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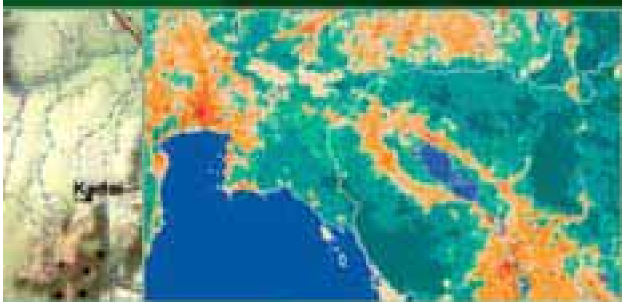
A WISDOM case study in Southeast Asia for the years 2000 and 2015



ENVIRONMENT AND NATURAL RESOURCES WORKING PAPER

[GEO-SPATIAL DATA AND INFORMATION] ENVIRONMENTAL MANAGEMENT ASSESSMENT AND MONITORING GLOBAL ENVIRONMENTAL CHANGE

POVERTY MAPPING
GEOGRAPHY OF POVERTY
GEOGRAFÍA DE LA POBREZA
GÉOGRAPHIE DE LA PAUVRETÉ

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Wood-energy supply/demand scenarios in the context of poverty mapping

A WISDOM case study in Southeast Asia for the years 2000 and 2015

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Forest Product Service (FOPP)

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Food and Agriculture Organization of the United Nations Rome, 2007

The conclusions given in this report are considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained.

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FOREWORD

This publication provides policy-makers and project personnel with tools to assess present energy flows and future energy scenarios. It uses a geographic information system to generate and manage data independently of political boundaries, integrating and analysing relationships among socio-economic and environmental variable and facilitates the identification of priority areas and population that deserve greatest attention in efforts to attain the Millennium Development Goals (MDGs). It is also useful in identifying the relevant data needed to analyse poverty alleviation, health issues and wood energy community forest programmes.

Over the years the WISDOM methodology has proven to be a flexible tool for the integrating wood energy data from different sectors. Its application in the Southeast Asia region leads to the mapping of areas where poor socio-economic and subsistence energy supply conditions co-exist, providing an important new dimension to the mapping of poverty.

This study also sets the base for expanded work into other bioenergy sectors besides the world energy field, which can benefit from the GIS analytical environment, building upon the poverty mapping methodologies developed by FAO with support from the Government of Norway.

Future work should incorporate additional data and information on other biofuels, such as energy crops and agricultural and livestock residues, in order to develop and extend the analytical framework to reflect the broader bioenergy sector.

It is hoped this publication will stimulate further analysis related to this topic.

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ABSTRACT

Current (2000) and projected (2015) woodfuel consumption patterns and supply potentials in continental Southeast Asia are analysed and mapped applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology. Combined with poverty data, the study helps define areas where poor rural and suburban populations that depend primarily on woodfuels for their subsistence energy supply are likely to suffer severe shortages, adding an indicator to the mapping of extreme poverty and a new tool for poverty alleviation policies and forestry and energy development planning.

Integrating several cartographic layers with multi-source field data provides maps of woody biomass stocking and potential sustainable productivity in 2000 and 2015 at a spatial resolution of less than 1 km. Woody biomass consumption maps matching the resolution of supply maps, coupled with likely population distribution in 2015 and model projections of woodfuel consumption, give future consumption scenarios. Combining these yields balance maps of woodfuel deficit and surplus areas.

This study is a starting point for expanding work in the agro-energy sector, which can benefit from the approach, the GIS analytical environment, the additional thematic layers and the nexus with forestry, energy and poverty alleviation issues.

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A WISDOM case study in Southeast Asia for the years 2000 and 2015
Prepared by Rudi Drigo

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Keywords:
woodfuel supply/demand balance; charcoal consumption; fuelwood consumption; woody biomass; wood energy; wood energy mapping; subsistence energy; bioenergy; energy deficit; poverty mapping; rural poverty; GIS; spatial analysis.

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ACRONYMS

30 arc-sec	30" x 30" latitude x longitude grid (approximately 0.9 x 0.9 km pixel size)
BAU	Business-as-usual [scenario]
BEF	Biomass Expansion Factor
BV	biomass of inventoried volume
Ch	charcoal [in Tables]
dbh	diameter at breast height
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Databases
FF	Fuel Fraction
FIVIMS	Food Insecurity and Vulnerability Information and Mapping System
FOPP	Forest Product Service, Forest Products and Economic Division, FAO
FRA	Forest Resources Assessment (FAO Forestry Department Programme)
Fw	fuelwood [in Tables]
GEZ2000	Global Ecological Zoning of the FAO Forest Resources Assessment for year 2000
GFPOS	Global Forest Product Outlook Study
GIS	Geographical Information System
GLC 2000	Global Land Cover Map 2000
GLCN	Global Land Cover Network
HH	household(s) [in Tables]
ICIV	*Institut de la Carte Internationale de la Végétation*, Tolouse (now *Laboratoire d'Ecologie Terrestre*)
IUCN	International Union for the Conservation of Nature and Natural Resources
i-WESTAT	Interactive Wood Energy Statistics database (FAO)
JRC	Joint Research Centre of the European Commission
LandScan	Worldwide population database compiled on a 30" x 30" latitude x longitude grid of the Oak Ridge National Laboratory (ORNL) Global Population Project
LC	Land Cover
MAI	Mean Annual Increment
MDG	Millennium Development Goal(s)
MODIS	Moderate Resolution Imaging Spectroradiometer
Pixel	(from "picture element") The smallest unit of a raster map. In this study the pixel size corresponds usually to 30" x 30" latitude x longitude.
RWEDP	Regional Wood Energy Development Programme
SDRN	Environment and Natural Resources Service of FAO Sustainable Development Department
TREES II	Tropical Ecosystem Environment observation by Satellite, phase II (JRC Programme)
UBET	Unified Bioenergy Terminology
UNEP	United Nations Environment Programme
VCF	Vegetation Continuous Field
VEF	Volume Expansion Factor
VOB	volume over bark of trees >10 cm dbh
WCMC	World Conservation Monitoring Centre
WDod	Wood Density (oven-dry)
WFF	Woodfuel Fraction
WHO	World Health Organization
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping

SUMMARY

The scope of the study was to analyse current woodfuel consumption patterns and supply potentials in the countries of continental Southeast Asia and to map with highest possible resolution different wood energy situations as of 2000 and to project status for 2015, applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology. In combination with poverty data, the study contributed to the definition of the areas within the subregion where rural and suburban populations living under the poverty line and depending primarily on woodfuels for their subsistence energy supply, are likely to suffer severe shortages. Subsistence energy shortages due to insufficient access to woody biomass add a new important indicator to the mapping of extreme poverty and a new dimension to poverty alleviation policies and programmes.

The study area included Cambodia, Lao PDR, Malaysia, Myanmar, Thailand, Viet Nam and Yunnan Province of China.

The integration of several cartographic layers (land cover maps, ecological zoning, protected areas, etc.) with field data from a variety of sources allowed the creation of maps of woody biomass stocking and potential sustainable productivity at a spatial resolution of less than 1 km. Most recent information on changes in forest area and land cover permitted projection of potential 2015 resources, assuming no major changes in current land use trends.

Similarly, the integration of population distribution maps with fuelwood and charcoal consumption values by sector and by rural and urban areas resulting from the review of a wide variety of sources, allowed the creation of woody biomass consumption maps matching the resolution of supply maps. Similarly, newly developed maps of likely population distribution in 2015 and model projections of woodfuel consumption allowed the definition of future consumption scenarios.

The integration of woodfuel productivity and consumption maps allowed the creation of balance maps showing the areas of woodfuel deficit and surplus. The woodfuel balance was estimated within a defined distance that was assumed as the gathering horizon of poor rural and sub-urban households that cannot afford marketed woodfuels, imported from distance sources, or that live far from market centres. Therefore, a deficit woodfuel supply/demand condition does not necessarily indicate a subsistence energy shortage. It rather means that either these populations can afford marketed woodfuels or alternative fuels, or they are likely to suffer subsistence energy shortages. In this perspective, the links with poverty become highly relevant.

In order to enable combination with other socio-economic parameters, which were available only by administrative units, individual pixel-level values of woodfuel balance were aggregated at sub-national level for a total of 655 administrative units.

KEY FINDINGS OF THE 2000 BASELINE SCENARIO

Figure 1 shows the result of the woodfuel supply/demand balance analysis, providing both a general overview on a total area basis and an estimate for sparse rural populations, reflecting their reliance on local biomass resources for subsistence energy needs, unlike the dense agglomerations that depend primarily on marketed fuels.

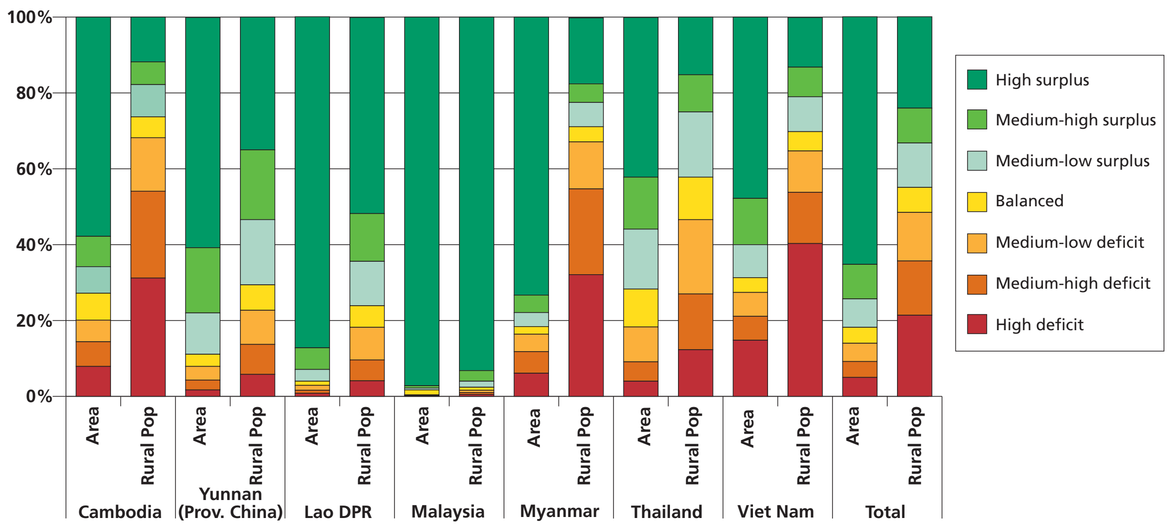
Some aspects deserve highlighting:

- According to the woodfuel supply/demand balance analysis the areas presenting more or less marked deficit conditions covered, in 2000, some 14 percent of the area of the subregion, with country values ranging between 0.4 for Malaysia and 27.4 for Viet Nam.

- From the demographic perspective, the results are far more striking. Besides localized high concentrations, such as rural settlements and urban areas that can be expected to be in high deficit, results showed that, overall, almost half of the sparse rural population (less than 2000 inhabitants per km^2) live in deficit areas.
- Of these sparse rural populations, 35 percent – i.e. 45 million people – live in areas with acute deficit conditions, comprising 27 million people in high deficit conditions and 18 in medium-high deficit conditions.

FIGURE 1

Distribution by country area and by sparse rural population of woodfuel supply/demand balance categories for 2000



KEY FINDINGS OF THE 2015 SCENARIOS

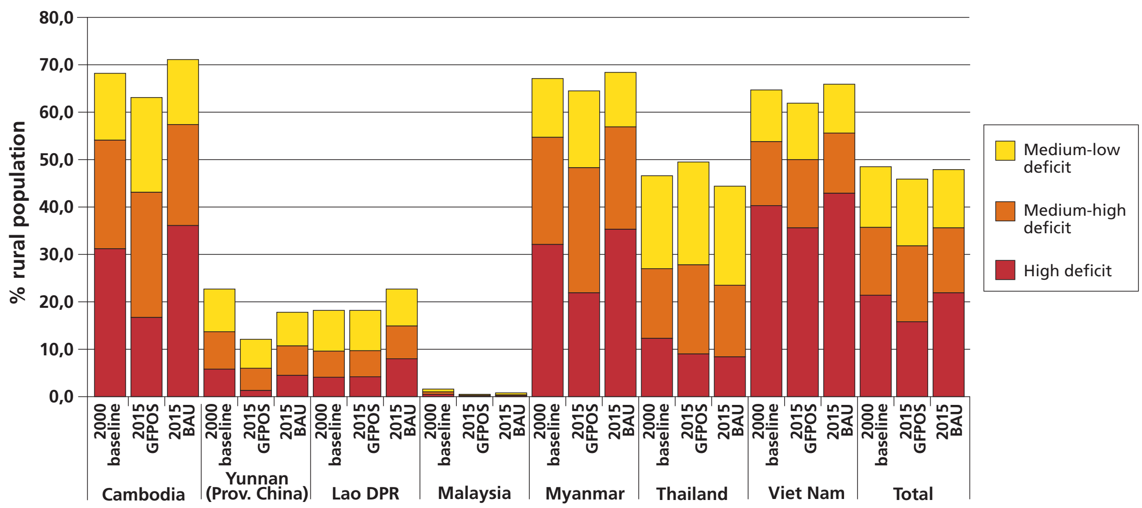
One of the most telling results of the analysis is the summary in Figure 2, which shows the distribution of sparse rural population in woodfuel-deficit areas as estimated for 2000 and as projected for 2015 based on two alternative scenarios. The following are worthy of note:

- According to the most likely scenario, the GFPOS-trend scenario, based on the consumption trends estimated in the FAO Global Forest Products Outlook Study (GFPOS) (FAO, 2001a), which assumes a general reduction in fuelwood consumption and a relative increase in charcoal consumption, 45.9 percent of the subregion's sparse rural population (56.8 million) will live in deficit conditions. Out of this population, over 39 million will face acute deficiencies (high to medium-high deficit areas). This represents a slight improvement with respect to the 2000 situation, but nevertheless it is clear evidence of how important and persistent the problem of woodfuel supply is likely to remain in the medium term for large segments of the population, especially rural and peri-urban poor.
- In the business-as-usual (BAU) scenario, which assumes constant per capita consumption rates, the sparse rural populations living in deficit areas will be very close to that estimated for year 2000, with over 59 million people living in areas with a negative supply/demand balance. Of these populations, 44 million will live in areas of acute deficiency.

- At the same time, it is estimated that a consistent fraction of the rural population lives in areas of high to medium-high surplus: 36 percent for the GFPOS-trend scenario and 34 percent for the BAU scenario. In these areas, the untapped (or unmanaged) sustainable production potential represents an accessible resource for poverty alleviation and socio-economic development.

FIGURE 2

Distribution of rural population by deficit woodfuel supply/demand balance categories in 2000 and in 2015 according to the GFPOS and BAU scenarios



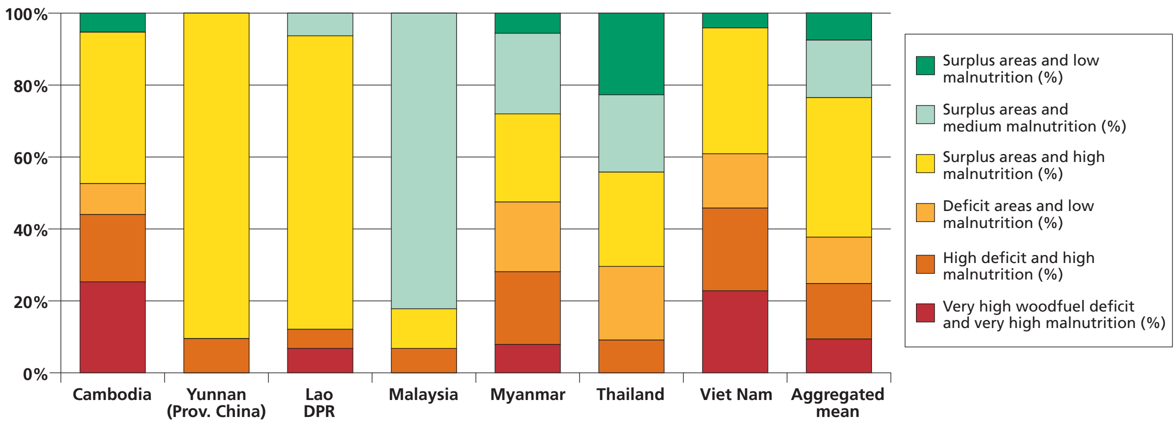
WOOD ENERGY AND POVERTY

Supply/demand balance maps depicting the situation in 2000 were combined with poverty-related indicators in order to group the population of the countries into categories determined by the combination of woodfuel availability and poverty. Due to lack of projected poverty parameters, this analysis was possible for only the 2000 data set. Results of this analysis (Figure 3) showed that, in 2000:

- Approximately one-quarter of the entire population of the subregion (rural and non-rural), i.e. some 66 million people, lived in concomitant conditions of poverty and woodfuel deficit.
- Almost one person in ten, i.e. some 25 million, lived in conditions that might be considered critical due to the interaction of worst conditions of woodfuel scarcity and poverty.
- Cambodia and Viet Nam were the countries appearing more vulnerable, with over 40 percent of the entire population facing malnutrition and woodfuel deficits, of which half faced critical conditions (concomitance of high to critical malnutrition and high to critical woodfuel deficit).
- Myanmar's situation appeared less critical, with some 28 percent of the population in the poverty/deficit zone, one-quarter of which faced critical conditions for both woodfuel supply and malnutrition.
- All other countries presented only pockets of poverty and deficit conditions, either due to better nutritional parameters (Thailand) or better biomass resources (Lao PDR, Malaysia, Yunnan).

FIGURE 3

Distribution of total country populations by woodfuel supply/demand balance categories and malnutrition status (estimates for 2000 baseline)



STRATEGIC PLANNING TOOL

WISDOM, and its various components, is a useful tool for strategic planning at regional, national and local policy levels. Its power is in its geographical and statistical data, which can support Geographical Information System (GIS) analysis for specific areas or can be combined with new thematic layers and thus assist strategic planning in new contexts and thematic perspectives. The maps and statistics included in the report are meant to describe the data and results considered to be of major relevance, but they far from exhaust the informative and analytical power of the underlying data set.

More than just a tool for wood energy specialists, the WISDOM environment supports the identification of vulnerable populations and ecosystems that require the attention of policy-makers. While designed for wood energy planning, the methodology can be applied to other sectors and serve for analysing alternative development scenarios in energy, agriculture, forestry and other macro-economic development plans.

The thematic layers produced in the study represent the beginning rather than the conclusion of an analytical process. They may, and hopefully will, support further level of analysis at both lower and higher geographical levels.

At lower levels, i.e. national and sub-national, they can serve as the basis for WISDOM analyses aimed at supporting and guiding policies on poverty alleviation within the perspectives of energy, forestry and rural development.

At higher levels, i.e. regional and global, they can provide qualified reference to regional and global wood energy mapping and contribute to poverty mapping in the framework of Millennium Development Goals (MDG) initiatives. In a wider context, the maps produced can provide useful references for other activities associated with international conventions, such as those on Climate Change, on Biological Diversity and on Desertification.

ACCURACY AND DATA RELIABILITY

Due to the lack of a single reliable data source on woody biomass and woodfuel consumption, this activity required the integration of information coming from a wide variety of sources, including data of undetermined reliability, and the assumption of subjective estimates to fill specific data gaps. Consequently, the maps produced in this study represent best approximations based on available data, to be used for the definition of priority zoning and strategic planning, rather than for operational planning, which requires reliable quantitative estimates. However, in spite of its approximation, this first definition of surplus and deficit areas provide a new and important insight on this sector and considerably circumscribes the areas requiring immediate attention and intervention, thus reducing the cost and enhancing the effectiveness of additional data collection and verification.

RECOMMENDATIONS

To improve on the accuracy of the analysis and at the same time to build on the knowledge developed in this study in relation to MDG, the following activities are recommended:

- Implement national WISDOM analyses, particularly in the geographical areas defined as higher priority in the present study.
- Improve supply scenarios at subregional level by
  - improving the estimation of woody biomass resources and sustainable productivity, with particular attention to the non-forest land uses that are important, but undocumented, sources of woodfuels;
  - undertaking Geographical Information System (GIS) studies in order to estimate physical accessibility of supply sources; and
  - assessing and mapping the production by forest and wood industries of residues suitable for energy use.
- Improve demand scenarios at subregional level, with particular attention to fuel substitution trends in different sectors and areas.
- Analyse interrelations between woodfuel scenarios and likely poverty and malnutrition situations in 2015, based on projected poverty-related socio-economic parameters, in order to define priority areas for action within the 2015 time frame for sustainable wood energy systems and poverty alleviation.
- In critical areas, measure and evaluate the interaction among woodfuel supplies, poverty levels, health and nutritional conditions.
- Take decisive multisectoral action (investigation and mitigation) in critical areas without awaiting further study results, since many of the results achieved appear adequate to identify urgent needs.

In addition, this study provides a starting point for expanding work in the agro-energy sector, which can benefit from the approach, the GIS analytical environment, the additional thematic layers and the nexus with forestry, energy and poverty alleviation issues.

It is therefore recommended that the WISDOM analytical framework be systematically enhanced to incorporate additional data and information on other biofuels, including energy crops and agricultural and livestock residues, in order to develop and extend the applications to reflect the broader bioenergy sector.

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.

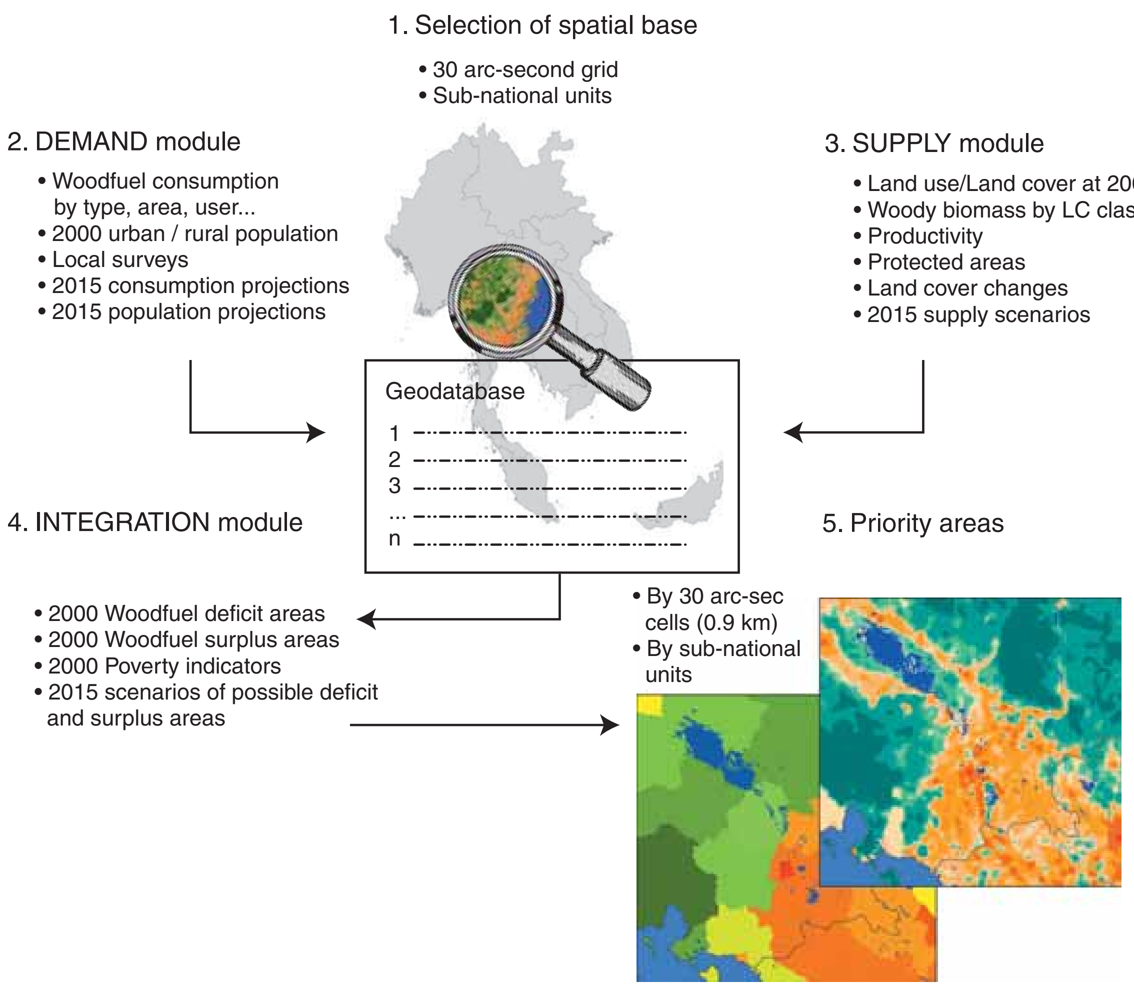
A detailed description of the WISDOM approach can be found in FAO (2003d).

