CHAPTER 1

INTRODUCTION

1.1 WOOD ENERGY AND POVERTY

1.1.1 Role of woodfuels

Globally, woodfuels are the main and often the only accessible energy sources for over two billion people, including the poorest segments of rural and sub-urban populations.

Concerning the role that woodfuels play in the forestry as well as in the energy sectors of the countries of continental Southeast Asia covered by the present study, it may be useful to recall that:

- the fraction of woodfuel production in total roundwood production in 2000 ranged between 18 percent in Malaysia and 98 percent in Cambodia, with an average of 75 percent (FAOSTAT; FAO Web site);
- the contribution of woodfuels to total primary energy consumption was estimated to range, in 2000, from between 5 and 10 percent in Malaysia to between 85 and 90 percent in Cambodia (FAO, 1997).

1.1.2 Subsistence energy in a local supply/demand context

For many poor households of developing countries, subsistence energy is not guaranteed. Subsistence energy is taken here to be the amount of energy needed to guarantee a basic level of health care (drinking water, heat) and nutrition (proper food preparation) in the household. The term subsistence energy is used by the International Commission of Agricultural Engineering (CIGR) – Section IV: Rural Electricity and other Energy Sources (http://www.cigr.org/sec4.htm). For these households, found not only in rural areas but also around urban centres, a deficit situation (demand higher than local supply capacity, coupled with marketed fuels at unaffordable prices) has a direct impact on the possibility of achieving the subsistence energy level necessary to cover essential uses, such as water boiling, food preparation and heating.

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

The effect of a deficit situation leads to:

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

BOX 1

WOODFUELS AND FOOD SECURITY

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

When supplies of woodfuel decline, people switch to other sources of fuel. In Bangladesh, India and Nepal, for instance, straw and cow dung are now being used for fuel instead of for feed and manure, thereby depriving the soil of natural fertilizers, with negative consequences for crop yields. In Nepal, freeing biomass and manure for use as fertilizer could increase grain production by as much as 25 percent (FAO, 1996b).

1.1.3 Wood energy and poverty mapping

Wood energy mapping, at national as well as at global level, serves several cross-sectoral purposes. It supports sustainable forest management and energy planning; it helps to understand the facts and potentialities of bioenergy; and it helps to identify the geographical areas under unsustainable pressure, where both the response to basic human needs – subsistence energy – and environmental sustainability are at risk.

In the context of poverty and food insecurity, the energy dimension is of particular relevance. Access, or not, to minimum subsistence energy levels adds an essential dimension to the analysis of global poverty, as it has critical and immediate influence on the health and nutrition of poor rural and sub-urban households.

Wood energy mapping, based on the integration of woodfuels demand with sustainable supply capacities, allows the definition of the areas where lack of accessible wood resources induces an extra burden on the poor, triggering a vicious cycle in which essential nutrients are burnt rather than returned to the soil, with negative consequences for the production of foodcrops.

1.2 STUDY RATIONALE

Many factors contribute to the marginal attention that the wood energy sector receives, not only at national but also at international levels. Among them, the following problems can be highlighted and can be related in various ways to the general inadequacy of the information on this sector.

- Lack of a coherent perception of the magnitude of wood energy in the energy and forestry sectors of both industrialized and developing countries.
- Resistance derived from the attitude, especially common in poor countries, that depicts fuelwood and charcoal as obsolete and backward in comparison with more "modern" fuels.
- The secondary role assigned to woodfuel production by forestry authorities, in spite of the fact that energy represents, worldwide, the main use of wood.
- Fragmentation and frequent inconsistencies within and between woodfuel production and consumption statistics.

The implementation of international conventions and compliance with declarations and commitments concerning renewable energy and sustainable development are hampered by lack of information on the distributions and size of woodfuel potentials, in terms of both production (biomass stocking and potential sustainable productivity) and consumption (expanding bioenergy applications).

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

In recent years, FOPP-WE has conducted national-level wood energy analyses in Mexico, Senegal and Slovenia, applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology, and now intends to develop a global overview of wood energy situations in relation to poverty, food security, climate change and sustainable forest management. In line with this objective, a subregional WISDOM study was recently carried out covering ten African countries, for which the FAO Africover Programme produced detailed land cover information. The East Africa WISDOM study was carried out in collaboration with the FAO/UNEP Cooperative Programme Global Land Cover Network (GLCN), the Geographical Information Systems Group of SDRN and the *Istituto Agronomico per l'Oltremare* (IAO) of Florence, Italy.

The present study, covering the countries of continental Southeast Asia, represents a second step towards the development of a global wood energy overview and, at the same time, a contribution to poverty mapping, by adding a new subsistence energy dimension.

In the context of SDRN, the present study contributes to the conceptual and empirical basis of the SDRN Poverty Mapping Project, and, in that context, to the development of a Multipurpose Information Base for improving food security, reducing poverty and ensuring environmentally sustainable development in the countries of continental Southeast Asia.

Overall, this activity brings its contribution to the realization of the Millennium Development Goals (MDG) in the countries of the subregion through the detailed analysis of the interrelations between poverty, environment degradation and areas with intensive fuelwood utilization. In fact, given the evident links between poverty, subsistence energy and environment, it is clear that integrated woodfuel programmes aiming at supplying subsistence energy needs as well as at generating employment and incomes will play an essential role in poverty alleviation and health improvement initiatives.

Specifically, the activity addresses central issues of MDG 1 (eradication of hunger and poverty) and MDG 7 (ensure environmental sustainability), to which FAO is committed.

The activity was conducted in two phases: a first phase oriented to map the situation in 2000; and a second phase that explored possible evolutions of the situation towards a horizon of 2015, which represents the MDG reference year.

1.2.1 Scope of Phase 1: Year 2000 baseline

In the general context described above, the scope of Phase 1 of the study was to prepare subregional wood energy maps representing woodfuel consumption levels and supply potential in 2000 in the countries covered by the Asia Poverty Mapping Project (FAO Project FNOP/INT/005/NOR), and to analyse relations and possible interactions between wood energy and poverty. This exercise was intended to contribute to poverty mapping, by adding an essential subsistence energy dimension.

The countries covered were Cambodia, Lao PDR, Malaysia, Myanmar, Thailand, Viet Nam and the Yunnan Province of China.

1.2.2 Scope of Phase 2: Year 2015 supply/demand scenarios

Starting from the 2000 baseline produced in Phase 1, and covering the same geographical area, the scope of Phase 2 was to explore the possible evolutions of the supply and demand scenarios towards 2015, on the basis of available demographic projections, woodfuel consumption trends and land cover changes.

1.2.3 Institutional synergies

The study benefited from collaborations and synergies between the Geographical Information Systems Group of the Sustainable Development Department of FAO (SDRN) working on the Poverty Mapping Project, which provided recent mapping of rural and urban population distribution in 2000 and 2015 projections, sub-national administrative layers and other poverty-related data, and the Wood Energy Programme (FOPP-WE) of the Forestry Department, which provided information and statistics on woodfuels.

CHAPTER 2

METHODOLOGY

The methodological approach followed in the study is based on the following three fundamental characteristics of wood energy systems (definitions of the main terms as used in this report are given in Annex 1):

- **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). Broad generalizations about the woodfuel situation and impacts across regions, or even within the same country, have often resulted in misleading conclusions, poor planning and ineffective implementation.
- **Heterogeneity of woodfuel supply sources.** Forests are not the sole sources of woody biomass used for energy. Other natural landscapes, such as 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).

2.1 WOODFUEL INTEGRATED SUPPLY/DEMAND OVERVIEW MAPPING (WISDOM)

In order to cope with the various dimensions of the topic, FOPP-WE 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, 2003d). 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, 2005e), Slovenia (FAO, 2004a) and Senegal (FAO, 2004b). At subregional level, WISDOM was implemented over the eastern and central Africa countries covered by the Africover Programme (FAO, in press).

The WISDOM methodology was preferred to other approaches, such as the Long-range Energy Alternatives Planning (LEAP) model (FAO, 1998a), for its thematic specificity (woodfuels rather than generic energy or forestry planning) and for its open framework, which allows a high degree of flexibility and adaptability in the heterogeneity and fragmentation of the data related to the production and consumption of woodfuels. In addition, WISDOM had been applied with good results in the earlier study conducted over east Africa, and consistency between the two subregional studies was seen as an advantage.

WISDOM, especially when applied at regional level, does not replace a detailed national biomass demand/supply balance analysis for operational planning, but rather it is oriented to support a higher level of planning, i.e. strategic planning and policy formulation, through the integration and analysis of existing demand and supply-related information and indicators. More than absolute and quantitative data, WISDOM is meant to provide relative or qualitative valuations, such as risk zoning or criticality ranking, highlighting, at the highest possible spatial detail, the areas deserving urgent attention and, if needed, additional data collection. In other words, WISDOM should serve as an assessing and strategic planning tool to identify sites for priority action.

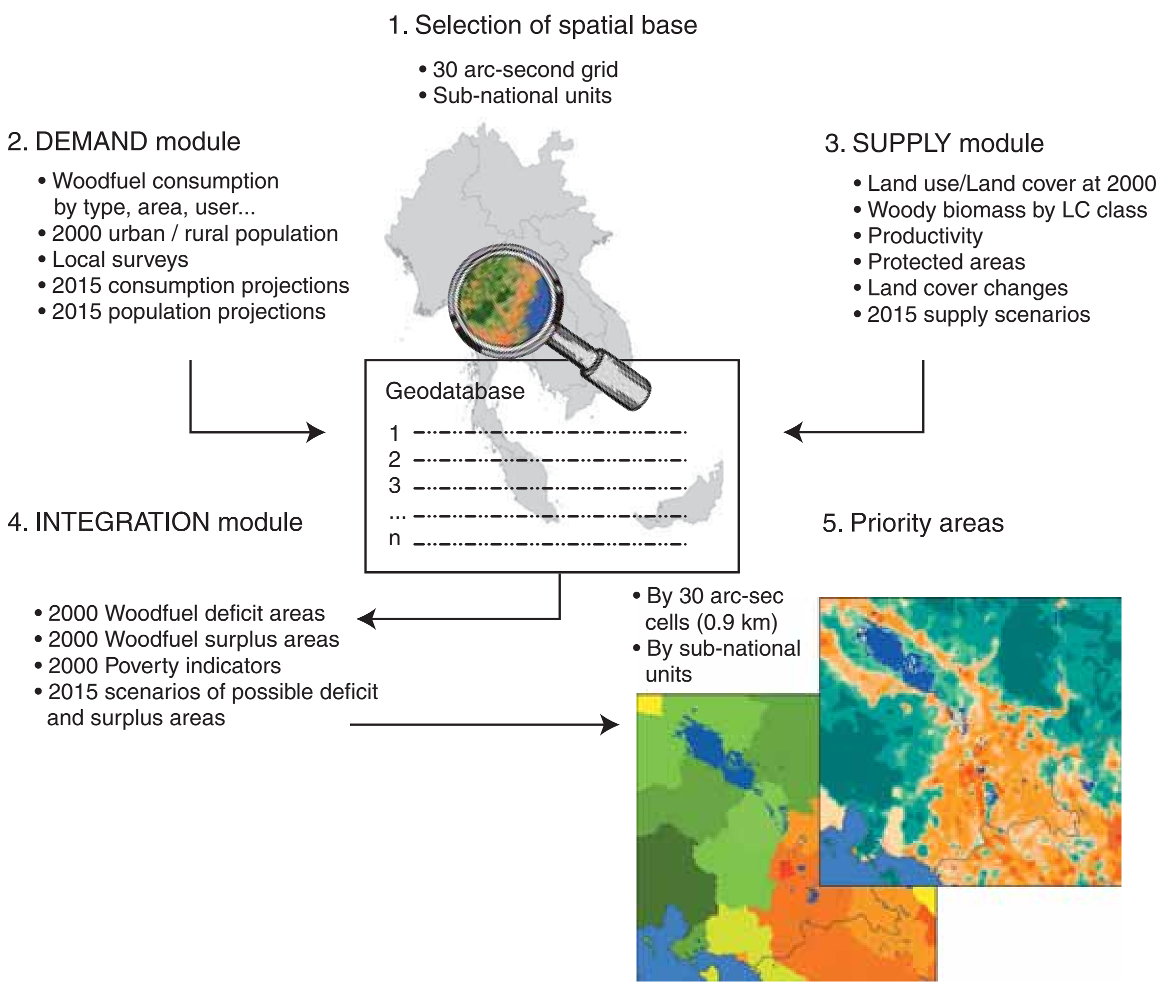
A detailed description of the WISDOM approach can be found in FAO (2003d).

