- The digital terrain model (90 m resolution) transformed into a slope map
- Map of settlements and populated places.

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.

FIGURE 23

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).



4.2.3.3 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 below in 4.3.3.2 Balance in a local context and “commercial” balance).

4.3 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.

4.3.1 Pixel-level balance

The supply/demand balance at pixel-level (or cell-level) 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 pixel 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 map is shown in Figure 24.

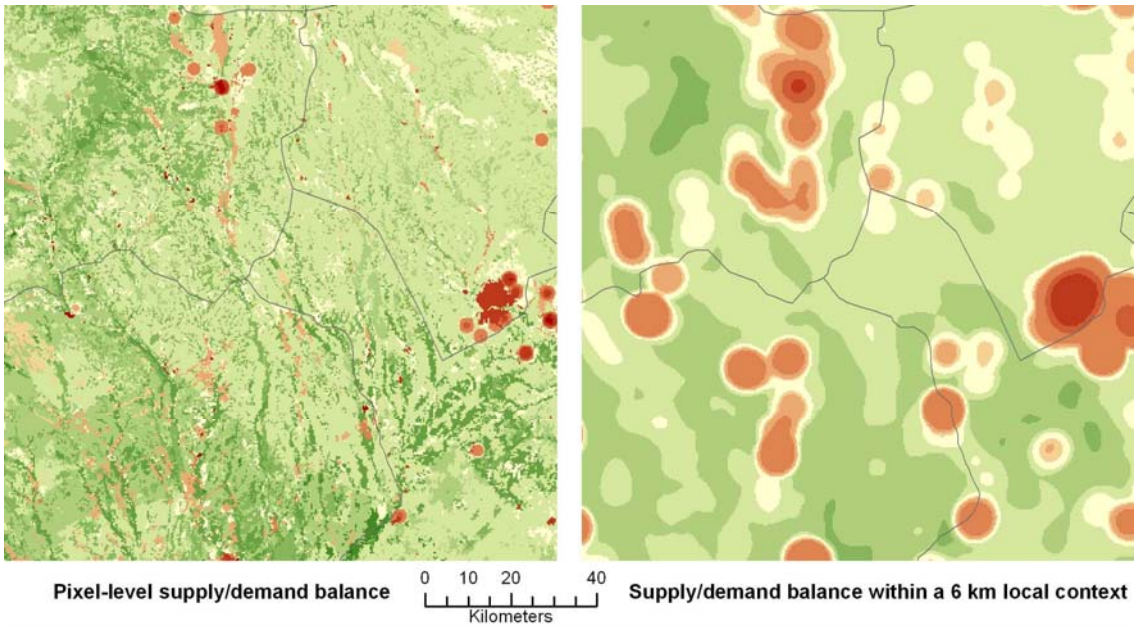
4.3.2 Local neighborhood balance

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 Darfur, 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 24, along with a pixel-level analysis covering the same area.

FIGURE 24

Balance calculated on a pixel-level basis (left map) and on a 6-km local context (right map)



4.3.3 "Commercial" balance

The "commercial" balance is analyzed with the purpose of determining more accurately 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 values for the minimum economically viable thresholds, that remain to be determined, the analysis was done with the purpose of defining for each Darfur State what theoretical threshold should be applied in order to satisfy on a sustainable basis the current demand in the three States. The principle of the thresholds applied was that they should give a positive balance in at least one state.

Given the different supply and demand situations found in the three Darfur states, three different minimum-surplus thresholds were determined of 200, 150 and 100 od kg ha^{-1} $year^{-1}$,as discussed in the Results Section 4.6.3.1 below.

4.5 WOODSHED ANALYSIS

Once the development of the WISDOM Base is complete and the commercial balance map is available, it is possible to outline the potential sustainable woodfuel/biomass supply zones of specific consumption sites, such as the 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 surplus areas is non-negative.

The estimation procedure for determining the woodshed of a selected consumption site is to progressively expand the area around such site 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.

In the present study the woodshed analysis was applied for two different purposes:

(i) for defining the sustainable supply zone of IDP camps under various supply and demand assumptions and

(ii) for analyzing the probable non-renewable biomass (NRB) fractions of current IDP consumption (or levels of overexploitation of wood resources around IDP camps) assuming varying supply distances.

For the first, the analysis followed the "classic" woodshed approach, aiming at the delineation of the territory which is necessary in order to supply on a sustainable basis the needed woodfuels.

For the second, the distance from the consumption sites (here IDP camps) was pre-determined on the basis of today's supply horizon according to available references (i.e. Young et al, 2009). Accordingly, the supply horizon was set at some 36 km on flat terrain or equivalent effort on steep and rough terrain. This area was further subdivided in three sub zones of equivalent distance. Scope of the

analysis was to assess the relation between demand and supply within such zones and to estimate what fraction of the demand could be met by the annual growth capacity (renewable fraction) and what fraction had to be met by overexploitation of wood resources (non-renewable fraction).

4.6 RESULTS

The main result of the WISDOM analysis is the geostatistical dataset. As summary of the main thematic elements, this section provides an overview of the most relevant maps produced in the modules and discuss the main findings. The spatial resolution of all maps is 100 m (cell of 1 hectare) Statistics concerning demand, supply and balance at Locality and State levels are summarized In Tables 5 and 7.

4.6.1 Demand for woody biomass

Figure 25 shows the spatial distribution of woody biomass consumption, including energy and other uses according to the business-as-usual (BAU) variant and to the Fuel Efficient Stove (FES) variant, assuming a strong and efficient dissemination of fuel-efficient stoves in rural and urban areas.

FIGURE 25

Woody biomass consumption maps. Large map: BAU variant. Small map: FES variant.

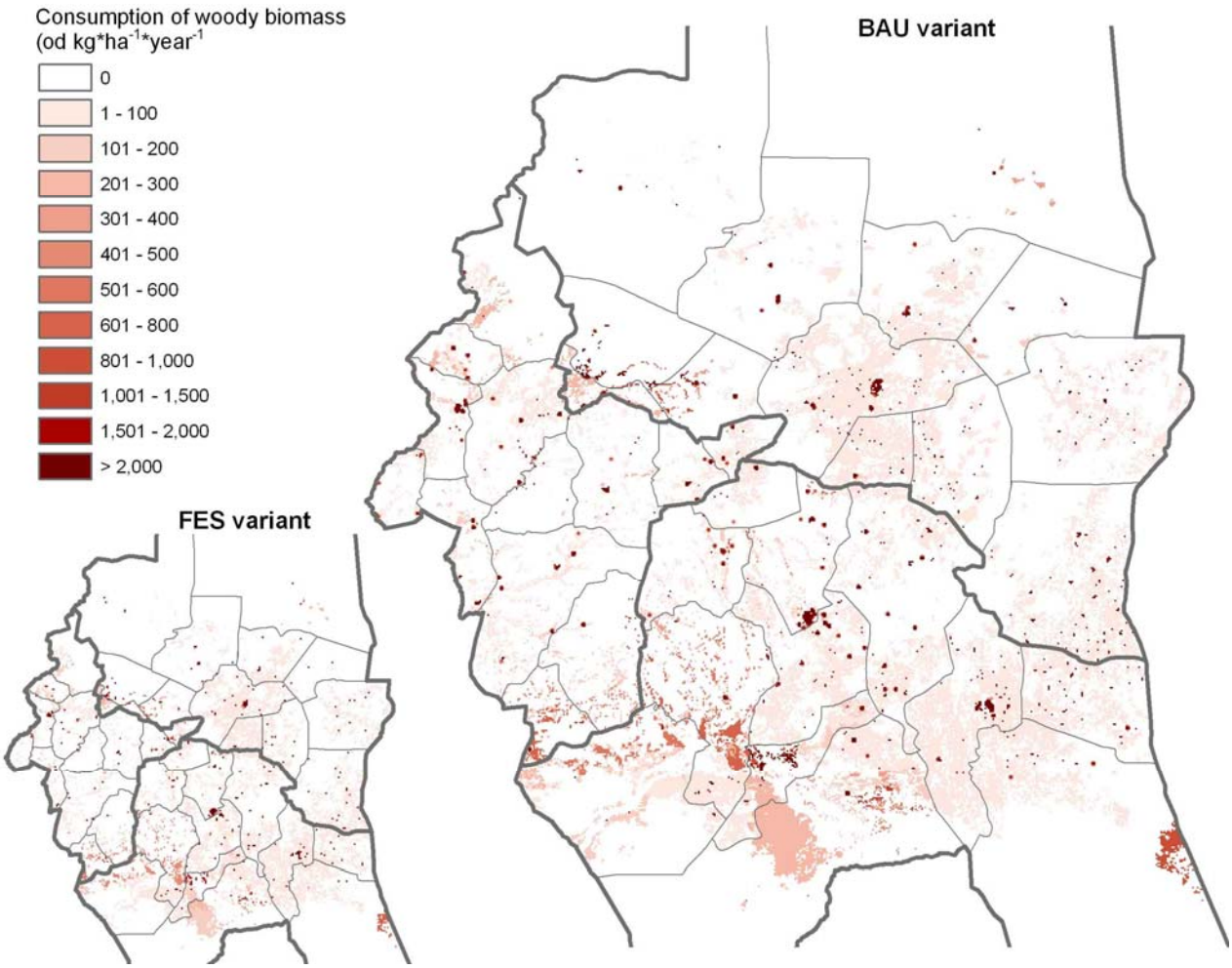


TABLE _

Woody biomass demand by Localities and States

	State Locality	Demand 2008 (BAU)	Demand 2011 (BAU)	Demand 2011 (FES scenario)
		'000 od t	'000 od t	'000 od t
	N. Darfur			
6101	Almalha	82	84	63
6102	Milleet	70	74	59
6103	Eltina	36	36	28
6104	Saraf-omra	107	110	84
6105	Alsiraif	78	80	60
6106	Kabkabiya	114	118	95
6107	Kotum	65	68	58
6108	Alkoama	35	35	27
6109	Alfashir	281	298	250
6110	Omkaddadah	45	47	36
6111	Kalamando	36	37	27
6112	Altowaisha - Alliayied	68	70	53
6113	Dar Elsalam	35	35	28
	N. Darfur total	**1,051**	**1,090**	**868**
	W. Darfur			
6201	Koulbos	32	32	25
6202	Sirba	40	41	33
6203	Kirainik	60	61	53
6204	Alginaina	129	141	121
6205	Baidah	24	24	19
6206	Habeela	47	48	38
6207	Azoom	20	20	16
6208	Zalingay	56	59	51
6209	Nairtaty	25	25	23
6210	Rokoro	9	9	8
6211	Wadi-Salih	72	74	60
6212	Wadi-Salih	33	33	26
6213	Omdukhon	30	31	24
	W. Darfur total	**576**	**599**	**497**
	S. Darfur			
6301	Shiairyya	143	148	123
6302	Niyala	335	366	314
6303	Jabal-Marra East	25	26	24
6304	Kass	136	142	118
6305	Id-Alfursaan	204	209	160
6306	Alssalam	133	135	116
6307	Aldiain	206	218	181
6308	Adeela	139	141	108
6309	Tolus	170	176	137
6310	Rihaid-Albirdi	103	106	81
6311	Booram	238	246	197
6312	Bahr-Alarab	120	123	93
	S. Darfur total	**1,952**	**2,036**	**1,652**
		3,579	**3,726**	**3,017**