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

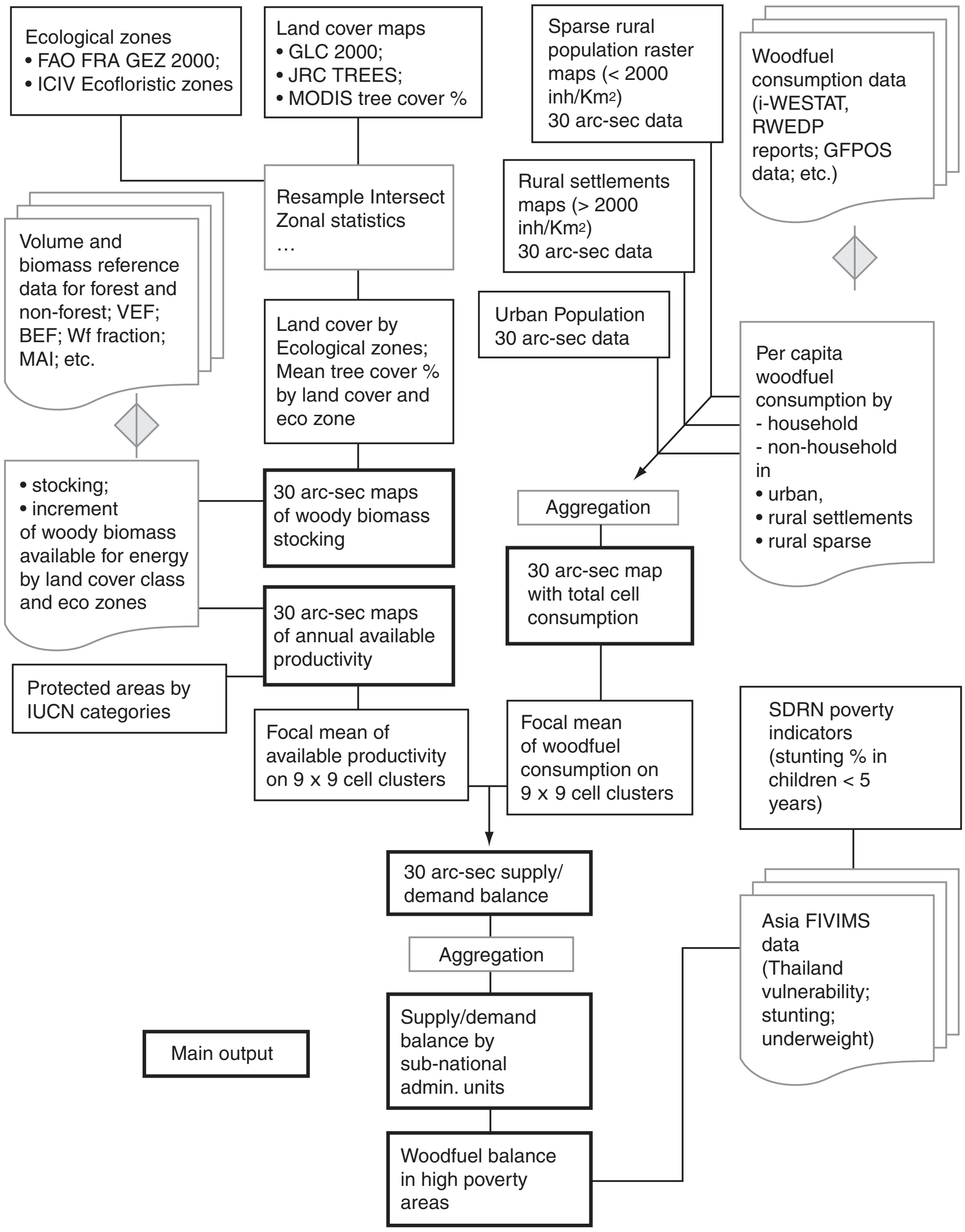


2.2 METHODOLOGY OF PHASE 1: 2000 BASELINE

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:

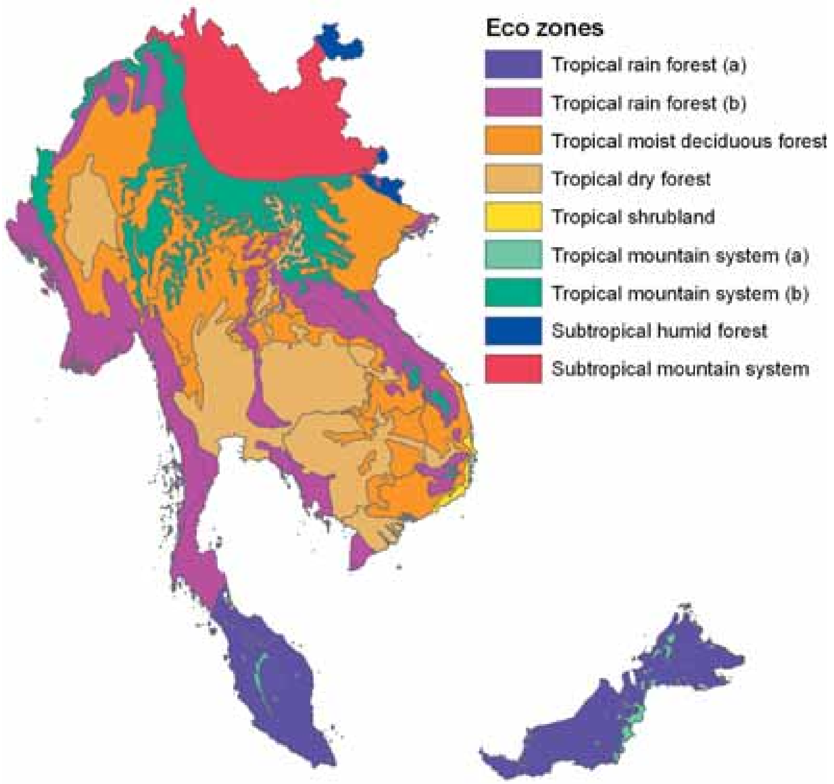
- FAO FRA 2000 Global Ecological Zoning (GEZ2000) <SEAsia_GEZ.shp>
- ICIV eco-floristic zone map <asi_ecf_polygon.shp>
- Modified GEZ2000 to subdivide the rainforest zone (referenced against ICIV eco-floristic data) and to match other raster data layers <gez9.grid>

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/km²) < rurpop_as30.grid>
- Rural settlements (>2000 inhabitants/km²) <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)

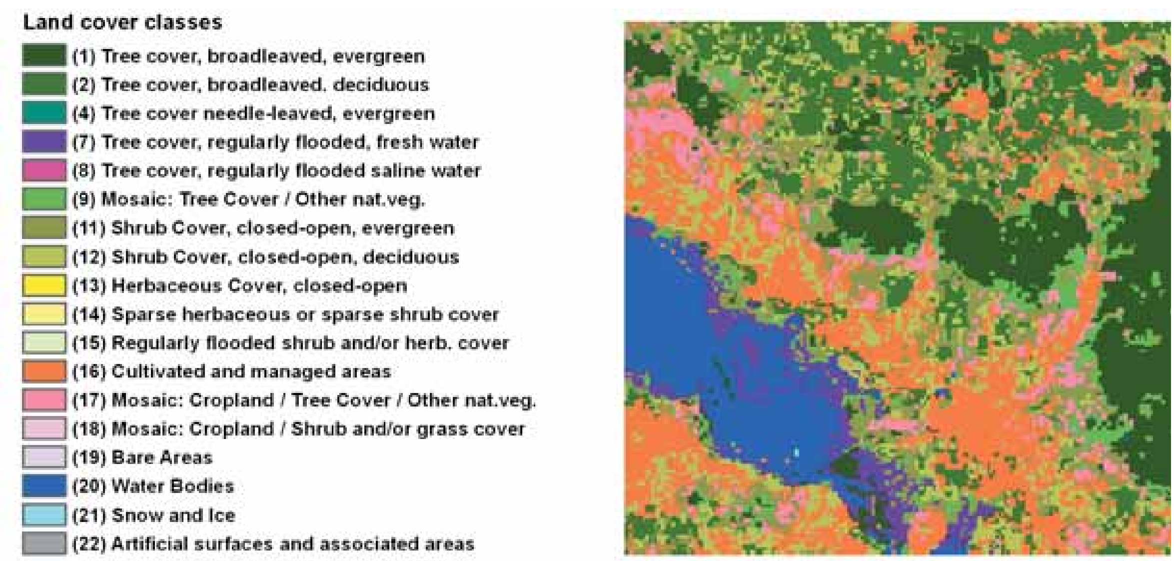


FIGURE 9
Ecological zone map

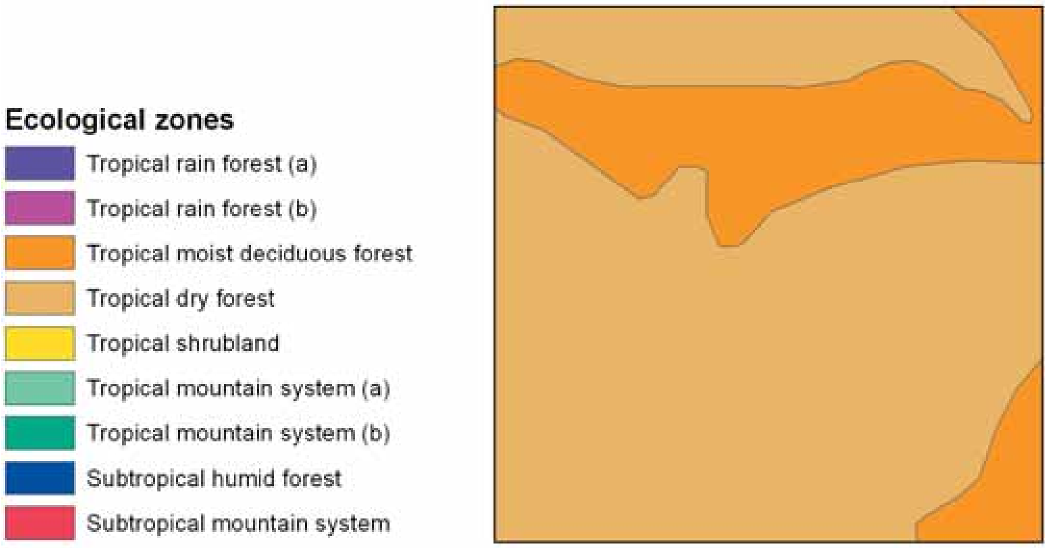


FIGURE 10
MODIS VCF Tree Cover percent

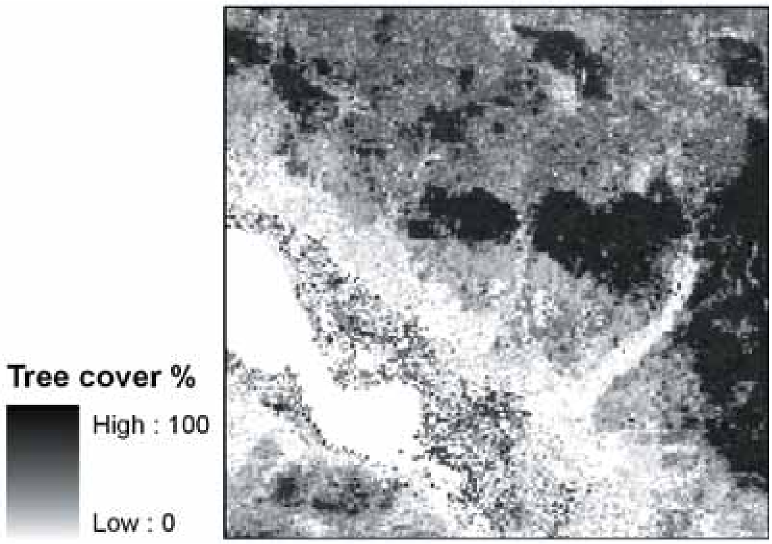


FIGURE 11
IUCN WCMC map of protected areas

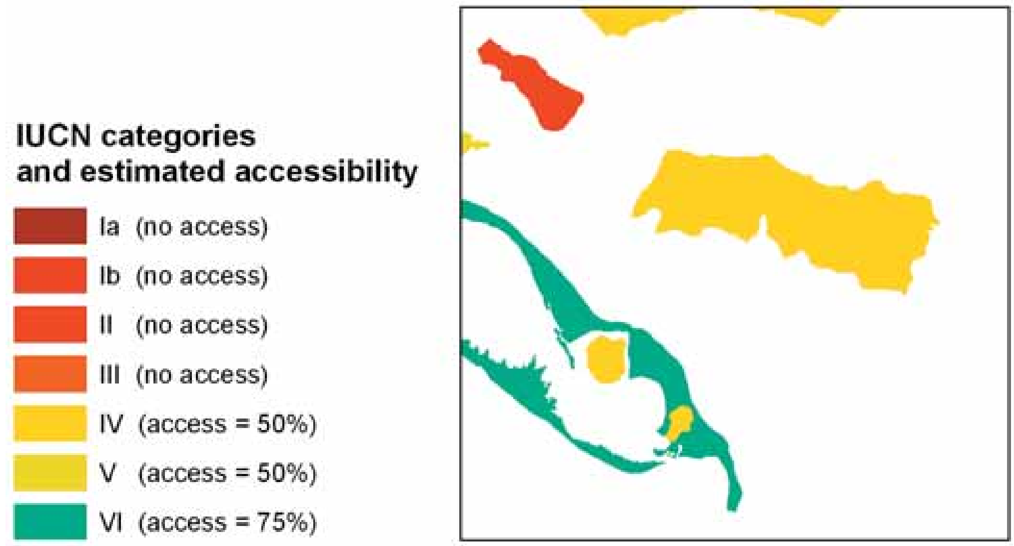


FIGURE 12
Woody biomass stock

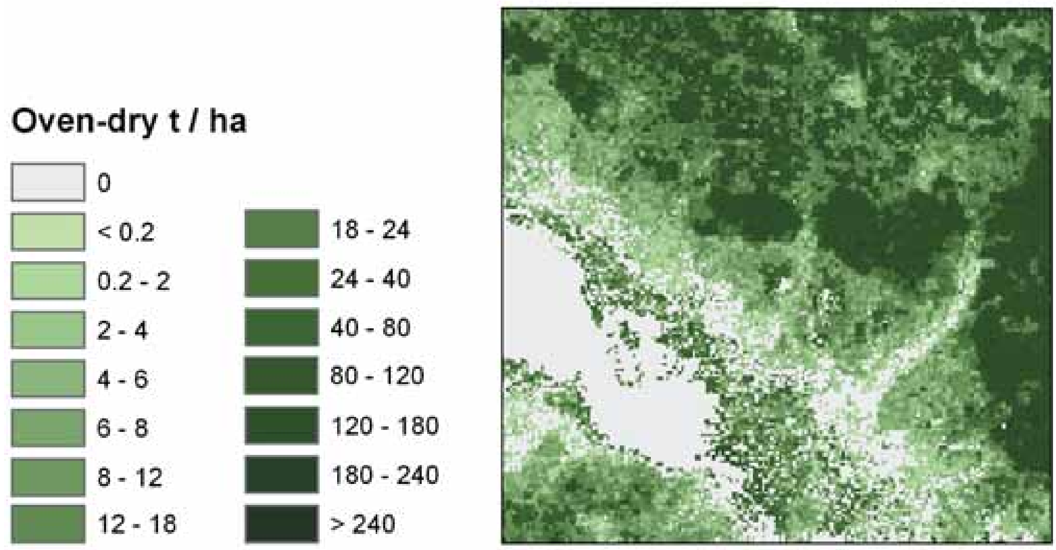
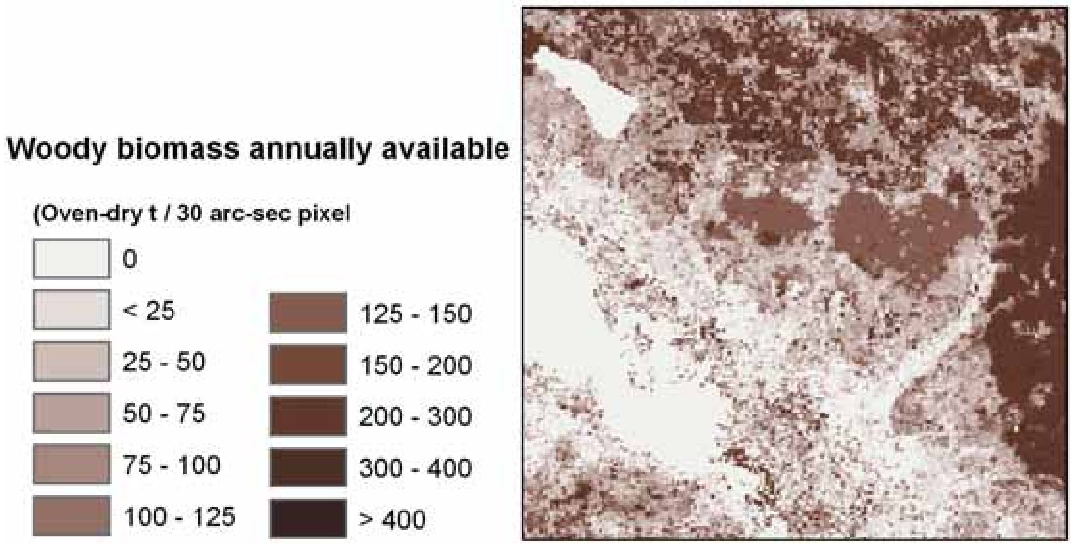


FIGURE 13

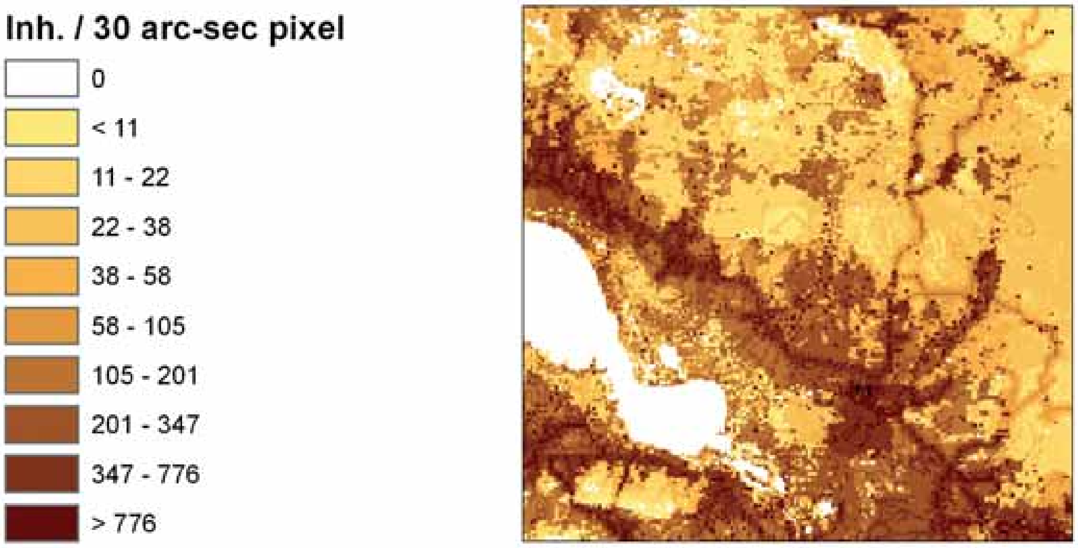
Woody biomass increment available for energy use



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

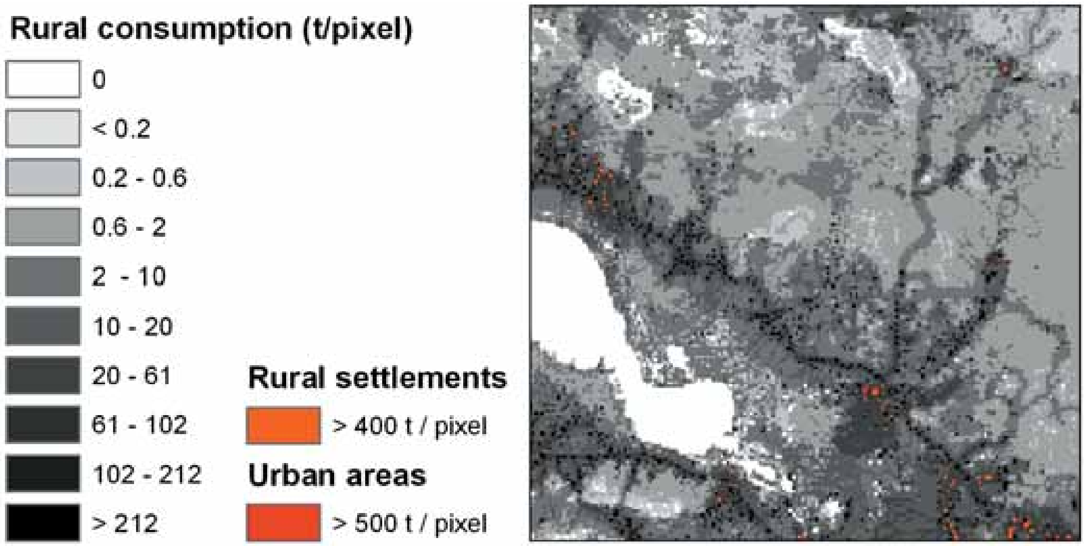
Population distribution in 2000, 30 arc-sec data set



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/km^2 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

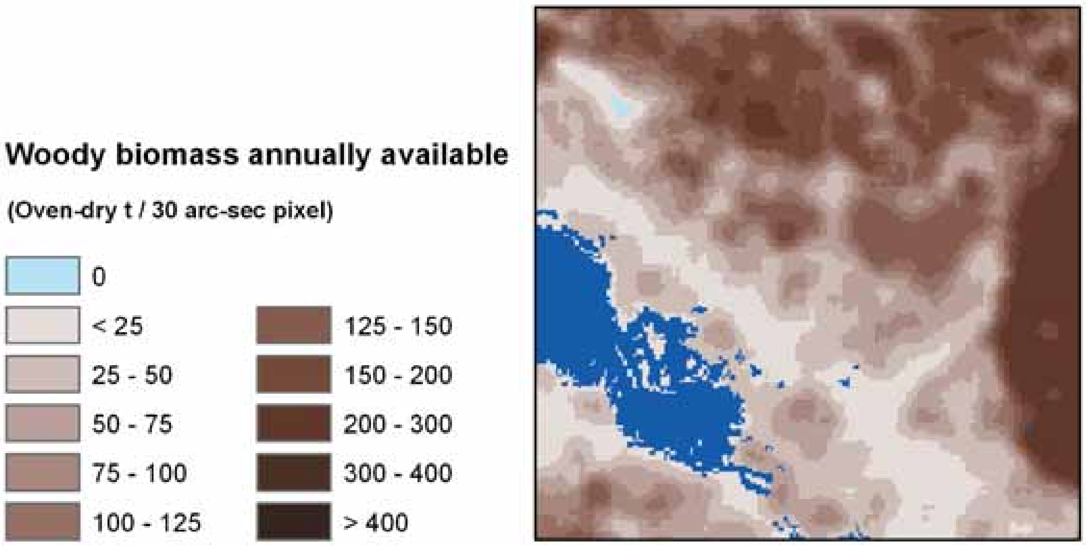


FIGURE 17
Focal mean (9 x 9) of woodfuel consumption

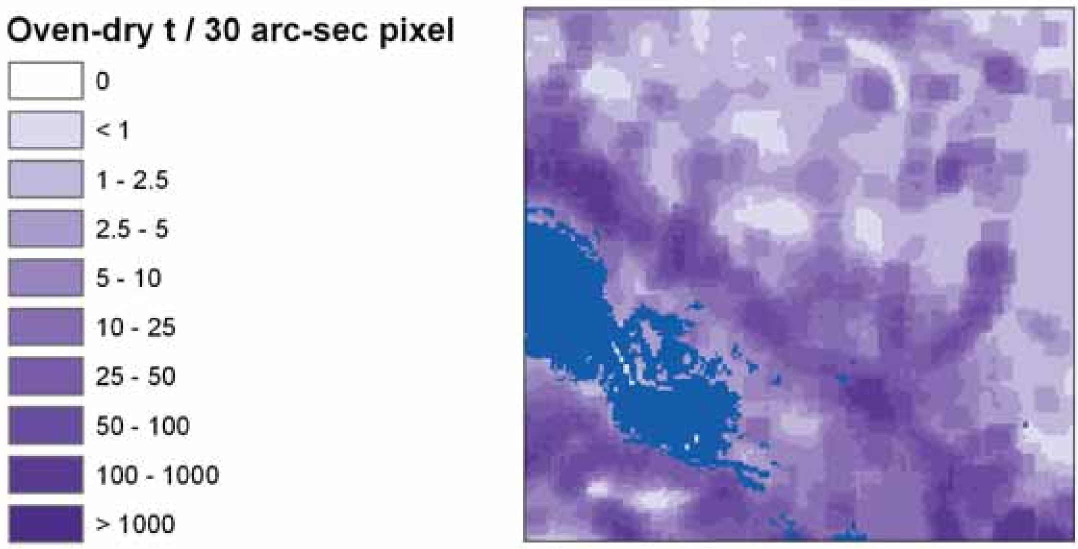
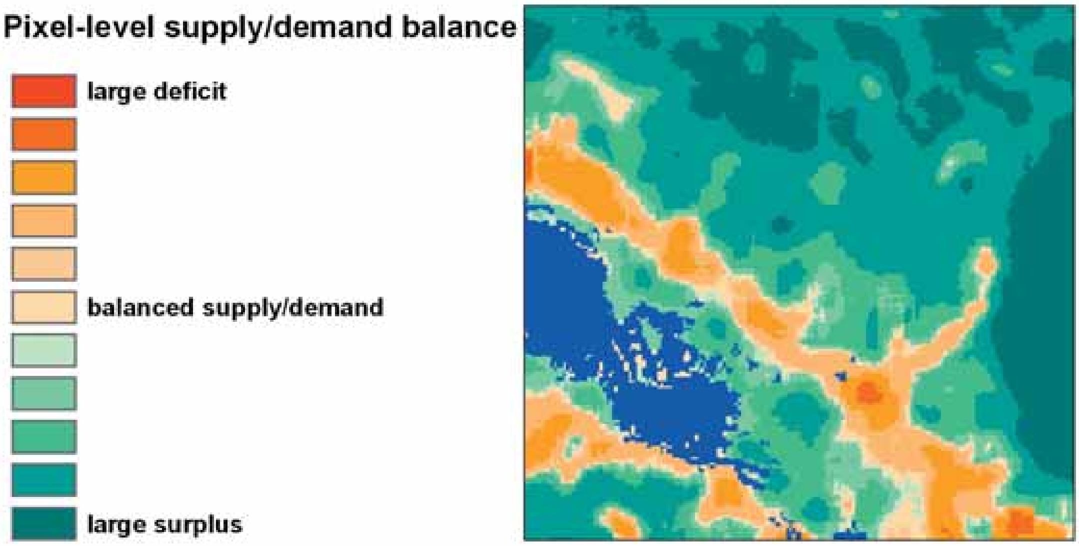


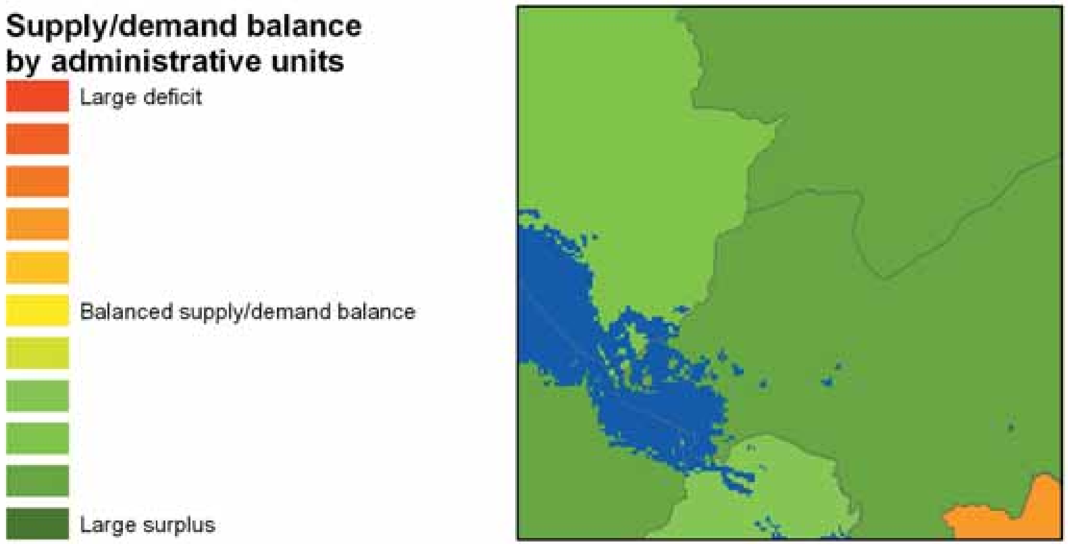
FIGURE 18
Focal mean (9 x 9) of supply/demand balance



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

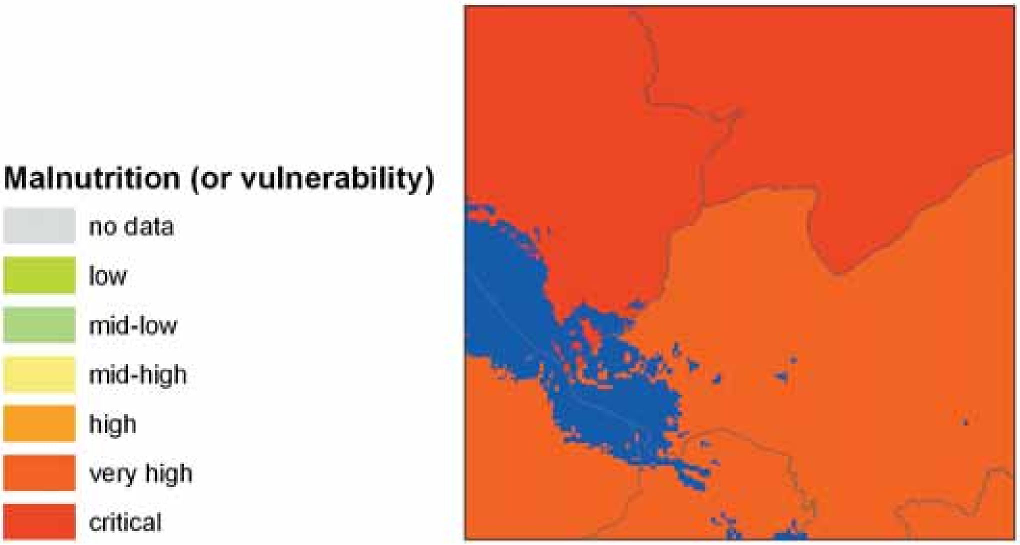
Supply/demand balance aggregated at administrative unit level



For full map, see Figure 35.

FIGURE 20

Poverty-related indicators by administrative units



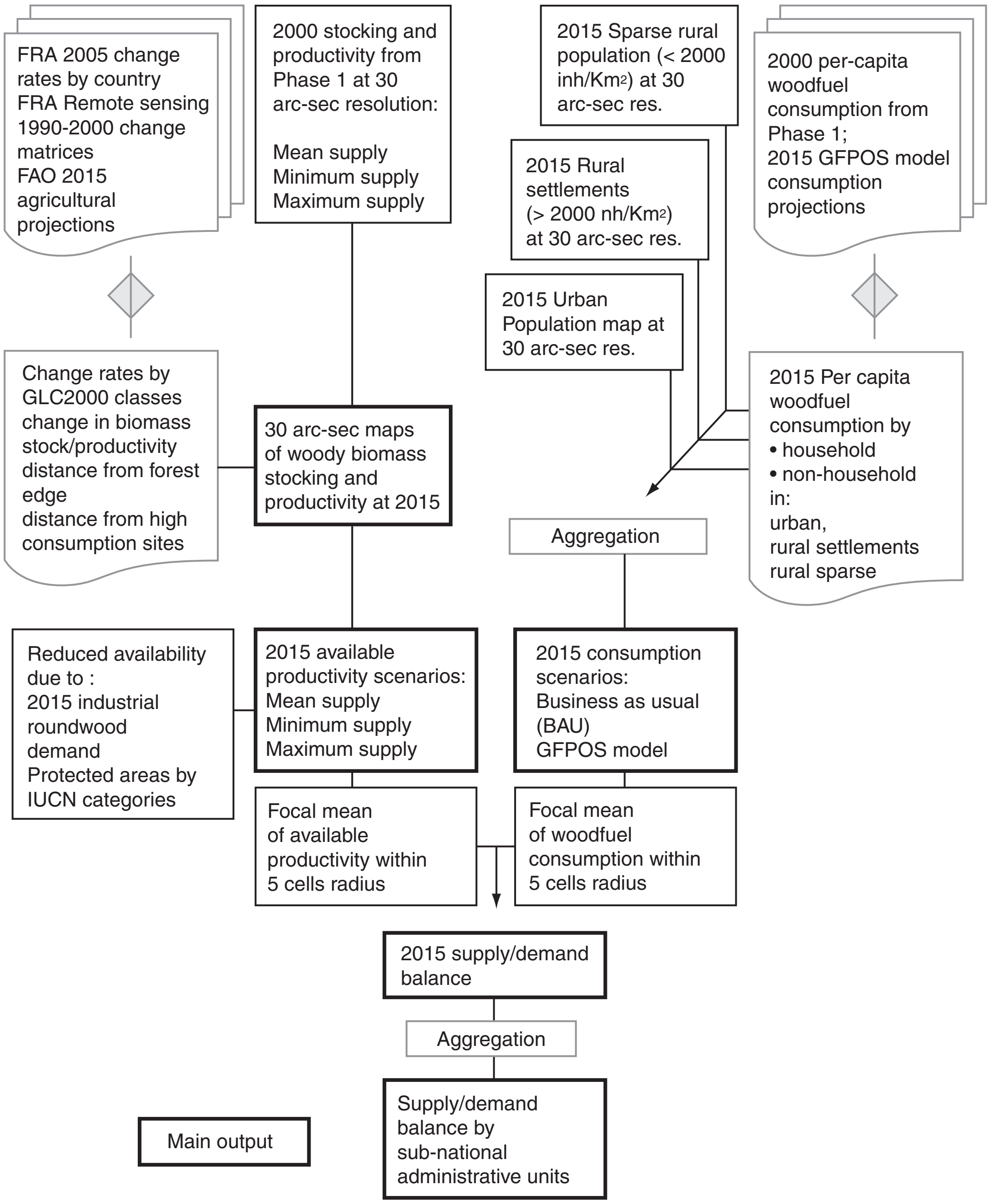
Stunting percent in children below 5; vulnerability ranking based on wide range of indicators in Thailand.
For full map, see Figure 36.