The use of WISDOM involves five main steps:

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

The diagram in Figure 4 provides an overview of the WISDOM main steps.

FIGURE 4
WISDOM steps

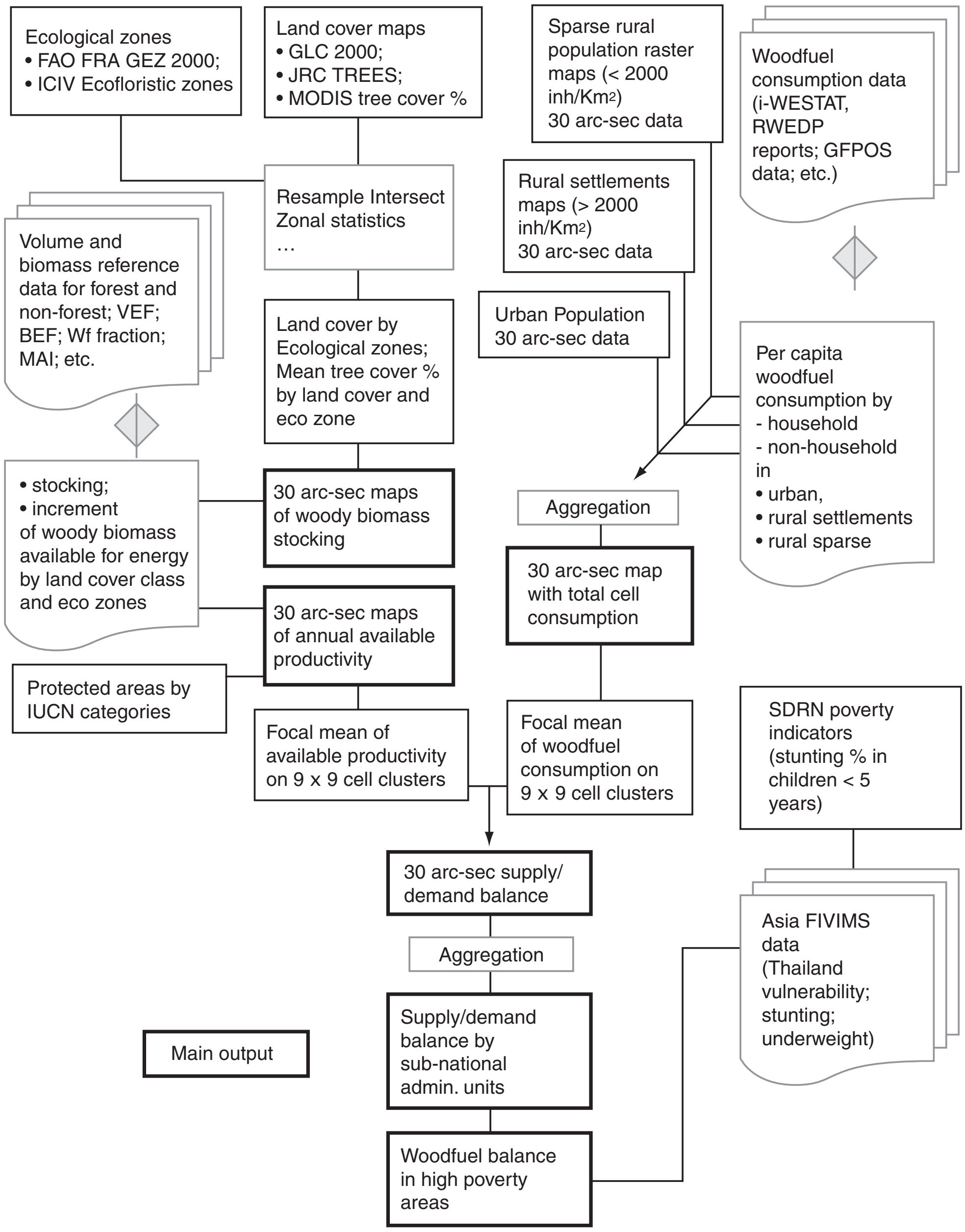


2.2 METHODOLOGY OF PHASE 1: 2000 BASELINE

The flowchart of the estimation process applied in the development of the baseline scenario for 2000 (Phase 1 of the study) is shown schematically in Figure 5. The main thematic elements, analytical steps and intermediate products are then described in subsequent sections.

FIGURE 5

Flowchart of main analytical steps of Phase 1: 2000 baseline



2.2.1 Selection of spatial bases

The definition of the spatial base, which is defined by the smallest territorial unit for which demand and supply parameter are estimated, was determined by the resolution of main reference data, i.e. land cover and population distribution data, which were all grid data at 30 arc-sec pixel size, representing individual units 0.92 x 0.92 km in size (at the equator).

For supply/demand balance analysis, the 30 arc-sec resolution appeared far too fine for achieving a meaningful supply/demand relation. Therefore, in order to maintain the 30 arc-sec pixel resolution but at the same time reflect the availability of wood resources in a convenient area surrounding each pixel, the supply/demand balance was based on derived data sets that reported, for each pixel, the average value within a 9 x 9 pixel cluster.

The 9 x 9 pixels define a territory in which supply/demand balance analysis is meaningful, especially for the fraction of woodfuel consumers that depend on local resources, and, most relevant, this format corresponds with the spatial base of the FAO Food Insecurity Vulnerability Mapping System (FIVIMS). This means that using this format for WISDOM analysis and wood energy mapping guarantees direct links and contributions to FIVIMS thematic layers and to poverty mapping.

In addition, sub-national administrative data was available. The sub-national administrative level and the size of the units varied considerably from country to country. The sub-national unit level was also used as a secondary level of aggregation in the supply-demand balance analysis. However, in order to maintain some level of homogeneity in size of units, the sub-national level of analysis varied from country to country, between the second and third administrative level.

Reference maps:

- shapefile with adm0 (country) and sub-national levels adm1, adm2 and adm3 (where available) <asiacover_subnational.shp>
- country layout at 30 arc-sec resolution matching population raster data <adm0_gr30.grid>

2.2.2 Supply Module

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

- Estimation and distribution of woody biomass stocking of natural formations and other land uses based on the available regionally consistent land cover data sets, ecological zoning and field data.
- Estimation and distribution of annual sustainable woody biomass productivity of land cover classes and the share available for energy use after deduction of other wood uses.
- Segmentation of wood resource data by legal accessibility classes based on IUCN-WCMC protected areas.

A subsequent phase of analysis, concerning the physical accessibility (based on distance from roads and on slope) could not be undertaken due to time constraints. However, to reduce the impact of the missing accessibility parameters, the analysis of woodfuel supply/demand balance was constrained to the resource horizon accessible to poor households' gathering capacities, i.e. within a distance of approximately 5 km of the homestead.

2.2.2.1 Estimation of woody biomass by land cover class

Land cover maps

Given the marked heterogeneity of national land use and land cover mapping, in terms of class definitions, thematic and geometric resolution, the preference was given to a regionally consistent data set that could allow a uniform approach over the entire study area. The land cover map selected as primary reference for the study was the Global Land Cover (GLC 2000) map, with the classes listed in Table 1.

TABLE 1

GLC 2000 classification

Code	Classes represented in the study area	Code	Classes represented in the study area
(1)	Tree cover, broadleaved, evergreen	(15)	Regularly flooded shrub and/or herb. cover
(2)	Tree cover, broadleaved, deciduous	(16)	Cultivated and managed areas
(4)	Tree cover, needle-leaved, evergreen	(17)	Mosaic: Cropland/Tree Cover/Other nat. veg.
(7)	Tree cover, regularly flooded, fresh water	(18)	Mosaic: Cropland/Shrub and/or grass cover
(8)	Tree cover, regularly flooded, saline water	(19)	Bare Areas
(9)	Mosaic: Tree Cover/Other nat. veg	(20)	Water Bodies
(11)	Shrub Cover, closed-open, evergreen	(21)	Snow and Ice
(12)	Shrub Cover, closed-open, deciduous	(22)	Artificial surface and associated areas
(13)	Herbaceous Cover, closed-open	(23)	No data
(14)	Sparse herbaceous or sparse srhub cover		

The Forest Cover Map produced by JRC TREES II Project, which represents the main source of GLC 2000 for the region, was used as secondary reference for a clearer understanding of GLC 2000 classes and a more consistent allocation of biomass density values.

In spite of the reference to the Land Cover Classification System (LCCS) (FAO, 2005f), the GLC 2000 classes provided no physiognomic information in terms of crown cover density, which would have made the allocation of biomass densities more consistent and reliable. At full resolution, LCCS data provides detailed physiognomic descriptions, including life forms, crown density and height parameters. In the study conducted on the ten countries covered by the Africover Programme (FAO, in press), the LCCS data allowed consistent and detailed estimation of biomass values.

In order to compensate for this limitation, land cover density information was derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) Vegetation Continuous Field (VCF) tree cover map. This map, which shows percentage crown cover values between 0 and 100, provided information on the variations of vegetation density within the GLC 2000 land cover classes. Accordingly, the average biomass density of each land cover class in each ecological zone (t/ha, based on available references) was associated with the average tree cover density of each land cover class, based on VCF data.

In each pixel, the biomass density was increased or decreased from the class mean according to the pixel's tree cover density and its variation from the mean tree cover density of the entire class. In practice, VCF data was used as a proxy for the distribution of the total biomass of a given class within such class.

Reference maps:

- Land Cover data
  - Primary reference: Regional version of the Global Land Cover (GLC 2000) map (re-sampled to 30 arc-sec pixel size to match population data) <glc_seasia30.grid>

  - Secondary reference: Forest Cover Map of continental Southeast Asia produced by JRC TREES II Project <contsea2000.grid>
- MODIS VCF percentage tree cover: Global land cover maps at 500-m resolution based on the Vegetation Continuous Field (VCF) algorithm applied to MODIS multiseasonal data sets (Hansen *et al.*, 2003). The maps were downloaded from the Global Land Cover Facility site: http://glcf.umiacs.umd.edu/data/
  - Original Eurasia and Oceania data sets at 500-m (approx 15 arc-sec) <LatLon.EUAS.2001.tree.grid> <LatLon.OC.2001.tree.grid>
  - Merged and re-sampled SE Asia dataset (30 arc-sec set matching other layers) <tc30.grid>
  - Mean tree cover percentage of each LC class in each ecozone calculated using Zonal Statistics functions <TC_lc_eco>

Ecological stratification

Given the limited number and uneven spatial distribution of field data on volumes and biomass, the preference was for a relatively simple classification system, with few classes within which an acceptable number of reference values could be found. The ecological stratification was therefore based on the FAO Global Forest Resources Assessment 2000 (FRA 2000) Ecological Zone map, which identified seven main zones in the area covered by this study.

In addition, in order to account for the considerable variations within the Tropical Rain Forest zone and the Tropical Mountain System zone that extends from the north of Myanmar to the equatorial forests of Malaysia, these zones were subdivided into two sub-zones. A wetter subzone (a), with dry season virtually absent and higher mean temperatures; and a drier sub-zone (b), with a defined dry season (up to four months) and relatively lower mean temperatures.