4.6.2 Woody biomass supply potential

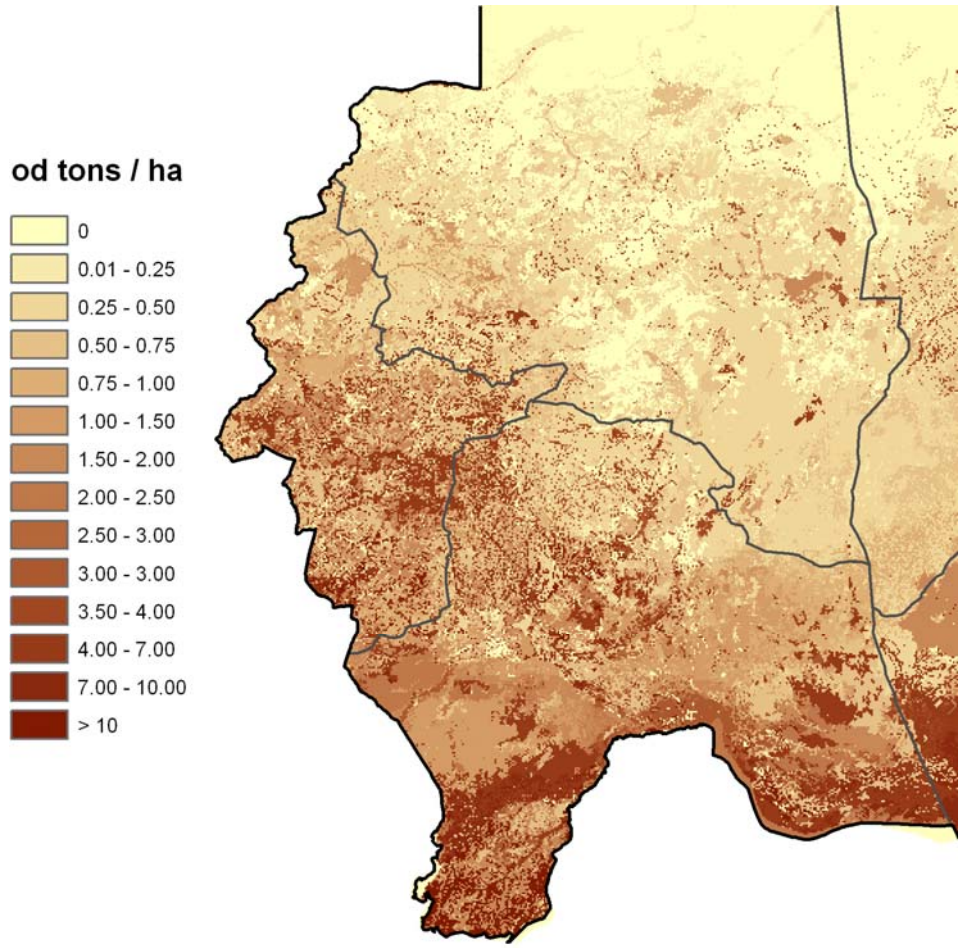
4.6.2.1 Stock

Figure 26 shows the map of the woody biomass stock, comprising the aboveground overbark biomass of stem and branches, excluding leaves and twigs.

Woody biomass stock estimates by state and by Locality are reported in Table 5.

FIGURE 26

Stock of woody biomass.

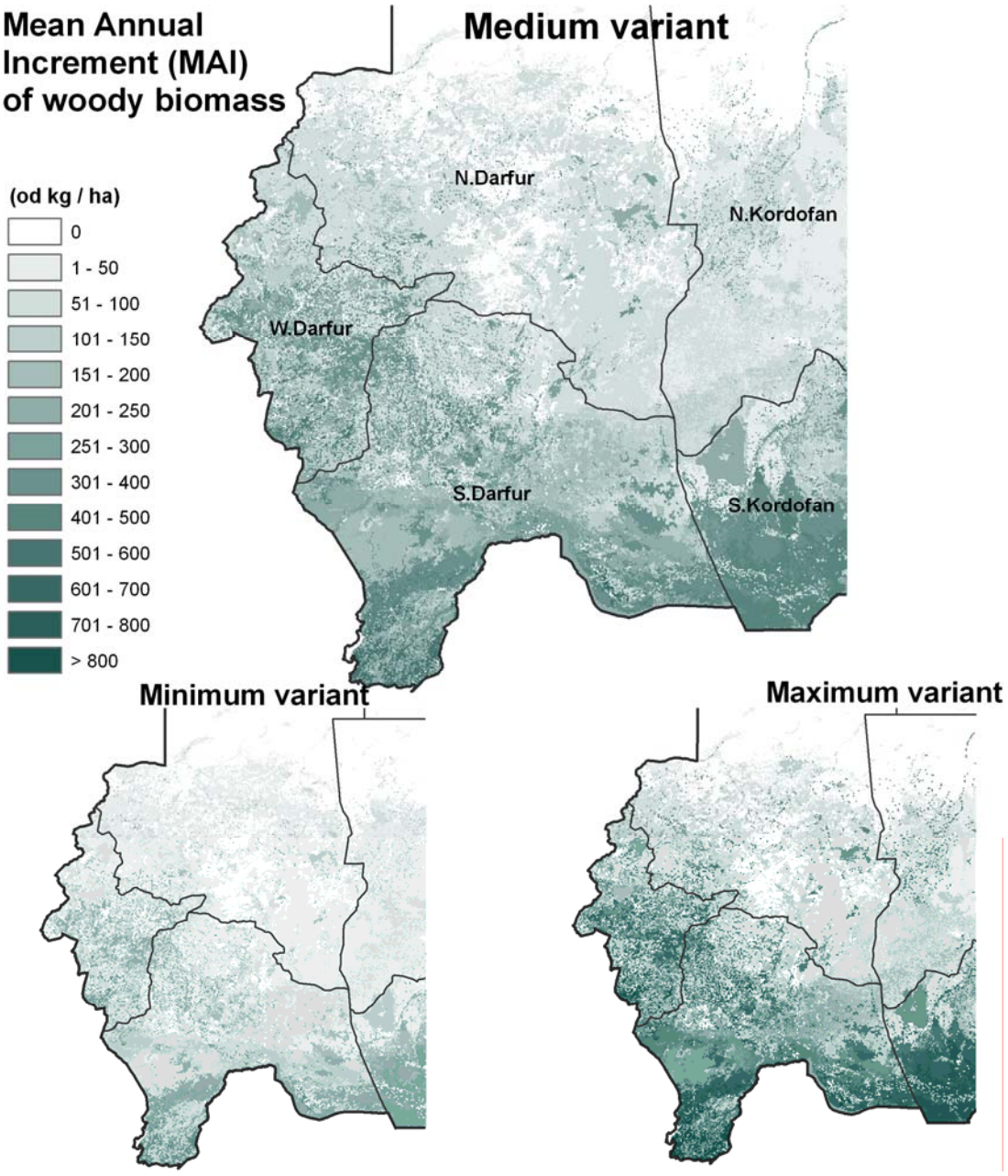


4.6.2.2 Productivity

Three Mean Annual Increment (MAI) rates were calculated on the basis of generic functions relating MAI an stock, shown in Figure 27. The MAI variant that appeared more realistic and that gave the best fit with the limited data available for Darfur is the Medium MAI variant, which is shown in slightly greater detail. Relevant statistics by state and by Locality are reported in Table 5.

FIGURE 27

Mean Annual Increment of woody biomass according to 3 different productivity rates. The Medium variant (top map), is the one considered more reliable and most frequently used in the subsequent phases of analysis.



4.6.2.3 Physically accessible productivity

The physically accessible MAI of woody biomass relative to the Medium variant is shown in Figure 28. The statistics by Locality and by State of all Supply layers are reported in Table 5.

FIGURE 28

Map of MAI-Medium variant (top map) and its estimated physically accessible fraction (bottom map).

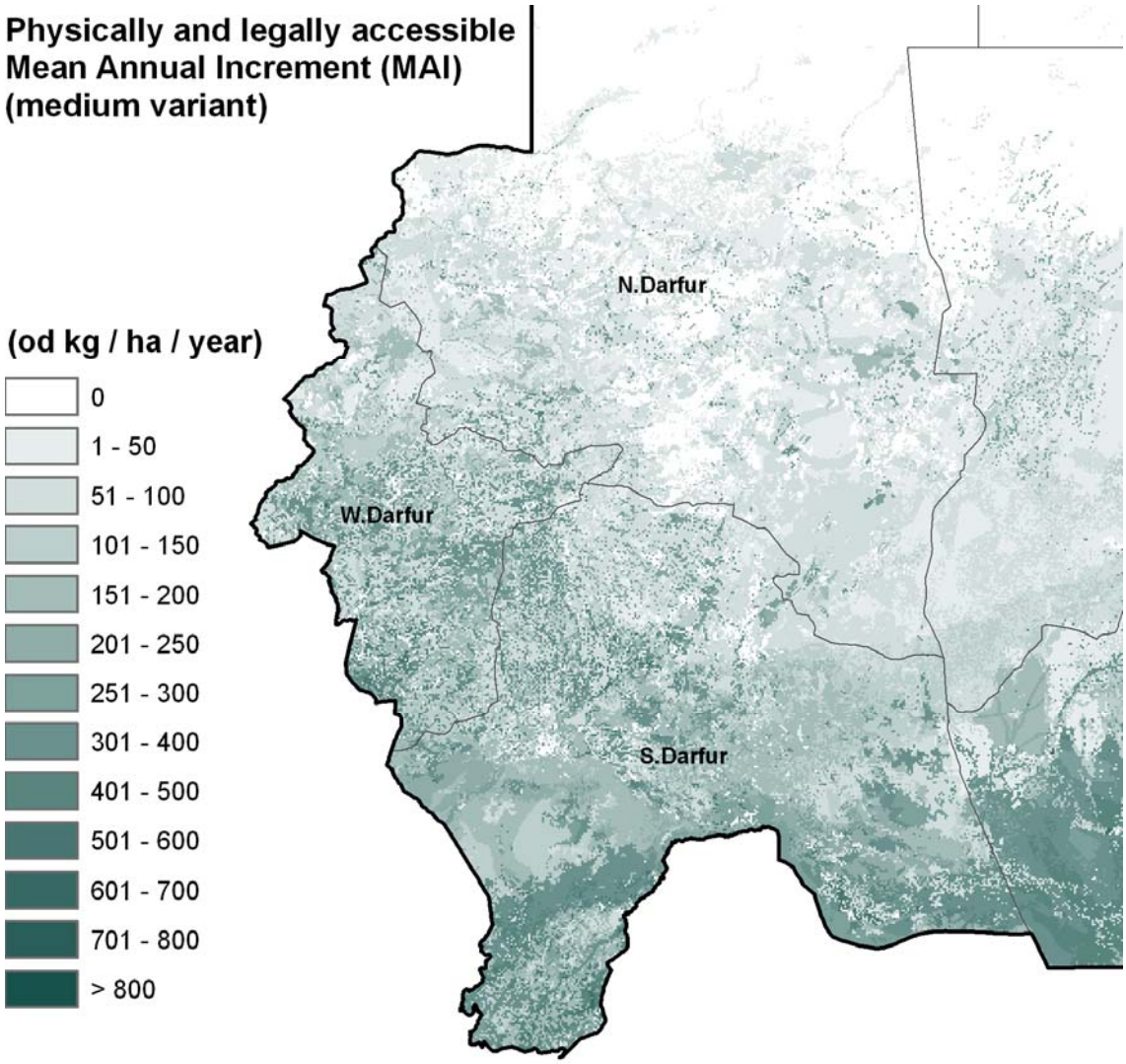


TABLE 5

Woody biomass stock and potential productivity statistics by Localities and States