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).

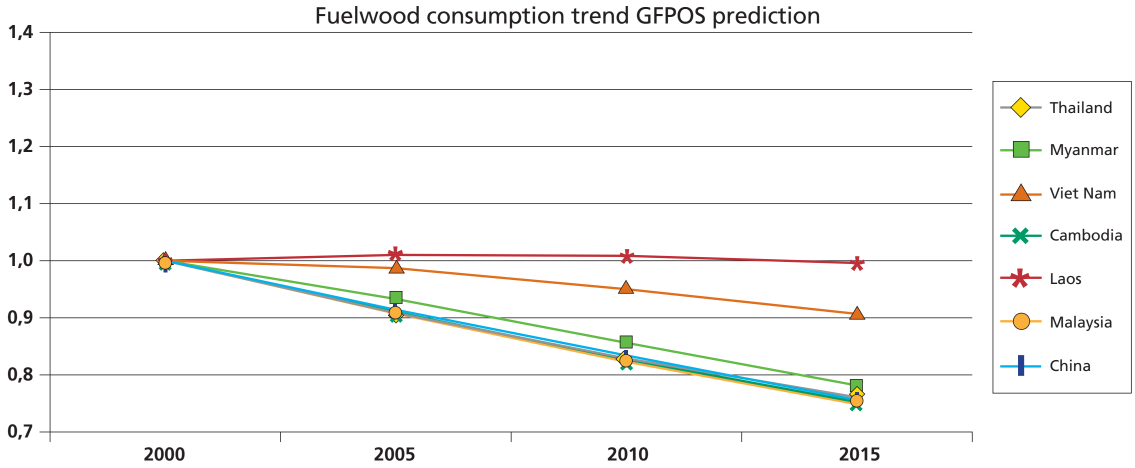
Two scenarios were considered:

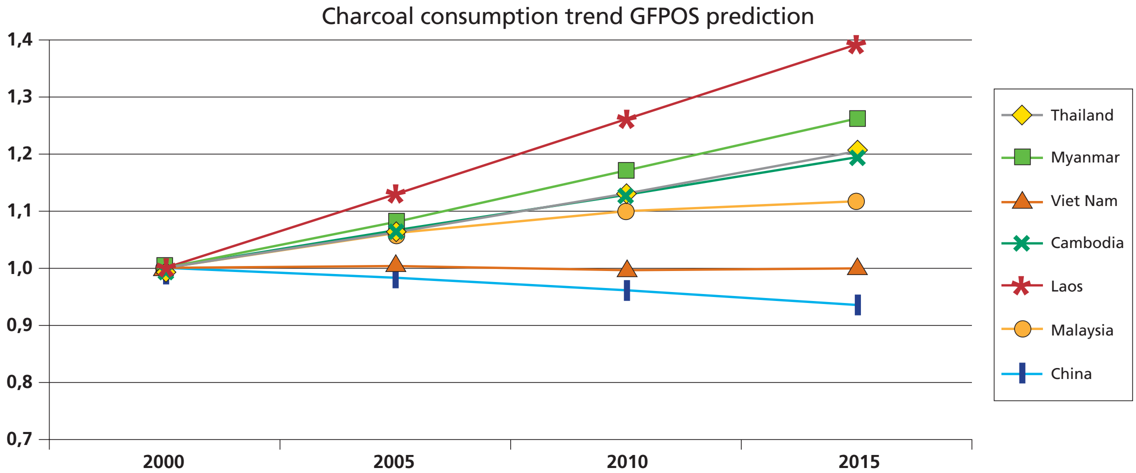
- **Business-as-usual (BAU) scenario**, in which the per capita consumptions estimated for 2000 were maintained constant and the trends were determined basically by population growth in rural and urban areas.
- **GFPOS trend scenario**, in which the consumption trends projected by the GFPOS model were 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

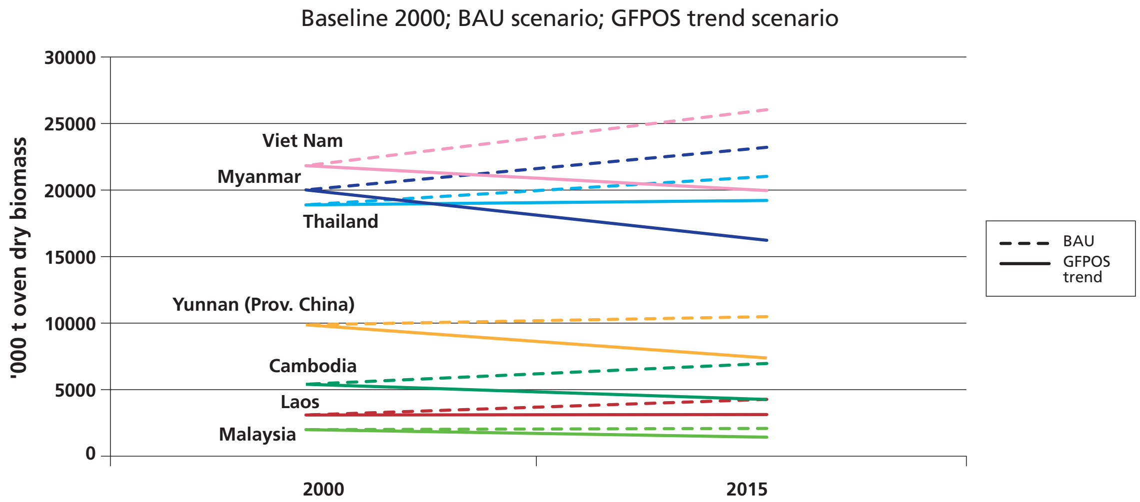
- Consumption in 2015 in sparse rural areas in kg/pixel (GFPOS-trend scenario) <rurspa15_kgtot.grid>

- 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.

CHAPTER 3

RESULTS (THEMATIC MAPS)

3.1 RESULTS OF PHASE 1: 2000 BASELINE

The results of the WISDOM process included databases on woody biomass potentials and woodfuel consumption, and a series of thematic maps resulting from the development of the Demand, Supply and Integration modules.

3.1.1 Supply module results

The set of data and parameters related to woody biomass density and productivity are summarized in Annex 2.

The maps resulting from the Supply module have a resolution of 30 arc-sec (raster maps with pixels of approximately 0.9 x 0.9 km) and concern the distribution of woody biomass stocking (Figure 24) and of potential annual productivity available for energy uses (Figure 25).

3.1.2 Demand module results

The set of data and parameters related to woodfuel consumption are summarized in Annex 4.

The maps resulting from the Demand module also have a resolution of 30 arc-sec and show the spatial distribution of woodfuel consumption by all sectors (household, industrial, commercial, etc.) in three geographical categories:

- Rural areas with population density <2000 inhabitant/km² (rural sparse).
- Rural areas with population density >2000 inhabitant/km² (rural settlements).
- Urban areas.

Figure 26 presents the spatial distribution of total woodfuel consumption resulting from the aggregation of the three layers.

3.1.3 Integration moule results

Woodfuel supply/demand balance

The maps resulting from the Integration module report, for each 30 arc-sec pixel, the balance between the consumption of woodfuels and potential sustainable supply in the 81 pixels formed by the 9 x 9 pixels cluster having the given pixel at the centre. Thus, the balance refers not to the resources within each pixel but to the area that is within 4 km from the central pixel, which may be considered the resource horizon accessible to poor households that depend prevalently on fuelwood gathering.

Two geographical representations were made:

- Original 30 arc-sec raster maps. This data set is presented at global level (Figure 27) as well as at national level (Figures 28 to 34).

- Sub-national aggregation of pixel-level balance results for a total of 655 sub-national administrative units (Figure 35).

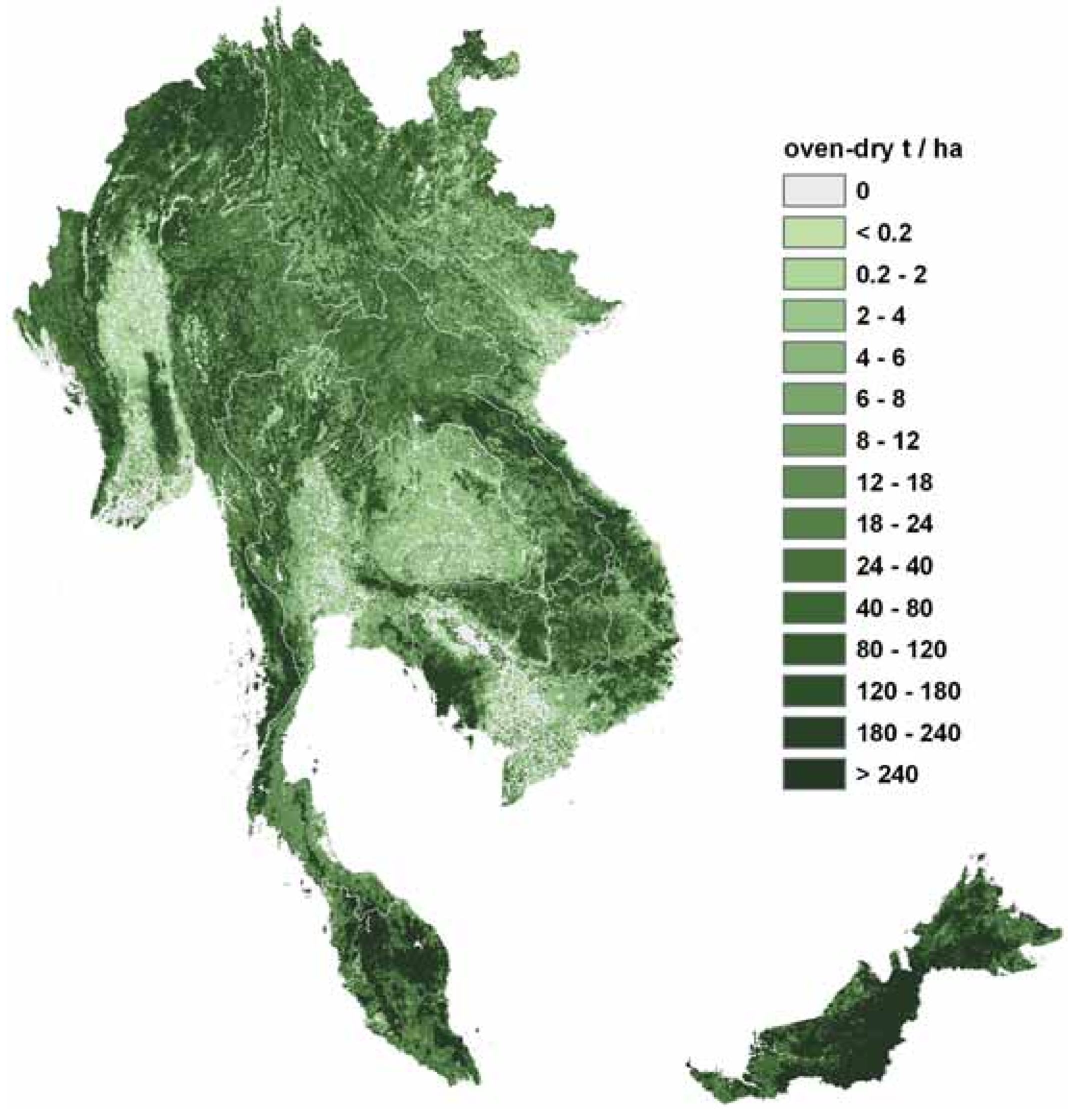
Woodfuel balance and poverty

The best available sub-national indicators related to poverty were merged into a single layer in order to create a fairly consistent subregional map (Figure 36).

The combination of the map of supply/demand balance with that of malnutrition/vulnerability allowed stratification of the area as well as the population, reflecting the interaction of both factors, and enabled identification of priority areas and populations facing at the same time acute supply shortages and critical poverty conditions. Figure 37 shows the results of the combination of woodfuel supply/demand balance and poverty categories. Country statistics on population vulnerability due to the concomitance of various woodfuel and poverty conditions are presented in Annex 6.

FIGURE 24

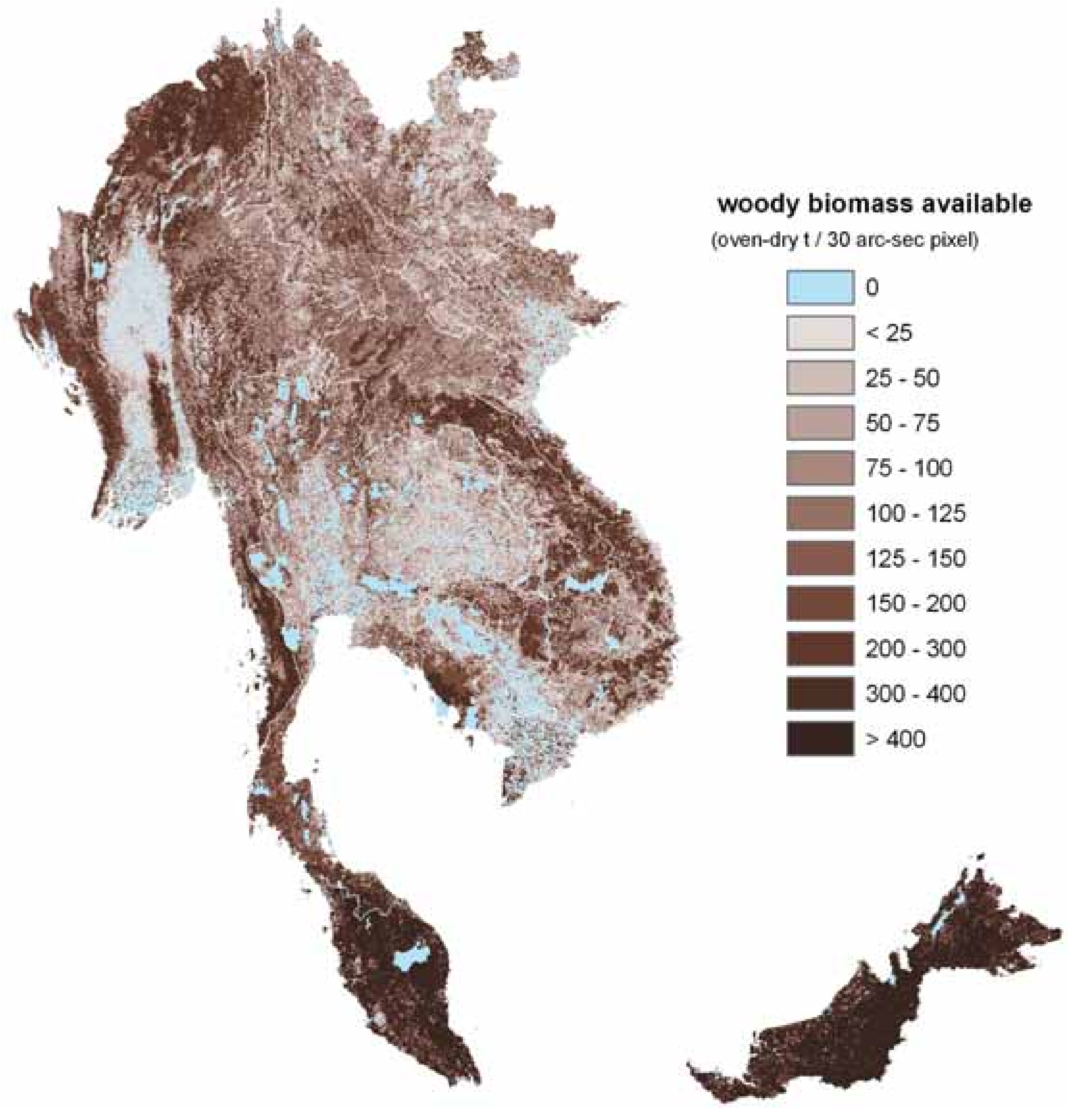
Supply module – Spatial distribution of woody biomass resources. Distribution of woody biomass stocking in 2000 at 30 arc-sec resolution (~0.9 x 0.9 km). For methodology, see Section 2.2.2



Map: wfbio_stock05.grid

FIGURE 25

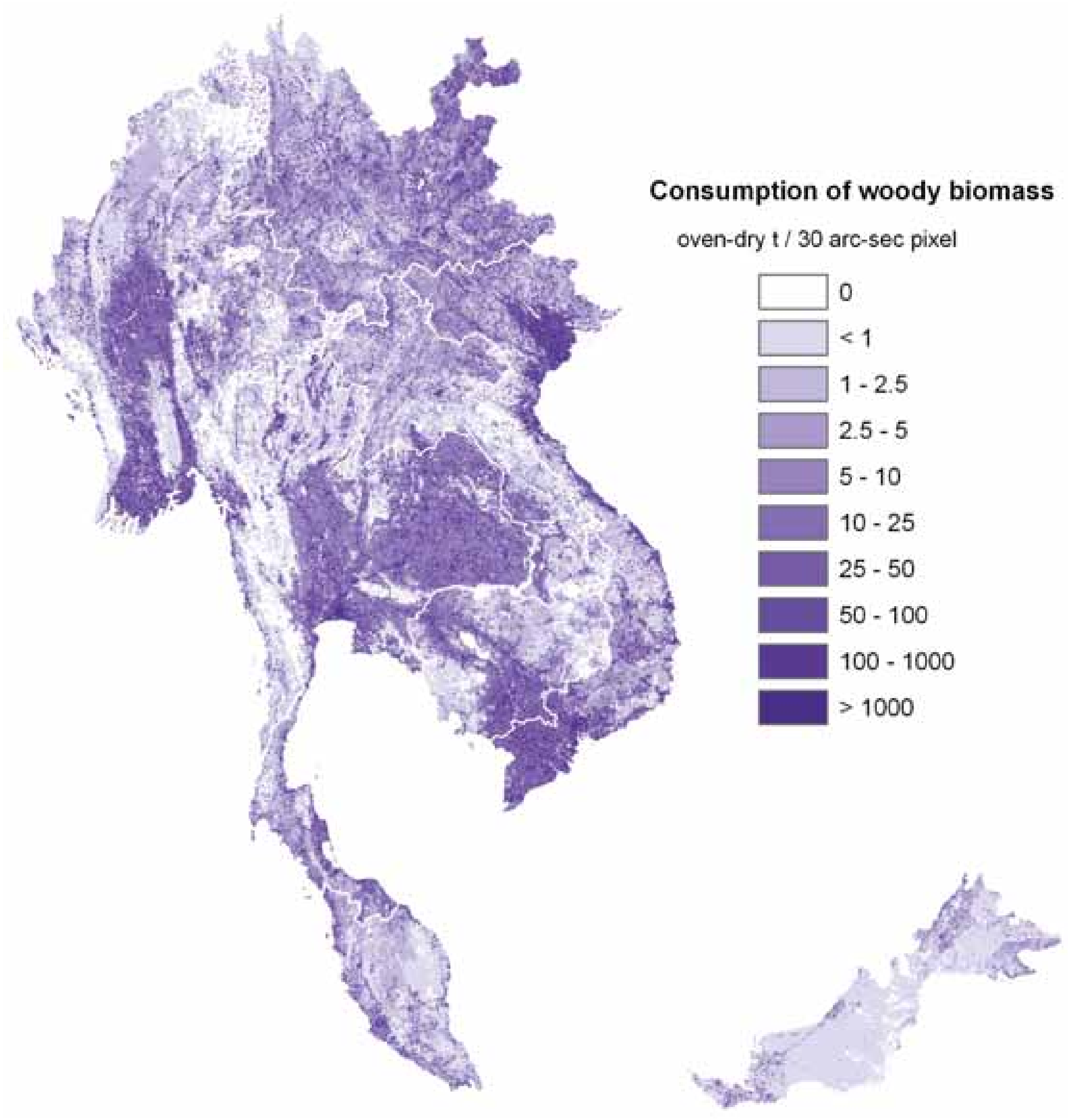
Supply module – Spatial distribution of woody biomass resources. Distribution of potential annual increment of woody biomass in 2000 at 30 arc-sec resolution (~0.9 x 0.9 km). For methodology, see Section 2.2.2



Map: wf_kg_avail06.grid

FIGURE 26

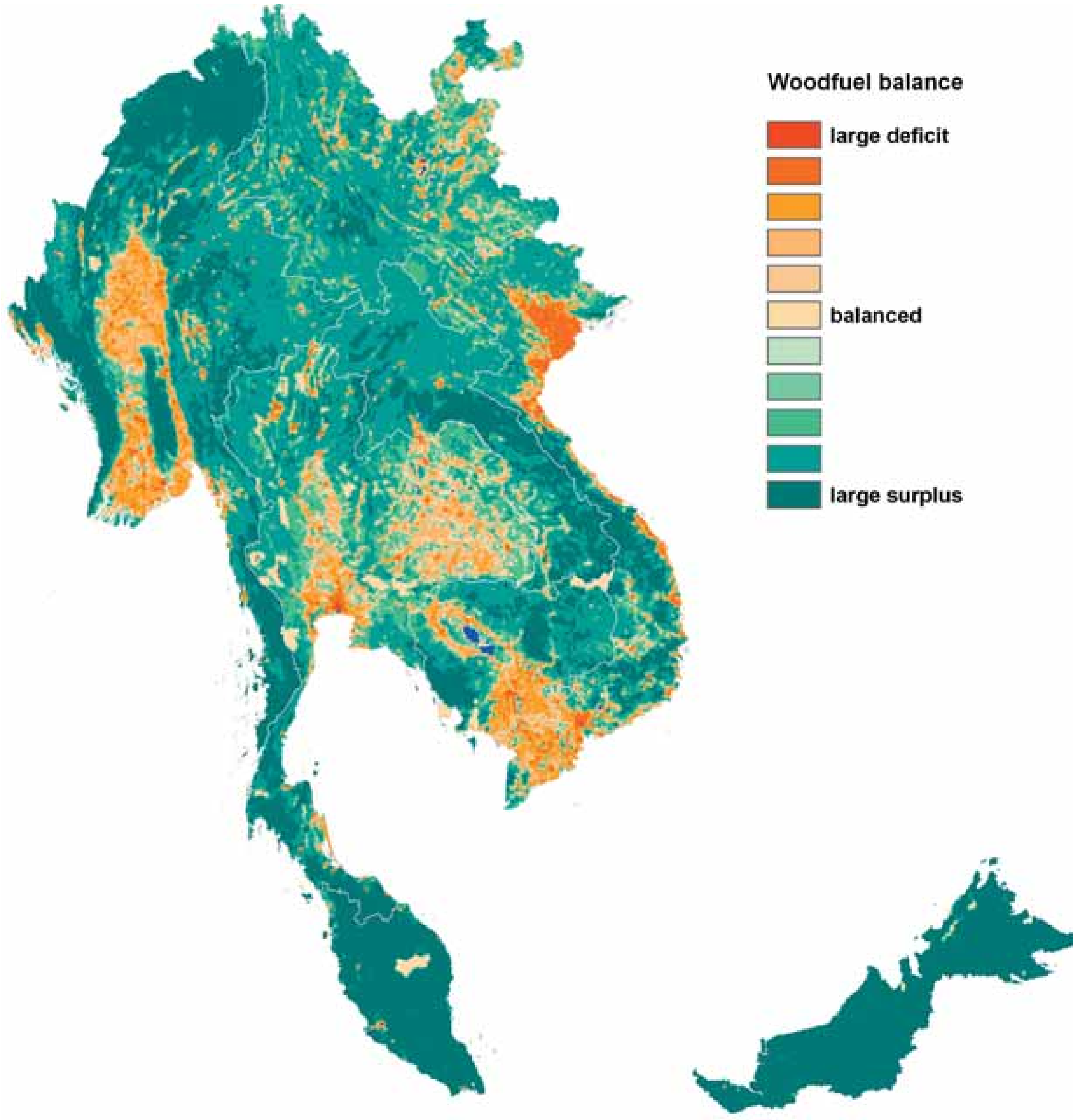
Demand module – Spatial distribution of woodfuel consumption in 2000 at 30 arc-sec resolution (~0.9 x 0.9 km). For methodology, see Section 2.2.3



Map: kgtot.grid

FIGURE 27

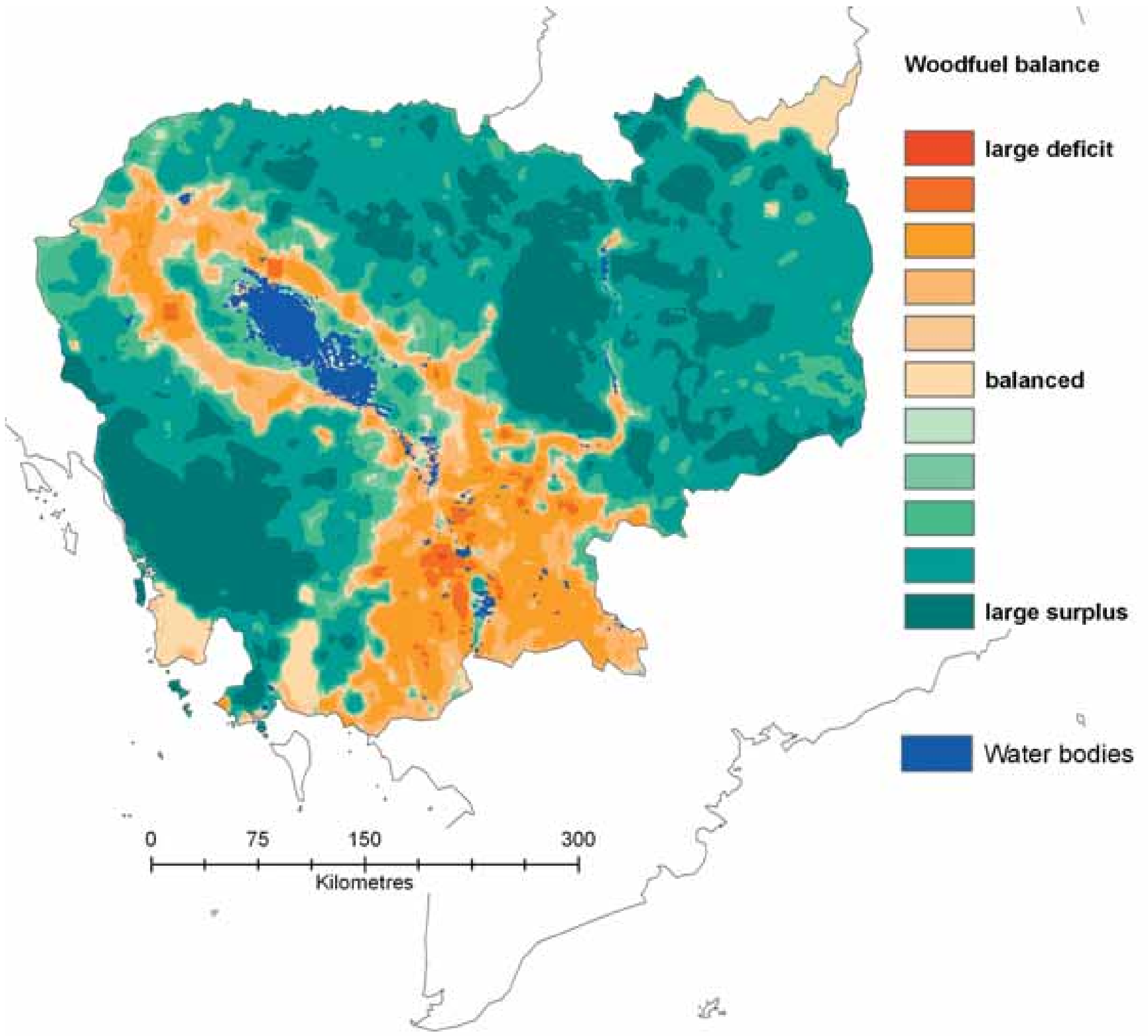
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – Subregional overview. For methodology, see Section 2.2.4.1