Such sub-zones were determined according to the Eco-Floristic Zones Map produced by ICIV, Tolouse, now *Laboratoire d'Ecologie Terrestre* (Blasco *et al.*, 1996; Bellan, 2000), which was the main source of the FRA 2000 Ecological Zone map.

The final ecological stratification used nine zones for the analysis (Figure 6).

Reference ecological zone maps:

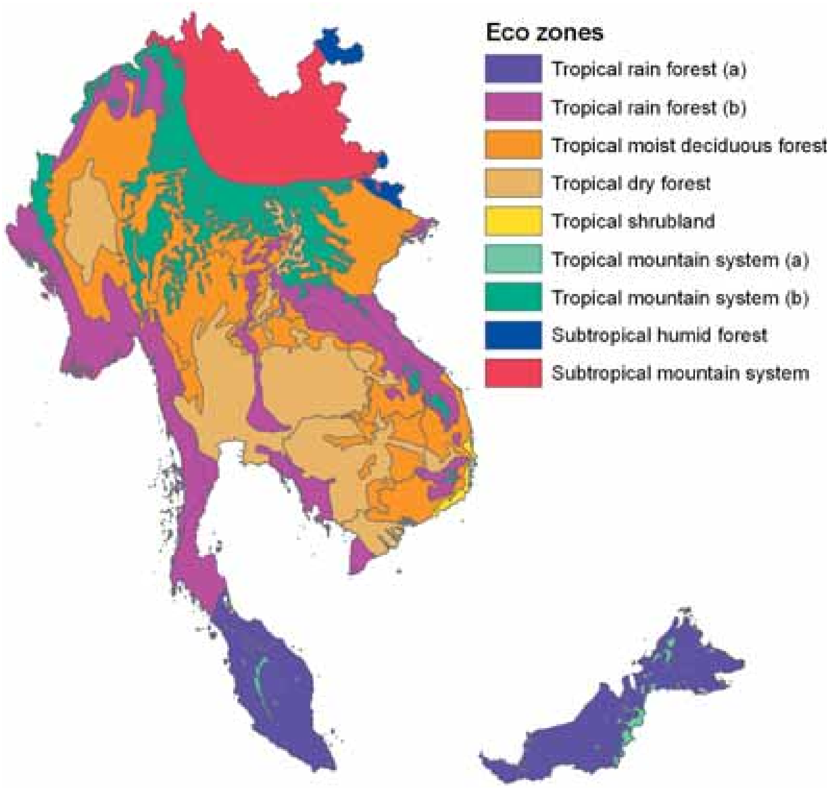
- FAO FRA 2000 Global Ecological Zoning (GEZ2000) <SEAsia_GEZ.shp>
- ICIV eco-floristic zone map <asi_ecf_polygon.shp>
- Modified GEZ2000 to subdivide the rainforest zone (referenced against ICIV eco-floristic data) and to match other raster data layers <gez9.grid>

Reference data on volumes and biomass

Direct field measurements of woody biomass are extremely rare events. Relatively more common are forest inventories, although they are usually limited to the "commercial" assortments (higher-diameter classes of timber species) of productive forests (FAO, 1997, 2001). Unproductive forests, in terms of timber quality, degraded forest formations, fallows, shrub formations, trees outside forests, farm trees, etc., are generally excluded from conventional surveys, although they often represent the main sources of fuelwood and, less frequently, of wood for charcoal.

The development of a system of quantitative values to be used in combination with the spatial layers required an extensive bibliographic search (physical and virtual libraries, Web search, personal communications, etc.) and review of documents on a wide variety of aspects. The list below provides an overview of the main

FIGURE 6
Ecological zones



elements that had to be determined and standardized in order to be able to proceed with the mapping of the stock and sustainable production of woody biomass for energy:

- **Forest sources of woody biomass.** Forestry data by formation, country and by ecological zone. Although no data was tailored specifically to our land cover classes and ecological zones, reference values with a reasonable correspondence could be extracted for most conditions. For the most important forest classes, the values collected allowed an estimate of a mean value of stem volume and woody biomass suitable as fuelwood, with minimum and maximum values where supported by an adequate number of data points, as reported in Annex 2, Tables A2.1 and A2.2. There were wide differences in data availability from country to country, which implies that results for a country poorly represented were based on other countries' data and are consequently less reliable. The main references sources on volumes of forest formations are reported in Annex 2, Table A2.5.
- **Non-forest sources of woody biomass.** This is definitely an area that needs to be developed with priority. In spite of the fact that most authors agree on the important role of non-forest sources in supplying fuelwood for household and industrial consumption, studies providing objective measurements are extremely rare. Studies on agroforestry and on trees outside forest (FAO/CIRAD, 2002) and on degraded forest formations provide references of local relevance, but which can not be generalized at the level of broad LC classes. The values assumed for non-forest LC classes, reported in Annex 2,

Tables A2.1 and A2.2 (class codes 11 to 22) should be considered as tentative only. The main reference sources on volumes or biomass of non-forest formations are given in Annex 2, Table A2.6.

- **Volume and biomass factors.** The conversion of volume data from forest inventories to total aboveground biomass implied the use of the following conversion factors:
  • Volume expansion factor (VEF)
  • Biomass density of wood (oven-dry; air-dry) (WD_{od}; WD_{ad})
  • Biomass expansion factor (BEF)
  The primary reference source for conversion factors was the work of Dr Sandra Brown, especially as summarized in *FAO Forestry Paper* No. 134 (FAO, 1997b). The equations used for the definition of the BEF for broadleaved forests were applied for dense forest formations only, since they were originally developed on measurements taken prevalently in dense forest conditions and they cannot be considered valid for open or very open formations, trees outside forest, etc. (S. Brown, pers. comm.). In lower-density formations, where the relation between the stem volume and the total tree biomass can be considered more stable, a fixed BEF of 3 was applied (S. Brown, pers. comm.; Brown and Lugo, 1984). Specific references for volume and biomass factors are given in Annex 2, Table A2.4.
- **Estimation of the woody component of total biomass suitable for fuelwood and for charcoal production.** The Woodfuel Fraction (WFF), which indicate the fraction of the total aboveground biomass composed of branches, stem and bark, but excluding leaves and twigs, was determined from references that reported measurements of the biomass of various tree components. Two factors were finally adopted, one for dense formations and one for open formations, and, on this basis, associated with land cover classes. Specific references on biomass by tree component are given in Annex 2, Table A2.4.

2.2.2.2 Estimation and distribution woody biomass available for energy use

Estimated mean annual increment of woody biomass by land cover class and ecological zone

As in the case of biomass stocking, the available information is limited to managed forest formations, with only tentative estimates for other sources of woody biomass, for which the quantitative estimates remain indicative only. For the scope of the present study, a simple approach was adopted, on the assumption that under normal conditions there is a direct positive relation between the stocking and the mean annual increment (MAI). The MAI was estimated as a percentage of the stocking, with lower percentage values for the highly stocked formation and higher percentage values for more open and disturbed formations and for farmlands, as indicated by the limited literature available. The estimated mean productivity values by land cover class, as well as the minimum and maximum range of values, are given in Annex 2, Table A2.3. Specific reference sources on volume and biomass increment are reported in Annex 2, Table A2.6.

Fraction of woody biomass available for energy use

The Fuel Fraction (FF), which represents the wood used for energy production as fraction of total wood removals in the country, was estimated using FAO country statistics on wood products other than fuel (industrial wood, construction, etc.) and the total sustainable productivity of the countries, estimated as described above.

The use of woody biomass for energy is important in all countries of this region, except Malaysia. This is shown in Table 2, which is based on FAOSTAT statistics on woodfuel production and on total roundwood production for 2000. The wood available for energy uses was calculated by deducting the amount of roundwood used for other purposes from the estimated woody biomass productivity in each country.

TABLE 2

Fraction of woodfuel production in total roundwood production for year (FAOSTAT data)

Country	Roundwood m^3	Wood Fuel m^3	Wood Fuel percent	Other uses m^3	Other uses percent
Cambodia	10 298 409	10 119 409	98	179 000	2
China (all country)	287 471 832	191 050 829	66	96 421 003	34
Lao PDR	6 438 960	5 871 960	91	567 000	9
Malaysia	18 440 720	3 345 720	18	15 095 000	82
Myanmar	38 083 000	34 471 000	91	3 612 000	9
Thailand	26 814 514	20 552 514	77	6 262 000	23
Viet Nam	30 868 548	26 685 548	86	4 183 000	14

Source: FAOSTAT Web site – http://faostat.fao.org/ Data accessed 12 Oct. 2005.

Legal accessibility

National Parks and other areas dedicated to the conservation of nature present various levels of restriction on the exploitation of wood resources. In order to account for these legal constraints, a tentative accessibility factor was allocated to the protected areas on the basis of IUCN definitions of Protected Area Management Categories. On such a basis, it was assumed that categories I to III give no access to wood exploitation, while categories IV and V allow controlled exploitation by local communities, tentatively estimated at 50 percent, and category VI allows even greater access, indicatively estimated at 75 percent. The map of protected areas, IUCN category definitions and estimated accessibility factors are given in Annex 3.

Reference maps:

- Protected areas with IUCN-WCMC categories I to VI <Asiacover_iucn1_6.shp>
- Derived 30 arc-sec raster map of exploitable fraction tentatively estimated according to protection categories <expl_pc_mask.grid>

2.2.2.3 Allocation of woody biomass stocking and productivity to individual pixels

Pixel-level estimation of woody biomass was carried out through the combination of the spatial and statistical elements described above, as summarized in the following expression:

Biomass stocking of $pixel_i$ ($Wbiostk_i$) = f (VOB_{10}/ha of LC_i; $Ecozone_i$; WD_{od}; BEF of $VOB_{10\,i}$; WFF_i; Tree cover weight; area of $pixel_i$)

where:

LC_i	=	land cover class in $pixel_i$
$Ecozone_i$	=	ecological zone in $pixel_i$
VOB_{10}/ha	=	Volume of overbark above 10 cm dbh associated with LC_i in $ecozone_i$
WD_{od}	=	wood density factor (oven-dry biomass in tonne per wood volume in m^3)
BEF of $VOB_{10\,i}$	=	biomass expansion factor to estimate total aboveground biomass from stem biomass of trees above 10 cm dbh
WFF_i	=	Fraction of total aboveground biomass suitable as fuelwood or wood for charcoal production
Tree cover weight	=	Tree cover percentage in $pixel_i$/mean tree cover percent of LC_i in $Ecozone_i$
area of $pixel_i$	=	All pixels have the same size in decimal degrees, but different areas according to their latitude.

Pixel-level estimation of annual available productivity of woody biomass potentially available for energy use was carried out through the combination of the spatial and statistical elements described above, as summarized in the following expression:

Available annual productivity of $pixel_i$ = f ($Wbiostk_i$; MAI% of LC_i; FF of $country_i$; legal constraint)

where:

$Wbiostk_i$	=	Biomass stocking of $pixel_i$
MAI% of LC_i	=	Mean Annual Increment as percentage of $Wbiostk_i$
FF of $country_i$	=	Fuel Fraction, or woody biomass remaining after other non-energy uses
legal constraint	=	the estimated exploitable fraction according to IUCN protection categories.

2.2.3 Demand Module

The scope of the Demand Module was to map the consumption of woody biomass used for energy production, i.e. as fuelwood and for charcoal production, at the defined minimum spatial level of analysis (30 arc-sec raster grid, or approximately 0.9 x 0.9 km).

2.2.3.1 Estimated woodfuel consumption at pixel level

Pixel-level estimation of total consumption of woody biomass for energy was carried out as follows:

Consumption in $pixel_i$ = f (number of persons in $pixel_i$; per capita household consumption in $country_i$ and ecological $zone_i$; per capita non-household consumption [fuelwood and wood for charcoal] in $country_i$)

Depending on pixel definition (rural sparse; rural settlement; urban) different per capita consumption rates were applied, as shown in Annex 4.