			Mean Annual Increment (MAI)			Annual accessible supply potential
	State Locality	**Stock**	Min	**Med**	Max	**Med**
		'000 t		'000 t		'000 t
	N. Darfur					
6101	Almalha	786	67	**101**	144	**89**
6102	Milleet	341	25	**39**	57	**36**
6103	Eltina	982	78	**125**	179	**115**
6104	Saraf-omra	150	9	**16**	24	**15**
6105	Alsiraif	505	34	**56**	84	**52**
6106	Kabkabiya	570	31	**53**	83	**46**
6107	Kotum	612	47	**76**	109	**70**
6108	Alkoama	503	36	**59**	91	**54**
6109	Alfashir	400	33	**51**	73	**48**
6110	Omkaddadah	645	52	**80**	114	**72**
6111	Kalamando	356	29	**47**	65	**44**
6112	Altowaisha-Alliayied	765	64	**105**	145	**97**
6113	Dar Elsalam	83	7	**11**	15	**11**
	N. Darfur total	**6,699**	**511**	**819**	**1,184**	**749**
	W. Darfur					
6201	Koulbos	560	38	**67**	99	**62**
6202	Sirba	149	11	**20**	28	**18**
6203	Kirainik	1,115	53	**100**	159	**95**
6204	Alginaina	549	26	**48**	78	**45**
6205	Baidah	422	18	**32**	53	**31**
6206	Habeela	840	34	**63**	104	**59**
6207	Azoom	899	37	**68**	115	**59**
6208	Zalingay	1,405	61	**111**	182	**101**
6209	Nairtaty	648	26	**47**	76	**43**
6210	Rokoro	198	11	**20**	31	**17**
6211	Wadi-Salih	3,218	117	**211**	350	**191**
6212	Wadi-Salih	1,840	74	**137**	227	**120**
6213	Omdukhon	941	35	**65**	106	**63**
	W. Darfur total	**12,785**	**542**	**988**	**1,607**	**905**
	S. Darfur					
6301	Shiairyya	1,305	76	**134**	208	**130**
6302	Niyala	510	32	**53**	85	**52**
6303	Jabal-Marra East	321	18	**32**	49	**28**
6304	Kass	1,551	63	**115**	191	**106**
6305	Id-Alfursaan	2,400	103	**189**	309	**183**
6306	Alssalam	1,779	76	**139**	229	**135**
6307	Aldiain	1,059	65	**128**	195	**123**
6308	Adeela	700	45	**89**	126	**86**
6309	Tolus	907	41	**77**	128	**73**
6310	Rihaid-Albirdi	2,737	132	**257**	433	**240**
6311	Booram	16,246	523	**955**	1,607	**886**
6312	Bahr-Alarab	9,778	365	**672**	1,127	**637**
	S. Darfur total	**39,293**	**1,540**	**2,841**	**4,687**	**2,679**
	Darfur total	**58,777**	**2,593**	**4,648**	**7,479**	**4,333**

4.6.3 Supply / demand balance

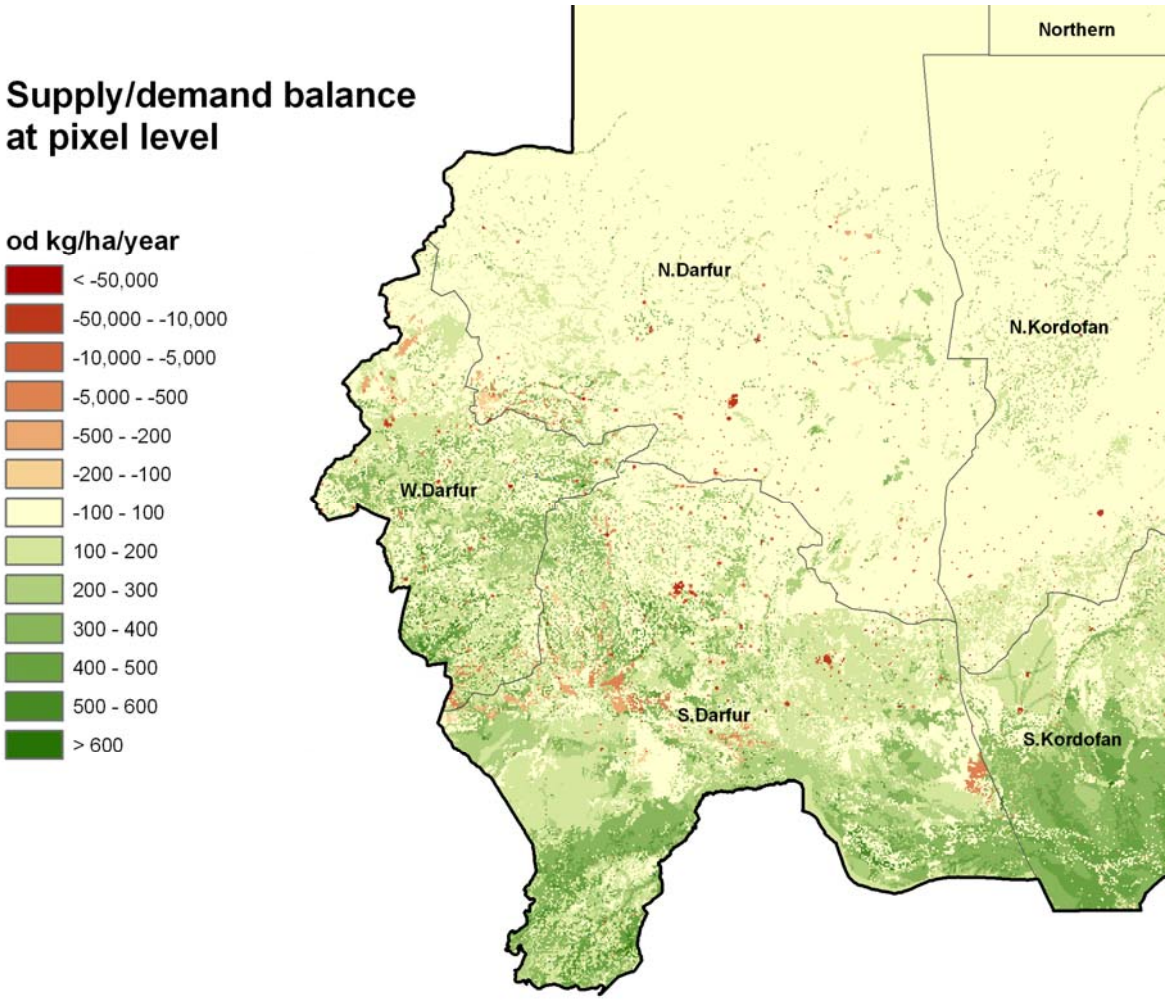
In order to describe the various planning dimensions of wood energy, the supply/demand balance analysis was carried out at various levels: (i) detailed map pixel level, which is the basis of all other balance analyses, (ii) in a local context emulating the informal self-supply horizon of rural and peri-urban households and, (iii) considering the "commercial" fraction of local surplus as source of formal and commercial woodfuel production systems serving distant consumption sites such as cities and IDP Camps.

4.6.3.1 Pixel-level balance

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. Figure 30 shows the Medium productivity- BAU consumption balance, which is the most realistic one used as basis for subsequent analyses.

FIGURE 30

Pixel-level supply/demand balance assuming medium productivity and BAU consumption



4.6.3.2 Balance in a local context and "commercial" balance

The balance calculated on a local context of 6 km is shown in Figure 31 (top). Comparing this map to the pixel-level balance shown in Figure 30, 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. The local balance shows an overall surplus of 606 thousand od tons, with state-level values of -320 for North Darfur, +290 for West Darfur and +643 for South Darfur (see Table 6). The local balance well describes the situation of rural areas, where the supply is mainly informal self-gathering, but is unrealistic when the commercial woodfuels and market conditions are considered.

The "commercial" balance analysis is based on the consideration that the management and commercial exploitation of sparse resources may be uneconomical. In the absence of true "economically accessible" thresholds, test analyses were carried out for different minimum resource availability thresholds. The supply resources considered in the analysis were the local surpluses resulting from the balance analyzed in a 6-km local context.

The thresholds so determined are not the "economically viable" ones but this analysis provides a good notion of the state-wise contexts and of the management challenges.

The results, shown in Figure 31 and summarized at State level in Table 6[7], indicate the following:

- By applying a minimum availability threshold of 100 kg/ha/yr to the surplus remaining after local consumption (at least 1.5 od t or 2.55 m^3 per hectare on a 15-years rotation), the "commercial" balance shows an overall deficit of -161 thousand od tons, with state-level values of -830 for North Darfur, +208 for West Darfur and +461 for South Darfur. This indicates that such threshold may be applied in West and South Darfur but not in the North.
- By applying a minimum availability threshold of 150 kg/ha/yr (2.25 od t or 3.8 m^3 per hectare on a 15-years rotation), the "commercial" balance shows an overall deficit of -725 thousand od tons, with state-level values of -894 for North Darfur, +46 for West Darfur and +123 for South Darfur. This indicates that such threshold may be applied only in West and South Darfur but with a much lower surplus margin.
- By applying a minimum availability threshold of 200 kg/ha/yr to the surplus remaining after local consumption (3 od t or 5 m^3 per hectare on a 15-years rotation), the "commercial" balance so determined shows an overall deficit of -1,360 thousand od tons, with state-level values of -917 for North Darfur, -180 for West Darfur and -263 for South Darfur. This indicates that such threshold cannot be applied at all.

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.