Map: f9_bal.grid

FIGURE 28

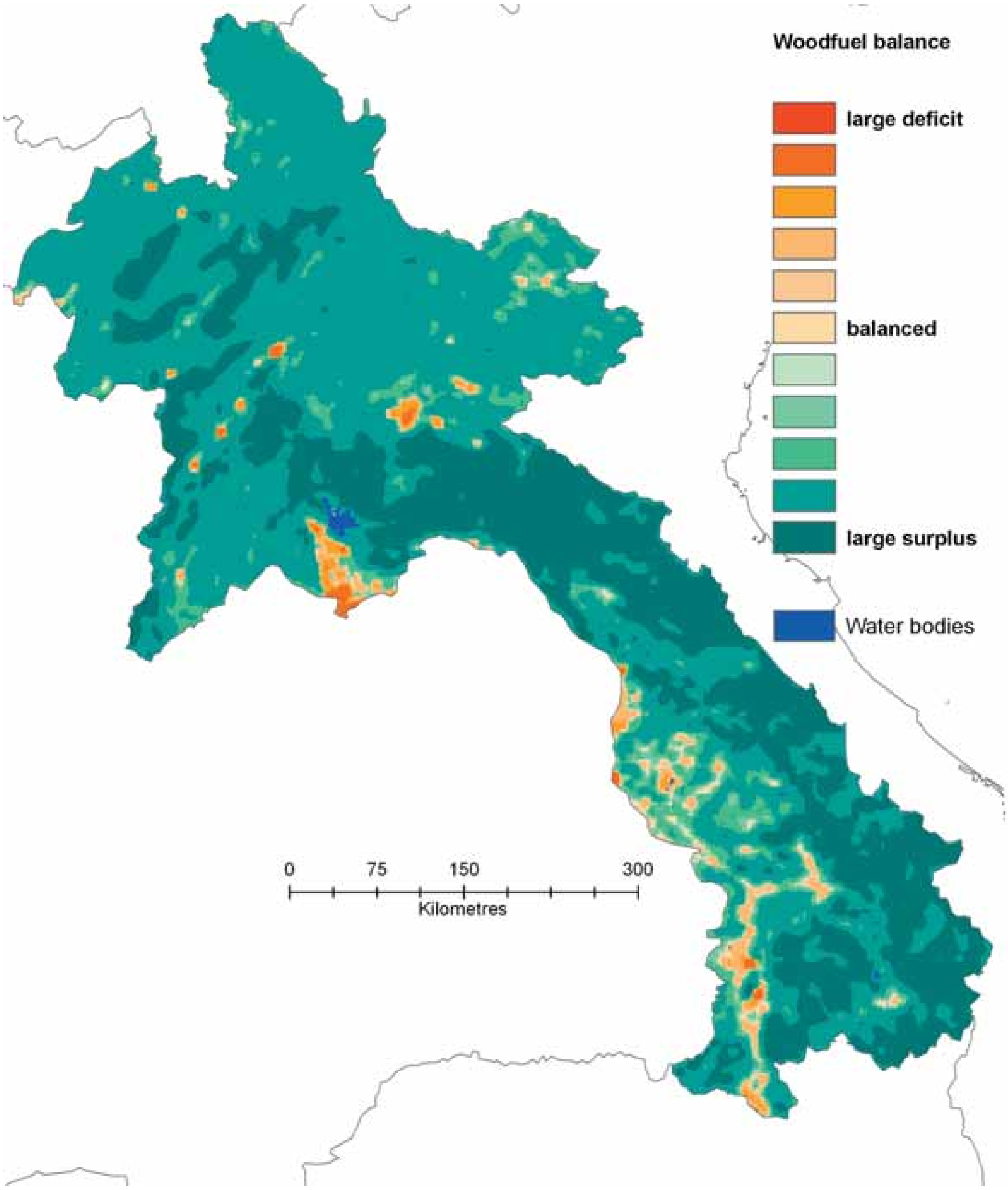
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – National data set for Cambodia. For methodology, see Section 2.2.4.1



Map: Cam_f9_bal.grid

FIGURE 29

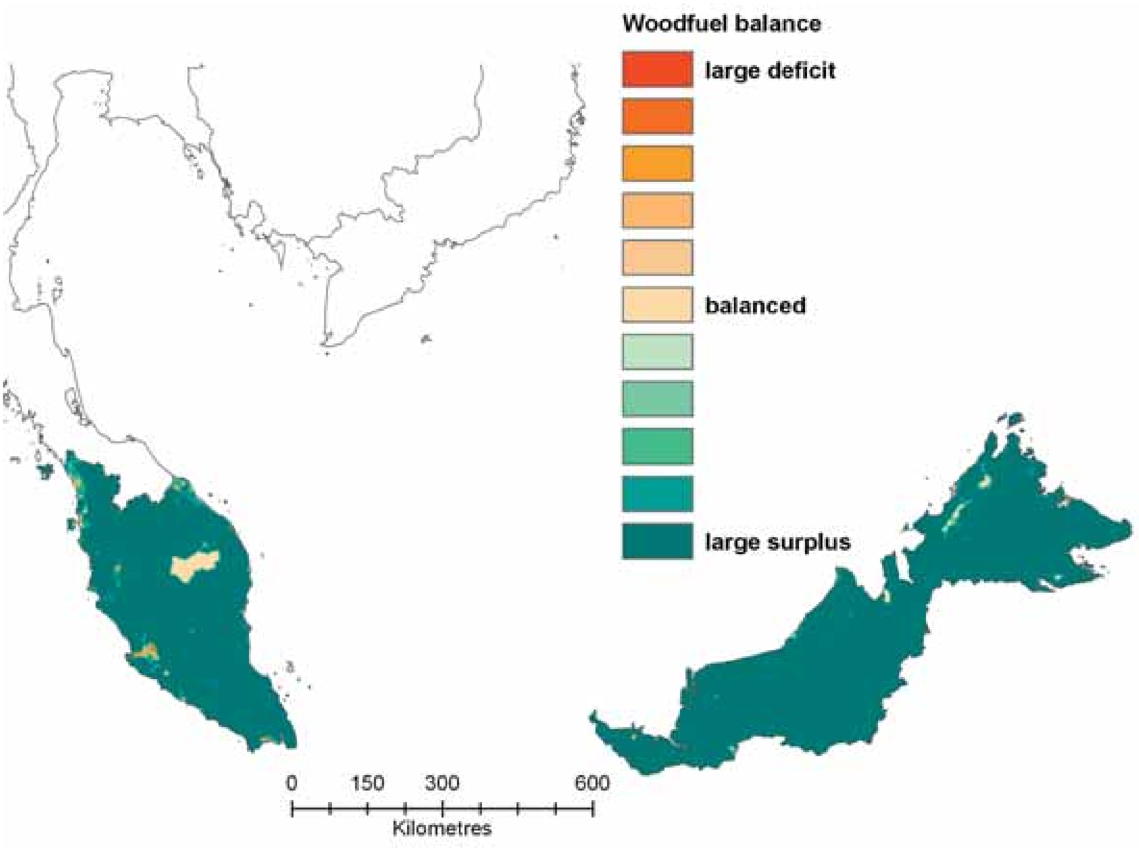
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – National data set for Lao PDR. For methodology, see Section 2.2.4.1



Map: Lao_f9_bal.grid

FIGURE 30

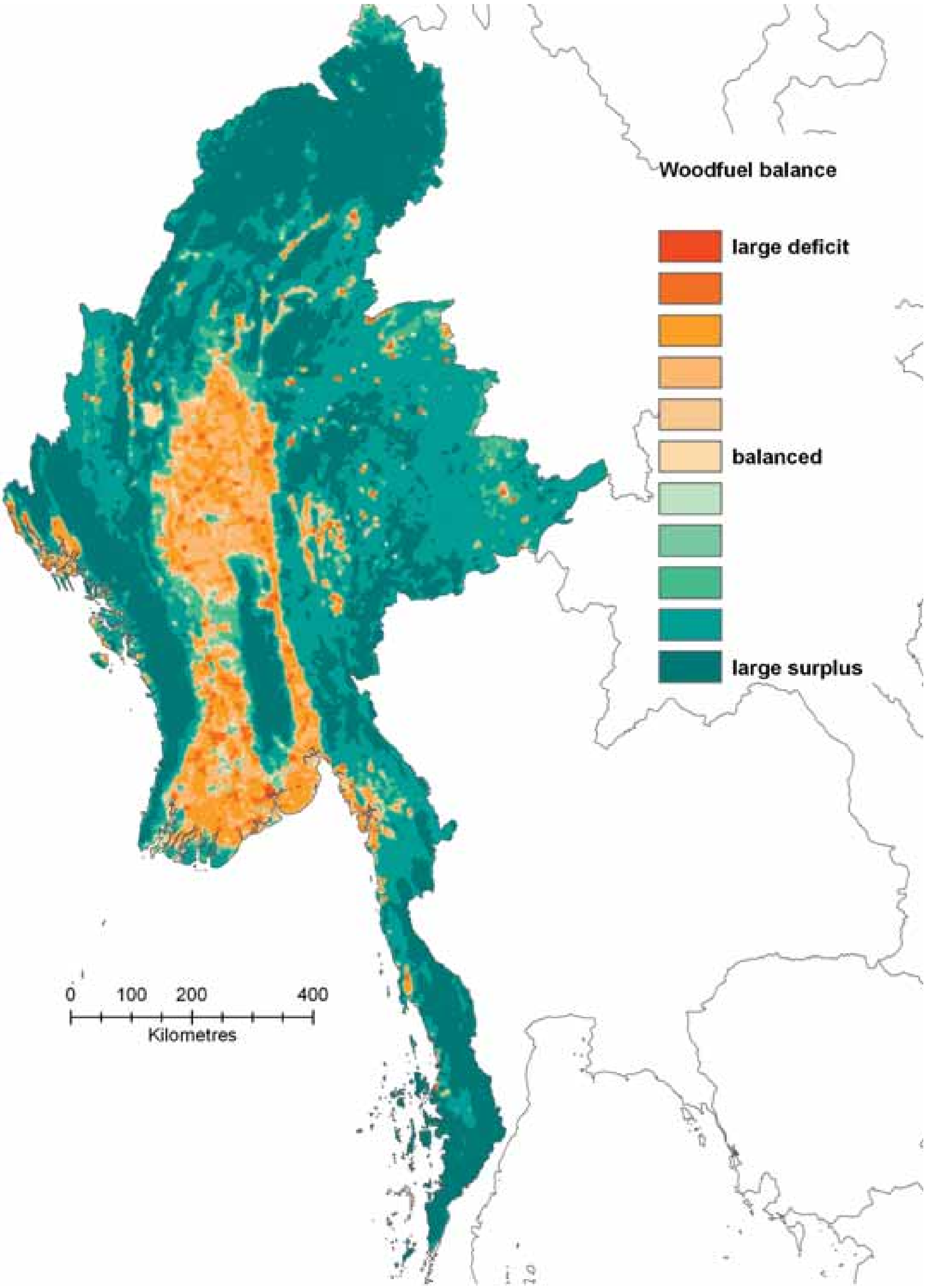
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – National data set for Malaysia. For methodology, see Section 2.2.4.1



Map: Mal_f9_bal.grid

FIGURE 31

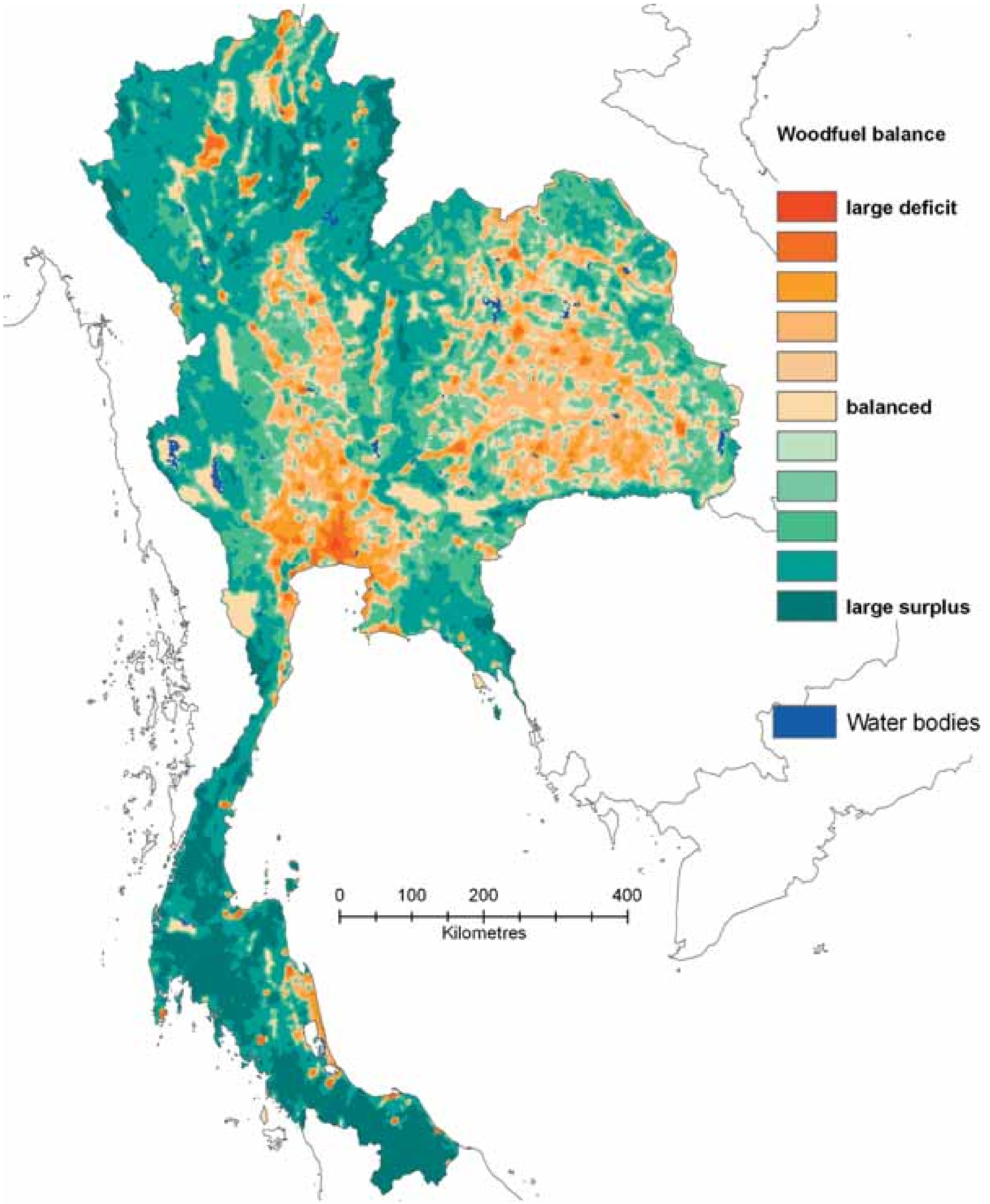
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – National data set for Myanmar. For methodology, see Section 2.2.4.1



Map: Mya_f9_bal.grid

FIGURE 32

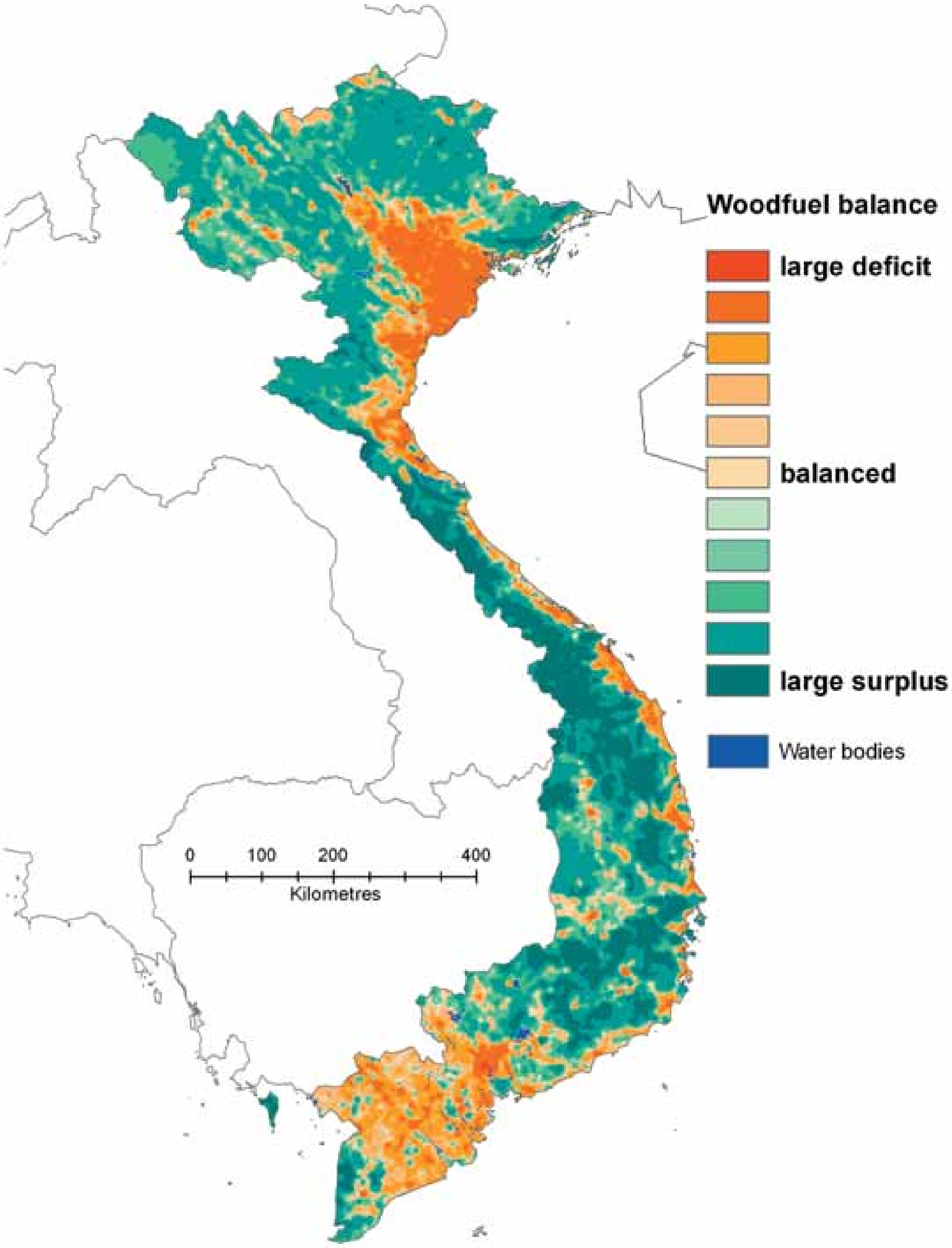
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – National data set for Thailand. For methodology, see Section 2.2.4.1



Map: Tha_f9_bal.grid

FIGURE 33

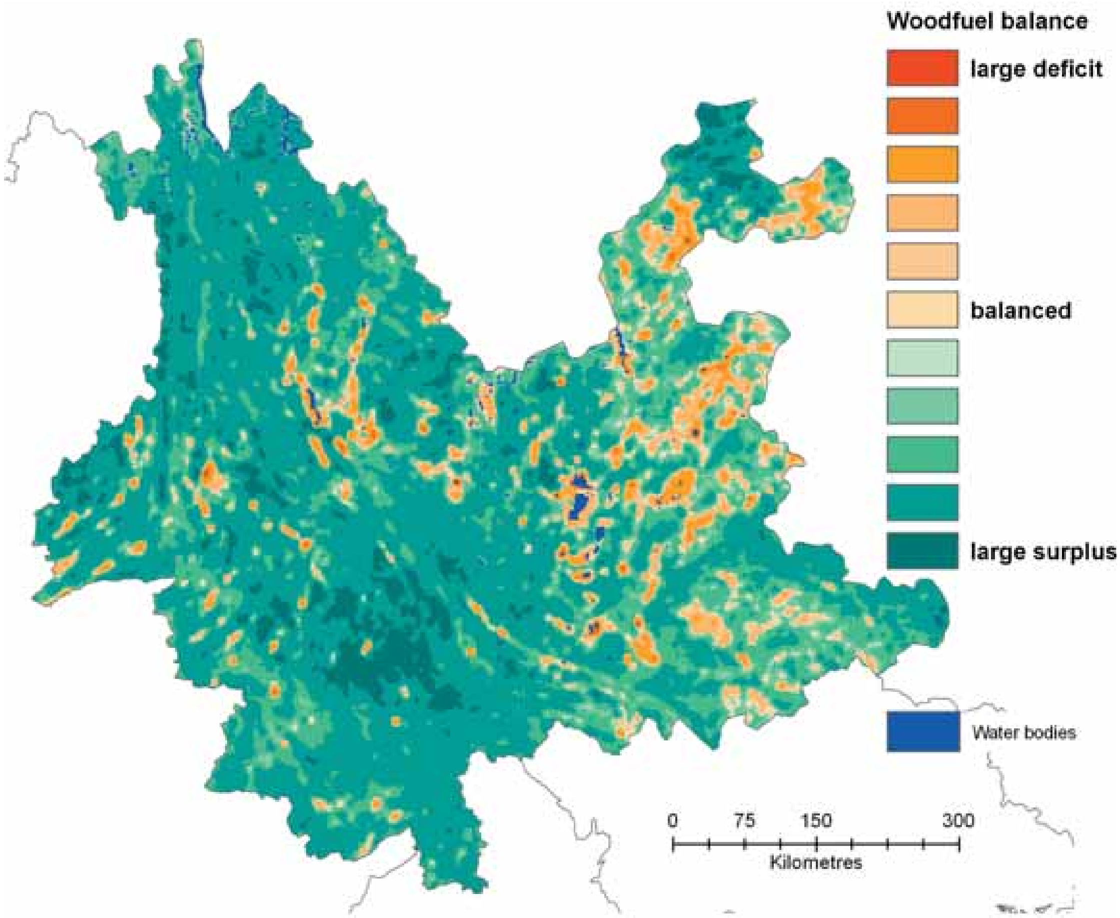
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – National data set for Viet Nam. For methodology, see Section 2.2.4.1.



Map: Vie_f9_bal.grid

FIGURE 34

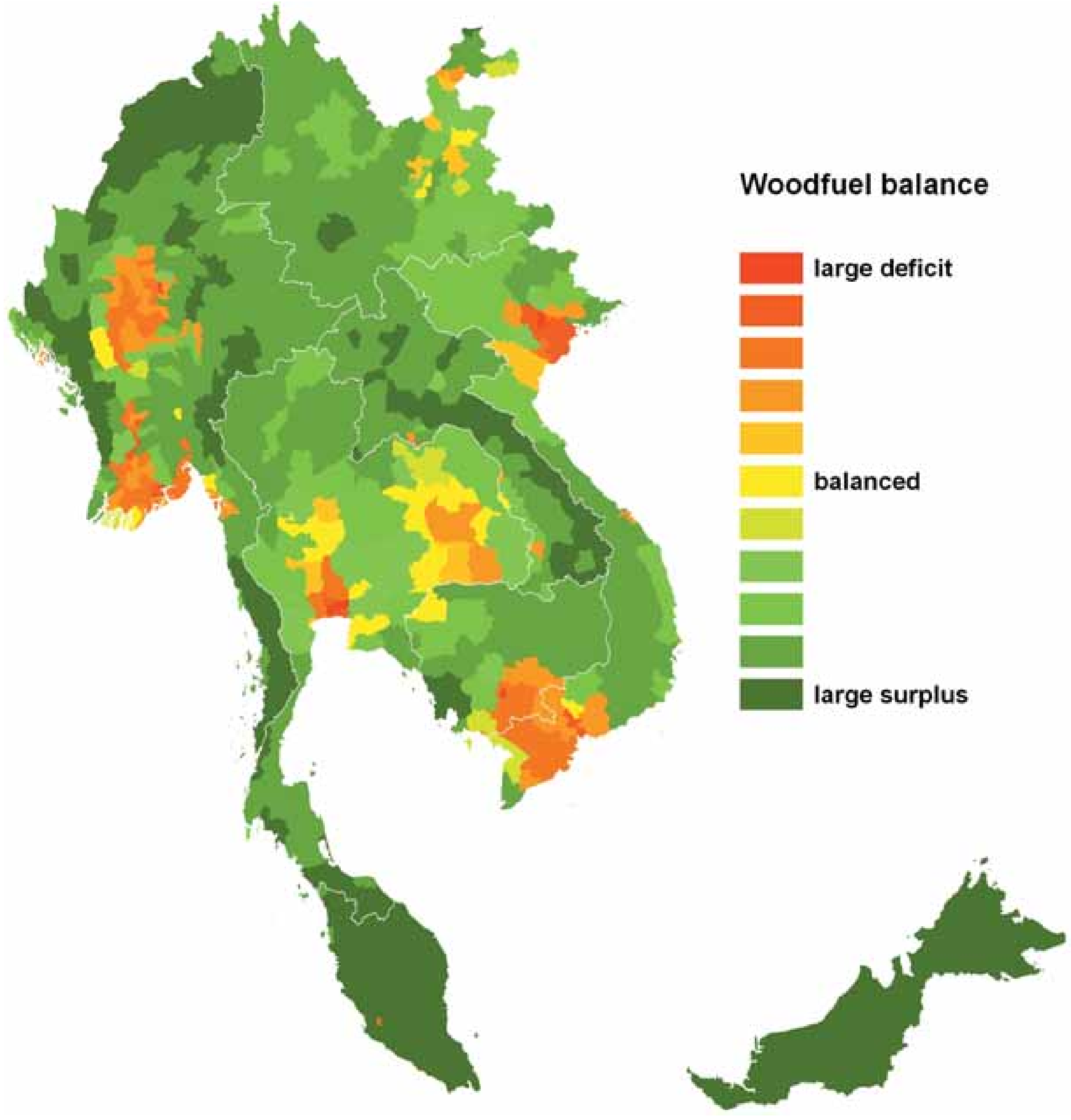
Integration module – Demand/supply balance and poverty based on 30 arc-sec data set. Map of pixel-level balance categories in 2000 – National data set for Yunnan Province, China. For methodology, see Section 2.2.4.1.