The total consumption map was created by merging the three complementary layers (consumptions in rural sparse, rural settlement and urban areas) to form a single raster map with pixel values reporting total woodfuel consumption in kg of oven-dry woody biomass <kgtot.grid>.

The spatial and statistical data available for the development of the demand module are discussed below.

Population data

Population distribution maps at 30 arc-sec pixel size (approximately 0.9 x 0.9 km in the study area) were derived from LandScan data and refined to match UN rural-urban population statistics for year 2000. The urban areas boundaries, necessary to separate and distribute urban and rural populations, were generated by FAO/SDRN on the basis of Radiance Calibrated Lights of the World, 2000, (NOAA, 2000) and UN urban population data for 2000 (FAO, 2005d).

The entire dataset was composed by the following non-overlapping and complementary raster maps:

- Rural sparse (<2000 inhabitant/km^2) < rurpop_as30.grid>
- Rural settlements (>2000 inhabitants/km^2) <rspop_as30.grid>
- Urban population <urb_30_10000.grid>

Administrative data set:

- shapefile with adm0 (country) and sub-national levels adm1, adm2 and adm3 (where available) <asiacover_subnational.shp>
- country layouts at 30 arc-sec resolution, matching population raster data <adm0_gr30.grid>

Woodfuel consumption data

The creation of the reference data set that was used for mapping woodfuel consumption required extensive review of existing data and the identification of suitable reference sources. The main data sources were the i-WESTAT multisource database (FAO, 2005a), which includes woodfuel statistics from many international, regional and national sources; regional studies (FAO, 1997a); country papers produced in the framework of the FAO Regional Wood Energy Development Programme (RWEDP) (FAO/RWEDP, 1997a) and of the EC-FAO Partnership Programme 2000–2002 (FAO, 2003c); the GFPOS database of woodfuel field surveys (FAO, 2001a); and other accessible sources. Country-specific references and sources are listed in Annex 4, Table A4.2. The specific parameters that were determined for each country were:

- Total fuelwood and charcoal consumption per country in 2000. Results of this review are reported, country by country, in Annex 4. The main sources and their estimates, which were extracted from i-WESTAT and elsewhere, demonstrate the wide discrepancies among different information sources and the generally low reliability of woodfuel statistics (see Annex 4, Table A4.2).
- Household fuelwood and charcoal consumption as fraction of total consumption.
- Non-household consumption fraction (as aggregation of industrial, commercial, institutional, etc.) and tentative estimation by rural sparse, rural settlement and urban areas.
- Rural household consumption (fuelwood and charcoal).
- Urban household consumption (fuelwood and charcoal).
- Estimation of per capita rural household consumption in rural areas (sparse) and in rural settlements (fuelwood and charcoal). Lacking distinct reference data for these different rural conditions, the people of rural settlements were assumed to have a consumption pattern intermediate between urban and average rural conditions. In general, rural settlements were assumed to have a higher charcoal consumption and lower fuelwood consumption compared with average rural conditions. The consumption in the remaining rural areas (with population density <2000 inh/km^2), which was labelled “rural sparse”, was derived from the remaining “unallocated” consumption and resulted in a higher fuelwood and lower charcoal consumption compared with average rural conditions.
- Estimation of per capita household consumption in mountain and lowlands conditions (fuelwood and charcoal). Lacking specific reference data, it was assumed that, due to the additional heating requirements in mountain conditions, the per capita consumption of fuelwood was double than that in lowlands.

All parameters were reduced to per capita values (including non-household consumption) in order to use population maps as a proxy for the spatial distribution of consumption. The consumption parameters thus estimated are shown in Annex 4. The total per capita consumption values per area and country are shown in Table 3.

TABLE 3

Summary values for annual per capita consumption of wood for energy in 2000, in cubic metres (m^3) of fuelwood and wood used for charcoal, in all sectors (household and non-household)

Country		Per capita annual total wood consumption for energy (all sectors) (m^3/person)		
		Rural sparse	Rural settlements	Urban
Cambodia	lowlands	0.73	0.67	0.66
Yunnan (Prov. China)	No distinction	0.56	0.33	0.18
Lao DPR	lowlands	0.86	1.13	1.02
	mountain	2.03	2.31	1.89
Malaysia	lowlands	0.27	0.33	0.06
	mountain	0.54	0.65	0.12
Myanmar	lowlands	0.74	0.64	0.58
	mountain	1.62	1.35	1.14
Thailand	lowlands	0.58	0.47	0.47
	mountain	0.80	0.68	0.72
Viet Nam	lowlands	0.60	0.40	0.41
	mountain	1.30	0.77	0.73

2.2.4 Integration Module

2.2.4.1 Woodfuel supply/demand balance

The scope of the Integration Module was to combine, by discreet land units (30 arc-sec pixels or sub-national units), the parameters developed in the demand and supply modules, in order to discriminate areas of potential deficit or surplus according to estimated consumption levels and sustainable production potentials.

The main result of the integration module was the balance between the fraction of the potential sustainable productivity available for energy uses and the total woodfuel consumption.

In order to account for the flux of woodfuels from neighbouring areas, but at the same time to keep the spatial resolution at 30 arc-sec, the calculation of the supply-demand balance was done using the ESRI GRID function FOCALMEAN (ArcGis desktop applications, ESRI 1999–2004). Through this function, new grid maps were created where pixel values were replaced by the mean value of the 9 x 9 pixels surrounding the original pixel. In addition, in order to account for the influence of national borders, FOCALMEAN was applied country by country. In order to avoid the negative influence of "no data" pixels in the calculation of focal means, a zero value was assigned to all the pixels outside the countries. The maps produced in the process were the following:

- Country-specific maps ("cty" replaced by individual country codes):
  - FOCALMEAN of supply module results per country <"cty"_f9_sp.grid>
  - FOCALMEAN of demand module results per country <"cty"_f9_dm.grid>
- Aggregated datasets:
  - merging of all national supply maps <"cty"_f9_sp.grid>
  - merging of all national demand maps <"cty"_f9_dm.grid>
- Woodfuel supply/demand balance. The calculation of pixel-level balance was done by subtracting the demand value from the supply value of each pixel:
  - Balance <f9_bal.grid> = value in <f9_sup.grid> minus value in <f9_dem.grid>
- For a country-level balance calculation, the individual country maps could be used.

Besides the inclusion of neighbour resources in pixel-level analysis, the balance did not consider the transportation of woodfuels between distant production and consumption sites. This is an element that requires additional analytical steps and should be covered in future studies.

As is, the woodfuel supply/demand balance parameter provides a useful indication of the ease or difficulty that poor rural households that depend on fuelwood gathering face in acquiring their daily subsistence energy.

2.2.4.2 Supply/demand balance aggregated by sub-national administrative level

In order to create a reasonably uniform sub-national level of analysis to be combined with poverty maps and other socio-economic layers, the pixel-level grid data was aggregated using ZONAL functions, where the zones were defined by the sub-national shapefile. Given that national sub-national administrative levels are extremely variable in size, different administrative levels were used for different countries in order to create a more homogeneous dataset:

- Administration level 1 was used for Thailand, Cambodia, Viet Nam and Malaysia
- Administration level 2 was used for Myanmar and Lao PDR
- Administration level 3 was used for Yunnan

As result, the attribute BAL_ADMIX, which reports the balance of woody biomass within the administrative unit (total deficit or surplus in kg), was added to the administrative map <asiacover_subnational.shp>. Individual balance results were produced for a total of 655 sub-national administrative units.

2.2.4.3 Minimum – maximum range of values

The datasets presented so far were developed using “mean” values. In order to represent the wide range of reference values, especially concerning biomass stocking and productivity, two additional datasets were produced, one assuming a lower range of values and one assuming a higher range of values (see “min” and “max” values in Annex 2, Tables A2.2 and A2.3). The minimum and maximum supply maps were combined with consumption maps to create two new woodfuel supply/demand balance maps, one assuming minimum supply and one assuming maximum supply.

The maps created in the process were the following:

- available woody biomass assuming minimum stocking (mean stocking * 0.57) and minimum mean annual increment (mean MAI * 0.5) <f9_sup_min.grid>
- available woody biomass assuming maximum stocking (mean stocking * 1.31) and maximum mean annual increment (mean MAI * 1.5). <f9_sup_max.grid>
- supply-demand balance based on minimum supply values. <f9_bal_minsup.grid>
- supply-demand balance based on maximum supply values. <f9_bal_maxsup.grid>

2.2.4.4 Integration of wood energy and poverty

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

The main poverty-related spatial data set available, provided by SDRN, was an indicator of malnutrition, i.e. a map of the incidence of stunt growth in children below 5 years old, as a percentage, by sub-national administrative units. This parameter is one of the best indicators of poverty, as indicated by the World Health Organization (see Annex 5).

Additional, and to some extent complementary, spatial information related to poverty was found on the Asia Food Insecurity and Vulnerability Information and Mapping System (FIVIMS) Web site (http://www.asiafivims.net/kids/gateway/index.html), which provides several socio-economic indicators for Asian countries.

At the time of analysis, the FIVIMS database was still rather poor and the indicators available at country level were heterogeneous and displayed several gaps. Nevertheless, all relevant parameters and indicators were inserted as attributes of the sub-national map. These included a wide range of parameters for Thailand, and a specific definition of vulnerability for 76 sub-national units, as described in Annex 5. The other countries presented unique (but not complete) nutrition indicators (wasting, underweight and stunting of children below 5 years old), most of which, however, were outdated compared with the dataset provided by SDRN.

FIVIMS data was finally used to fill the gaps in the more recent SDRN dataset on stunting in a few districts of Lao PDR and insular Malaysia (where underweight indicators were used as a surrogate), and for the vulnerability index of Thailand, which was based on the combination of numerous parameters. The Thailand vulnerability index appeared more detailed, spatially and thematically, and more recent than the stunting figures from the SDRN map, which were dated 1992.

Both SDRN and FIVIMS statistics were converted into map attributes of the reference administrative map <asiacover_subnational.shp>. In the final combined code (P_PROX_SD) the preference was given to stunting conditions, since this was the most common indicator and has a high correlation with poverty. Where such parameters were not available (Malaysia only), the ranking was based on underweight values. For Thailand, the vulnerability index was used instead.

The attribute P_PROX_SD of map <asiacover_subnational.shp> contains the final combined ranking. The WHO classification of malnutrition indicators and ranking thresholds are reported in Annex 5.

According to the thresholds indicated in the WHO classification of malnutrition, the indicators were ranked as critical (code 6), very high (code 5), high (code 4), mid-high (code 3), mid-low (code 2) and low (code 1). A similar ranking was applied for Thailand's vulnerability index, although the parameters there were different and there is no direct comparability with other countries. The results are shown later, in Figure 36.

The combination of the two *independent* attributes included in shapefile <asiacover_subnational.shp>, one related to poverty (P_PROX_SD) and one related to supply/demand balance (BAL_ADMIX), allowed the analysis of spatial relation and the definition of the areas that could be considered critical under both perspectives. The results of the integration are shown later, in Figure 37.

Country statistics on population vulnerability due to the concomitance of various woodfuel supply/demand balance and poverty conditions are presented in Annex 6.

2.2.5 Example of data layers used and produced

In order to visualize the various steps of the process, Figures 7 to 20 show the cartographic data layers that were used and produced for a small area of central Cambodia. Specific aspects of the data used and the processing carried out in the Demand, Supply and Integration modules are discussed in the following sections. The maps are shown as an example of the sequence of spatial data layers produced and involved in the analysis of woodfuel consumption and production potential.