TABLE 6

State-level "local balance" and "commercial" balance applying thresholds of 100, 150 and 200 kg/ha/year ('000 od t)

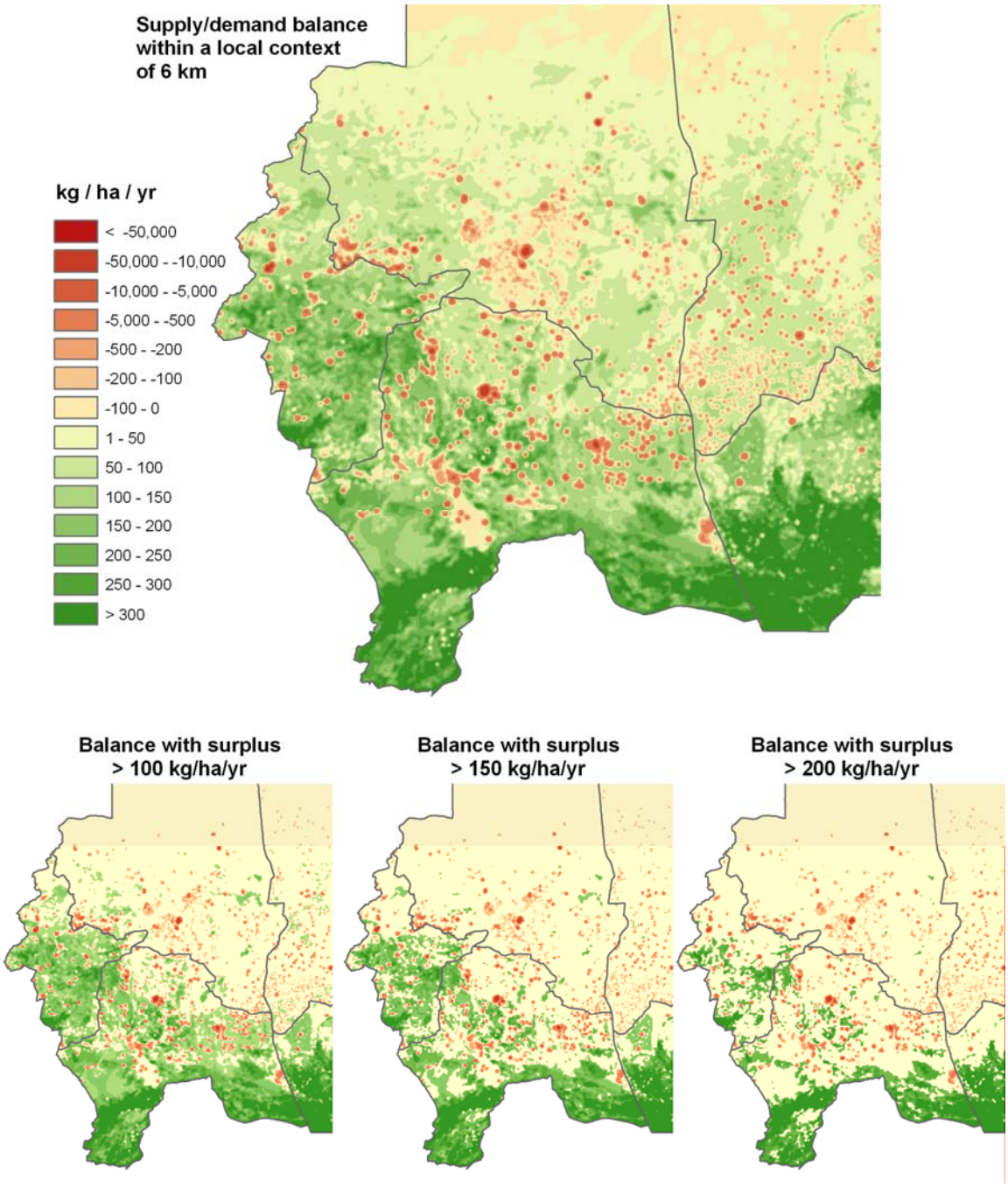
	Local balance (no threshold	surplus >100kg	surplus >150kg	surplus >200kg
North Darfur	-320	-830	-894	-917
West Darfur	290	208	46	-180
South Darfur	643	461	123	-263
Tot Darfur)	**606**	**-161**	**-725**	**-1360**

[7] 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 Table 7 further below reporting sub-national statistics, several Localities present deficit conditions even when the overall state balance shows a surplus.

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 that must be deducted from the demand through alternative fuels, such as LPG, renewable energy (solar, wind) and through the widespread dissemination of Fuel-Efficient Stoves.

FIGURE 31

Supply/demand balance within a local context (top map) and "commercial" balance maps applying surplus thresholds of 200, 150 and 100 kg/ha/year.



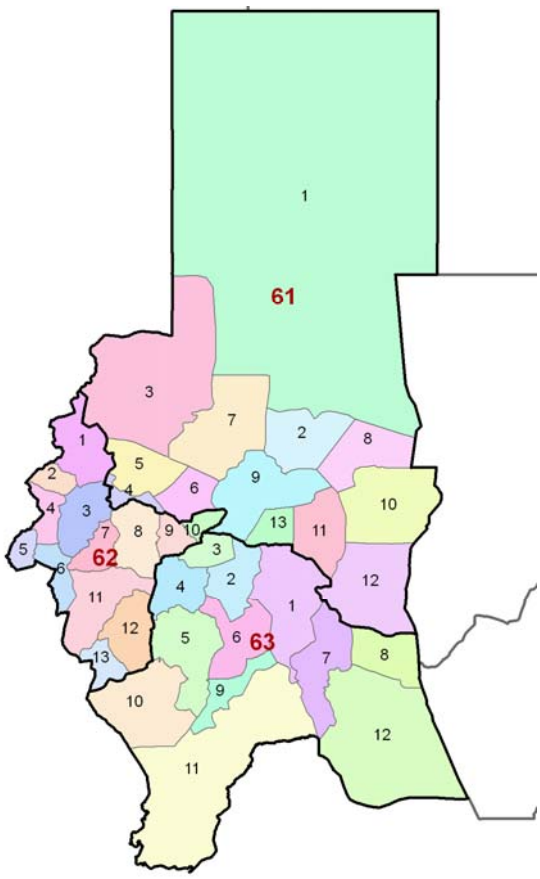
4.6.3.3 Summary statistics by Localities

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 summary statistics resulting from the analysis are presented by Localities, whose layout is shown in Figure 32[8].

FIGURE 32

Darfur States and Localities' codes



Summary statistics concerning supply parameters are reported in Table 5 above (see end of Section 4.6.2 Woody biomass supply potential), while demand and balance parameters are presented in Table 7 below.

The pixel-level balance values are positive for most Localities for BAU consumption variant and even better for the FES variant, as shown in figure 33 where the impact of the two consumption variants may be compared. As mentioned before, however, these balances are theoretical since they assumes the efficient operational management of all wood resources, including those with extremely low density.

A more realistic vision is provided by the commercial balances based on the 6km local balance and application of minimum surplus thresholds, shown in the last three columns of Table 7.

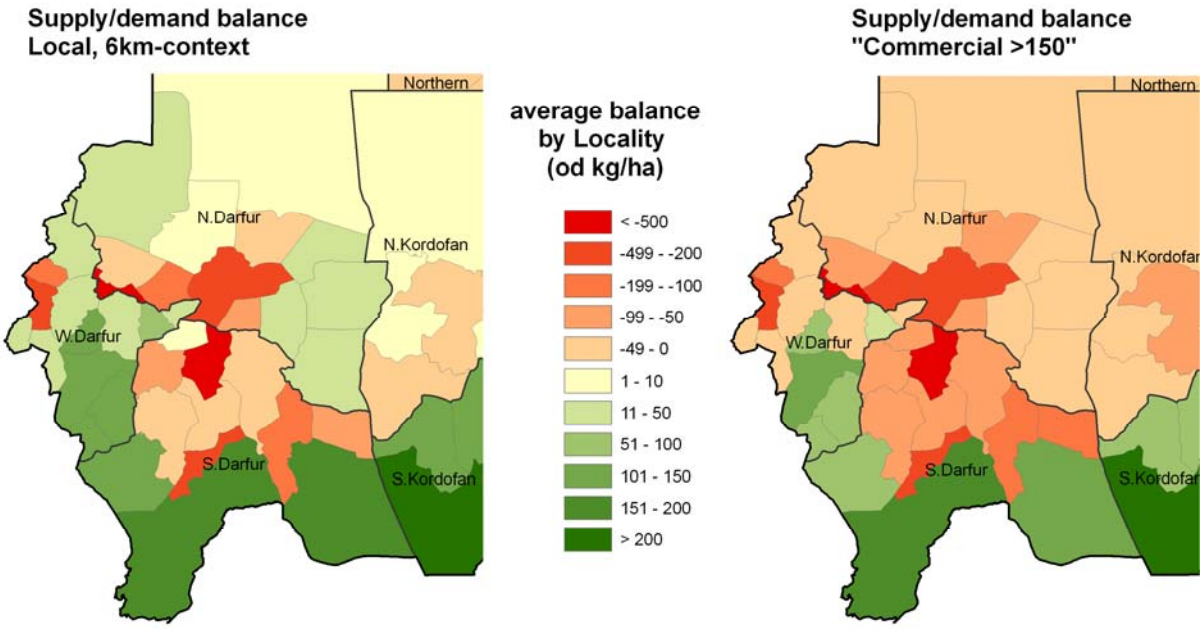
The commercial balance statistics show that there are Localities presenting deficit conditions in commercial balance even when the corresponding State-level balance is positive. These Localities may be considered as woodfuel "hot spots" and should be given high priority of intervention. State-wise, and by decreasing priority order, these Localities are:

- In North Darfur: all Localities present negative commercial balance even when the lowest threshold (100 kg surplus) is applied.
- In West Darfur: Alginaina, Sirba, and Koulbos are the Localities that present significant negative commercial balance when the 150 kg threshold is applied.
- In South Darfur: all Localities, except Rihaid-Albirdi, Booram and Bahr-Alarab, present negative commercial balance whichever threshold is applied.

[8] See Table 5 or Table 7 for Locality names. Code structure: 2 digits for State and 2 digits for Locality.

FIGURE 33

Maps of Local balance and "commercial" balance (surplus >150kg/ha/yr) by Locality.



Summary statistics by Localities are reported in Table 7.

4.6.4 Woodshed analysis

Woodshed analysis was done with two different purposes: (i) for defining the sustainable supply zone of IDP camps under various supply and demand assumptions and (ii) for analyzing the probable non-renewable biomass (NRB) fractions of current IDP consumption (or levels of overexploitation of wood resources around IDP camps) assuming varying supply distances.

4.6.4.1 IDP camps' sustainable woodshed areas

Figure 34 shows the theoretical woodshed zones assuming the sustainable management of all wood resources of the medium productivity variant combined to BAU demand variant (red limits) and to FES demand variant (blue limits). This is obviously theoretical since many formations are too scarce in woody biomass to justify management costs.

4.6.4.1 IDP Camps' non-renewable biomass analysis

The woodshed zones defined above represent the area deemed necessary for the sustainable supply and not the current supply area, that is determined by biomass stock availability and distance with little consideration for sustainability.

By setting a pre-defined supply distance from the IDP Camps reflecting today's pressure zone for woodfuel and other woody biomass extraction, it is possible to estimate the probable non-renewable biomass (NRB) fraction of current IDP consumption and to infer on the levels of overexploitation of wood resources around IDP camps. The territory around the camps considered in the analysis included areas up to 36 km distance from camp sites (on flat and accessible terrain or equivalent-effort distances on steep slopes). Figure 35 shows an example of the territories around IDP camps considered in the analysis.