Map: Yun_f9_bal.grid

FIGURE 35

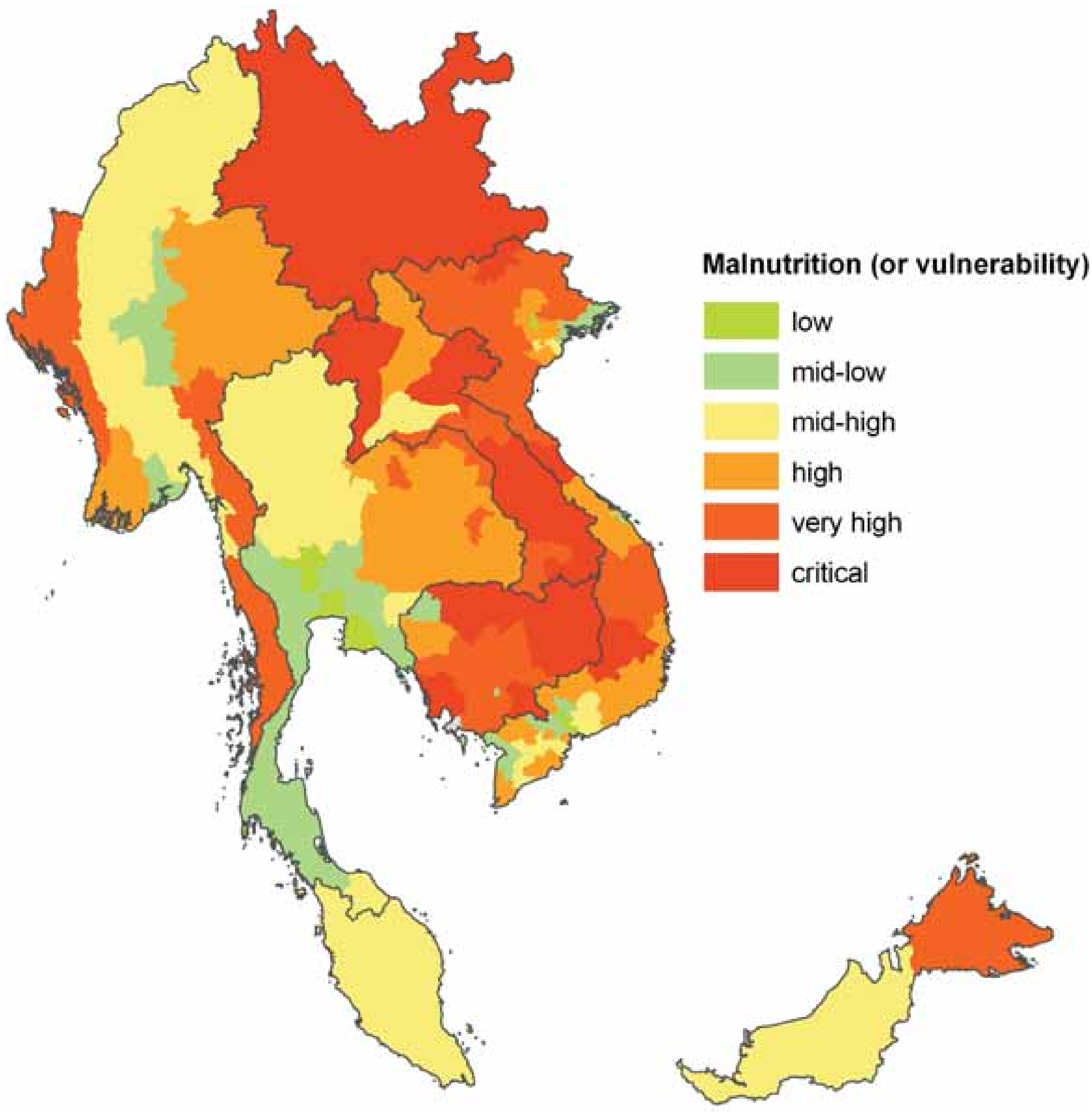
Supply/demand balance by sub-national administrative units. Year 2000. For methodology, see Section 2.2.4.3



Map: asiacover_subnational.shp
Attribute: BAL_ADMIX

FIGURE 36

Map of poverty based on best available indicators by sub-national administrative units. For description, see Section 2.2.4.4



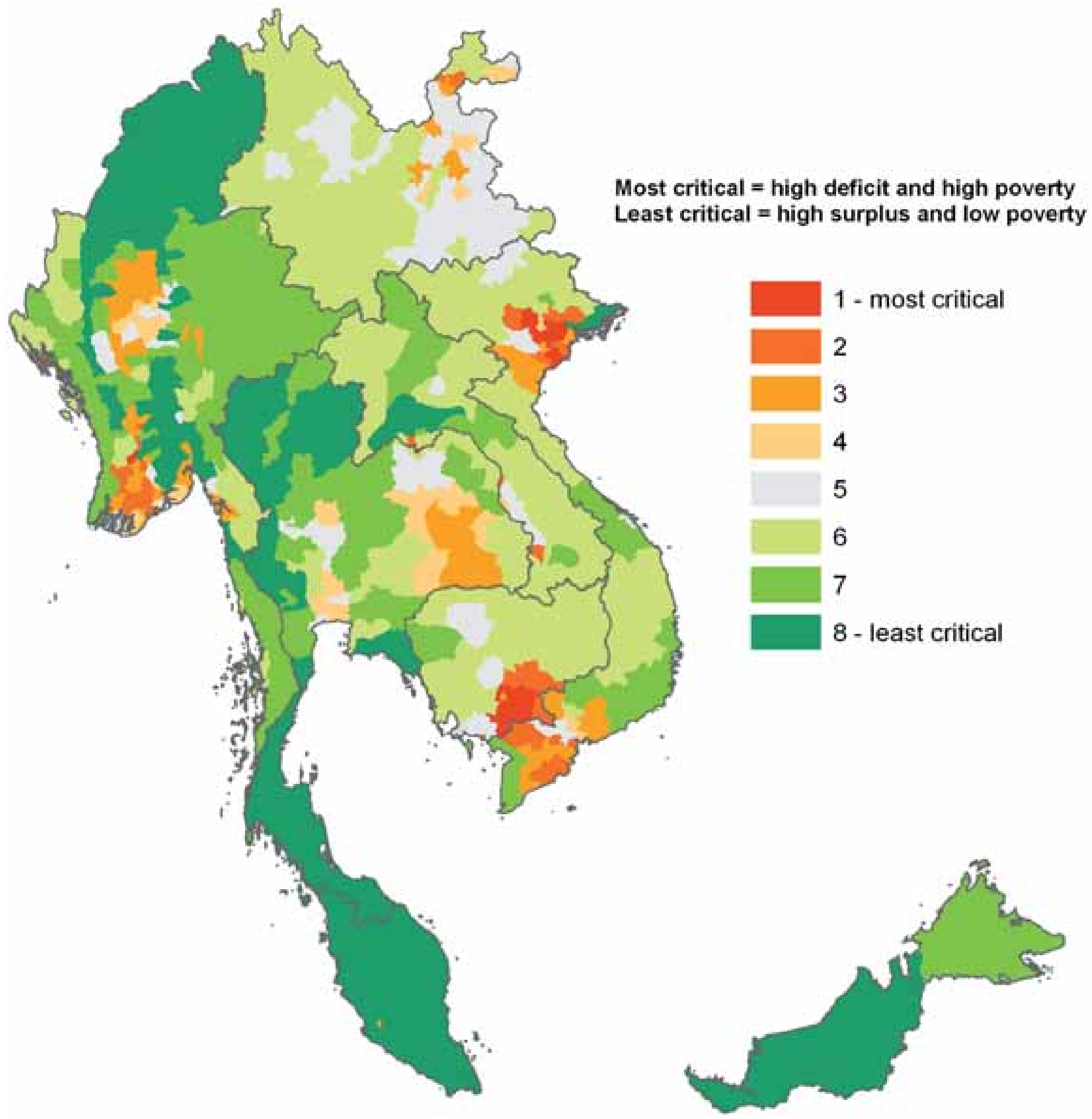
Map: asiacover_subnational.shp
Field: P_prox_sd

Malnutrition:
Stunting: Yunnan, Myanmar, Lao DPR, Vietnam, Cambodia
Underweight: Malaysia
Sources: FAO SDRN; Asia FIVIMS

Vulnerability based on multiple criteria (Thailand only)
Source: Asia FIVIMS

FIGURE 37

Critical poverty and woodfuel conditions in 2000. For description, see Section 2.2.4.4



Map: asiacover_subnational.shp
Field: combined_r

		Malnutrition or vulnerability					
		low	mid-low	mid-high	high	very high	critical
balance		1	2	3	4	5	6
critical deficit	1	4	3	2	1	1	1
very high deficit	2	4	3	2	1	1	1
high deficit	3	5	4	3	2	1	1
medium deficit	4	5	5	3	3	2	2
light deficit	5	6	5	4	3	3	3
balanced	6	6	6	5	4	4	4
light surplus	7	7	7	6	5	5	4
mid-low surplus	8	7	7	7	6	5	5
mid-high surplus	9	8	8	7	7	6	5
high surplus	10	8	8	8	7	6	6
very high surplus	11	8	8	8	7	7	6

3.2 RESULTS OF PHASE 2: 2015 SCENARIOS

The result of Phase 2 consists of a series of thematic maps, at 30 arc-sec resolution, depicting potential situations in 2015 in terms of woody biomass supply potentials, likely woodfuel consumption levels and the combination of these two to predict possible supply/demand balance scenarios.

3.2.1 2015 supply potential

The results of the supply 2015 module include maps of total woody biomass stocking and maps of estimated productivity levels potentially available for energy use after deductions reflecting access restrictions in protected areas, and after deduction of the woody biomass needed for non-energy uses predicted in 2015. In order to account for the high variability in reference data on stocking and mean annual increment, three situations were considered: a mean productivity variant (most likely condition); a minimum productivity variant; and a maximum productivity variant. The difference between the predicted supply potential in 2015 and the 2000 baseline, limited to the mean productivity variant, is also shown. Amidst a general decrease due to deforestation and forest degradation processes, the map shows an increase in Yunnan as result of extensive natural and man-made forestation processes, and a reduction in Malaysia due to the predicted high industrial roundwood production and hence the comparatively lower resource available for energy uses. Figure 38 shows the distribution of woody biomass potentially available for energy use in 2015 according to the mean, minimum and maximum productivity variants.

3.2.1 2015 demand scenarios

The woodfuel consumption in 2015 was predicted assuming two basic scenarios: one based on the consumption trends estimated by the GFPOS model (GFPOS-trend scenario), and another one based on the assumption that the 2000 per capita woodfuels consumptions in rural and urban areas remained basically unchanged, and change reflected population growth rates (BAU scenario). The differences between the two scenarios with respect to 2000 baseline consumption are shown in Figure 39. The main distinction is in the generalized increment of the BAU scenario as opposed to the generalized reduction for the GFPOS-trend scenario. The main exception is in Thailand, where the increment in charcoal consumption according to GFPOS trends offsets the reduction in fuelwood consumption, with a resulting increment in biomass consumption in rural areas. The results of the two scenarios, which present relatively small differences, are shown in Figure 40.

3.2.1 2015 supply/demand balance

Following the same approach as adopted in Phase 1 for mapping the 2000 situation, the analysis was conducted at pixel level, but not in isolation, by considering the values of the surrounding pixels. In this case, the pixels within a 5-pixel radius were used to compute pixel-level balances.

Data are presented by 30 arc-sec resolution and by sub-national administrative units:

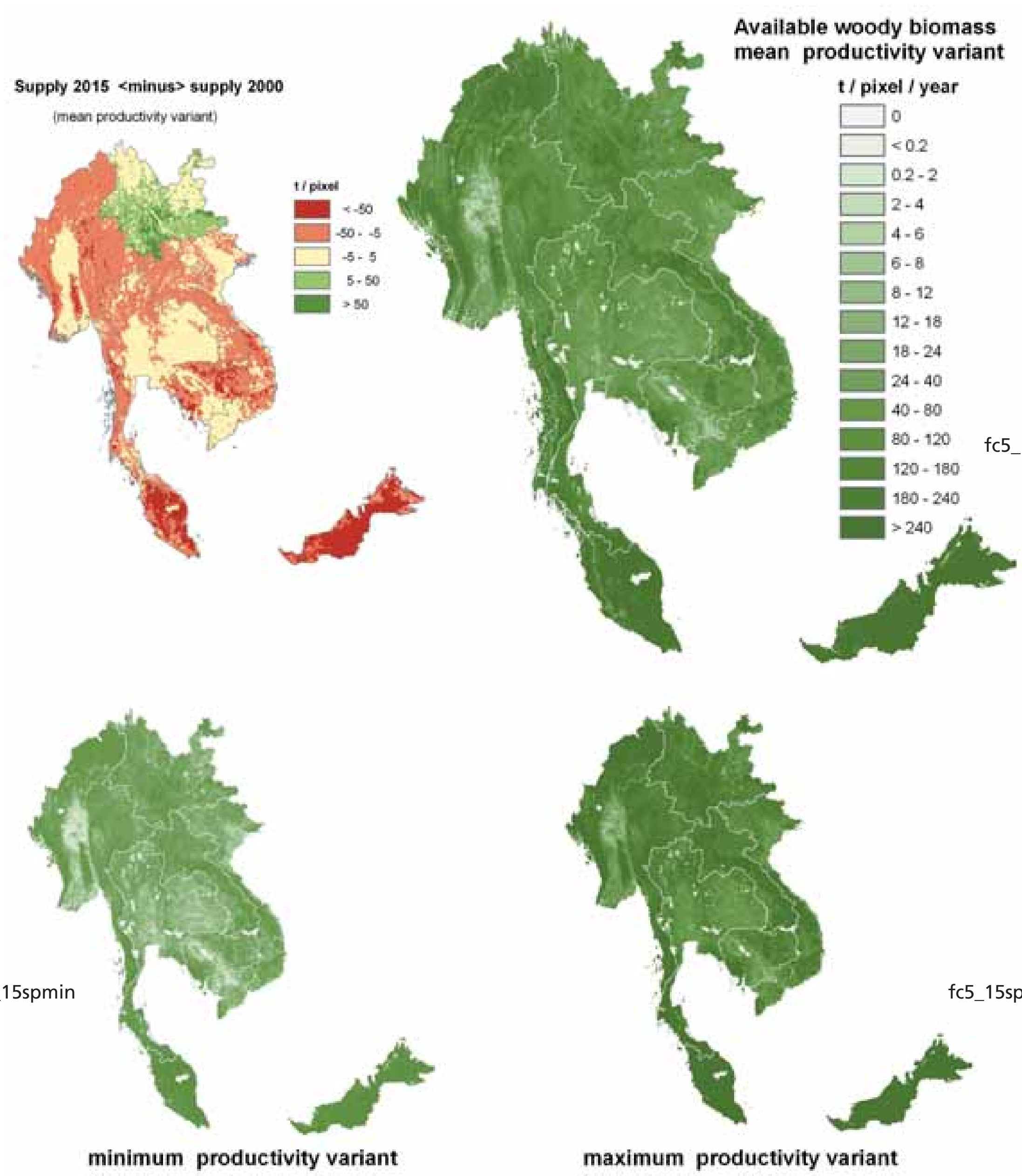
- **30 arc-sec maps.** The maps resulting from the combination of the GFPOS-trend consumption scenario and the three supply variants are shown in Figure 41. The maps resulting from the combination of the BAU consumption scenario and the three supply variants are shown in Figure 42. Figure 43 shows the evolution of the balance from the 2000 baseline according to the two scenarios, where the aspects of Yunnan and Malaysia described above are clearly visible.
- **Administrative-unit maps.** Sub-national aggregation of pixel-level balances was done for 655 sub-national administrative units. The maps resulting from the combination of the two consumption scenarios and the mean productivity variant are shown in Figure 44.

Population distribution by balance categories

Statistics reporting the distribution of population by different balance situations were computed after ranking the quantitative values into balance categories using the same thresholds as used for the 2000 analysis. The tables reporting populations (total and sparse rural only) by countries and by balance categories for all consumption scenarios and supply variants are given in Annex 9.

FIGURE 38

2015 supply potential. Predicted woody biomass availability for energy use in 2015 shown as mean, minimum and maximum productivity variants, and difference from 2000 baseline. For methodology, see Section 2.3.1



fc5_15sp

fc5_15spmin

fc5_15spmax

FIGURE 39

2015 demand scenarios. Changes in woodfuel consumption between 2000 and 2015. For methodology, see Section 2.3.2

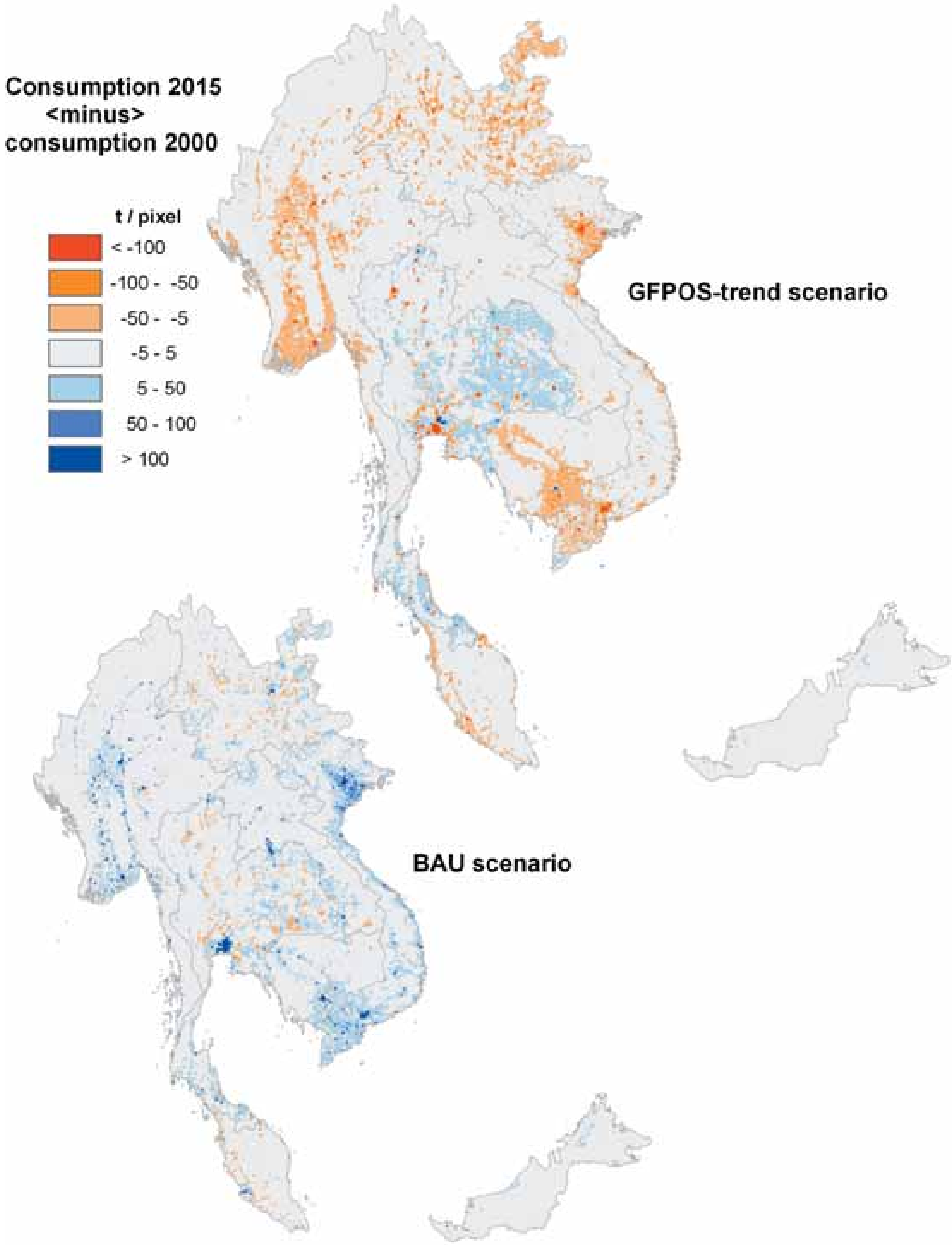


FIGURE 40

2015 demand scenarios. Predicted woodfuel consumption in 2015 for GFPOS-trend and BAU scenarios. For methodology, see Section 2.3.2

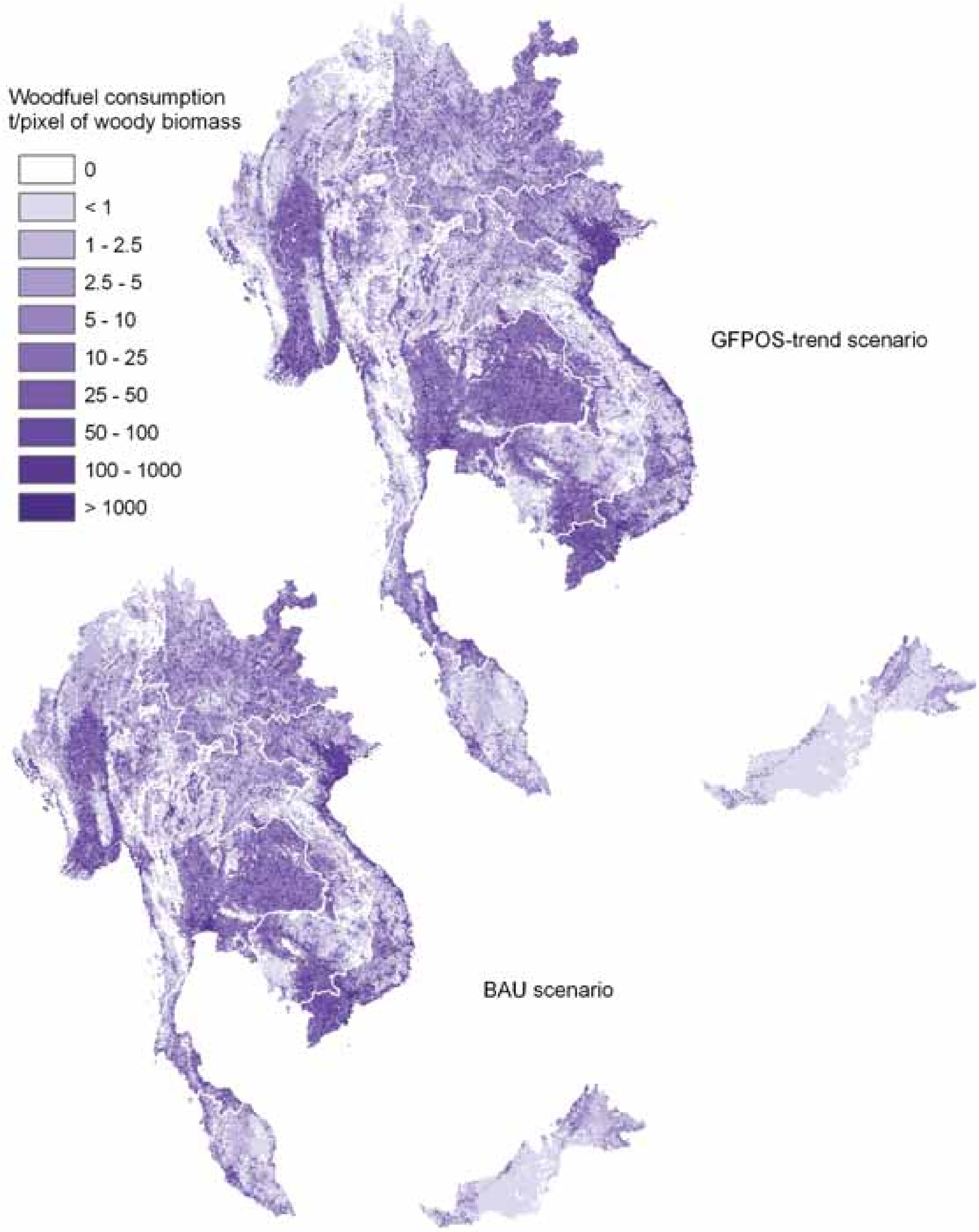


FIGURE 41

Pixel-level woodfuel supply/demand balance in 2015 for GFPOS-trend scenario – Regional level. Predicted supply/demand balance scenarios based on the 30 arc-sec data set. For methodology, see Section 2.3.3.1

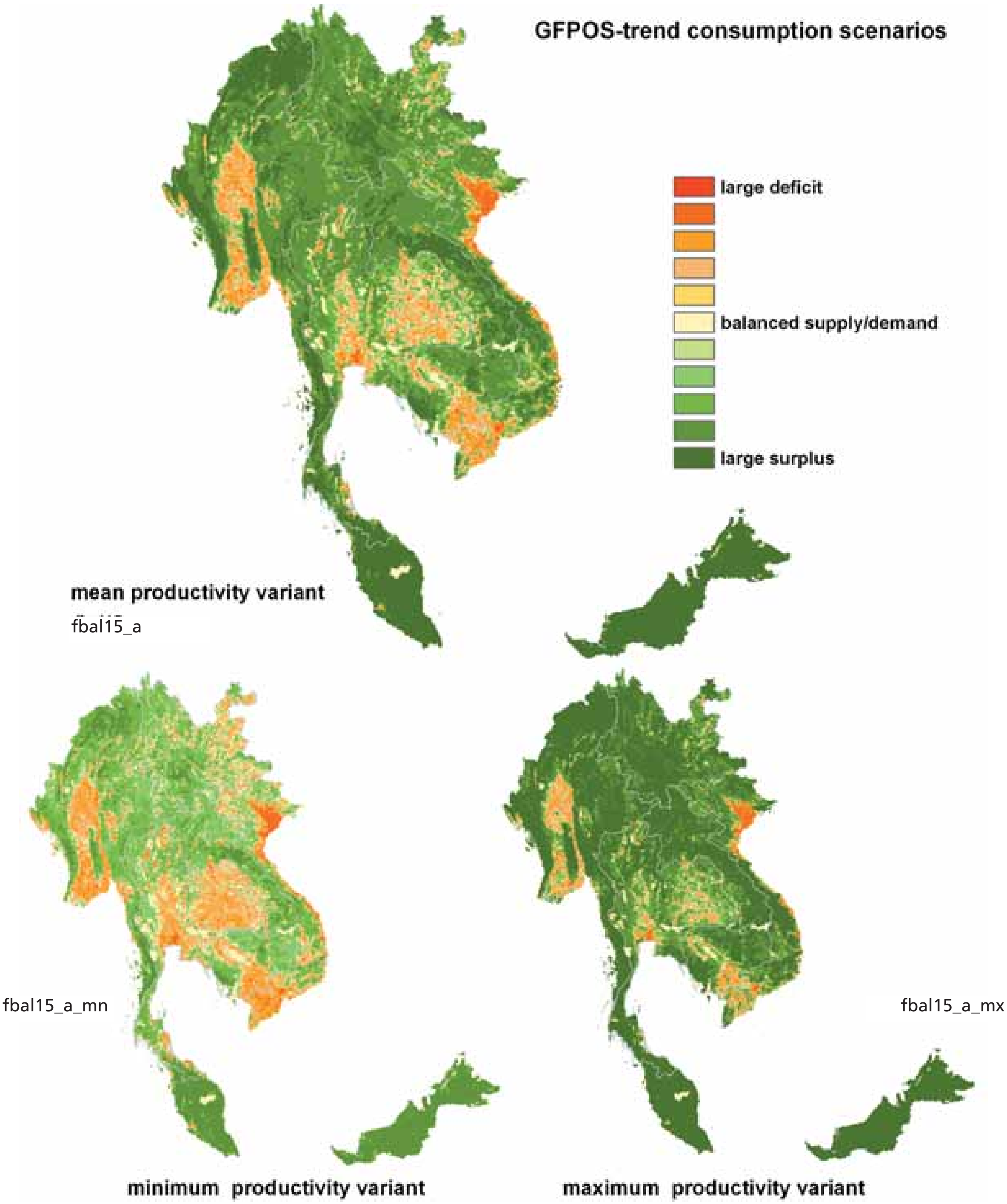


FIGURE 42

Pixel-level woodfuel supply/demand balance in 2015 for BAU scenario – Regional level. Predicted supply/demand balance scenarios based on the 30 arc-sec data set. For methodology, see Section 2.3.3.1

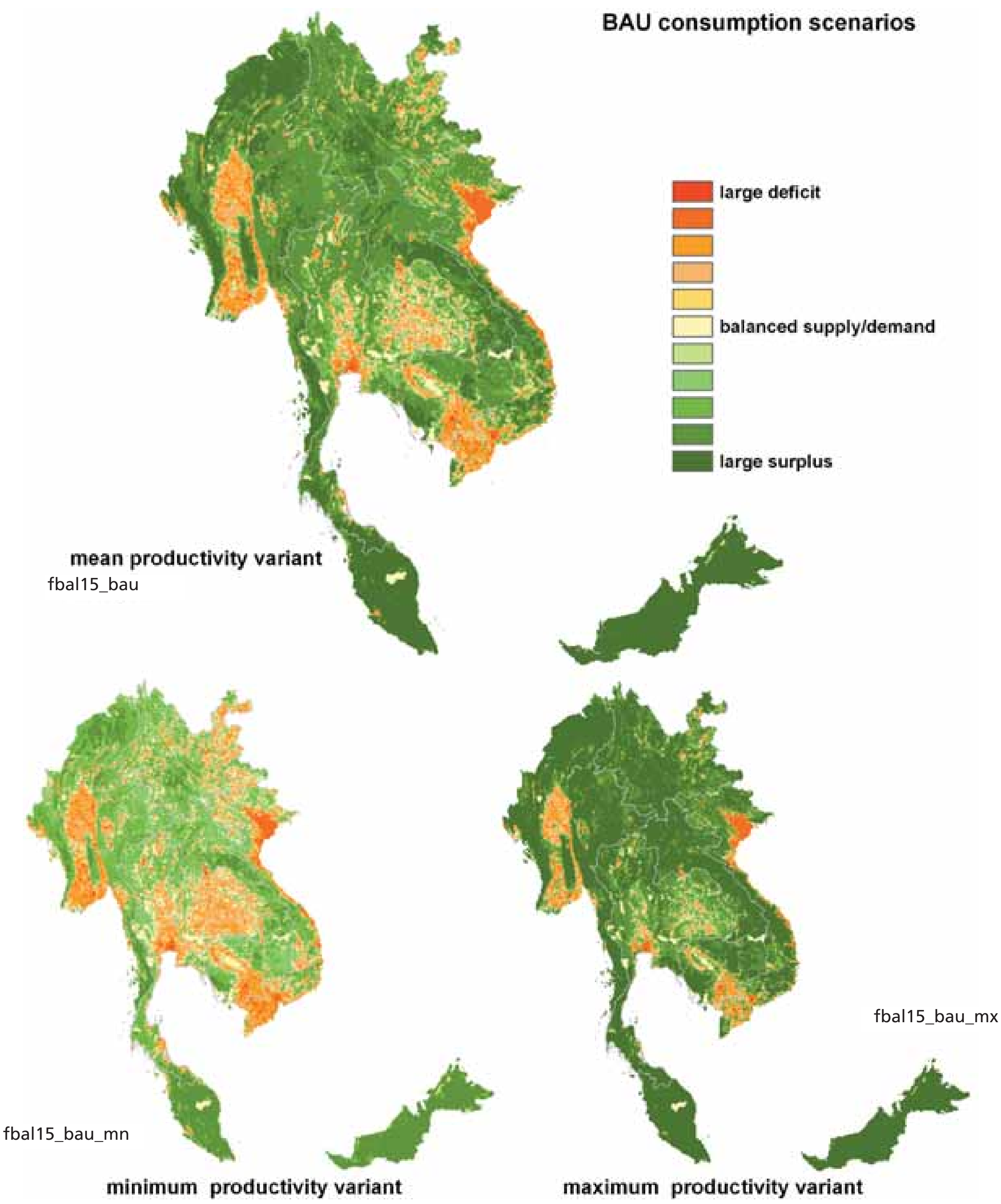


FIGURE 43

Evolution of supply/demand balance according to GFPOS-trend and BAU scenarios – Regional level. Predicted supply/demand balance scenarios based on the 30 arc-sec data set. For methodology, see Section 2.3.3.1