FIGURE 7

Location of the example area

FIGURE 8

GLC 2000 data (30 arc-sec)

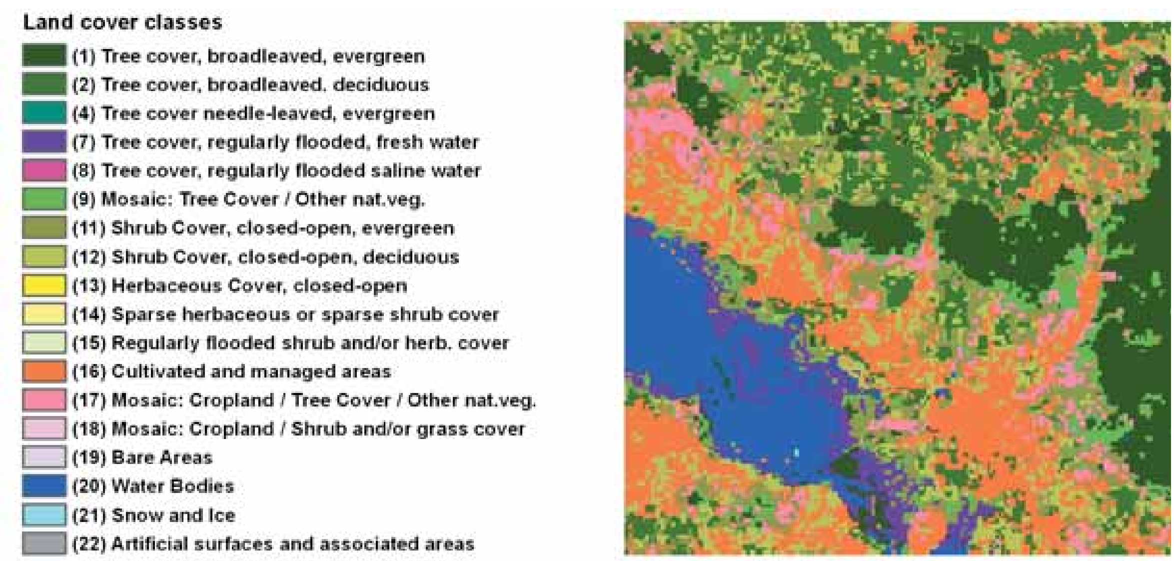


FIGURE 9

Ecological zone map

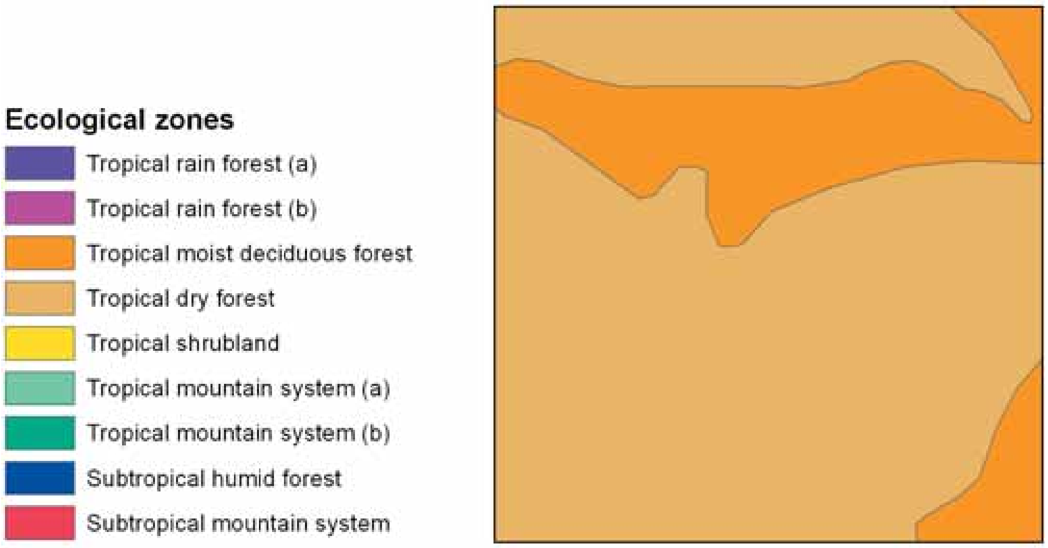


FIGURE 10

MODIS VCF Tree Cover percent

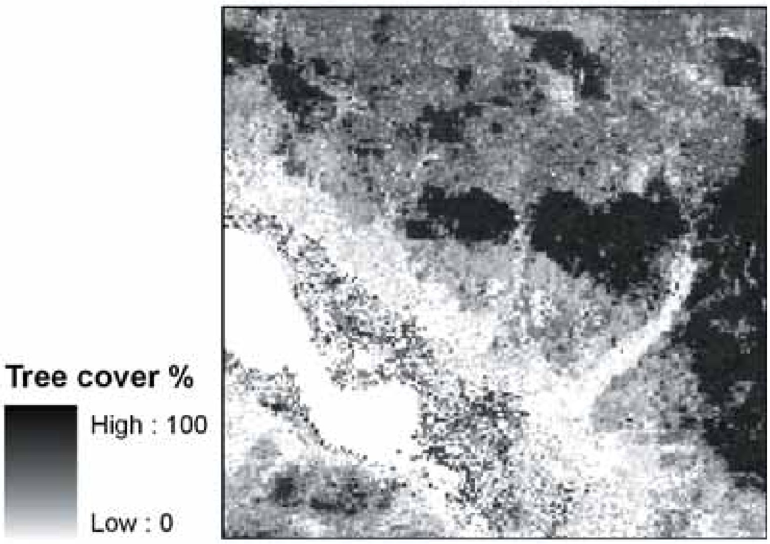


FIGURE 11

IUCN WCMC map of protected areas

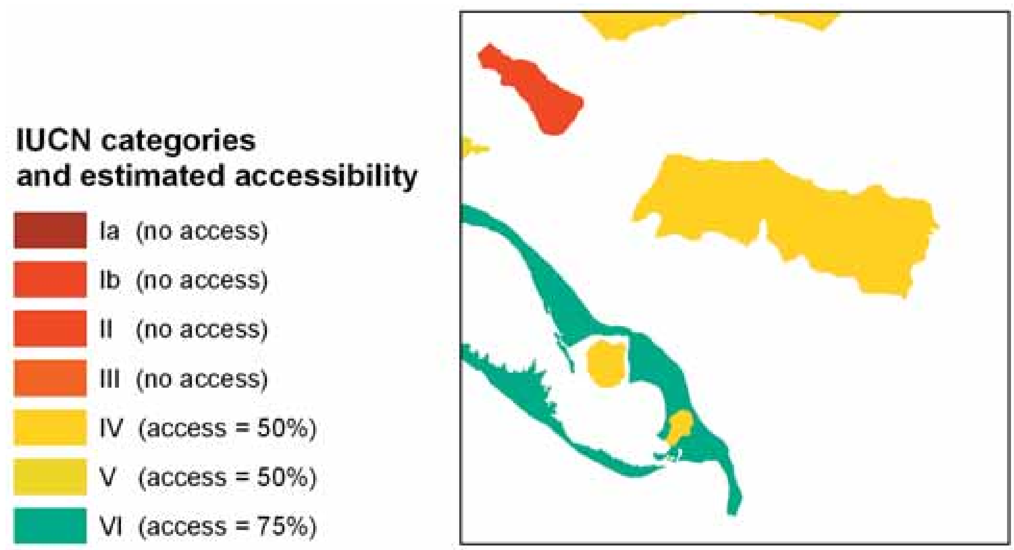


FIGURE 12

Woody biomass stock

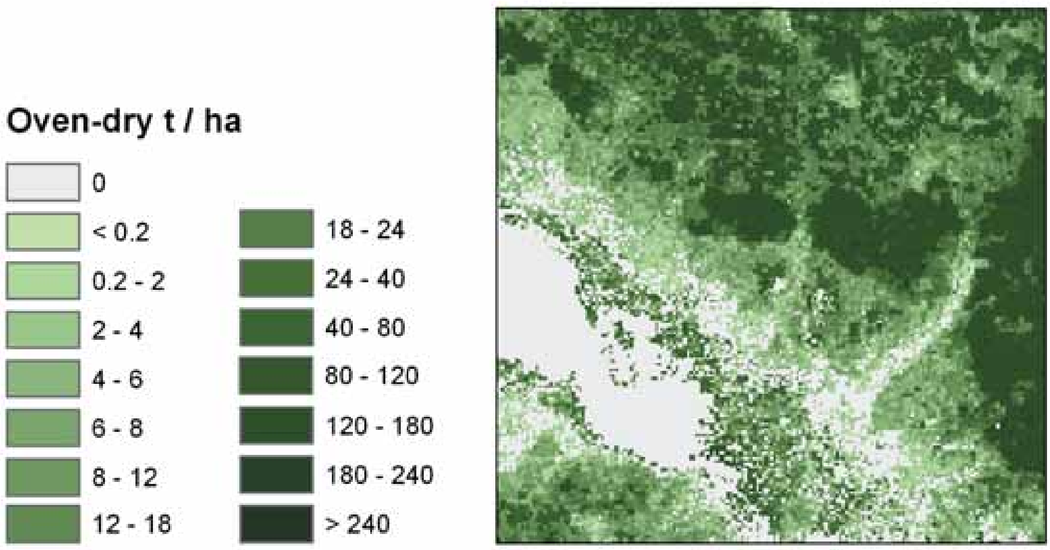
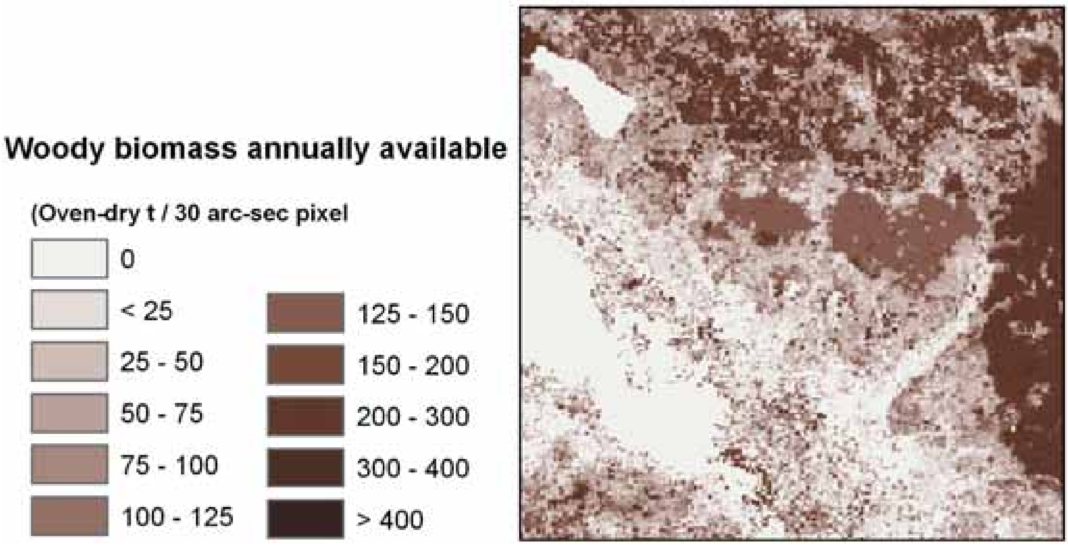


FIGURE 13

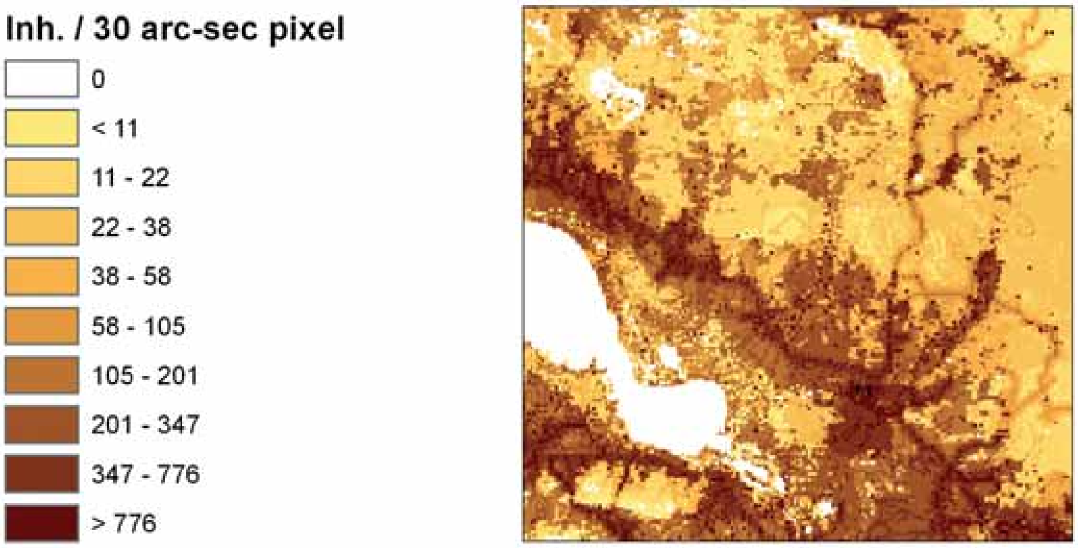
Woody biomass increment available for energy use



The increment was estimated as a fraction of stocking (fraction determined by land cover class), and reduced by the proportion of wood used for other non-energy use assessed country by country, and according to IUCN protection categories.