TABLE 7

Summary supply/demand balance 2011 by Localities and States (values are thousand tons of woody biomass)

State_EN	code	Locality_Name	Accessible MAI Med-var. (od t)	Consumption 2011 BAU variant	Consumption 2011 FES variant	Pixel-level Balance FES variant	Pixel-level Balance BAU variant	Local balance Bau variant	"commercial" surplus >100kg (Med-BAU)	"commercial" surplus >150kg (Med-BAU)	"commercial" surplus >200kg (Med-BAU)
N_Darfur	6101	Almalha	89	84	63	26	5	5	-76	-78	-80
	6102	Milleet	36	74	59	-23	-37	-37	-59	-61	-61
	6103	Eltina	115	36	28	87	78	78	-21	-31	-31
	6104	Saraf-omra	15	110	84	-69	-95	-87	-89	-90	-90
	6105	Alsiraif	52	80	60	-8	-28	-20	-49	-58	-60
	6106	Kabkabiya	46	118	95	-49	-72	-73	-89	-100	-104
	6107	Kotum	70	68	58	12	2	2	-53	-58	-58
	6108	Alkoama	54	35	27	27	18	20	-13	-21	-29
	6109	Alfashir	48	298	250	-202	-250	-251	-277	-279	-279
	6110	Omkaddadah	72	47	36	37	26	25	-25	-30	-32
	6111	Kalamando	44	37	27	17	8	8	-19	-21	-21
	6112	Altowaisha - Alliayied	97	70	53	45	28	28	-30	-39	-42
	6113	Dar Elsalam	11	35	28	-17	-24	-25	-29	-29	-29
W_Darfur	6201	Koulbos	62	32	25	37	30	30	0	-16	-24
	6202	Sirba	18	41	33	-15	-23	-20	-28	-31	-32
	6203	Kirainik	95	61	53	42	34	30	19	-2	-23
	6204	Alginaina	45	141	121	-76	-96	-97	-101	-110	-119
	6205	Baidah	31	24	19	12	6	6	4	-3	-11
	6206	Habeela	59	48	38	22	12	9	7	-2	-19
	6207	Azoom	59	20	16	44	39	39	38	29	4
	6208	Zalingay	101	59	51	50	42	30	24	-7	-34
	6209	Nairtaty	43	25	23	19	18	17	15	7	-5
	6210	Rokoro	17	9	8	8	8	7	0	-4	-6
	6211	Wadi-Salih	191	74	60	132	118	121	118	99	52
	6212	Wadi-Salih	120	33	26	95	87	87	81	63	22
	6213	Omdukhon	63	31	24	39	32	32	30	24	13
S_Darfur	6301	Shiairyya	130	148	123	8	-18	-18	-59	-83	-100
	6302	Niyala	52	366	314	-262	-314	-307	-331	-338	-340
	6303	Jabal-Marra East	28	26	24	4	2	0	-14	-19	-21
	6304	Kass	106	142	118	-12	-36	-35	-39	-49	-72
	6305	Id-Alfursaan	183	209	160	23	-27	-27	-39	-68	-115
	6306	Alssalam	135	135	116	19	0	-10	-19	-37	-62
	6307	Aldiain	123	218	181	-57	-94	-97	-113	-162	-178
	6308	Adeela	86	141	108	-22	-55	-55	-65	-94	-102
	6309	Tolus	73	176	137	-64	-102	-101	-106	-114	-122
	6310	Rihaid-Albirdi	240	106	81	159	134	134	123	81	17
	6311	Booram	886	246	197	689	640	641	628	569	472
	6312	Bahr-Alarab	637	123	93	543	514	517	494	438	361
		North Darfur	**749**	**1,090**	**868**	**-119**	**-341**	**-327**	**-830**	**-894**	**-917**
		West Darfur	**905**	**599**	**497**	**409**	**307**	**290**	**208**	**46**	**-180**
		South Darfur	**2,679**	**2,036**	**1,652**	**1,027**	**643**	**643**	**461**	**123**	**-263**
		Tot Darfur	**4,333**	**3,726**	**3,017**	**1,316**	**608**	**606**	**-161**	**-725**	**-1,360**

The result of this analysis, shown in Table 8, indicates that, with exception of West Darfur, the 36 km belt around the camps cannot provide sufficient "renewable" woody biomass to satisfy the demand. This means that, if the supply area here considered is realistic, a large fraction of the exploitation is against the biomass "capital", i.e. the stock, rather than against its "annual interest rate", i.e. the MAI, with consequent depletion of wood resource base and environmental degradation. State-wise, the results indicate the following:

- the situation is particularly serious in North Darfur, where the NRB fraction ranges between 95% at close distance and 79% when the maximum distance is considered;
- relatively better appears the situation in West Darfur where NRB fraction is 70% at close distance but reduces to 0% for a horizon of 36 km;
- South Darfur presents an intermediate situation, with an NRB fraction of 78% at close distance, reducing to 41% for an harvesting horizon of 36 km.

Obviously, in all cases the NRB fraction increases if smaller supply belts are considered.

Based on the available geodataset, other specific analyses can be carried out, targeting selected sites and/or testing different supply horizons and management intensities.

TABLE 8

Analysis of supply/demand balance and non-renewable biomass (NRB) within pre-determined woodshed areas around IDP Camps.

Distance from camps or equivalent effort	Area	Supply Md	cumulative Supply Md	BAU Consumption	cumulative BAU Consumption	Med-BAU balance	cumulative Med-BAU balance	NRB fraction
	km^2	od tons	od tons	od tons	od tons	od tons	od tons	**(%)**
N_Darfur								
< 12 km	5,096	26,801	26,801	519,406	519,406	-492,605	-492,605	**94.8**
12 - 24 km	10,556	54,927	81,729	120,368	639,774	-558,045	-1,050,650	**87.2**
24 - 36 km	12,951	69,630	151,358	78,523	718,297	-566,939	-1,617,589	**78.9**
W_Darfur								
< 12 km	9,022	140,384	140,384	477,513	477,513	-337,129	-337,129	**70.6**
12 - 24 km	14,711	234,992	375,376	46,121	523,634	-148,258	-485,387	**28.3**
24 - 36 km	13,443	216,575	591,951	39,871	563,505	28,446	-456,942	**0.0**
S_Darfur								
< 12 km	18,158	267,478	267,478	1,200,470	1,200,470	-932,992	-932,992	**77.7**
12 - 24 km	27,095	408,569	676,047	284,149	1,484,619	-808,572	-1,741,564	**54.5**
24 - 36 km	21,746	323,745	999,792	224,436	1,709,055	-709,263	-2,450,827	**41.5**

Note: The distance from the camps considered are 36 km over accessible flat terrain or an equivalent effort over rough and steep terrains.

FIGURE 34

Woodsheds of Darfur's IDP camps according to BAU and FES consumption scenarios.

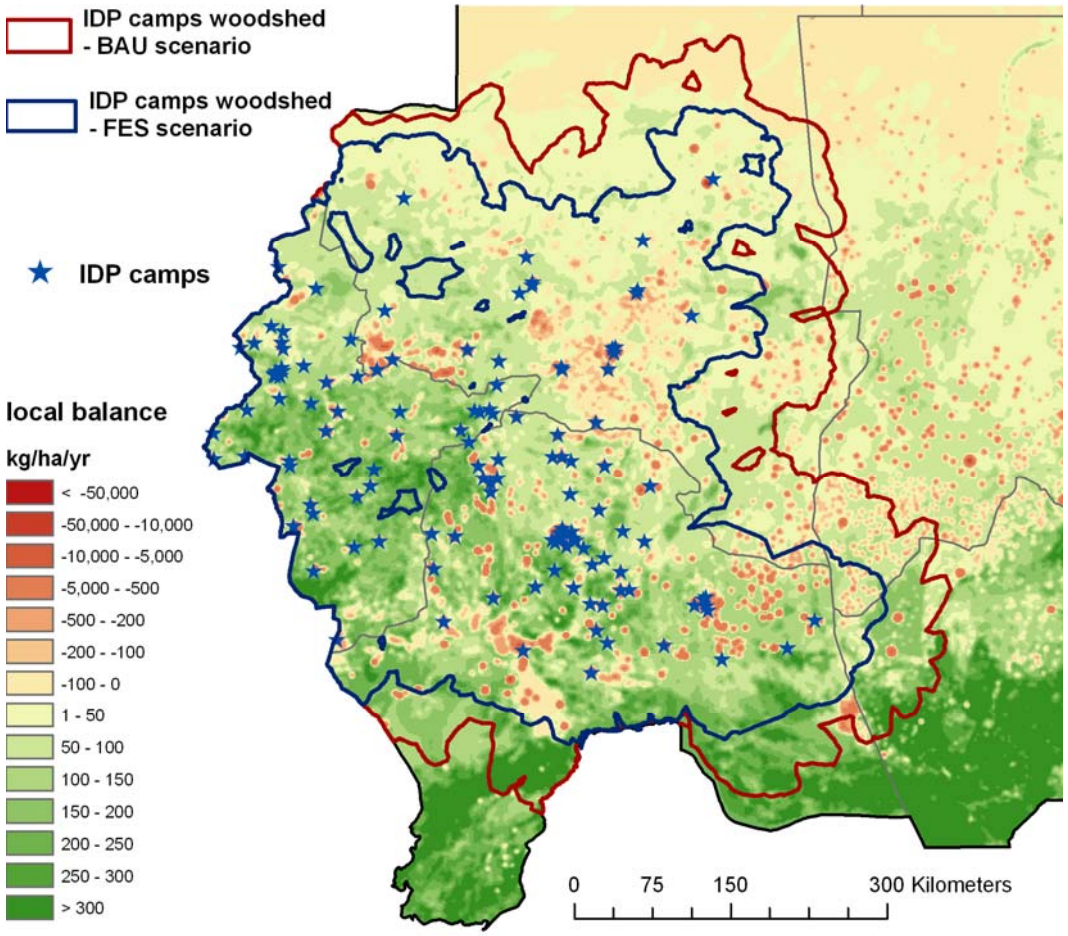
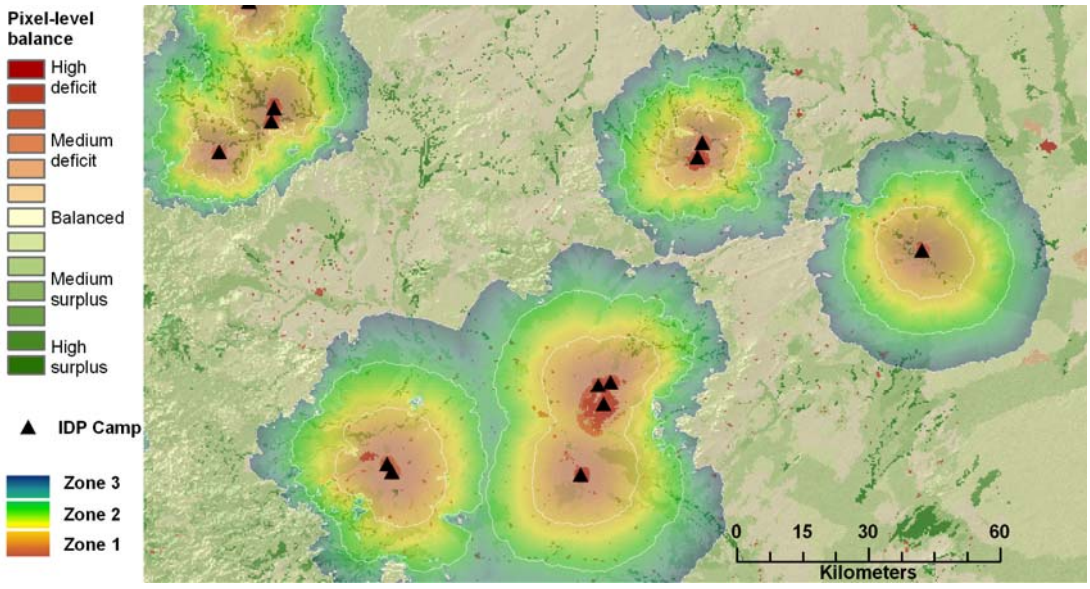