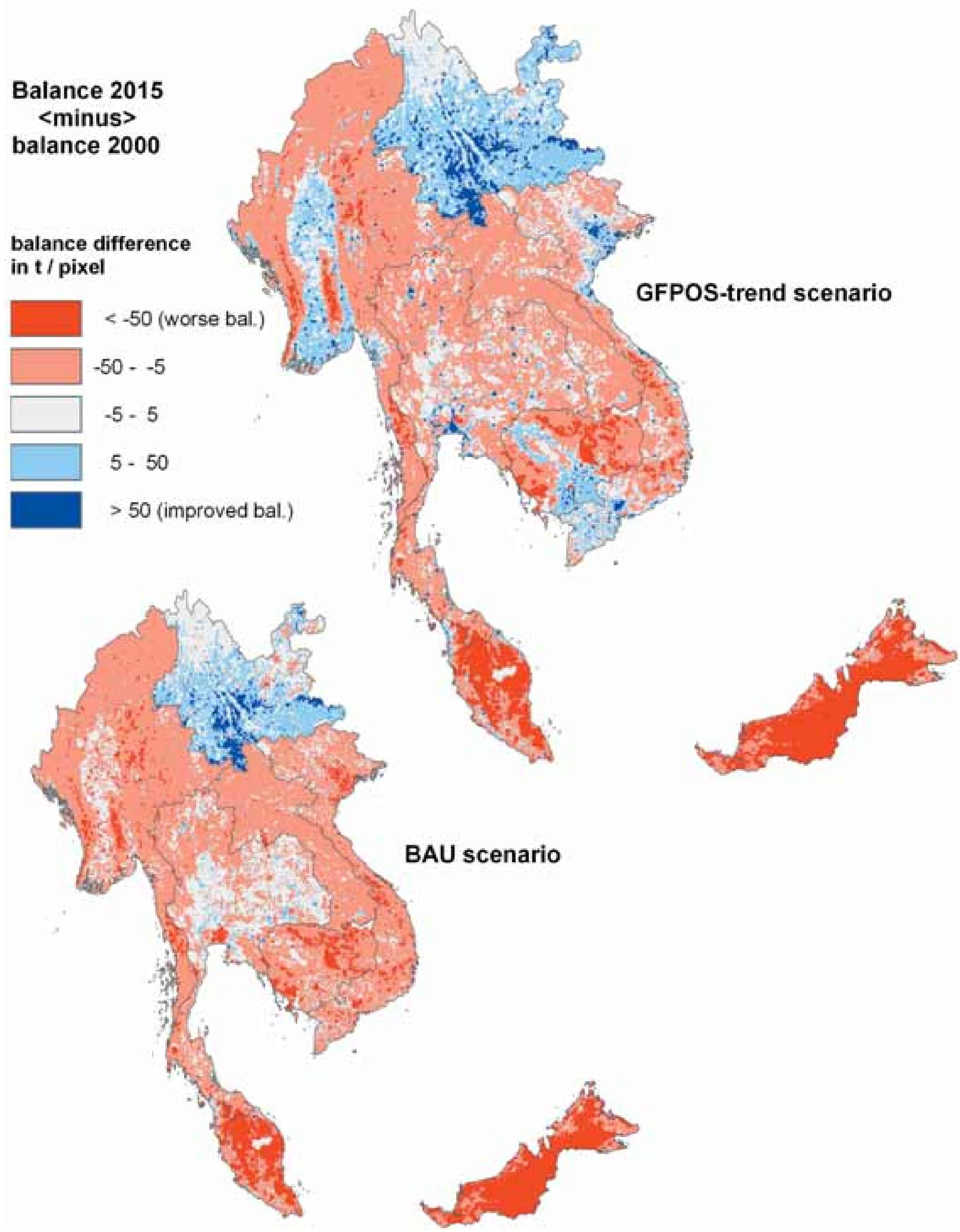
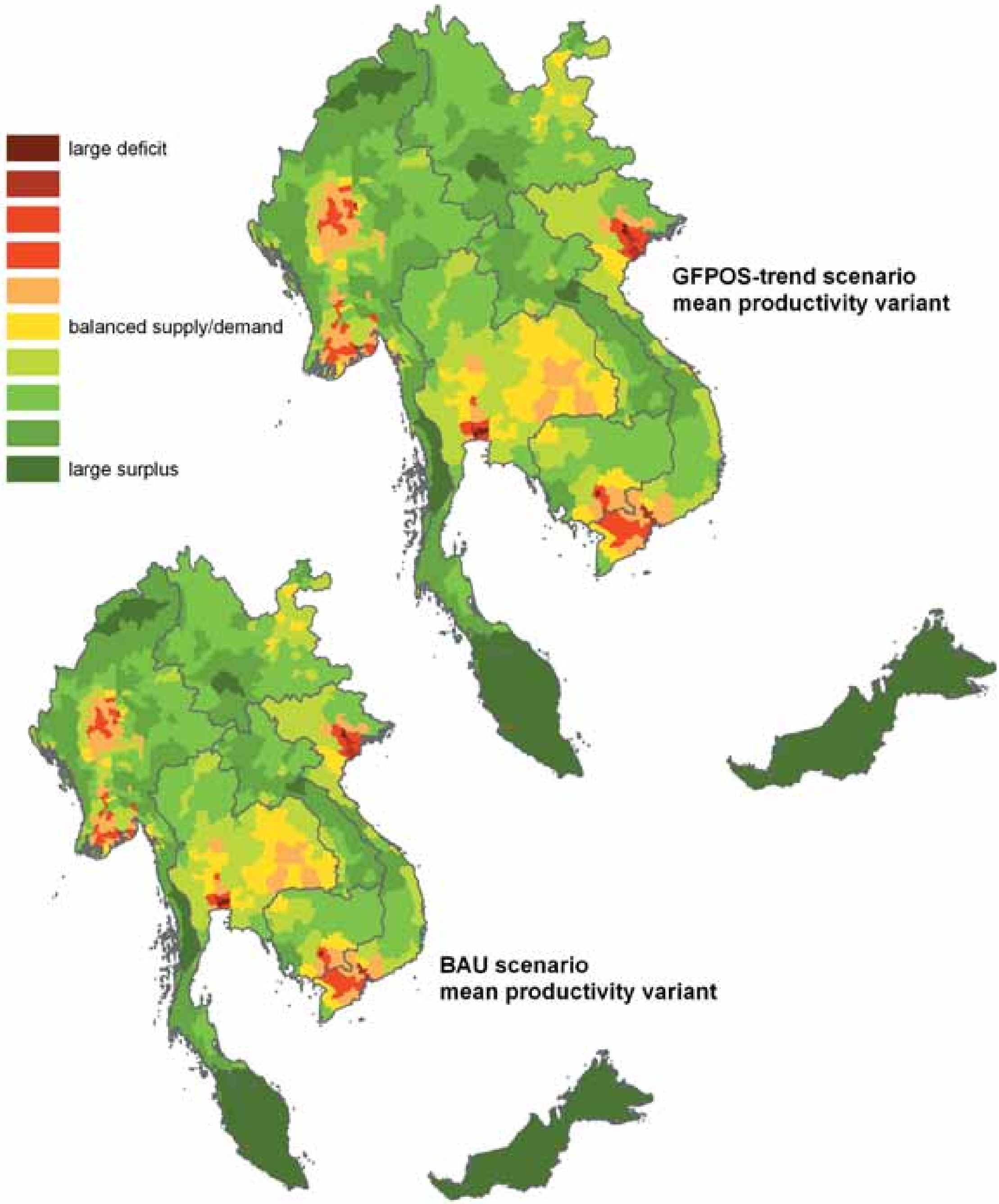


FIGURE 44

Projected 2015 supply/demand balance by sub-national administrative units for GFPOS-trend and BAU scenarios (mean productivity variant only). For methodology, see Section 2.3.3.2



CHAPTER 4

ANALYSIS OF RESULTS

4.1 SITUATION IN 2000

4.1.1 Woodfuel deficit and poverty

4.1.1.1 Deficit areas

At national aggregated level, all countries presented positive balances between the estimated total consumption and the fraction of the total national increment of woody biomass available for energy use. However, these balances have little meaning because they hide important local variations and also because the access limitations due to physical aspects have yet to be determined.

The areas that present a more or less marked deficit in the local demand/supply balance, calculated for 9 x 9 pixel windows, cover some 14 percent of the cumulative country areas. The occurrence and distribution of deficit areas within the countries is uneven, as shown in Table 4. There are countries where deficit areas are relevant, such as Viet Nam and Cambodia, and others where these areas appear marginal (Lao PDR, China) or negligible (Malaysia).

TABLE 4

Areas in different woodfuel supply/demand balance categories by country (data for 2000)

	Percent of countries' land area under different balance conditions						
	High deficit	Medium-high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Cambodia	7.9	6.5	5.7	7.1	7.0	8.0	57.8
Yunnan (Prov. China)	1.7	2.6	3.6	3.2	10.9	17.2	60.7
Lao PDR	0.8	0.8	1.3	1.1	3.1	5.7	87.3
Malaysia	0.2	0.1	0.1	1.3	0.5	0.6	97.2
Myanmar	6.1	5.7	4.6	2.0	3.7	4.6	73.3
Thailand	4.0	5.1	9.2	10.0	15.8	13.7	42.1
Viet Nam	14.8	6.3	6.3	3.9	8.7	12.2	47.8
Aggregated totals	**5.0**	**4.2**	**4.8**	**4.2**	**7.5**	**9.1**	**65.3**

The most detailed spatial distribution of the various balance categories can be observed in Figure 27 (subregional overview) and in Figures 28 to 34 (individual country maps).

Aggregating pixel values by sub-national administrative units helps in identifying priority action areas for government attention (Figure 35).

4.1.1.2 Affected populations

The percentages of rural populations living in the various supply/demand balance categories are shown in Table 5. It is obvious, and expected, that densely populated areas, such as urban areas and rural settlements, present conditions of high deficit, since the balance is calculated within a limited distance, yet it is rather striking that, overall, almost half of the "sparse" rural population live in deficit areas. In countries like Cambodia, Viet Nam and Myanmar, virtually two-thirds of the entire rural population live in areas that present deficit conditions, i.e. there is not sufficient woody biomass available within a 5 km radius of their home.

Over 35 percent of all "sparse" rural dwellers live in areas presenting marked deficit conditions (medium-high to high deficit). In absolute numbers, this corresponds to some 45 million people, of which 27 million people live in high deficit and 18 million in medium-high deficit conditions.

This does not always necessarily imply that the entire population in these areas faces a real energy deficiency. Rather, it means that either these populations can afford marketed woodfuels or alternative fuels, or they are likely to suffer subsistence energy shortages. In this perspective, the links with poverty become very close. In such a situation, and without specific intervention, the poorer segments of the population are likely to suffer serious woodfuel shortages and consequent negative impacts on their nutrition and health conditions.

TABLE 5

Rural populations living in different woodfuel supply/demand balance categories in 2000

	Percentage of rural population (density below 2000 inh/km²)						
	High deficit	**Medium-high deficit**	**Medium-low deficit**	**Balanced**	**Medium-low surplus**	**Medium-high surplus**	**High surplus**
Cambodia	31.2	22.9	14.1	5.5	8.5	6.0	11.8
Yunnan (Prov. China)	5.8	7.9	9.0	6.7	17.2	18.4	35.0
Lao PDR	4.1	5.5	8.6	5.7	11.7	12.6	51.7
Malaysia	0.5	0.5	0.6	0.8	1.6	2.8	93.2
Myanmar	32.1	22.6	12.4	4.0	6.4	4.9	17.4
Thailand	12.3	14.7	19.6	11.2	17.2	9.8	15.2
Viet Nam	40.3	13.5	10.9	5.1	9.2	7.8	13.1
Total rural population	**21.4**	**14.3**	**12.8**	**6.6**	**11.7**	**9.2**	**24.1**

4.1.1.3 Woodfuel balance and poverty

The integration of supply/demand balance with poverty-related malnutrition indicators (Figures 35 to 37) permitted stratification of the population of the countries of the subregion into categories determined by the combination of the two factors. Results of this analysis, summarized in Table 6, showed that approximately one-quarter of the entire population of the subregion, i.e. some 66 million people, live concomitant conditions of poverty and woodfuel deficit (red and orange areas in the table), and almost one person in ten, i.e. some 25 million, live in conditions that can be considered very serious due to the interaction of the worse conditions under both perspectives (red area).

TABLE 6

SE Asia population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1	3.3	1.8					5.1	"very serious conditions" total 9.4
very high deficit	2	2.7	1.0	0.8	3.8	0.2		8.5	
high deficit	3	0.5	1.8	4.1	4.1	0.9	0.4	11.7	
medium deficit	4		1.4	2.5	2.3	1.9	0.5	8.6	"serious" total 15.3
light deficit	5	0.3	0.1	0.2	0.5	1.3	1.2	3.6	
balanced	6	0.5	0.6	0.8	1.7	0.2	0.4	4.2	
light surplus	7		0.6	0.1	0.7	0.2	0.5	2.2	"serious"+ "very serious" = 24.7
	8	0.1	1.5	0.5	2.4	0.6	2.1	7.2	
	9	0.2	0.7	2.3	2.2	5.5	5.0	15.9	
	10		2.7	5.0	4.4	2.4	8.4	22.8	
very high surplus	11		0.7	7.3	0.2	1.5	0.4	10.1	
		7.6	**12.9**	**23.6**	**22.3**	**14.8**	**18.9**	**100.0**	

The national-level analyses revealed considerable differences among the countries, as shown in the country-level tables in Annex 6, and summarized in Table 7 below.

Following the same definitions applied in Table 6, Cambodia and Viet Nam are the countries that appeared more vulnerable, with approximately one-quarter of the entire population in the "red" zone, and almost as many in the "orange" zone. Myanmar's situation appeared less critical, but nevertheless with a sizeable share of the population in deficit areas. All other countries presented only pockets of poverty and deficit conditions, either due to better nutritional parameters (Thailand) or biomass resources (Lao PDR, Malaysia, Yunnan).

TABLE 7

Country-level summary of population with malnutrition symptoms living in woodfuel deficit areas in 2000

	Population with critical malnutrition and high (percent) (A)	Population in less critical deficit and poverty areas (percent) (B)	Population presenting malnutrition symptoms living in woodfuel deficit areas (A+B)
Cambodia	25.3	18.7	44.0
Yunnan (China)		9.5	9.5
Lao PDR	6.8	5.3	12.1
Malaysia		6.8	6.8
Myanmar	7.9	20.2	28.0
Thailand		9.1	9.1
Viet Nam	22.8	23.0	45.8
Aggregated mean	**9.4**	**15.4**	**24.7**

4.2 WOOD ENERGY SCENARIOS IN 2015

4.2.1 National level balance

At aggregated national level, and assuming mean and maximum productivity variants, all countries present positive supply/demand balance in 2015, as shown in Annex 9.

However, it is important to emphasize that "supply" refers to "potentially available" quantities, since physical accessibility of biomass resources was not analysed in this study. The true accessible woody biomass for energy use is certainly less than the nominally available quantity, and therefore the surplus here estimated is more apparent than real.

The balance becomes negative or very close to zero in Cambodia, Thailand and Viet Nam for both consumption scenarios if minimum productivity levels are assumed. However, such low levels of productivity are possible at local levels, but unlikely as a general condition.

These aspects further support the consideration that wood energy systems are highly location specific and that aggregated values generally fail to convey the true situation of a country, which would include both surplus and deficit conditions that call for different policies and management solutions.

4.2.2 Main deficit areas and affected population in 2015

4.2.2.1 Deficit areas

The percent of country areas in different woodfuel balance categories for all consumption and supply scenarios are reported in Annex 9.

According to the most likely scenario, which assumes a general reduction in fuelwood consumption and a relative increase in charcoal consumption (GFPOS-trend scenario), and applying the mean productivity variant, some 13.9 percent of the subregional area will present a deficit condition in 2015, a share that is practically equal to that estimated for 2000 (14 percent). The only change appears to be an increase in the "moderate" categories (medium-level deficit and surplus) and a small decrease in the extreme categories (high deficit and surplus).

If a BAU scenario is considered, in which the per capita consumption is assumed constant, the overall deficit area increases to some 15.1 percent, with a significant increase in mainly the high-deficit category.

4.1.2.2 Populations by supply/demand balance categories in 2015

The percent of total and sparse rural populations living in different balance conditions for all consumption and supply scenarios are reported in Annex 9.

In the most likely scenario (GFPOS-trend + mean productivity), 67 percent of the population in the sub region, i.e. over 215 million people, will live in areas presenting deficit conditions. This is not as dramatic as it may seem. In fact, this value includes urban populations, among whom woodfuel use is less common, and includes consumers that purchase woodfuels from the market and therefore do not depend on locally available resources.

More significant for the scope of the study is the status of rural populations, and especially the poorest segments, for which local resources are the main source of subsistence energy.

TABLE 8

Sparse rural population (<2000 inh/km²) living in different woodfuel supply/demand balance conditions in 2015 (percent; GFPOS-trend consumption scenario; mean productivity)

	Percent of rural population (density <2000 inh/km²)						
	High deficit	**Medium-high deficit**	**Medium-low deficit**	**Balanced**	**Medium-low surplus**	**Medium-high surplus**	**High surplus**
Cambodia	16.7	26.4	20.0	8.2	11.6	7.9	9.2
Yunnan (Prov. China)	1.3	4.7	6.1	4.7	13.9	16.9	52.4
Lao PDR	4.2	5.5	8.5	5.5	12.3	13.8	50.3
Malaysia	0.1	0.2	0.2	0.6	0.9	1.7	96.3
Myanmar	21.9	26.4	16.2	4.8	7.7	5.9	17.0
Thailand	9.0	18.8	21.7	10.7	16.1	9.5	14.2
Viet Nam	35.6	14.4	11.9	5.7	10.5	8.9	13.0
Total rural population	**15.8**	**16.0**	**14.1**	**6.5**	**11.6**	**9.5**	**26.5**

According to the most likely scenario, 45.9 percent of sparse rural population, or 56.8 million, will live in deficit conditions, compared with the 48.5 percent (61 million) of 2000. Out of this population, 31.8 percent (39.4 million) will face acute deficiencies (high to medium-high deficit areas). Here also, there is a small improvement with respect to the situation in 2000, where the acute-deficiency group was 35.7 percent (45 million) of rural dwellers.

In the BAU scenario, which assumes constant per capita consumption rates, the sparse rural populations living in deficit areas will be very close to 2000 estimates, with 47.9 percent (59.3 million) of people living in deficit areas and 35.6 percent (44 million) of people facing acute scarcity.

As mentioned before, these figures alone do not identify persons actually facing subsistence energy shortage. In fact, only the fraction that cannot afford commercial fuels, and therefore the poorest segments of the society, are likely to suffer directly from the lack of sufficient and locally accessible woody biomass. At the same time, alongside the rural poor, subsistence energy supply remains a problem for the poorest dwellers of booming suburbs and rural settlements, who can not afford commercial energy.

It is also estimated that a consistent fraction of the rural population will live in areas of high to medium-high surplus: 36 percent for the GFPOS-trend and 34 percent for the BAU scenarios. In these areas, the untapped (or unmanaged) sustainable production potential represents an accessible resource for poverty alleviation and socio-economic development. Such resources could be rationally managed through efficient bioenergy systems to create energy for development, income and employment in local, and usually decentralized, communities. A strengthened bioenergy sector would reduce the dependency of the countries on oil imports and would reduce greenhouse gas (GHG) emissions derived from non-renewable fuels.

The combined analysis of woodfuel balance conditions and poverty indicators, which could be done for 2000, could not be done with the 2015 dataset due to lack of projected and spatialized socio-economic indicators related to poverty.

CHAPTER 5

CONCLUSIONS

5.1 CONTRIBUTION TO POLICY FORMULATION

Relevance of wood energy

The present study confirmed the relevance of the wood energy sector in the countries of continental Southeast Asia, although with marked differences from country to country. Consumption and supply conditions projected to 2015 indicated that woodfuels would remain important, although with some changes due to a reduction in the consumption of fuelwood and an increase in the consumption of charcoal in a context dominated by marked processes of urbanization.

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

With respect to forestry and energy planning at national level, the information produced in this study still lacks details on physical accessibility to wood resources, and other specific national aspects. Nonetheless, the presented information represents a first step in this direction and allows segmentation of countries into zones characterized by different biomass stocking, consumption levels and local supply/demand balance conditions in relation to poverty.

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

- woodfuel production can become a primary forest management objective and an important driver for sustainable rural development; or, to the contrary, where
- exploitation patterns driven by woodfuel demand will go far beyond the regeneration capacity of natural formations, calling for alternative action in collaboration with energy and agriculture stakeholders and institutions.

However, deficit conditions should not be interpreted as a direct cause of deforestation, as it was sometimes done in the past (FAO, 1983), because it is now clear that such direct cause–effect mechanisms are rare. The research conducted in the last decade, including comprehensive field studies and projects, has shown that woodfuel demand and supply patterns are very site specific and that there are mechanisms of adaptation that divert the pressure on wood resources, at least for larger surfaces (Leach and Mearns, 1988; Arnold *et al.*, 2003; Mahapatra and Mitchell, 1999; FAO/RWEDP, 1997a)

It is, however, legitimate to believe that these pronounced deficit conditions may imply (i) the use of non-sustainable sources, such as land clearings for conversions to permanent agriculture, or shifting cultivations that may temporarily release large amounts of wood; and (ii) potentially non-sustainable pressure on more accessible natural formations, with their inevitable progressive degradation. Another probable effect may be a widespread shift to lower-grade biomass fuels, such as straw, residues and cow dung. All such effects pose further burdens on the environment, on agricultural productivity and, inevitably, on the poorest segments of the society that depend on these dwindling resources.

For energy agencies, wood energy maps can support the formulation of policies and strategies. Promotion of modern wood and bioenergy systems, or, in contrast, subsidizing alternative fuels could be optimized and implemented in synergy with the forestal and agricultural sectors.

In the context of poverty alleviation, the maps combining woodfuel supply/demand conditions with poverty indicators prepared for the 2000 baseline situation on the basis of available socio-economic and nutritional parameters, support the better definition of target groups and priority areas of intervention. Missing spatially-discreet poverty indicators projected to year 2015, the scenarios developed in this study may be used themselves as indicators of access, or not, to affordable subsistence energy, to be associated with other parameters.

5.2 A NEW DIMENSION IN THE PROCESS OF MAPPING EXTREME POVERTY

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

In view of their implications for poor households' subsistence energy supply, the definition of deficit and surplus in a local context acquires particular relevance in the efforts to map poverty and extreme poverty, a key item in the struggle to achieve MDG 1 (eradicate extreme poverty and hunger) and MDG 7 (ensure environmental sustainability).

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

Energy-related indicators are limited to access/not access to electricity or other "conventional" energy sources for which formal statistics exist. This, from an energy perspective, inevitably leads to grouping all populations outside the grid as a single category, while there are conditions such as access or not access to "traditional" energy sources that can strongly influence the living conditions of poor households and the pressure on surrounding environments.

As pointed out in FAO (2003b), "Environmental degradation contributes to poverty through worsened health and by constraining the productivity of those resources on which the poor rely. Moreover, poverty restricts the poor to acting in ways that harm the environment. Poverty is often concentrated in environmentally fragile ecological zones where communities face and contribute to different kinds of environmental degradation."

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

BOX 2

POVERTY AND FOOD INSECURITY INDICATORS

Poverty categories

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

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

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

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

Food-insecurity categories

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

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

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

Source: FAO, 2003a.

The results of the study, summarized in the foregoing section, indicate that, in 2000, a large fraction of the population of the region lived in conditions of local supply/demand deficit and that the situation in 2015 would probably not improve significantly. More specifically, the study allowed areas to be identified within countries where woodfuel deficit conditions, in 2000, were coupled with high malnutrition. In these areas, the woodfuel deficit would be likely to aggravate malnutrition and health problems.

In contrast, rural communities living in areas of high surplus, equally displayed by the maps, might benefit from the untapped potential productivity for the generation of energy for development, income and employment.

The mapping of these areas represents a significant contribution to the challenging task of mapping poverty and food insecurity.

5.3 DATA QUALITY AND ANALYTICAL CONSTRAINTS

5.3.1 2000 baseline

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

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

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

- **Data quality.** Reference data, such as the total woodfuel consumption for a given country and the urban/rural consumption ratios, are estimates rather than objective measurements. The estimation processes behind such estimates are poorly documented or, more often, totally unknown (FAO/RWEDP, 1997a; FAO, 1997b, 2005a). The estimation of woody biomass stocking and productivity was based on regionally consistent, but rather coarse, land cover maps whose accuracy at local level is far from optimal, and on field survey references that provided only indicative values for most non-forest classes. This means that the maps produced in this study cannot be more than "best approximations" based on available data, and therefore to be used for the definition of priority zoning rather than for quantitative calculations.
- **Error margin.** It is not possible to estimate the error associated with the results of the study, since the quantitative results were not based on a uniform statistical approach but rather on a mosaic of extremely heterogeneous data sources, and also since no analysis of map accuracy was undertaken. A rough idea of the possible margin of error associated with biomass stocking and productivity, for instance, might be derived from the range of values found in the literature. The values for stocking ranged around the mean, with a factor of between 0.57 and 1.3, and a similar factor range was found for the mean annual increment (0.5 to 1.5 of the mean). Combining the two factors, it is possible to find locations where the actual productivity is as low as 0.3, or as much as 1.8, times the mapped mean. However, as can be observed from the maps shown in Figure 41, where the woodfuel supply/demand balance is mapped according to all three productivity variants (mean, minimum and maximum), the different levels of stocking and productivity affect the extent but not the locations of the main deficit areas. This tends to confirm that, as may be explained by fuzzy logic, the resulting maps acquire a reliability of their own thanks to the concurrence of so many factors and in spite of the weakness of individual quantitative parameters. Field action may therefore be implemented with good confidence within the core priority areas, while additional data may be collected in order to build up more reliable quantitative estimates where the situation is less clear and investment appears justified.

- **Spatial analysis.** The integration of supply and demand parameters and balance calculation were done with reference to an area of approximately 9 km x 9 km around each pixel. They are meaningful for locally constrained production/consumption patterns, but they do not account for imported woodfuels that may, in fact, be transported from far distances, especially in the case of charcoal. However, the area considered for supply/demand balance is consistent with the gathering horizon of rural consumers that cannot afford marketed woodfuels or that live far from market centres.
- **Sub-national aggregation.** Pixel-level parameters were aggregated at sub-national level to yield a total of 655 sub-national administrative units. The aggregation by territorial units provided balance results that go beyond the fuelwood gatherer horizon and that account for the consumption and supply potential of the entire unit. In addition, the sub-national data set allows a direct combination with socio-economic aspects that are always reported by territorial units. In this study, woodfuel supply/demand balance results were combined with best available poverty indicators in order to highlight the provinces or districts more vulnerable from a subsistence energy perspective.
- **Poverty indicators.** Much work needs to be done for mapping poverty at an acceptable spatial and thematic resolution. For the present study, only nutritional indicators were available (mainly incidence of stunt growth in children below 5 years old), except for Thailand, where a more complex vulnerability index had been developed.
- **Wood energy and poverty.** The present study can contribute significantly to the evaluation of poverty areas by adding a new indicator related to subsistence energy. In this perspective, the information available on malnutrition and vulnerability allowed a first-level identification of the areas that, presenting both woodfuel deficit and poverty conditions, are likely to suffer from shortages of subsistence energy.

At the same time, given that woodfuels are the “staple” fuels of the poorest segments of the population, poverty indicators may help to reinforce woodfuel balance analyses and the screening of priority areas. It may be assumed, in fact, that deficit conditions are truly so in the areas where household consumptions are high (poor areas), while in relatively richer areas such conditions may be more apparent than real, because marketed woodfuels transported from distant areas, together with other fuels, are accessible alternatives.

5.3.2 2015 Scenario development

Existing information on land cover changes, predictions of population distribution in 2015 and modelling studies of likely trends in woodfuel consumption induced the perception that scenario development of woodfuel consumption and production potential was possible and justified in the context of MDG efforts. However, given the limitations in the reference data sources used for the creation of the 2000 baseline, the development of future wood energy scenarios could only achieve an additional, and inevitably coarser, level of approximation.

One important element of the main information ingredients used in scenario development that may help to understand the additional level of approximation that this analysis implied, is the inevitable “smoothing” of predicted trends. The prediction of 2015 supply and demand situations was based mainly on assumed country-level land cover changes, population growth and woodfuel consumption projections. Not being able to predict “where” such changes will take place, the values were distributed somehow uniformly over the entire country area. Concerning forest areas, for instance, the probability of change was distributed evenly within buffer zones determined by distance from forest edge and high consumption sites. This process produced “smoothed” maps that cannot reflect the true site-specific character of wood energy systems and their dynamics.