FIGURE 14

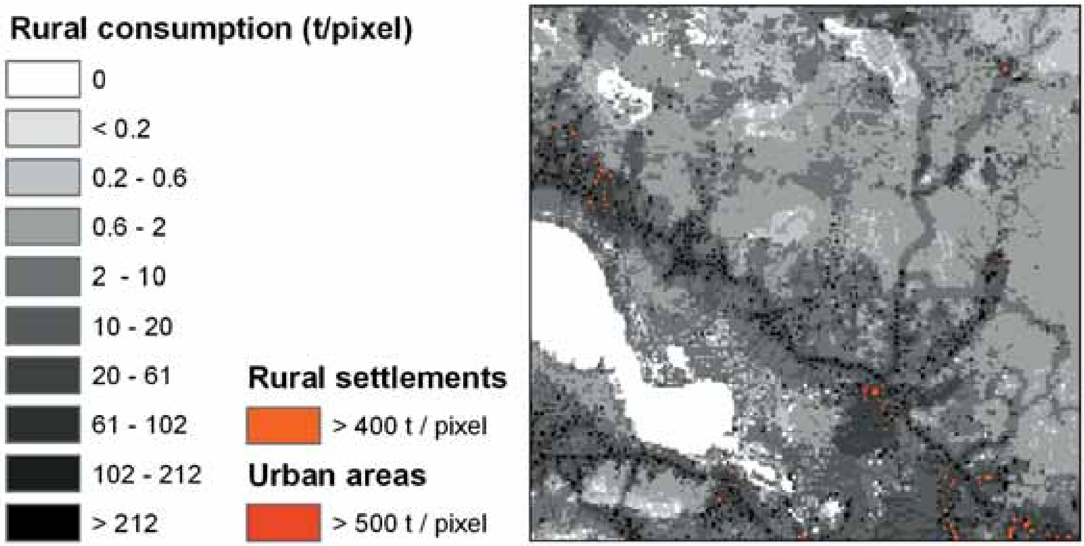
Population distribution in 2000, 30 arc-sec data set



Rural and urban population maps provided numbers of people in the 30 arc-sec pixels (approximately 0.9 x 0.9 km) matching medium-variant UN Population statistics.
Rural population data was further categorized as rural "settlements" and rural "sparse" using the 2000 inhabitants/km² as a threshold.

FIGURE 15

Woodfuel consumption by pixel



This map was created using population data and, for each country, average per capita consumption in: sparsely populated rural areas, rural settlements and urban areas, for mountain areas and lowlands.

FIGURE 16

Focal mean (9 x 9) of Woodfuel supply

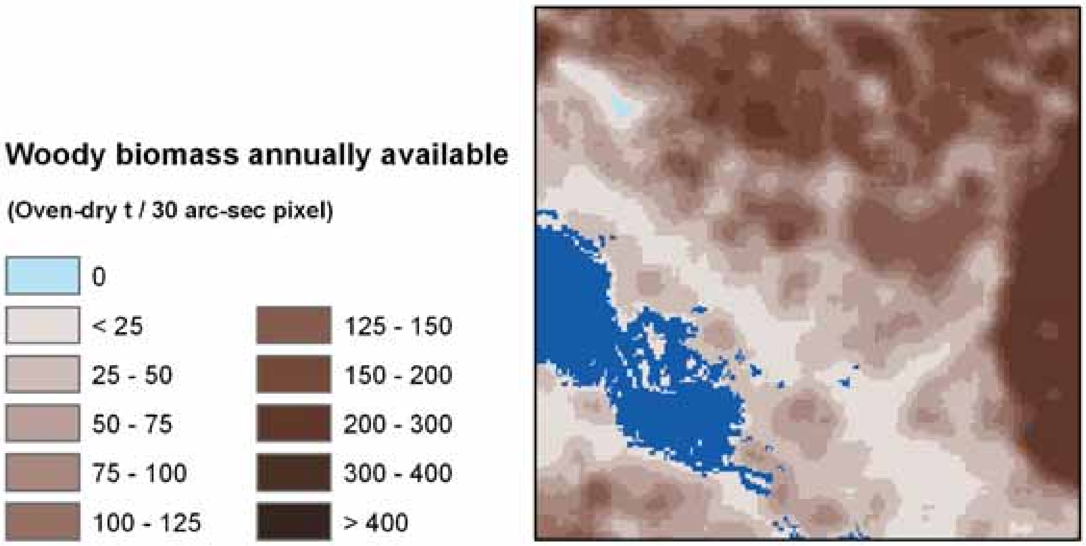


FIGURE 17

Focal mean (9 x 9) of woodfuel consumption

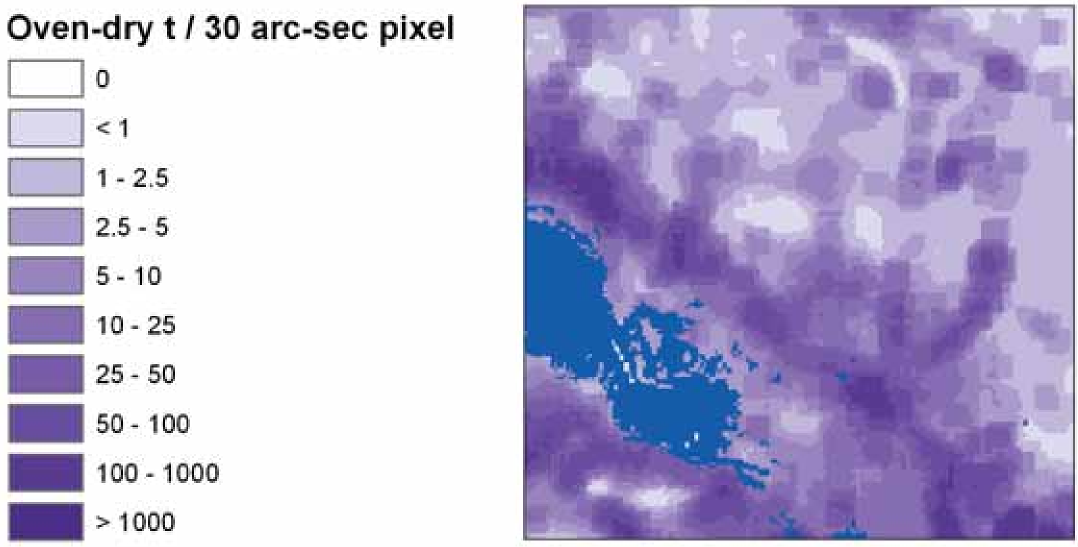
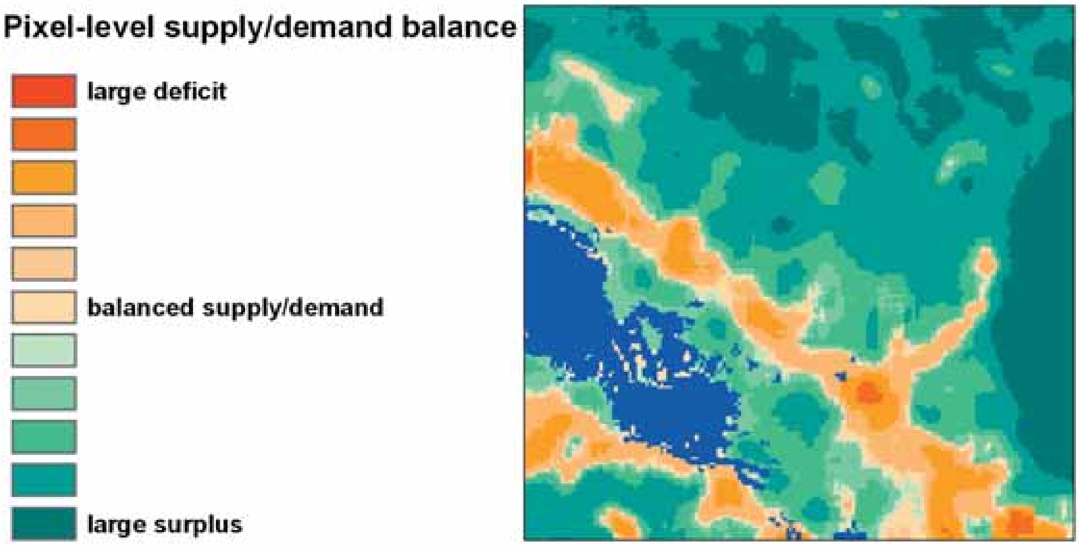


FIGURE 18

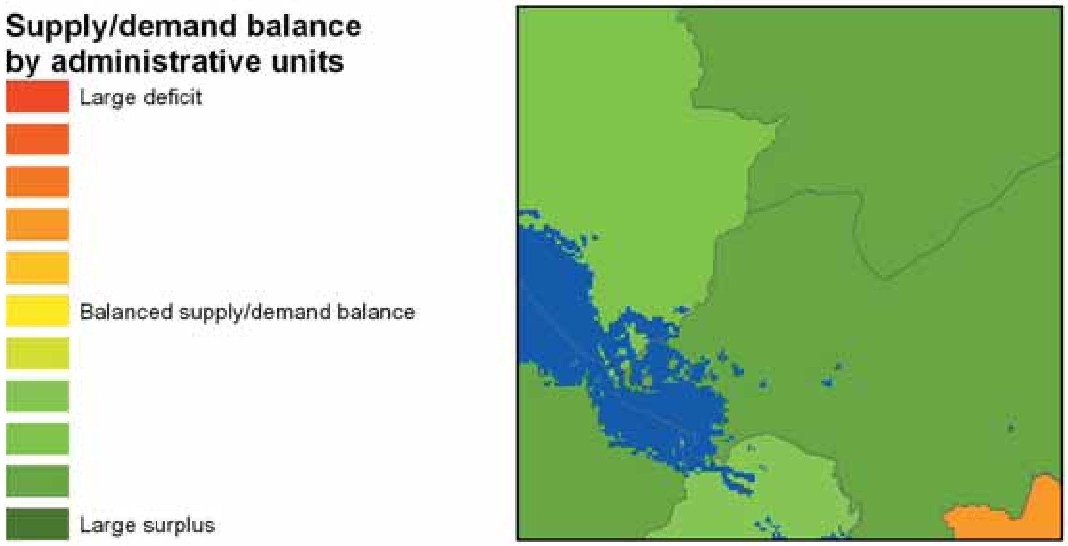
Focal mean (9 x 9) of supply/demand balance



This map was created subtracting, pixel by pixel, the average consumption in the surrounding 9 X 9 pixels from the average productivity of the surrounding 9 X 9 pixels. This map indicates the capacity of local wood resources to satisfy local demand and it is therefore meaningful for the poorest consumers depending on local supplies, but less so for marketed woodfuels. For full map, see Figure 27 (regional overview) and 28 (Cambodia map).