FIGURE 35

IDP camps' woodshed with pre-defined cost-distance values. Example location NE of El Fasher



In the example shown the value assumed is 36 km on a flat accessible terrain or equivalent effort over rough and steep terrains. The supply/demand balance within these woodsheds and an estimation of the non-renewable fraction of the consumed woody biomass is given in Table 8.

5
CONCLUSIONS AND RECOMMENDATIONS

5.1 FINDINGS AND CONCLUSIONS

WISDOM Darfur is conceived as a strategic planning tool to be maintained, deepened and, most important, used by forestry, energy and rural development planners, emergency and relief operators, etc., concerned with wood energy planning, environmental impact assessment, integrated land management, etc..

The analytical conclusions, thematic maps and tables here presented should be considered as the first step in the analysis of this sector and not its conclusion. The effort of creating a comprehensive vision in spite of current data limitations implied several assumption and values attributions that are here openly presented and that need to be replaced by objective data, when available, in order to reduce the margin of approximation and improve overall analytical accuracy.

Moreover, further layers of analysis may be included, linking woodfuel deficit to poverty and vulnerability, or exploring the nexus between woodfuel deficit, the use of farm residues as fuel versus livestock feeding on one side and soil fertility on the other.

Main findings

Demand for woody biomass

- The total annual consumption of woody biomass in 2011 according to the business-as-usual (BAU) consumption variant, all uses included, is estimated at 6.3 million m^3, or 3.7 million oven-dry tons
- With 93 % of the total woody biomass use, the household sector is by far the most important demand sector. This value is higher in rural areas (98%) and lower in urban areas (77%), where industrial uses are concentrated. 86% of the household consumption goes to cooking and the rest to construction, maintenance and furniture. This value is lower in rural areas (83%) and higher in urban areas (95%).
- The big building wave consequent to the influx of the international community, which boosted brick production to extreme levels, seems to have passed but the impact of this use sector remains serious. The present study assumes an annual fuelwood consumption of over 100,000 m^3, which is less than the wave peak but 4 times higher than pre-war situation.
- The consumption by the Institutional, commercial and industrial sectors (bricks included) is estimated at 453,000 m^3
- The dissemination of Fuel Efficient Stoves (FES), which is one of the ways to reduce the consumption of fuelwood and provide other benefits, has been done in IDP camps with good results but only marginally in rural and urban areas. It is estimated that a widespread and intensive stove programme in rural and urban areas ("FES" consumption variant) may reduce the total consumption by a maximum of 1.2 million m^3 (from 6.3 to 5.1 million m^3, or from 3.7 to 3 million oven-dry tons).
- LPG presently plays a marginal role as substitute of charcoal and fuelwood in Darfur and is likely to remain so for the near future, unless it is heavily promoted and subsidized. After a rapid increase in 2003 as consequence of the influx of emergency operators, the LPG consumption in whole Darfur stabilized around 700 tons only.

Woody biomass supply potential

- The total stock of woody biomass in Darfur states is estimated at 99.8 million m^3, or 58.8

million oven-dry tons.

- The estimated Mean Annual Increment according to the medium productivity variant is 7.9 million m^3, or 4.6 million oven-dry tons.
- The physically accessible productivity is estimated at 7.4 million m^3, or 4.3 million oven-dry tons.

Supply/demand balance and woodshed analysis

- The supply/demand balance, assuming business-as-usual (BAU) demand and Medium accessible productivity, shows an overall surplus of 0.6 million oven-dry tons (1 mln m^3). Assuming the full impact of the FES consumption variant, the surplus rises to 1.3 million od tons (2.2 mln m^3). These results indicate that there is a theoretical sustainable potential but give no guarantee of economic sustainability (see below). Moreover, these summary results do not reflect the geographic distribution of deficit and surplus areas.
- Considering that the management and commercial exploitation of sparse resources may be uneconomical, balance analyses were carried out for "economically accessible" resources through the application of different minimum resource availability thresholds to local surpluses. The results for North Darfur show that, even with a low threshold of 100 kg $*ha^{-1}*yr^{-1}$ (corresponding to 1.5 od t or 2.55 m^3 per hectare on a 15-years rotation) the resources are insufficient to match the commercial demand. For South Darfur and West Darfur the positive balance may be achieved with a "medium" threshold of 150 $kg*ha^{-1}*yr^{-1}$ (2.25 od t or 3.8 m^3 per hectare on a 15-years rotation). The threshold of 200 kg/ha/yr (3 od t or 5 m^3 per hectare on a 15-years rotation) is definitely too high, as it shows negative balance in all states.
- Due to the deep deficit in North Darfur, Darfur as a whole shows a negative "commercial" balance even when the lowest threshold is applied, which is a clear indication that demand reduction and increase productivity must be strongly promoted.
- The main issue now is to define the limit set by commercial fuelwood and charcoal producers. If the thresholds mentioned above are profitable for local operators then the potential for sustainable wood energy system is confirmed. If, on the contrary, the minimum thresholds defined by the operators will be higher, there will be need to integrate even more consistently the supply from other sources (other areas or new plantations, or woodfuel import from South Sudan and RCA) and/or reduce the demand through alternative fuels and FES programs.
- Woodshed analysis revealed the extent of territory around consumption sites (IDP camps, in this case) that must be managed for woodfuel production in order to meet the demand, according to various supply and demand scenarios. When realistic productivity and demand assumptions are adopted, the woodshed expands to include the majority of Darfur territory, highlighting the difficulty of the situation and emphasizing that all users (urban, rural, IDP, industries, etc.) are equally competing for the resource and that the strategies must address them all.
- The analysis of supply/demand balance around IDP camps allowed to determine the probable Non Renewable Biomass (NRB) fraction associated to current supply systems and thus the associated risks of degradation and deforestation. The analysis was done considering distance from the camps of 13, 24 and 36 km (or equivalent efforts over rough terrain), the latter one being indicated as the limit of current supply zone. The results show that:
    - the situation is particularly serious in North Darfur, where the NRB fraction ranges between 95% at close distance and 79% when the maximum distance is considered;
    - relatively better appears the situation in West Darfur where NRB fraction is 70% at close distance but reduces to 0% for a horizon of 36 km;
    - South Darfur presents an intermediate situation, with an NRB fraction of 78% at close distance, reducing to 41% for an harvesting horizon of 36 km.

  The analysis can be carried out for specific locations, i.e. individual IDP camps, in order to assess environmental impacts and to target project action.

Main conclusions

In support to the formulation of a comprehensive wood energy strategy for Darfur, covering IDP Camps as well as other residential, industrial, commercial and institutional uses, the following conclusions are of particular relevance:

Wood energy issues

- Darfur as a whole seems to have the theoretical potential, in terms of mean annual increment (MAI) of woody biomass, to match the current demand, but good part of the resources are too sparse to be economically accessible and the true balance is therefore clearly negative.
- Spontaneous and unplanned harvesting is impacting on the capital (stock) rather than on its interest rate (MAI), provoking degradation and depletion of natural resources.
- Converting the spontaneous harvesting into sustainable wood energy systems requires major efforts including:
    - intensive and locally tailored participatory management planning,
    - plantation establishment,
    - Fuel Efficient Stoves programmes in rural and urban areas.
- Providing alternative livelihood strategies for rural populations currently dedicated to fuelwood and charcoal production for sale at IDP camp sites are important and beneficial but assuming that this would reduce the pressure on wood resources is probably erroneous. If the demand remains, other would respond and reducing the exploitation in one areas would simply displace it over another area. More efficient would be to rationalize the supply/demand chain by promoting equitable and sustainable resource management, thus consolidating income sources wherever feasible.
- The margin between the demand and the growth potential is limited and the economic viability of sustainable commercial wood energy systems needs to be carefully evaluated. The results show an overall negative balance for Darfur as a whole even when applying low thresholds, primarily due to the deep deficit of North Darfur. Positive balance can be met in West and South Darfur only if formations with low productivity (and thus with limited attraction for private operators) are put under operational management.
- The values derived from the application of minimum resource availability thresholds, presented above, give us the context and constraints in which forest management planning must operate. The economic viability of sustainable production systems is evidently very limited, especially in North Darfur, and must be discussed and defined area by area with forest managers and local operators. Where the commercial balance remains negative, the supply strategies must be complemented by tree planting and the demand must be reduced by FES and fuel substitution programmes.
- From all above it is evident that strategy options must be locally tailored in order to be effective, and that the main contribution of the WISDOM tool is in supporting geo-referenced priority zoning under various policy items and assumptions.

Communication strategy

- The deep nexus between subsistence energy, livestock management, sustainable forestry and farming requires multi-sectoral strategies based on in a shared analytical context.
- The comprehensive and spatial-explicit vision of supply and demand is a basic pre-requisite to wood energy planning and strategy formulation at local and national levels and synergies among institutions and agencies for an integrated multi-sectoral approach are essential.
- In order to promote institutional awareness on the findings and on the planning support offered by WISDOM Darfur it is necessary to continue on the communication strategy aiming at state-

level administrators and operators as well as to national institutions, agencies and donors community[9]..

Shared knowledge

- Given the cross-sectoral and multidisciplinary character of wood energy, the development of WISDOM Darfur would have been impossible without the contributions from many national institutions, international agencies and NGOs. During WISDOM development all efforts were made to guarantee the transparency of the process through meetings, presentations and open discussions on the assumptions made and data weaknesses, and to make of WISDOM a shared product. As partial documentation of the cross-sectoral nature of the process, Annex 3 presents the list of participants to the meetings held during the final stage of analysis.
- Given the limits of existing data, the development of the WISDOM geostatistical database implied many assumptions and tentative value attributions. Competent critics are most welcome, especially if they can correct possible misinterpretation of existing data or if they can indicate new and more reliable references.