It is hoped, however, that thanks to the relatively high resolution of some layers, especially concerning population distribution, the results will support the identification of areas and of segments of the population that deserve highest attention in forthcoming MDG activities, such as the areas where further data collection would make most sense in the context of poverty alleviation, health improvement and woodfuel and community forestry programmes.

CHAPTER 6

FOLLOW-UP RECOMMENDATIONS

6.1 NATIONAL WISDOM ANALYSES

Effective action towards the establishment of sustainable wood energy systems and poverty alleviation requires a field-based approach and solid institutional synergies. It is therefore recommended that WISDOM analyses be undertaken at national level in collaboration with forestry, energy and rural development agencies and other stakeholders.

The result of the present study can provide valuable input for donors and policy-makers in the identification of priority areas and countries where such WISDOM analyses are urgently needed.

6.2 IMPROVING SUBREGIONAL ESTIMATES AND SCENARIO DEVELOPMENT

In consideration of the high relevance that this type of study has in the framework of the MDG, and specifically MDG 1 (eradication of hunger and poverty) and MDG 7 (ensure environmental sustainability), it is recommended that the detailed analysis of the interrelations between poverty, environment degradation and areas with intensive fuelwood utilization be continued and improved.

However, the analysis is severely constrained by the scarcity of spatially-discrete parameters and indicators related to poverty. For the present study, only nutritional indicators were available, except for Thailand, where a more complex vulnerability index had been developed. It is therefore strongly recommended that resources be invested in the collection and mapping of the poverty-related parameters, including economic aspects such as household income levels and purchasing capacity, that are essential for defining the true impact of biomass scarcity on subsistence energy supply.

Considering the quality of reference data available and the need to expand the scope of the analysis in relation to MDG objectives, it is recommended that the following activities be undertaken:

- Improve supply scenarios at subregional level:
  - Improve the estimation of woody biomass resources on the basis of national land cover maps and additional field data collection. Particular attention should be given to forest and agricultural plantations and to non-forest land uses that are important sources of woodfuels, yet whose productive capacities are scarcely documented.
  - Undertake GIS-based studies based on transportation networks and terrain characteristics in order to estimate physical accessibility of woody biomass supplies.
  - Assess and map the production and use of forest and wood industries residues.
- Improve demand scenarios at subregional level:
  - Update information on fuelwood and charcoal consumption in rural, rural settlements and urban areas, and analyse and verify the consumption trends assumed by the GFPOS model in different sectors and areas. *Inter alia*, an element of great interest will be the influence of high oil prices on fuel substitution rates.

- Analyse interrelations with poverty zoning, based on other socio-economic parameters, and define priority areas for action within the 2015 time frame for sustainable wood energy systems and poverty alleviation.
- In critical areas, measure and evaluate the interaction among woodfuel supplies, poverty levels, health and nutritional conditions.
- Take decisive multisectoral action (investigation and mitigation) in critical areas without awaiting further study results, since many of the results already available are sufficient to identify urgent needs.

In addition, this study provides a starting point for expanding work in the agro-energy sector, which can benefit from the approach, the GIS analytical environment, the additional thematic layers and the nexus with forestry, energy and poverty alleviation issues.

It is therefore recommended that the WISDOM analytical framework be systematically enhanced to incorporate additional data and information on other biofuels, including energy crops and agricultural and livestock residues, in order to develop and extend the applications to reflect the broader bioenergy sector.

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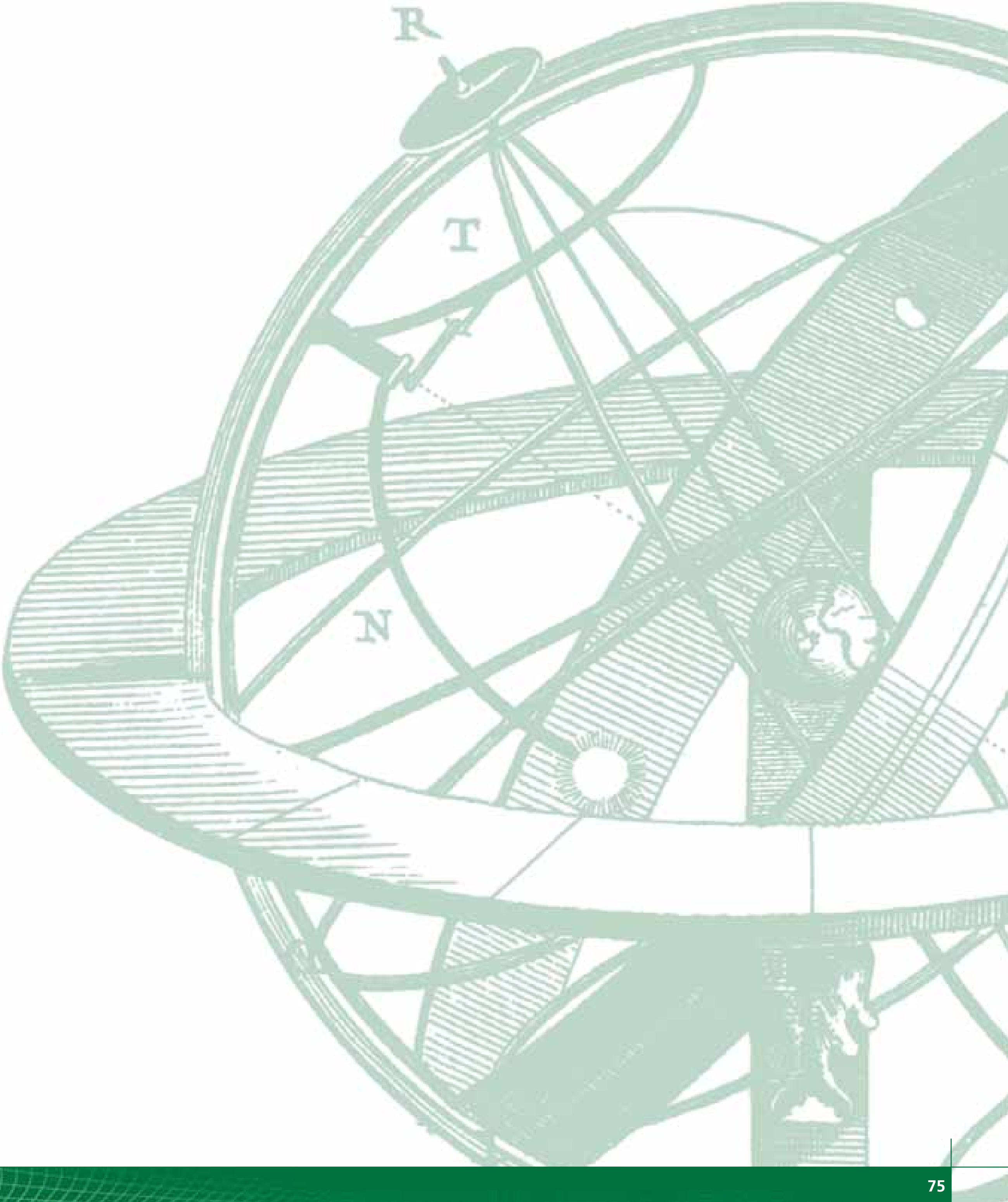
ANNEX 1

DEFINITIONS AND CONVERSION FACTORS



DEFINITIONS OF MAIN TERMS

Definitions are taken from the Unified Bioenergy Terminology (UBET) (FAO, 2004c).

Wood energy systems =	All the (steps and/or) unit processes and operations involved for the production, preparation, transportation, marketing, trade and conversion of woodfuels into energy.
Woodfuel =	All types of biofuels originating directly or indirectly from woody biomass. This category includes fuelwood, charcoal and black liquor (the latter being not significant in the context of this study since its cycle is entirely within the paper industry)
Fuelwood =	Woodfuel where the original composition of the wood is preserved. This category includes wood in the raw and also residues from wood processing industries.
Charcoal =	Solid residue derived from carbonization, distillation, pyrolysis and torrefaction of fuelwood.

Basic parameters and conversion factors:

Wood – Net Calorific Value (30 percent moisture content, dry basis)	13.8	MJ/kg
Charcoal – Net Calorific Value (5 percent moisture content, dry basis)	30.8	MJ/kg
Charcoal/fuelwood	165	kg charcoal/m^3
Wood density (air-dry)	725	kg/m^3
Wood density (oven-dry)	593	kg/m^3

See also main factors applied and relevant references in Annex 2.

ANNEX 2

SUPPLY MODULE. WOODY BIOMASS STOCKING, PRODUCTIVITY AND REFERENCES

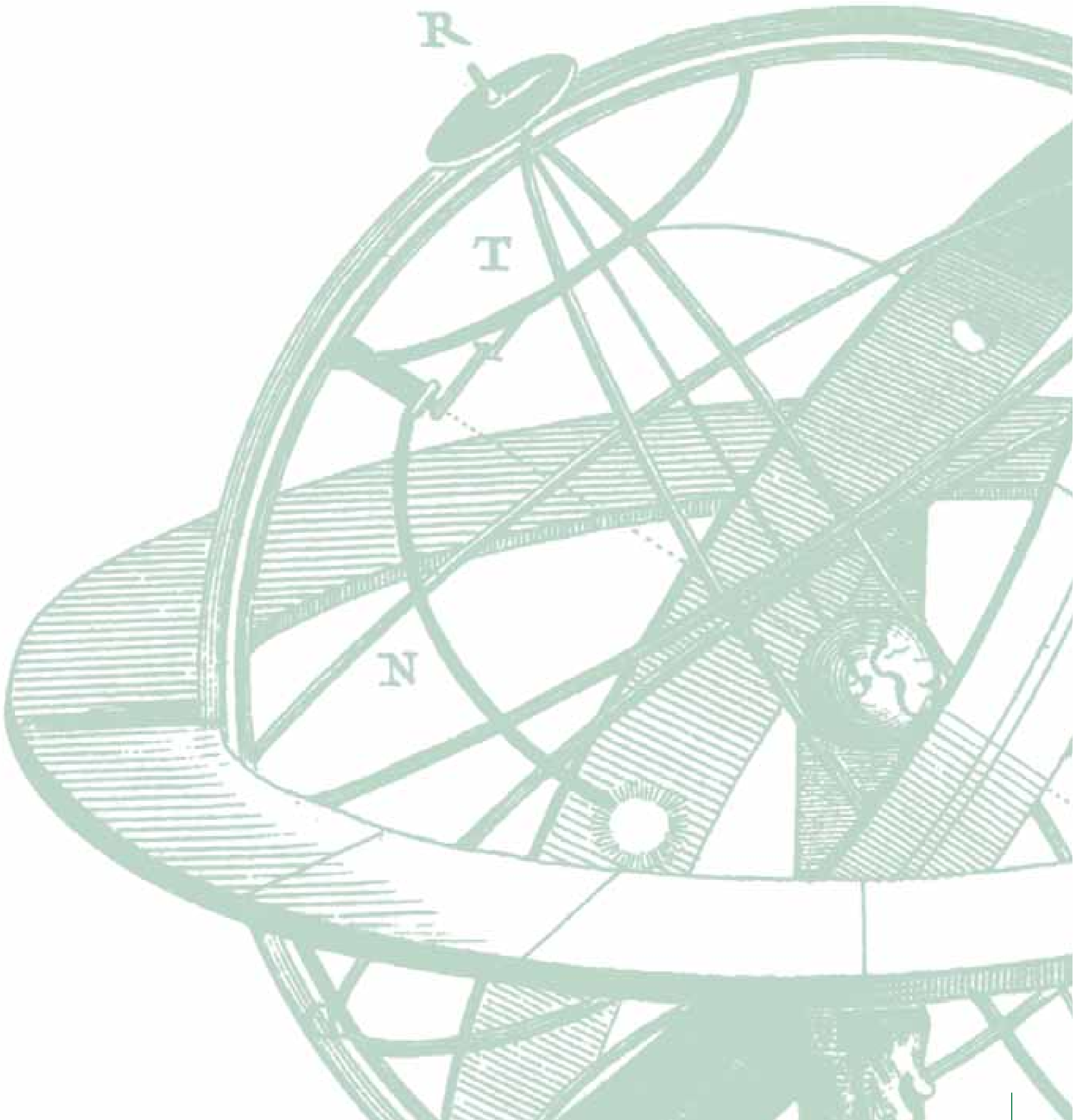


TABLE A2.1

Stem volume over bark of trees with DBH >10 cm. Volume expressed as m³/ha)

		Tree cover, broadleaved, evergreen	Trees, broadleaved, deciduous closed/open	Tree cover needle-leaved, evergreen	Tree cover, regularly flooded, fresh water	Tree cover, regularly flooded saline water	Mosaic: Tree Cover/Other natural vegetation	Shrub Cover, closed-open, evergreen	Shrub Cover, closed-open, deciduous	Herbaceous Cover, closed-open	Sparse herbaceous or sparse shrub cover	Regularly flooded shrub /herbaceous cover	Cultivated and managed areas	Mosaic: Crops/Trees/Other natural vegetation	Mosaic: Crops/Shrub and/or grass cover	Bare Areas	Water Bodies	Snow and Ice	Artificial surfaces
		1	2	4	7	8	9	11	12	13	14	15	16	17	18	19	20	21	22
Tropical rain-forest	max	241	124				61												
11-TAr	mean	135	83	103	30	30	44	29	29	15	15	15	5	10	10	2			2
	min	68	41			15	18												
Tropical rain-forest,	max	318					106												
equatorial	mean	245			180	180	82	54	54	27	27	27	9	18	18	5			5
10-TAr_Eq	min	164					55												
Tropical mountain	max	318					106												
system, equatorial	mean	245			180	180	82	54	54	27	27	27	9	18	18	5			5
5-EqM	min	164					55												
Tropical mountain	max	93					31												
system	mean	69	66	90			23	15	15	8	8	8	3	5	5	1			1
16-TM	min	31					10												
Tropical moist	max	140	111	173			42												
deciduous forest	mean	83	66	78		30	24	16	16	8	8	8	3	5	5	1			1
12-TAwa	min	48	31	60			13												
Tropical dry forest	max	110	99				35												
13-TAwb	mean	74	56		20	30	21	14	14	7	7	7	2	5	5	1			1
	min	48	29			15	13												
Tropical shrubland	max	110	99				35												
14-TBSh	mean	74	56		20	30	21	14	14	7	7	7	2	5	5	1			1
	min	48	29			15	13												
Subtropical humid	max			173			58												
forest	mean	90		97			31	21	21	10	10	10	3	7	7	2			2
21-SCf	min			60			20												
Subtropical mountain	max																		
system	mean	90		90			30	20	20	10	10	10	3	7	7	2			2
25-SM	min																		

Note: numbers in header are class codes.

TABLE A2.2

Woody biomass suitable as fuelwood or wood for charcoal production, expressed as t/ha

		Tree cover, broadleaved, evergreen	Trees, broadleaved, deciduous closed/open	Tree cover needle-leaved, evergreen	Tree cover, regularly flooded, fresh water	Tree cover, regularly flooded saline water	Mosaic: Tree Cover/Other natural vegetation	Shrub Cover, closed-open, evergreen	Shrub Cover, closed-open, deciduous	Herbaceous Cover, closed-open	Sparse herbaceous or sparse shrub cover	Regularly flooded shrub /herbaceous cover	Cultivated and managed areas	Mosaic: Crops/Trees/Other natural vegetation	Mosaic: Crops/Shrub and/or grass cover	Bare Areas	Water Bodies	Snow and Ice	Artificial surfaces
		1	2	4	7	8	9	11	12	13	14	15	16	17	18	19	20	21	22
Tropical rain-forest 11-TAr	max	254	183				121												
	mean	190	150	70	47	47	64	43	43	21	21	21	7	14	14	4			4
	min	136	64			24	27												
Tropical rain-forest, equatorial 10-TAr_Eq	max	291					160												
	mean	256			220	220	140	80	80	40	40	40	13	27	27	7			7
	min	210					81												
Tropical mountain system, equatorial 5-EqM	max	291					160												
	mean	256			220	220	140	80	80	40	40	40	13	27	27	7			7
	min	210					81												
Tropical mountain system 16-TM	max	159					46												
	mean	137	134	61			34	22	22	11	11	11	4	7	7	2			2
	min	48					15												
Tropical moist deciduous forest 12-TAwa	max	194	173	117			62												
	mean	150	134	53		47	36	24	24	12	12	12	4	8	8	2			2
	min	75	48	41			19												
Tropical dry forest 13-TAwb	max	172	163				51												
	mean	142	88		31	47	30	20	20	10	10	10	3	7	7	2			2
	min	75	45			24	19												
Tropical shrubland 14-TBSh	max	172	163				51												
	mean	142	88		31	47	30	20	20	10	10	10	3	7	7	2			2
	min	75	45			24	19												
Subtropical humid forest 21-SCf	max			117			85												
	mean	156	156	66			46	30	30	15	15	15	5	10	10	3			3
	min			41			30												
Subtropical mountain system 25-SM	max																		
	mean	156	156	61			44	29	29	15	15	15	5	10	10	2			2
	min																		

Note: numbers in header are class codes.

TABLE A2.3

Estimated productivity (as a percentage of stock)

	Tree cover, broadleaved, evergreen	Trees, broadleaved, deciduous closed/open	Tree cover needle-leaved, evergreen	Tree cover, regularly flooded, fresh water	Tree cover, regularly flooded saline water	Mosaic: Tree Cover/Other natural vegetation	Shrub Cover, closed-open, evergreen	Shrub Cover, closed-open, deciduous	Herbaceous Cover, closed-open	Sparse herbaceous or sparse shrub cover	Regularly flooded shrub /herbaceous cover	Cultivated and managed areas	Mosaic: Crops/Trees/Other natural vegetation	Mosaic: Crops/Shrub and/or grass cover	Bare Areas	Water Bodies	Snow and Ice	Artificial surfaces
	1	2	4	7	8	9	11	12	13	14	15	16	17	18	19	20	21	22
max	3	3	3	3	3	6	6	6	7.5	7.5	7.5	22.5	22.5	22.5	15			15
mean	2	2	2	2	2	4	4	4	5	5	5	15	15	15	10			10
min	1	1	1	1	1	2	2	2	2.5	2.5	2.5	7.5	7.5	7.5	5			5

Note: column numbers in header are class codes.

TABLE A2.4

Main factors applied and related references

Item		Factors	Notes	References
Wood density	Air-dry WD_{ad}	0.725	t/m³	Standard FAO wood density value at 12 percent moisture
	Oven-dry WD_{od}	0.593	t/m³	Calculated from Reyes *et al.* (1992) using formula: oven-dry = 0.0134+0.8*(biomass at 12 percent moisture)
Biomass expansion factor (BEF)	Dense broad-leaf forests (VOB_{10} >60)	EXP(3.213 -0.506*L_n(BV))	for BV<190 (BV = VOB_{10} *oven-dry WD)	FAO, 1997b – see Equation 3.1.4 on page 8
		1.74	for BV >190	
	Open broad-leaf formations (VOB_{10} <60)	3.0		S. Brown, pers. comm. Brown and Lugo, 1984.
	Coniferous forests	1.3		FAO, 1997b.
Volume expansion factor (VEF) from VOB_{30} to VOB_{10}		Exp(1.3 -0.209*Ln(VOB_{30}))	for VOB_{30} <250 m³/ha (VOB_{30} = volume over bark of free bole of trees with DBH >30 cm)	FAO, 1997b.
		1.3	for VOB_{30} >250 m³/ha	
Woodfuel fraction (WFF) Fraction of total aboveground biomass suitable as woodfuel	Including stem, bark and branches; excluding leaves and twigs	0.88	for denser forest formations (classes 1 to 8)	S. Brown, pers. comm., 2005. Brown and Lugo, 1990. Gurumurti, Raturi and Bhandari, 1984. Ketterings *et al.*, 2001.
		0.83	for open formations (classes 9 to 23)	Negi *et al.*, 1984.

Key to acronyms: BV = biomass of inventoried volume in t/ha, calculated as the product of VOB/ha (m³/ha) and wood density (WD) (t/m³). L_n = natural logarithm.

TABLE A2.5

Main references sources for volumes of forest formations

Ecozone	Country	References
Tropical rainforest (a)	Malaysia	For evergreen: Fourth National Forest Inventory for Peninsular Malaysia 2001–2003. From FRA 2005 country report. For swamp forest: Forestry and forest industries development. A National Forest Inventory of West Malaysia 1970-1972. FO:DP/MAL/72/009. Technical Report 5. Rome.
Tropical rainforest (b)	Thailand	Thailand Forest Inventory data (FAO FRA Documentation)
	Myanmar	Evergreen forest: Inventory of Kunchaung Forest Reserve from: Thang H. C. 1992. Review of the evergreen forest management system in Myanmar. FAO MYA/85/003. For deciduous and sparse trees: Burma National forest inventory. Summaries of 7 units . FAO WP 5, 7, 8–12. Inventories 1982–83 in Pegu Province.
	Lao PDR	FRA 2000 country report; tentative allocation by ecozone
	Viet Nam	FRA 2000 country report; tentative allocation by ecozone
	Cambodia	Data reported in Field Document No. 10 of project CMB 95/002: Report on establishment of a forest resources inventory process in Cambodia. [Results refer to dense forest] Forest Survey of the Lowlands West of the Cardamomes Mountains, 1967 (Reported in FAO, 1971).
Tropical mountain system (a)	Malaysia	For evergreen: Fourth National Forest Inventory for Peninsular Malaysia 2001–2003. From FRA 2005 country report.
Tropical mountain system (b)	Thailand	Thailand Forest Inventory data (FAO FRA Documentation)
	Lao PDR	FRA 2000 country report; tentative allocation by ecozone
	Viet Nam	FRA 2000 country report; tentative allocation by ecozone
Tropical moist deciduous forest	Thailand	Thailand Forest Inventory data (FAO FRA Documentation)
	Lao PDR	FRA 2000 country report; tentative allocation by ecozone
	Cambodia	Data reported in Field Document No. 10 of project CMB 95/002: Report on establishment of a forest resources inventory process in Cambodia. [Results refer to dense forest conditions; over 80 percent of areas have crown cover >70 percent] FRA 2005 country report estimate for lower range of mixed evergreen–deciduous forests.
	Viet Nam	FRA 2000 country report; tentative allocation by ecozone
Tropical dry forest	Thailand	Thailand Forest Inventory data (FAO FRA Documentation)
	Cambodia	Data reported in Field Document No. 10 of project CMB 95/002: Report on establishment of a forest resources inventory process in Cambodia. [Results refer to dense forest conditions; over 80 percent of areas have crown cover >70 percent] FRA 2005 country report estimate for average deciduous forests.
Tropical shrubland		Marginal area in SE Viet Nam. Values assumed equal to Tropical Dry Forest
Subtropical humid forest	Viet Nam	FRA 2000 country report; tentative allocation by ecozone
Subtropical mountain system	Yunnan (Prov. China)	White Book *China Forest Resources Report (2005)* published by State Forestry Administration, P. R.C World Bank. Forest resource development and protection project. Staff appraisal report 12762-CHA, 1994

TABLE A2.6

Other reference sources

	References
Non-forest sources of woody biomass	Forestry Sector Outlook Study, 1997. Wood Materials from Non-Forest Areas. Prepared by N. Vergara, Asia-Pacific Forestry Sector Outlook Study Working Paper No. APFSOS/WP/19. Pandey D., 2002. in Trees outside forests. Towards better awareness. *FAO Conservation Guide* 35. Anonymous. 2000. Woodfuel from non-forest areas. *Wood Energy News*, 15(1).
Mean Annual Increment (MAI)	D. Alder. 1983. Growth and yield of mixed tropical forests. Unpublished FAO consultancy report. Bedel, F., Durrieu de Madron, L., Dupuy, B., Favrichon, V., Maître, H.-F., Bar-Hen, A. & Narbonni, P. 1998. Dynamique de croissance dans des peuplements exploités et éclaircis de forêt dense africaine. Dispositif de M'Baiki en République Centrafricaine (1982–1995). CIRAD, Montpellier, France. Document Forafri, 1. 72 p. Fourth National Forest Inventory for Peninsular Malaysia 2001–2003. From FRA 2005 country report. FAO/RWEDP. 1997b. Data Collection and Analysis for Area-Based Energy Planning. A Case Study in Phrao District, Northern Thailand. Prepared by J. Siteur. RWEDP Field Document, No. 48 World Bank. 1992. Background report on biomass sector. Prepared by P. Ryan for *Wood Energy in Myanmar*. RWEDP Report, No. 33. World Bank. 1996. Cambodia forest policy assessment. World bank Report 15777-KH.

ANNEX 3

PROTECTED AREAS

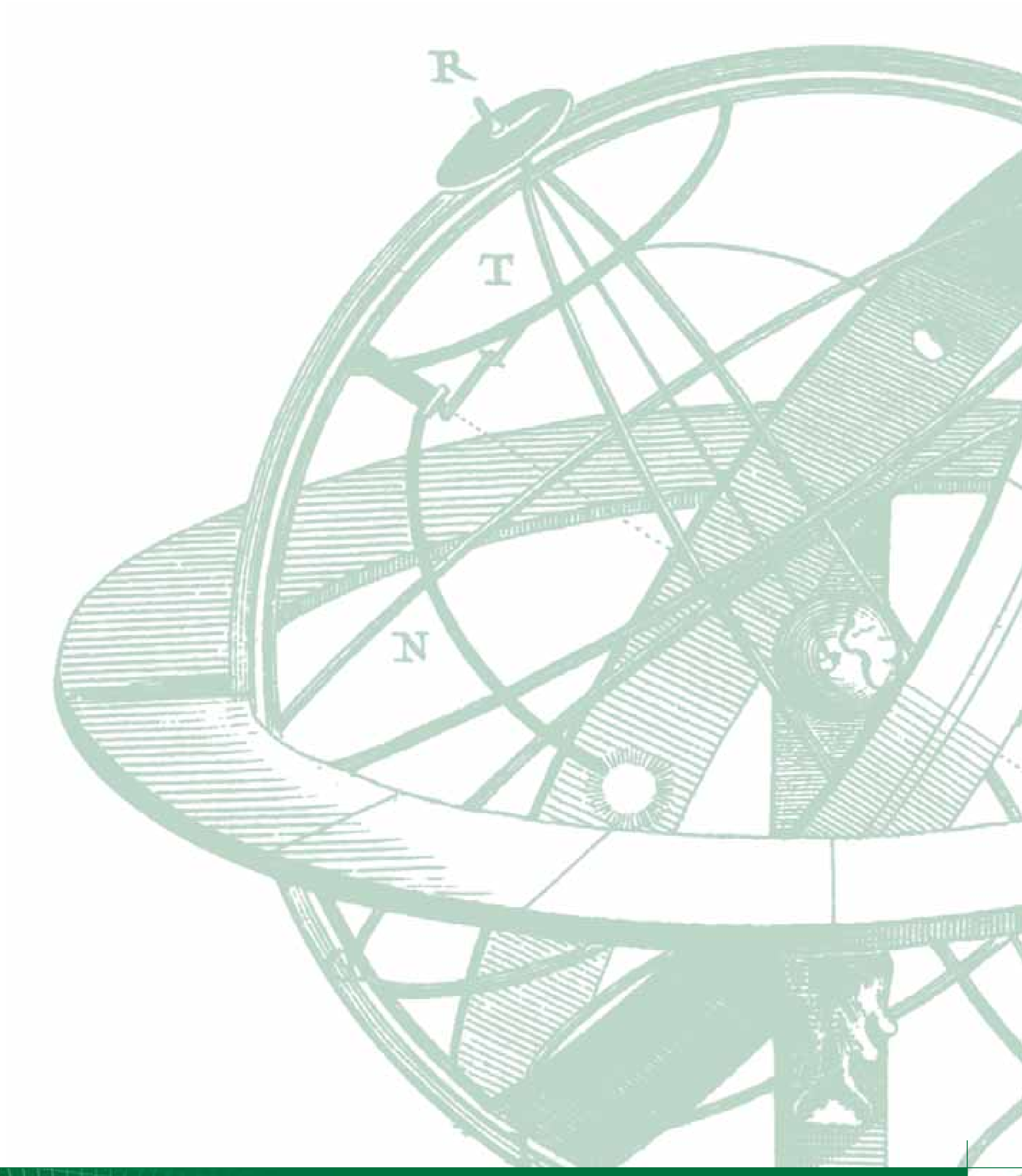
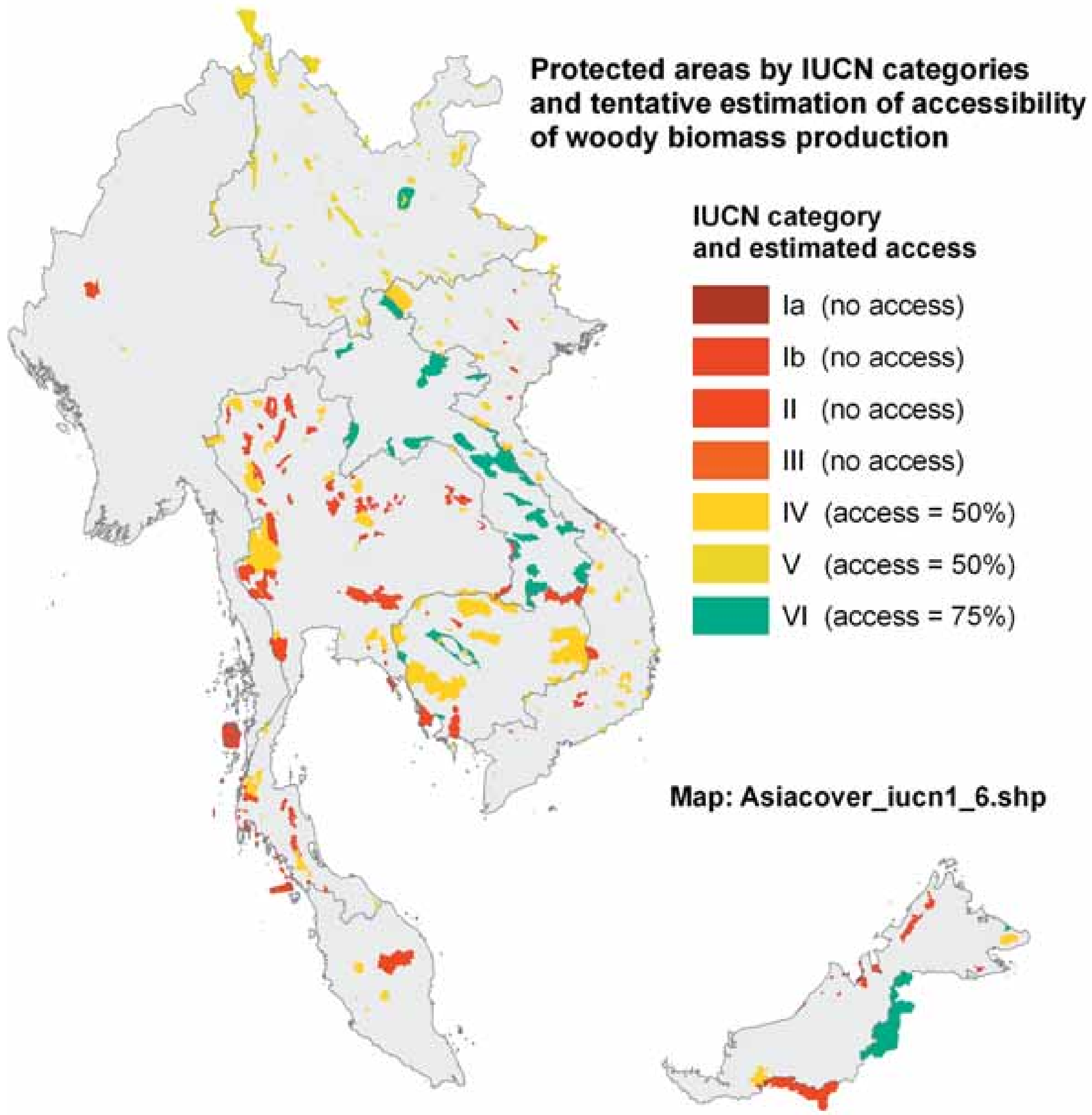


FIGURE A31

Protected areas by IUCN categories and tentative estimation of accessibility of woody biomass production



PROTECTED AREA MANAGEMENT CATEGORIES

IUCN has defined a series of six protected area management categories, based on primary management objective. These are summarized in Table A3.1.