FIGURE 19

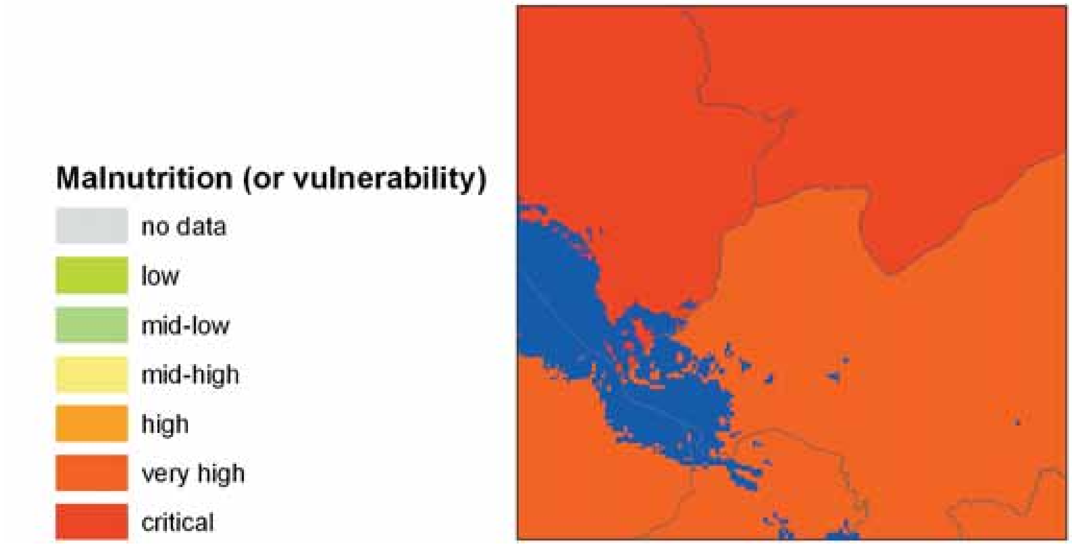
Supply/demand balance aggregated at administrative unit level



For full map, see Figure 35.

FIGURE 20

Poverty-related indicators by administrative units



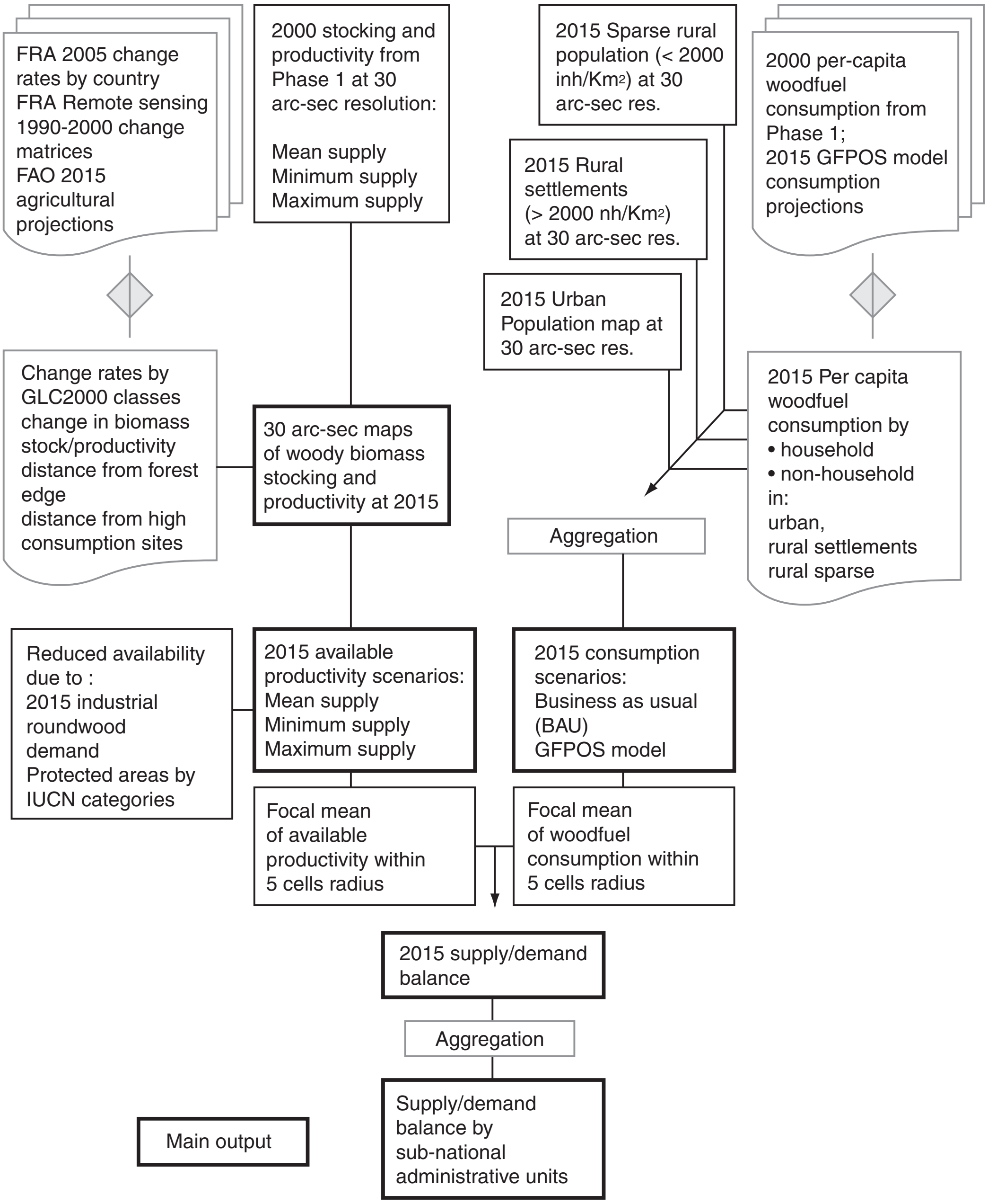
Stunting percent in children below 5; vulnerability ranking based on wide range of indicators in Thailand.
For full map, see Figure 36.

2.3 METHODOLOGY OF PHASE 2: 2015 SCENARIOS

The flowchart of the estimation process applied in the development of the 2015 scenarios (Phase 2 of the study) is shown schematically in Figure 21. The main thematic elements, analytical steps and intermediate products are described in the subsequent sections.

FIGURE 21

Flowchart of main analytical steps of Phase 2: 2015supply/demand scenarios



2.3.1 Supply scenarios

The procedure for the estimation of woody biomass availability in 2015 was based on the year 2000 baseline produced in Phase 1 and on the estimation of likely changes in forest and land cover in the period 2000–2015, based on the following sources (For references and descriptions, see Annex 7):

- National forest area change statistics over the period 2000–2005, published by the FAO Forest Resources Assessment 2005.
- Subregional results, for continental SE Asia, of the Remote Sensing Survey conducted in the framework of FRA 1990 and FRA 2000 (FAO, 1996a, 2001). The result for the period 1990–2000 consists of a transition matrix, which can be represented in form of a biomass flux diagram. In the case of Viet Nam, use was made of the 4 sample plots located in the country and covering one-quarter of its surface.
- FAO agricultural projections for 2015.

The probable spatial distribution of the estimated change in forest area (and stocking) was based on the following steps:

1. Definition of best match between FRA forest and GLC 2000 land cover classes in 2000, starting from dense forest formation in GLC 2000 and then estimating the fraction of other wooded lands that are probably included in the FRA forest definition in each country.

2. Definition of change fraction to be applied to GLC 2000 classes in order to achieve the estimated change.

3. Definition of buffers within forest areas based on:
   - distance from forest edge (forest/non-forest interface): 1 km; 5 km; 10 km; >10 km; and
   - distance from major consumption sites: 0–75 km; 75–150 km; >150 km. Major consumption sites were defined as the largest concentrations of deficit supply/demand balance in 2000 (greater than 50 000 t deficit within 10 pixels radius).

4. Definition of different protection categories based on IUCN protected areas that would reduce the risk of forest change (see Annex 3).

5. Spatial distribution of probability of change in GLC classes of forest and other wooded areas (as fraction of 2000 value) according to buffer values and IUCN protection categories. The available national forest change statistics included only *net* forest area change and provided no estimation of forest increase (occurring in non-forest areas) and decrease (occurring in forest areas). In consideration of the fact that the net change was always negative (except for China), the estimated forest area change was deducted entirely from 2000 forest classes.

   A different procedure was followed for China, whose forest area has been reported to have increased considerably in the last decade (see comments in Annex 7). In case of Yunnan, for which there are no separate forest change statistics, the increment in forest area was assumed to take place in the large "other wooded lands" classes, where as much as 4.6 million hectare are expected to become forest. The woody biomass increase factor in these areas was estimated at 2.6. But, since there is no way to predict which areas will change and which will not, an average increase factor of 0.76 was applied to the whole "other wooded land" area.

6. Definition of the change in woody biomass stocking associated with the forest area changes based on change matrices and the flux diagrams of FRA 1990–2000 remote sensing. The analysis of 1990–2000 subregional change matrix showed that there is some difference, in terms of percent variation, between the rate of change of forest area and the rate of change of woody biomass stocking. Not all changes implied total loss of biomass, and other changes occurred within the forest that do not represent deforestation. A representation of the change processes observed over the period 1990–2000 in continental SE Asia is provided by the biomass flux diagram in Annex 7. It should be clarified that the FRA remote sensing survey had a pan-tropical scope and that the results at subregional level have no statistical significance due to the limited number of sampling units located in the subregion (10 units only). Nevertheless, the subregional change matrix provides interesting insight into the land cover change processes that well complement the crude national forest change rates, especially in this case, where there is a remarkable agreement between the subregional net annual forest change rates given by country data (varying between -0.55 percent for 1990–2000 and -0.65 percent for 2000–2005) and by the remote sensing survey (-0.61 percent over 1990–2000 for the definition of forest best fitting the FRA definition). This said, the results of subregional transition matrices for the period 1990–2000 indicated that:
   - The factor of biomass loss in the process of deforestation represented, on average, 0.89 due to the fact that some classes of destination (end class in the process of change) maintained a certain biomass stock (e.g. 1 percent deforestation corresponded to 0.89 percent of biomass loss).
   - Along with changes in forest area, there were processes of degradation and amelioration over an area of forest approximately one-fifth of the net deforestation area; these processes implied a biomass loss corresponding to some 8.9 percent of that lost due to forest area change.
   - The combination of the two preceding elements determined a biomass change rate (in forest formations) that corresponded to some 97 percent of the forest area change rate.
   - The changes in woody biomass stocking outside forests, i.e. in shrub lands and short fallow shifting cultivations, were -9.2 percent and -5 percent respectively. The change in other land cover (croplands, rangelands, grasslands, built-up areas, etc.) was a marginal increase of less than 1 percent over 10 years. All these changes did not include natural and anthropogenic forestation, which were accounted for in the net forest area change, as mentioned above.

7. Estimation of woody biomass changes outside forest areas based on change matrices and flux diagrams of FRA 1990–2000 remote sensing surveys.

8. Mapping of woody biomass stocking in 2015.

9. Mapping of exploitable woody biomass productivity in 2015, based on IUCN protection categories.

10. Mapping of woody biomass productivity potentially available for energy use after deduction of wood amounts required by industries, estimated on the basis of the FAO Forest Products Outlook Study (FAO, 1998b), which predicted a 2010 scenario. To meet the temporal reference of the study, the 2010 results of the global forest products model were further extrapolated to 2015.