Weaknesses of approach and data

- WISDOM Darfur is still in its "prototype" version. It provides a comprehensive vision but a user-friendly interface for consultation, updating and maintenance has not yet been developed.
- The updated WISDOM Darfur presents the situation between 2010 and 2011. The vision provided by the current dataset is a "snapshot" that becomes out-of-date with the changing of the situation.
- Concerning the demand module, the main weaknesses are related to the reliability and completeness of demographic data, including regular resident and nomadic populations and IDP. The census subdivision and administrative maps show several inconsistencies and there is a poor correspondence between 2008 census statistics and IDP statistics for the same period, as it may be justified by the fluidity of the situation..
- Concerning the supply module, the main weakness is due to the absence of reliable data on the mean annual increment and on the sustainable and economically accessible productivity.
- Concerning the Integration module, other thematic layers can and should be added to the analysis in order to identify and delineate priority areas of intervention with cross-sectoral dimension. Most immediate thematic layers may include:
    - Water availability for population, livestock and farming.
    - Livestock presence and transhumance routes.
    - Poverty
    - Vulnerability
    - Access to services (health market schools, etc.)….

5.2 RECOMMENDATIONS

The underlying recommendation to all following ones is that peace and security return to Darfur. Minimal security condition is a basic pre-requisite to most, if not all, recommended sustainable resource management actions.

[9] A workhop 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.

Short term recommendations (< 2 years)

- 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:
    - Conduct state-level workshops to present WISDOM's findings, discuss the assumptions made and define follow-up actions aiming at the appropriation of the WISDOM tool by state-level institutions and agencies
    - 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.
- The State-level SIFSIA Unit will be the "natural" data repository of WISDOM data. Along with the principle of data sharing and transparency, it is recommended to define an operational data handling and storage policy. The institutional repository of the WISDOM dataset 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.
- 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 Darfur. 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.
- Complement the biomass component with other essential thematic layers such as water, farming systems and livestock, poverty and vulnerability, in order to allow integrated cross-sectoral analyses
- Define a programme of natural resource monitoring and management in support of conflict resolution
- Define priority areas of intervention in a cross-sectoral analytical context and prepare a folder of project proposals for donors' consideration, including:
    - FES projects in rural and urban areas, giving priority to the areas showing marked deficit conditions.
    - Agro-forestry projects
    - Establishment of short rotation forest plantations
    - Fuel substitution programs
    - …
- Design capacity building actions aiming at strengthening institutional planning capacities at national and state levels and the full appropriation of the WISDOM experience by the relevant national and state government entities.

Medium term recommendations (< 5 years)

- Undertake capacity building programs for national and state-level institutions on planning tools

(i.e. WISDOM and related tools) and sustainable resource management.

- Undertake Fuel Efficient Stove programs in rural and urban areas, giving priority to the areas showing marked deficit conditions.
- Undertake new planting and agro-forestry programs in the areas surrounding IDP camps (hopefully abandoned) and urban areas which were degraded and deforested due to woodfuel overexploitation.
- Introduce/promote participatory sustainable forest management and woodfuel production practices as source of livelihood in connection to returnees and resettlement programs.
- Undertake detailed state-level forest inventories with the scope of assessing the stock and the productivity of biomass resources.
- In collaboration with State Land Commissions, collect and organize/digitize Forest Reserves information in order to clarify and/or define access rights and governance issues.
- Prepare cross-sectoral resource management master plan for the whole of Darfur including forestry, livestock and agriculture, energy and poverty reduction, and other relevant planning sectors.

Long term recommendations (> 5 years)

- Prepare local operational management plans in the framework of the comprehensive master plan and in synergy with local stakeholders.
- Implement participatory resource management programs aiming at the creation of rural woodfuel markets, wherever feasible.

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ANNEXES

ANNEX 1: LAND COVER CLASSES AND ASSOCIATED WOODY BIOMASS STOCK AND MAI 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 2: RESERVED FORESTS IN DARFUR STATES

North Darfur	Location (entry point)		Area		Registration	Gazetted No
RF Name	Lat	Lon	feddam	ha	date	
Wadi golo (1)	13.617	25.283	2,099	882	15.6.1953	853
Solenga	-	-	638	268	15.6.1953	853
Hezam al Fashir	13.067	25.3	2,800	1,176	21.11.1993	900628
Wadi golo (2)	13.619	25.284	449	189	15.1.1957	903
Um kaddada	13.617	26.667	975	410	15.1.1970	1093
Menan	14.2	24.367	100	42	15.1.1967	1023
Emtidad hezam al Fashir	13.069	25.305	2,800	1,176	21.11.1993	900628
Um gewaiza	14.25	27.25	8,060	3,385	14.9.1995	900628
Um sedir	13.75	27.383	1,131	475	14.9.1995	900628
Fashar	-	-	741	311	15.1.1957	903
Total North Darfur			**19,793**	**8,313**		

West Darfur	Location (entry point)		Area		Registration	Gazetted No
RF Name	Lat	Lon	feddam	ha	date	
Zalengi	13.1	23.467	15	6	15.1.1957	903
Karari	-	-	221	93	15.2.1957	904
Martigelo	12.917	24.117	5,406	2,271	15.6.1958	922
Wallaaa	13.033	24.05	68	29	15.6.1958	922
Kaibi	13.05	24.067	769	323	15.10.1959	938
Gallabat	12.767	23.422	12,482	5,242	15.6.1961	959
Galol baldong	12.95	24.2	29,110	12,226	6.10.1996	900628
Krondali	12.733	23.767	12,381	5,200	11.1.1995	900628
Um eroag & baida	12.942	23.683	5,745	2,413	11.1.1995	900628
Edd al galaga	13.167	23.433	19,307	8,109	11.1.1995	900628
Korondali Fatima keral	12.85	23.583	32,941	13,835	11.1.1995	900628
Koar	-	-	32,118	13,490	17.8.1994	900628
Wadi mandi al hamiah	12.4	23.9	45,150	18,963	17.8.1994	900628
Logy	13	24.35	6,345	2,665	17.8.1994	900628
Goz lambai	12.867	24.367	5,101	2,142	17.8.1994	900628
Tortenga	12.95	24.35	7,228	3,036	17.8.1994	900628
Ayoar	13.033	23.638	4,600	1,932	11.1.1995	900628
Yanmo	12.733	22.967	3,829	1,608	5.6.1995	900628
Mara	12.25	23.133	4,182	1,756	5.6.1995	900628
Mono	11.867	23	16,440	6,905	5.6.1995	900628
Um khair	12.35	22.8	11,536	4,845	5.6.1995	900628
Gimbeel	11.633	22.917	13,180	5,536	5.6.1995	900628
Saraf magin	11.883	23.5	107,208	45,027	5.6.1995	900628
Talolo	12.75	23.267	7,011	2,945	5.6.1995	900628
Al karo	12.283	22.44	23,550	9,891	5.6.1995	900628
Goz kobra	-	-	4,606	1,935	5.6.1995	900628
Hegair	13.1	23.117	6,929	2,910	5.6.1995	900628
Darbain	-	-	11,210	4,708	5.6.1995	900628
Malawi & berair	-	-	30,523	12,820	5.6.1995	900628
Rokunga	12.033	23.088	1,251	525	5.6.1995	900628
Magli	-	-	6,202	2,605	5.6.1995	900628
Nago	12.217	23.075	3,678	1,545	5.6.1995	900628
Saraf boya	-	-	15,100	6,342	21.11.1993	900628
Total West Darfur			**485,422**	**203,877**		

South Darfur	Location (entry point)		Area		Registration	Gazetted No
RF Name	Lat	Lon	feddam	ha	date	
Kondowa	12.016	24.967	995	418	15.6.1955	882
Tonu	11.917	24.75	20,800	8,736	15.11.1967	1049
Geraida	11.25	25.15	13,903	5,839	15.9.1968	1065
Emtidad Kondowa	12.018	24.968	1,670	701	15.5.1969	1075
Ragag	10.867	24.75	50,170	21,071	15.12.1969	1095
Neyala	12.043	24.871	31	13	15.12.1969	1095
Kas	12.483	24.283	143	60	15.12.1969	1095
Al deaain	11.461	26.167	927	389	15.11.1975	1181
Al ratrataia	9.822	24.5	15,000	6,300	20.11.1993	900628
Goz dango	10.283	23.917	178,680	75,046	21.5.1994	900628
Saselgo	10.867	23.3	221,547	93,050	21.5.1994	900628
Wadi sharmoat	10.617	23.95	379,095	159,220	21.5.1994	900628
Um dafoag	9.717	24.35	33,856	14,220	21.5.1994	900628
Jabal dango	10.25	24.75	254,666	106,960	21.5.1994	900628
Hmada	12.917	25.433	143,200	60,144	21.5.1994	900628
Emtidad ragag	10.869	24.753	45,150	18,963	21.5.1994	900628
Ganamat wad al baid	10.05	25	6,580	2,764	21.5.1994	900628
Al senaita	10.7	23.567	11,500	4,830	21.5.1994	900628
Um meshaiter	9.817	24.7	244,459	102,673	21.5.1994	900628
Um roag	10.683	23.5	44,420	18,656	21.5.1994	900628
Brages al faras	10.5	26.117	175,274	73,615	24.5.1995	900628
Burma	10.25	26.5	223,222	93,753	24.5.1995	900628
Al totahana	11.5	27.133	57,237	24,040	24.5.1995	900628
Al merair	10.25	27.317	384,272	161,394	24.5.1995	900628
Mariam	10.617	26.867	182,406	76,611	24.5.1995	900628
Dar al salam	11.45	26.417	58,837	24,712	29.5.1995	900628
Al sahab	11.75	26.417	51,670	21,701	29.5.1995	900628
Sharef	11.25	27	93,245	39,163	29.5.1995	900628
Al bewaita	11.417	26.833	73,523	30,880	29.5.1995	900628
Al suntah ramad	11.417	25.6	22,389	9,403	29.5.1995	900628
Al nemir	11.367	25.933	38,713	16,259	29.5.1995	900628
Aradaib al sarig	10.65	25.983	61,844	25,974	29.5.1995	900628
Rehaid al taror	11.583	24.283	23,344	9,804	16.10.1996	900628
Beir tableya	11.133	25.422	2,870	1,205	15.10.1996	900628
Hezam tolos	11.117	24.533	3,302	1,387	15.10.1996	900628
Malwi	11.317	25.317	4,428	1,860	15.10.1996	900628
Semo al maeida	9.633	24.5	288,522	121,179	17.8.1994	900628
Turdat bagratain	11.217	24.8	5,243	2,202	29.3.1996	900628
Ied al fersan al shargia	11.533	24.383	9,166	3,850	29.3.1996	900628
Nogo	0	0	8,900	3,738	25.4.2005	20091764
Boara	0	0	46,832	19,669	25.4.2005	20091764
Al gadeem	11.537	26.191	376	158	25.4.2005	20091764
Gewegin	11.16	26.093	1,835	771	25.4.2005	20091764
Um sageia	10.349	26.367	17,980	7,552	25.4.2005	20091764
Hezam abu karinaka	11.614	26.564	1,071	450	25.4.2005	20091764
Hezam adeila	11.353	27.024	1,071	450	25.4.2005	20091764
Al sharaya	11.1	26.128	2,149	903	25.4.2005	20091764
Al magnoanah	11.02	26.207	223	94	25.4.2005	20091764
El fefi	10.15	24.969	28,000	11,760	11.3.1997	900628
Total South Darfur			**3,534,736**	**1,484,589**		
Darfur States total			**4,039,951**	**1,696,780**		

ANNEX 3: LIST OF MAIN THEMATIC MAPS USED AND PRODUCED

The following list is limited to the main map layers produced and used for the 2011 Update.

The Update 2011 of the Darfur analysis is largely based on the map layers produced for WISDOM Sudan. Hence, for a detailed description of the mapping procedures followed for the national-level map layers, see WISDOM Sudan Report (Drigo, 2012).

Table A3.1 Detailed WISDOM analysis within IDPs woodshed

Raster maps have **cell size of 100m** (cell =1 ha)

Darfur filename	format	Description / processing
Cartographic base		
		Land cover
lc_20nov	v	Land cover map. PRELIMINARY Version covering the AoI around IDP regions of Darfur available at 20 November 2010
lccs_03	**r**	**Land Cover Map of Sudan.** **Merge of all LCCS state maps of Sudan. Version February 2012.** **Raster version of "WISDOM_code" (numeric values associated to Map_Code and LCCS_code)**
		Administrative
State_Darfur.shp	v	Darfur State boundaries
Localities_Darfur_from_AUmap.shp	v	Localities in Darfur derived from Administrative Unit map AU__Darfur.shp. This map do not correspond exactly to the Census 2008 units.
AU__Darfur.shp	v	Administrative Units (subdivision of Localities) of Darfur States. This map do not correspond exactly to the Census 2008 units.
North_Loc.shp	v	Localities of North Sudan
Sudan_Settlements_Apr2008.shp	p	Map of human settlements
		IDP Camps
Darfur_Affected_Population_Apr_1_2009_rev090709_wgs84.shp	v	IDP location and attributes received from OCHA
IDP_Apr09.shp	v	IDP location and attributes limited to the most recent completed dataset (April 2009). Derived from Darfur_Affected_Population_Apr_1_2009_rev090709_wgs84.shp
		Rainfall map
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)
Accessibility maps		
n10_30e20	r	Merging of DEM tiles
ns_dem3as	r	Clipping of n10_30e20 on N Sudan
ns_dem100	r	Resampling of ns_dem3as to 100 m
Slope_ns	r	Slope map percent based on ns_dem100
dist00	r	Merging of Darfur and North Sudan communication layers = merge(dist0_1_darf, dist0_ns)
dist0_ns_darf	r	Starting feature of cost distance analysis
acc2_fin	r	Physical accessibility map of Sudan. 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	r	Legal accessibility map of Sudan (% accessible according to IUCN protection categories
acc_phy_leg	r	Physical and legal accessibility map of Sudan. Accessibility (% accessible) based on physical and legal factors. = int(acc2_fin * leg_acc_perc / 100 + 0.5)

Supply Module		
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_3		**Map of woody biomass stock of Sudan**
mai3_mn	r	Mean Annual Increment of Sudan (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Minimum variant.
mai3_md	r	**Mean Annual Increment of Sudan (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Medium variant.**
mai3_mx	r	Mean Annual Increment of Sudan (MAI) of woody biomass in kg / ha, d.m. (also value / pixel)- Maximum variant.
		Accessible mean annual increment
acmai3md3	**r**	**Accessible MAI of Sudan (fromLCCS2011) – Medium variant. (kg / pixel, d.m. (also / ha)**

DEMAND Module		
		POPULATION Mapping
adj_pop_adm	r	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
urb_AU_26nov	v	selected urban polygons from lc_20nov located in Urban AU
urb_au26nov0	r	raster of urb_AU_26nov above (value 0) used for mapping of urban population
rur_lc_p_fac5	r	population factors associated to LC classes (settlements and croplands) used for distribution of rural population (sparse rural and rural settlements)
rur_mul5_10k	r	multiplier of rur_lc_p_fac5 to obtain rural population per pixel values recl_adj_pop_adm_mult5_rur_pix_10000.txt
rur_5_100	r	Rural population according to census2008 and land cover data. Number of person / 1-ha pixel * 100.
urb100	r	Urban population according to census2008 and land cover data. Number of person / 1-ha pixel * 100.
idp100f2km	r	IDP population (ref:April 2009) smoothed within a 2km radius around IDP Camp points. Person / 1-ha pixel * 100
Pop100idp2km	r	Preliminary population map adding all component = rur_5_100 + urb100 + idp100f2km
mult3_10k	r	Correction factor to be applied to Pop100idp2km to adjust population values at state level to Census 2008 totals = reclass(adj_pop_adm, recl_state_mult3_10k.txt)
pop100_st3	r	Population map (including IDP camps) adjusted to state-level totals . Persons /1-ha pixel * 100 = int((5000 + (pop100idp2km * mult3_10k)) / 10000)
		Woody biomass consumption mapping
con_pc_rur4	r	Per capita consumption in rural areas – BAU variant (od kg / person / year) = reclass(adj_pop_adm, recl_adj_au_cons_pc_rur4.txt)
con_pc_urb4	r	Per capita consumption in urban areas – BAU variant (od kg / person / year) = reclass(adj_pop_adm, recl_adj_au_cons_pc_urb4.txt)
con_pc_idp4	r	Per capita consumption inIDP camps – BAU variant (od kg / person / year) = reclass(adj_pop_adm, recl_adj_au_cons_pc_idp4.txt)
con4_kg	**r**	**Total consumption per 1-ha pixel – BAU variant (od kg / ha / year)** = int((500000 + (con_pc_rur4 * rur_5_100 + con_pc_urb4 * urb100 + con_pc_idp4 * idp100f2km) * mult3_10k) / 1000000)
conpc_rurfes4	r	Per capita consumption in rural areas – FES variant (od kg / person / year) = reclass(adj_pop_adm, recl_adj_au_cons_pc_rur_fes4.txt)
conpc_urbfes4	r	Per capita consumption in urban areas – FES variant (od kg / person / year) = reclass(adj_pop_adm, recl_adj_au_cons_pc_urb_fes4.txt)

conpc_idpfes4	r	Per capita consumption inIDP camps – FES variant (od kg / person / year) = reclass(adj_pop_adm, recl_adj_au_cons_pc_idp_fes4.txt)
con4_kgfes	**r**	**Total consumption per 1-ha pixel – FES variant (od kg / ha / year)** = int((500000 + (conpc_rurfes4 * rur_5_100 + conpc_urbfes4 * urb100 + conpc_idpfes4 * idp100f2km) * mult3_10k) / 1000000)
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 in Sudan (od kg / ha / year) = merge(darfcon08_kg, con08_2) * n_s_msk1
con11_tot_2	r	**Total consumption in 2011** in Sudan (od kg / ha / year) = merge(darfcon11_kg, con11_2) * n_s_msk1
con11_d_fes	r	Total consumption in 2011 in Sudan assuming the **FES Variant on Darfur states** only (od kg / ha / year)

INTEGRATION Module	
bal_md_3	**Sudan-level Pixel-level balance – Medium variant (kg / pixel (ha)**
bal_md6km_i3	**Sudan-level Local balance** (context of 6 km)
	Commercial balance based on LCCS2011
c100balmd6k	**Sudan-level** "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	**Sudan-level** "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	**Sudan-level** "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)
DAR_BAL_FES	**Pixel-level balance – Medium variant (kg / pixel (ha)** assuming the **FES consumption Variant on Darfur states** only. **= acmai3md2 - con11_d_fes**

WOODSHED analysis		
		Woodshed calculations in : woodshed & idp buffer zones NRB.xls
		IDP camps' sustainable woodshed areas
cd20_eq	r	Reclass of cd29nov_i (20 classes equal interval) to be used as cost factor in woodshed analysis
cd_idp_50eq_2	r	Cost distance map from IDP camps (start IDP; cost: cd20_eq)
acc_idp_200	r	Accessibility buffers (200 classes) from IDP camps based on cd_idp_50eq_2 on equal interval
acc_idp200gc	r	Geographic projection of acc_idp_200
new_idp103.shp		IDP Camps' woodshed referring to Medium MAI and BAU demand (all resources considered)
new_idp52.shp		IDP Camps' woodshed referring to Medium MAI and FES demand (all resources considered)

	IDP Camps' non-renewable biomass analysis
cd_idp_mx40k	Cost-distance from IDP Camps with pre-fixed maximum value of 40000 (corresponding to a distance of 36 km on a flat terrain or equivalent efforts on rough terrain.
idp_3zones	cd_idp_mx40k divided into 3 equal-distance zones
idp3z_state	Combination of idp_3zones and Darfur States map used to analyse the NRB fraction by state at 12, 14 and 36 km distances (or equivalent efforts on rough terrain)

ANNEX 4: WISDOM DARFUR MEETINGS AND WORKSHOPS

In addition to the numerous meetings held with individual institutions and agencies to acquire data and present the activity, several wide meetings and workshops were held for presentation of the WISDOM Darfur methodology and findings, and discussion of policy implications concerning Darfur's IDP issues[10].

The first workshop on WISDOM Darfur was held at the **Conference Hall of the National Forests Corporation, Khartoum, on December 2nd, 2010**, in the framework of the FAO-supported National Forest Programme Workshop. The meeting was attended by 23 participants from the Management and the Technical Units of FNC Headquarters in Khartoum.

A second open meeting was held at **FAO Conference room, Khartoum, on 10th December 2010**. The meeting was attended by approximately 50 people from a wide range of institutions, agencies and NGOs active in the context of Darfur emergency and development programmes, including:

CONCERN	World-wide Charity registered in Ireland
DLC	Darfur Land Commission
EU	European Union Delegation
FEWS NET	Famine Early Warning Systems Network
GAA/WHH	Welthungerhilfe/German Agro Action
HAC	Humanitarian Aid Commission in Sudan
ICRC	International Committee of the Red Cross
NIDAA	Sudanes Development Call Organization
OCHA	Office for the Coordination of Humanitarian Affairs of United Nations
Practical Action	UK-registered charity and sustainable development corporation
Tearfund	UK Christian relief and development agency
UNEP	United Nations Environment Programme
UNICEF-WASH	United Nations Children's Fund - Water, Sanitation and Hygiene
USAID	U.S. economic and humanitarian assistance
WFP	World Food Programme

A workshop to present and discuss the findings of the WISDOM 2011 Update on Darfur region with focus on IDP Camps was held in **El Fasher, North Darfur on 26th February 2012**. 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 that operate in the area and in relation to IDP Camps.

[10] More workshops and training sessions were held in the framework of WISDOM Sudan, as described in the relevant SIFSIA N report (Drigo 2012).