    There are reasons to believe that the GFPOS projections for several countries of Asia tended to overestimate industrial roundwood production and consumption levels due to a stagnation in demand that was longer than expected, and to other complex market interactions (FAO, 2005b). However, lacking corrected projections for the countries of this study, the GFPOS values were used (see Annex 7), remembering that a higher-than-real industrial roundwood production value results in a more conservative, and wiser, estimation of woody biomass available for energy.

The process resulted in a set of 30 arc-sec grid maps:

- Woody biomass stocking in kg/ha <wfbio_stk2015.grid>
- Mean annual increment in kg/ha <mai2015_kg_ha.grid>
- Mean annual increment in kg/pixel <mai2015_kgtot.grid>
- Exploitable annual increment in kg/pixel after deduction of IUCN protection categories <mai2015_expl.grid>
- Annual increment in kg/pixel available for energy uses after deduction of woody biomass needed for other uses <wf2015kg_avl1.grid>

2.3.2 Demand scenarios

The prediction of the consumption of woodfuels in 2015 was based on 2000 consumption levels estimated in Phase 1 (values reported in Annex 4), on predicted rural and urban population distribution in 2015 (FAO, 2005d) and on the consumption trends predicted by the FAO Global Forest Product Outlook Study (GFPOS) (FAO, 2001a).

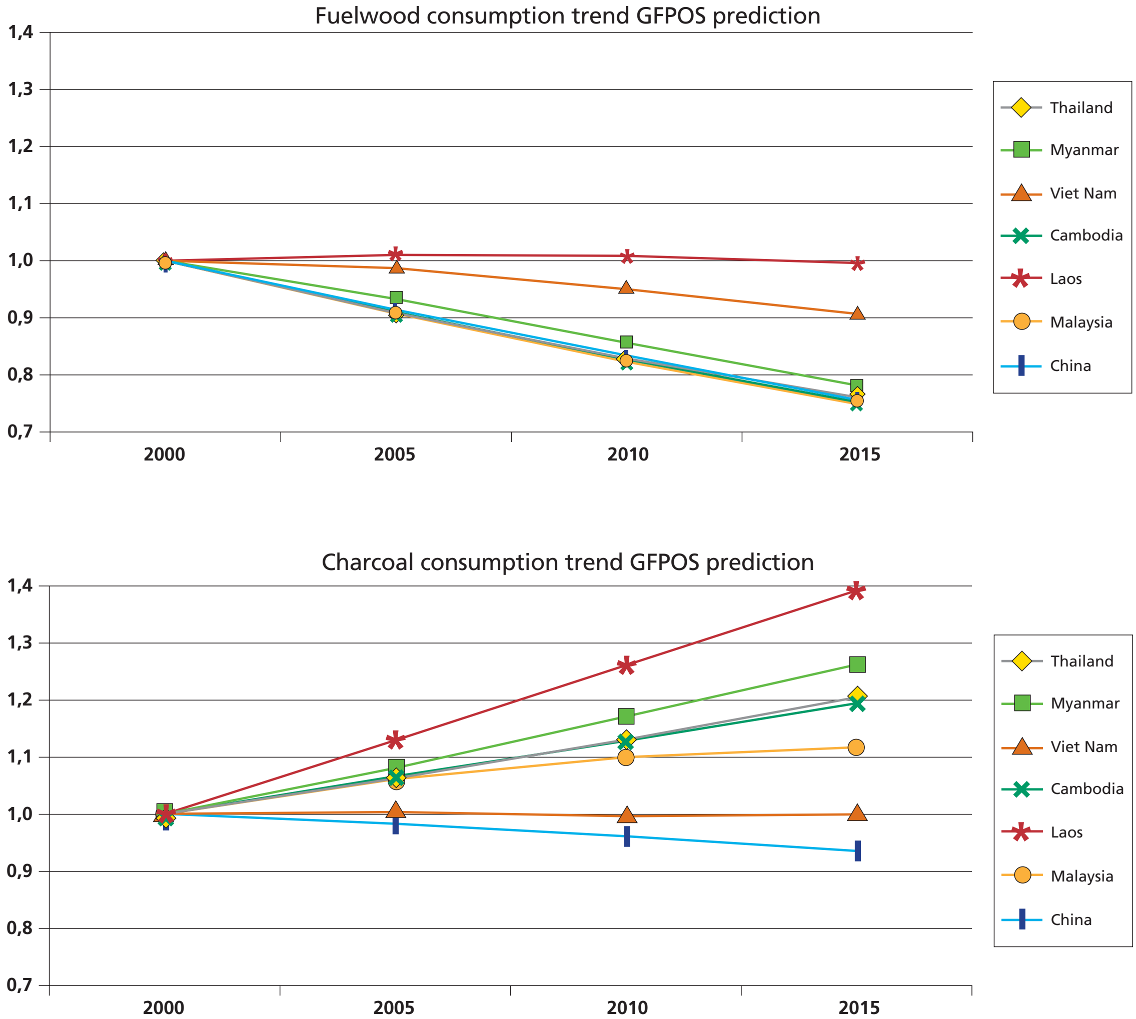
Two scenarios were considered:

- **Business-as-usual (BAU) scenario**, in which the per capita consumptions estimated for 2000 were maintained constant and the trends were determined basically by population growth in rural and urban areas.
- **GFPOS trend scenario**, in which the consumption trends projected by the GFPOS model were applied to the 2000 consumption (Phase 1 estimates). In order to spatially distribute the consumptions in 2015, new per capita consumption rates were calculated and applied to the predicted rural and urban populations. Additional information on the GFPOS modelling approach and predictions is given in Annex 8.

Given the general decreasing trends in fuelwood consumption from the GFPOS model for these countries, as shown in Figure 22, this can be considered as a lower-consumption scenario. The increased charcoal consumption predicted by GFPOS, also shown in Figure 22, did not offset fuelwood reduction due to the relatively modest charcoal quantities. Only in the case of Thailand did the GFPOS-predicted charcoal trend associated with the comparatively high amounts estimated in 2000 balance the fuelwood reduction, and the total woody biomass consumption in rural areas resulted in values higher than predicted by the BAU scenario. Figure 23 shows the different trends in national consumptions according to the two scenarios. Additional information on consumption scenarios is given in Annex 8.

FIGURE 22

Consumption trends in total fuelwood and charcoal consumption predicted by GFPOS, expressed as a proportion of 2000 consumption



The process resulted in the following 30 arc-sec maps:

BAU scenario

- Consumption in 2015 in sparse rural areas in kg/pixel (BAU scenario) <rurspa15kgbau.grid>
- Consumption in 2015 in rural settlements in kg/pixel (BAU scenario) <rurset15kgbau.grid>
- Consumption in 2015 in urban areas in kg/pixel (BAU scenario) <urb15kgbau.grid>

The three maps above were merged to create:

- Total consumption in 2015 in kg/pixel (BAU scenario) <cons_kg_15bau.grid>

GFPOS-trend scenario

- Consumption in 2015 in sparse rural areas in kg/pixel (GFPOS-trend scenario) <rurspa15_kgtot.grid>

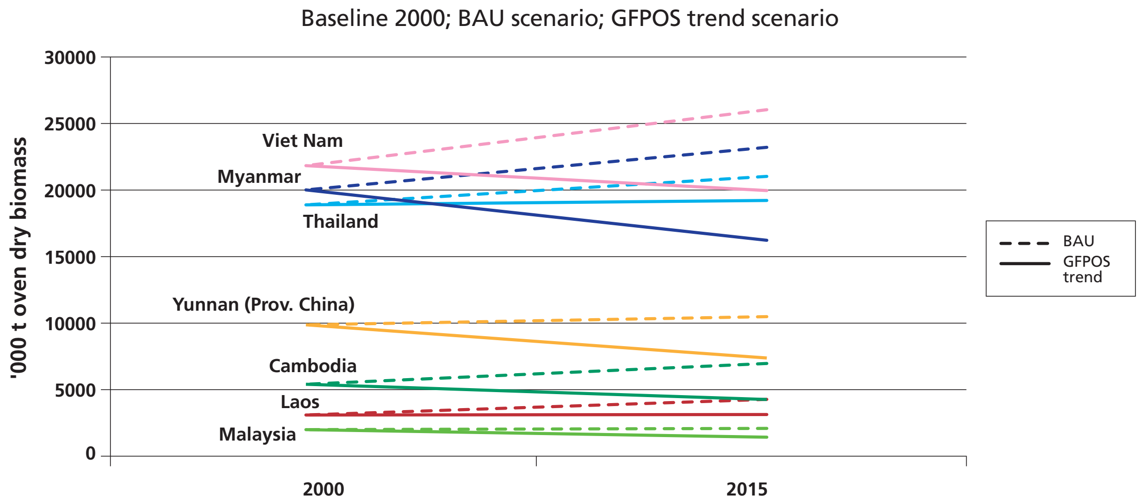
- Consumption in 2015 in rural settlements in kg/pixel (GFPOS-trend scenario) <rurseta15_kgtot.grid>
- Consumption in 2015 in urban areas in kg/pixel (GFPOS-trend scenario) <urb15_kgtot.grid>

The three maps above were merged to create:

- Total consumption in 2015 in kg/pixel (GFPOS-trend scenario) <cons_kg_15a.grid>

FIGURE 23

Woody biomass consumption scenarios



2.3.3 Supply/demand balance scenarios

2.3.3.1 Pixel-level balance analysis

Following the same approach as used for Phase 1, the supply/demand balance analysis for 2015 was done using the FOCALMEAN GRID function in order to "smooth" the result of each pixel with the supply and demand values of surrounding pixels. In this case, the pixel values were replaced by the average values of the pixels within a 5-pixel radius.

The function was applied country by country, in order to represent the influence of national boundaries, and finally aggregated to form subregional maps. In addition, in order to represent the variability of biomass stocking and productivity, minimum and maximum supply levels were also calculated.

The process resulted in the following 30 arc-sec maps:

- Mean available supply in kg of woody biomass per pixel <fc5_15sp.grid>
- Minimum available supply in kg of woody biomass per pixel <fc5_15spmin.grid>
- Maximum available supply in kg of woody biomass per pixel <fc5_15spmax.grid>
- Woody biomass consumption according to the GFPOS-trend scenario <fc5_15dm_a.grid>
- Woody biomass consumption according to the BAU scenario <fc5_15dm_bau.grid>

The balance was calculated combining three supply scenarios and two demand scenarios and produced the following maps:

	Supply		
Consumption	Mean productivity <fc5_15sp.grid>	Minimum productivity <fc5_15spmin.grid>	Maximum productivity <fc5_15spmax.grid>
GFPOS-trend scenario <fc5_15dm_a.grid>	<fbal15_a.grid>	<fbal15_a_mn.grid>	<fbal15_a_mx.grid>
BAU scenario <fc5_15dm_bau.grid>	<fbal15_bau.grid>	<fbal15_bau_mn.grid>	<fbal15_bau_mx.grid>

2.3.3.2 Sub-national level balance analysis

As for Phase 1, pixel-level balance results were aggregated at sub-national levels in order to facilitate the integration of the thematic aspects with other socio-economic aspects that are usually available at administrative unit level, rather than by geographical distribution. The units of aggregation were the same as those adopted for the 2000 baseline analysis (see Section 2.2.4.2).

The results of the balance analysis of all combinations of consumption scenarios and supply variants were aggregated to form 655 units in total, and inserted as fields in the attribute table of shapefile <subnat_admmix.shp> in geodatabase <adm_bal.mdb>. The sub-national units used in this aggregation are defined in field CTY_ADMIX of shapefile <subnat_admmix.shp>.

2.3.3.3 Balance categories and computation of population statistics

To compute statistics of populations living in different supply/demand conditions, and to be able to compare 2000 and 2015 results, the continuous values were converted into balance categories using the same class thresholds as used in the analysis for 2000. Categories codes and thresholds values are reported in Annex 9.