TABLE A3.1

Summary descriptions of IUCN Protected Area Management Categories

Category	Description
Ia	Strict Nature Reserve: protected area managed mainly for science **Definition:** Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.
Ib	Wilderness Area: protected area managed mainly for wilderness protection **Definition:** Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.
II	National Park: protected area managed mainly for ecosystem protection and recreation **Definition:** Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
III	Natural Monument: protected area managed mainly for conservation of specific natural features **Definition:** Area containing one, or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.
IV	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention **Definition:** Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.
V	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation **Definition:** Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.
VI	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems **Definition:** Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

These categories are defined in detail in the *Guidelines for Protected Areas Management Categories* published by IUCN in 1994.

ANNEX 4

DEMAND MODULE. REFERENCES ON WOODFUEL CONSUMPTION

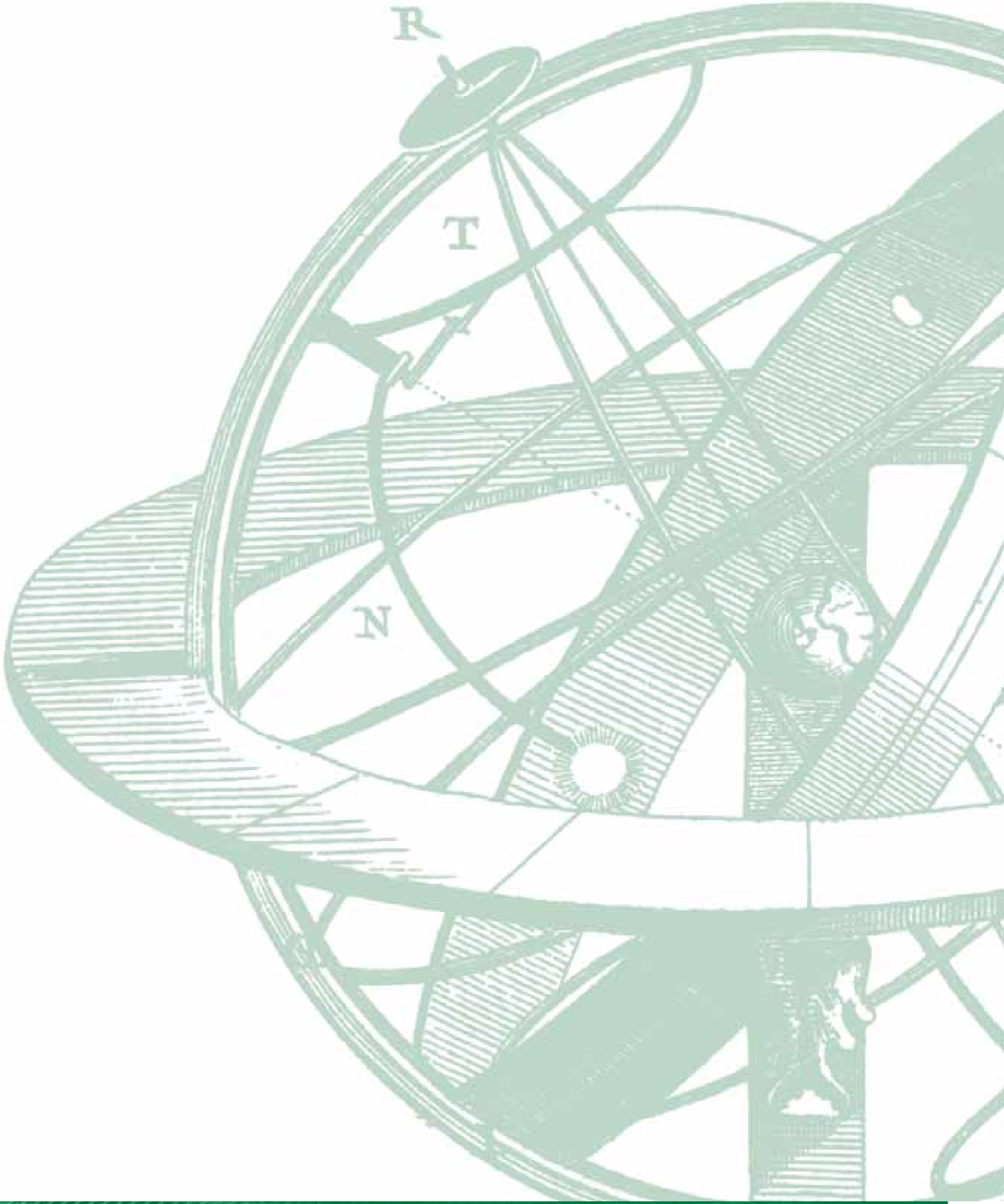


TABLE A4.1

Summary of total and per capita fuelwood and charcoal consumption
Highlighted values are those used in the analysis and mapping process

		Per capita woodfuel consumption								Total household (HH) consumption		Total Non-HH consumption		Best 2000 estimate of total national consumption	
		m³ of fuelwood (Fw) and wood for charcoal (Ch)								fuelwood (Fw) and wood for charcoal (Ch) ('000 m³)					
		Rural general		Urban		Rural sparse		Rural settlement							
		Fw	Ch	Fw	Ch	Fw	Ch	Fw	Ch	Fw	Ch	Fw	Ch	Fw	Ch
Cambodia	HH consumption	0.69	0.00	0.49	0.08	0.73	-0.01	0.59	0.04						
	Non-HH consumption			0.01	0.07	0.00	0.01	0.01	0.03						
	Total per capita use	0.69	0.00	0.51	0.15	0.73	0.00	0.60	0.07	8 582	212	69	335	8 651	547
	Lowlands			**0.51**	**0.15**	**0.73**	**0.00**	**0.60**	**0.07**						
	Mountain			**1.02**	**0.15**	**1.46**	**0.00**	**1.19**	**0.07**						
Yunnan (Prov. China)	HH consumption	0.48	0.00	0.18	0.00	0.56	0.00	0.33	0.00						
	Non-HH consumption			0.00	0.00	0.00	0.00	0.00	0.00						
	Tot per capita consumption	0.48	0.00	0.18	0.00	0.56	0.00	0.33	0.00	16 790	0	0	0	16 790	0
	lowlands			**0.18**	**0.00**	**0.56**	**0.00**	**0.33**	**0.00**						
	mountain			**0.18**	**0.00**	**0.56**	**0.00**	**0.33**	**0.00**						
Lao DPR	HH consumption	0.98	0.01	0.66	0.15	0.99	0.01	0.82	0.08						
	Non-HH consumption			0.21	0.00	0.02	0.00	0.30	0.00						
	Total per capita use	0.98	0.01	0.87	0.15	1.01	0.01	1.12	0.08	4 859	202	391	0	5 250	202
	lowlands			**0.87**	**0.15**	**0.85**	**0.01**	**1.05**	**0.08**						
	mountain			**1.74**	**0.15**	**2.02**	**0.01**	**2.23**	**0.08**						
Malaysia (Peninsular)	HH consumption	0.19	0.01	0.00	0.01	0.22	0.01	0.09	0.01						
	Non-HH consumption			0.06	0.00	0.05	0.00	0.23	0.00						
	Tot per capita use	0.19	0.01	0.06	0.01	0.27	0.01	0.32	0.01	1 265	126	1 265	0	2 530	126
	lowlands			**0.06**	**0.01**	**0.26**	**0.01**	**0.32**	**0.01**						
	mountain			**0.11**	**0.01**	**0.53**	**0.01**	**0.64**	**0.01**						
Myanmar	HH consumption	0.78	0.00	0.54	0.06	0.81	-0.01	0.66	0.03						
	Non-HH consumption			0.00	0.00	0.00	0.00	0.00	0.00						
	Total per capita use	0.78	0.00	0.54	0.06	0.81	-0.01	0.66	0.03	33 632	852	0	0	34 332	852
	lowlands			**0.51**	**0.06**	**0.75**	**-0.01**	**0.60**	**0.03**						
	mountain			**1.08**	**0.06**	**1.63**	**-0.01**	**1.32**	**0.03**						
Thailand	HH consumption	0.18	0.31	0.08	0.14	0.20	0.35	0.13	0.23						
	Non-HH consumption			0.17	0.08	0.02	0.01	0.08	0.04						
	Total per capita use	0.18	0.31	0.25	0.22	0.22	0.36	0.21	0.26	9 621	16 813	4 013	1 947	13 634	18 759
	lowlands			**0.25**	**0.22**	**0.22**	**0.36**	**0.21**	**0.26**						
	mountain			**0.50**	**0.22**	**0.44**	**0.36**	**0.42**	**0.26**						
Viet Nam	HH consumption	0.44	0.01	0.15	0.09	0.62	-0.04	0.30	0.05						
	Non-HH consumption			0.17	0.00	0.05	0.00	0.06	0.00						
	Total per capita use	0.44	0.01	0.32	0.09	0.67	-0.04	0.36	0.05	28 766	2 050	6 827	0	35 593	2 050
	lowlands			**0.32**	**0.09**	**0.64**	**-0.04**	**0.36**	**0.05**						
	mountain			**0.64**	**0.09**	**1.35**	**-0.04**	**0.72**	**0.05**						

Note: Proportional Distribution of non-household consumption is: Urban areas 0.5; Rural settlements 0.3; Rural sparse 0.2.

TABLE A4.2

Estimates of national consumption of fuelwood and charcoal according to various sources
The highlighted values were selected as current best reference and used for the calculation of per-capita consumption in the Demand Module. Highlighted values are those used in the analysis and mapping process. Production in '000 m³

Cambodia
"Best" current references
Fw Country report, which has a slightly lower value than FAOSTAT (based on the regional GFPOS model). WETT 99 figures appear less reliable as they were based on earlier FAOSTAT values.
Ch Country report, which has a much higher value than FAOSTAT (based on the global GFPOS model). WETT 99 figures appear less reliable as they are far lower and based on earlier FAOSTAT values.

	Main source	Source details	1995	1996	1997	1998	1999	2000
Fw	Country Report	GCP/RAS/173/EC Cambodia report by Sok Bung Heng - Final Draft Report of the "Desk Study on national woodfuels and wood energy information analysis –Cambodia"						**8 651**
	FAOSTAT (2003)	FAO estimate	10 767	10 570	10 575	10 327	10 119	9 931
	GFPOS 1970-2030	Household Fuelwood model: Regional; non-HH Fw model: continental	10 814	10 647	10 586	10 337	10 130	9 931
	WETT99 Best estimate	FAOSTAT (1998) years 1981–1998	6 518	6 680	6 838	6 968		
Ch	Country Report	GCP/RAS/173/EC Cambodia report by Sok Bung Heng - Final Draft Report of the "Desk Study on national woodfuels and wood energy information analysis –Cambodia"						**546.8**
	FAOSTAT (2003)	FAO estimate	173	176	182	184	196	188
	GFPOS 1970-2030	Charcoal model: Global	173	176	182	184	186	188
	WETT99 Best estimate	Reference not available	13	13	13	13	0	0

Yunnan (Prov. China)
"Best" current references
Fw Tuukka Castrén and Wang Song Jiang, 1999. Timber trade and wood flow–study, Yunnan, China.
Ch

	Main source	Source details	1995	1996	1997	1998	1999	2000
Fw	Country report	Nguyen Chi Trung, Forest Science Institute of Viet Nam, Hanoi.						**16790**
Ch	Country report	Nguyen Chi Trung, Forest Science Institute of Viet Nam, Hanoi.						**0**

Lao PDR
"Best" current references
Fw Country report
Ch Country report

	Main source	Source details	1995	1996	1997	1998	1999	2000
Fw	Country Report	GCP/RAS/173/EC Lao PDR report by Mr Oukham Phiathep, Planning Dept., Ministry of Agriculture and Forestry. Main ref: 1997 STENO (sec.source 149) a	4534	4701	4836	4966	5108	**5250**
	FAOSTAT (2003)	FAO	5641	5672	5704	5718	5744	5770
	GFPOS 1970–2030	Household Fuelwood model: Regional; non-HH Fw model: continental	5641	5672	5704	5718	5744	5770
	UN Energy Statistics 1995	Reference not available	4404					
	WETT99 Best estimate	FAOSTAT (1998) years 1981-1997	357	366	374	390		
Ch	Country Report	GCP/RAS/173/EC Lao PDR report by Mr Oukham Phiathep, Planning Department, Ministry of Agriculture and Forestry. Main ref: 1997 STENO and other consumption studies (i.e. UNDP/FAO Luang Prabang Watershed Management Proj.). Projections based on population growth.	176	182	187	192	197	**202**
	FAOSTAT (2003)	FAO estimate	89	92	94	96	99	102
	GFPOS 1970-2030	Charcoal model: Global	89	92	94	96	99	102
	WETT99 Best estimate	FAOSTAT (1998) years 1981–1998	830	855	885	879		

see next page

TABLE A4.2 (cont.)

Malaysia

"Best" current references

Fw Regional GFPOS model

Ch The global GFPOS model correspond to charcoal production statistics from government sources provided in Heruela's (FAO, 2003c) review and seems to well represent the marginal role that wood energy plays in Malaysia today.

	Main source	Source details	1995	1996	1997	1998	1999	2000
Fw	FAOSTAT (2003)	FAO estimate	3 299	3 127	3 126	3 100	3 039	**3 185**
	GFPOS 1970–2030	HH Fw model: Regional; non-HH Fw model: continental	3 450	3 378	3 312	3 263	3 224	3 187
	IEA (2002)	IEA Secretariat estimates	4 378	4 474	4 474	4 483	4 590	4 705
	RWEDP	Reference not available	7 696					
	UN Energy Statistics 1995	Reference not available	9 586					
	WETT99 Best estimate	FAOSTAT (1998) years 1982-1998	7 110	7 267	7 423	7 562		
Ch	FAOSTAT (2003)	FAO estimate	143	145	146	150	154	
	GFPOS 1970–2030	Charcoal model: Global	143	145	146	150	154	**159**
	IEA (2002)	IEA Secretariat estimates	2 424	2 479	2 479	2 485	2 485	2 485
	Other National	ASEAN Energy Review	1 120	2 480				
	RWEDP	Reference not available	1 120					
	WETT99 Best estimate	FAOSTAT (1998) years 1980–1995	2 588	2 566	2 685	2 740		

Myanmar

"Best" current references

Fw The official Figures of FAOSTAT, which correspond well to the data submitted by Ministry of Energy to IEA

Ch In the middle of this extremely wide range of estimates, the values of the GFPOS national model appear more realistic. The model estimates show a reasonable match with the values submitted by the Ministry of Energy to IEA.

	Main source	Source details	1995	1996	1997	1998	1999	2000
Fw	FAOSTAT (2003)	FAO estimate	17 959	18 260				
	FAOSTAT (2003)	Official Figure			31 448	32 083	34 071	**34 332**
	GFPOS 1970-2030	Household Fuelwood model: Regional; non-HH Fw model: continental	18 769	18 645	18 549	18 211	18 035	17 863
	IEA (2002)	Data from Ministry of Energy, 1985–2002. Secret. estimates based on 1990 data from World Bank, Programme Sectoral Review of Energy, by J. Sousing et al., Washington D.C., 1991.	34 102	33 557	34 178	34 808	34 695	35 063
	IEA nonOECD_99	Reference not available	30 050		32 779			
	Other National	Myanmar Energy Balances	31 170	30 673	31 165			
	Other National	Paper - Myanmar Internship for National Training on Wood Energy Planning	30 052					
	UN Energy Statistics 1995	Reference not available	19 966					
	WETT99 Best estimate	FAOSTAT (1998) years 1981-1998	19 244	19 594	19 954	18 989		
Ch	FAOSTAT (2003)	Official Figure	276	195			70	58
	GFPOS 1970-2030	Charcoal model: National	785	802	820	827	839	**852**
	IEA (2002)	Data from Ministry of Energy, 1985–2002. Secret. estimates based on 1990 data from World Bank, Programme Sectoral Review of Energy, by J. Sousing et al., Washington D.C., 1991.	1 261	1 279	1 291	1 297	739	667
	IEA non-OECD_99	Reference not available	4 408	1 969				
	Other National	Myanmar Energy Balances	1 299	1 305	522			
	UN Energy Statistics 1995	Reference not available	1 876					
	WETT99 Best estimate	Reference not available	276	195	210			

see next page

TABLE A4.2 (cont.)

	Thailand							
	"Best" current references							
Fw	Country Report							
Ch	Country Report							
	Main source	Source details	1995	1996	1997	1998	1999	2000
Fw	Country Report	GCP/RAS/173/EC Thailand report by Sriluck Tatayanon, RFD. Surveys by Dept. Energy Development & Promotion (Energy in HH of rural area, 1997; Thailand energy situation, 1997 and 2000).	12 324	12 018	13391	13341	13 722	**13 634**
	FAOSTAT (2003)	FAO estimate	13 927	13 651	13 555	13 448	13 241	13 263
	GFPOS 1970-2030	HH Fw: Regional; non-HH Fw model: continental	13 851	13 586	13 515	13 429	13 343	13 262
	IEA (2002)	Thailand Energy Situation, Ministry of Science, Technology and Energy, National Energy Administration.	12 210	11 908	13 268	13 218	13 595	13 508
	IEA nonOECD_99	Reference not available	15 981	16 354				
	Other National	ASEAN Energy Review	15 981					
	Other National	Thailand Energy Situation	12 324	12 018	13 391	13 341		
	RWEDP	Reference not available	15 843	16 358	16 450			
	UN Energy Statistics 1995	Reference not available	70 833					
	WETT99 Best estimate	FAOSTAT (1998) years 1981–1998	32 289	32 544	32 797	33 430		
Ch	Country Report	GCP/RAS/173/EC Thailand report by Sriluck Tatayanon, RFD. Surveys by Dept. Energy Development & Promotion (Energy in HH of rural area, 1997; Thailand energy situation, 1997 and 2000).	20 695	18 924	18 726	18 570	18 273	**18 759**
	FAOSTAT (2003)	FAO estimate	6 875	6 954	7 034	7 120		
	GFPOS 1970-2030	Charcoal model: National	6 875	6 954	7 034	7 120	7 204	7 290
	IEA (2002)	Thailand Energy Situation, Ministry of Science, Technology and Energy, National Energy Administration.	22 291	20 382	20 176	19 982	19 667	20 182
	IEA nonOECD_99	Reference not available	38 136	40 575				
	Other National	ASEAN Energy Review	38 136					
	Other National	Thailand Energy Situation	37 806	40 583	37 436			
	Other National	Thailand Energy Situation 1998	20 695	18 924	18 726	18 570		
	RWEDP	Reference not available	37 806	40 583	37 436			
	UN Energy Statistics 1995	Reference not available	38 160					
	WETT99 Best estimate	FAOSTAT (1998) years 1982–1998	3 990	4 047	4 036	4 115		

see next page

TABLE A4.2 (cont.)

Viet Nam

"Best" current references

Fw Ch Country report by Nguyen Chi Trung, Forest Science Institute of Viet Nam, who quotes the Institute of Energy and presents also urban/rural breakdown. 2000 value extrapolated from 1995–1999 series through linear equation.

	Main source	Source details	1995	1996	1997	1998	1999	2000
Fw	Country report	Nguyen Chi Trung, Forest Science Institute of Viet Nam, Hanoi.	32 519	32 792	33 340	33 614	34 161	**35 593**
	FAOSTAT (2003)	FAO estimate	26 025	26 030	26 093	26 033	26 004	26 029
	GFPOS 1970–2030	Household Fuelwood model: Regional; non-HH Fw model: continental	26 129	26 103	26 107	26 049	26 038	26 029
	IEA (2002)	Secretariat estimates based on 1992 data from Viet Nam Rural and Household Energy Issues and Options: Report No. 161/94, The World Bank, ESMAP, Washington, D.C., 1994.	40 880	42 806	43 671	44 629	43 558	44 124
	IEA non-OECD_99	Reference not available	38 554	40 872				
	Other National	ASEAN Energy Review	38 554					
	Other National	Viet Nam - Review of Policies and Legislation Affecting Wood Energy Production, Trade and Use & Institutional Aspects of Wood Energy Plans, Policies and Strategies.	39 448					
	RWEDP	Reference not available	42 879					
	UN Energy Statistics 1995	Reference not available	29 748					
	WETT99 Best estimate	FAOSTAT (1998) years 1981–1997	30 166	30 734	31 292	31 707		
Ch	Country report	Nguyen Chi Trung, Forest Science Institute of Viet Nam, Hanoi.	1 931	1 948	1 980	1 996	2 029	**2 050**
	FAOSTAT (2003)	FAO estimate.	664	661	660	658	657	622
	GFPOS 1970-2030	Charcoal model: Global	664	661	660	658	657	656
	IEA (2002)	Secretariat estimates based on 1992 data from Viet Nam Rural and Household Energy Issues and Options: Report No. 161/94, The World Bank, ESMAP, Washington, D.C., 1994.	3 345	3 503	3 576	3 655	3 570	3 618
	IEA nonOECD_99	Reference not available	3 164	3 345				
	WETT99 Best estimate	FAOSTAT (1998) years 1990-1998	17	49	107	107		

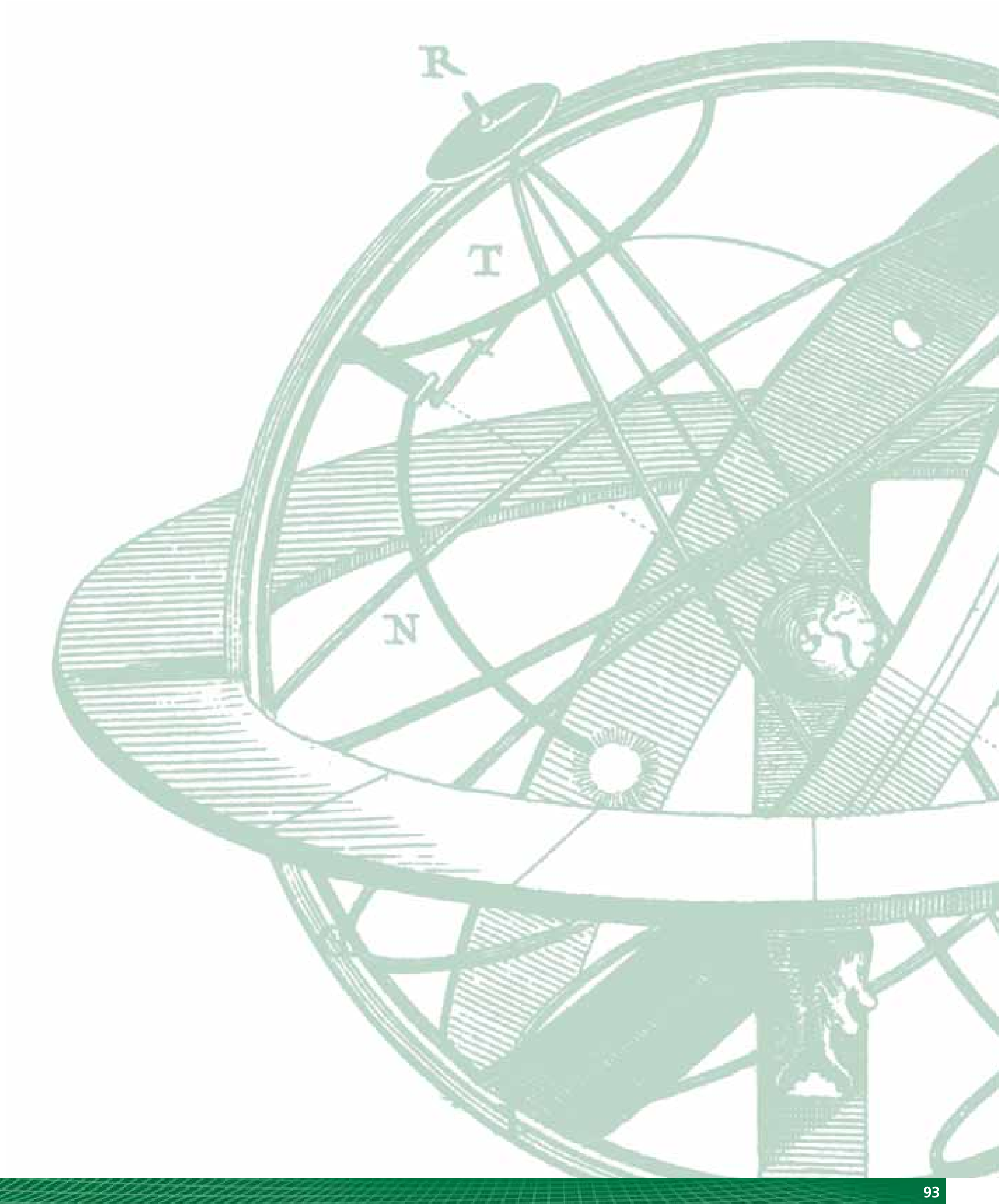
Notes:

1. Data extracted from the interactive Wood Energy Statistics database – i-WESTAT (FAO, 2005a).
2. Primary sources were:

ESMAP	Energy Sector Management Assistance Programme (joint World Bank–UNDP Programme).
FAOSTAT (2003)	Consumption estimates based on 2003 edition of FAOSTAT data.
GFPOS	Global Forest Products Outlook Study carried out by the Forestry Policy and Planning Division of FAO Forestry Department.
IEA	International Energy Agency.
IEPE	Institut d'economie et de politique de l'energie (Grenoble, France).
WETT99 Best estimates	Wood Energy Today for Tomorrow, 1999. An activity of the FAO Wood Energy Programme that analysed wood energy information worldwide. Indicates values defined in that study as "best estimates".

ANNEX 5

NUTRITIONAL STATUS INDICATORS



WORLD HEALTH ORGANIZATION CLASSIFICATION

Definition and interpretation of children's nutritional status indicators

For both age groups (children 0–5 and 5–10 years old) the same anthropometric indicators are used and compared across populations in relation to the United States National Center for Health Statistics set of reference values (NCHS/CDC/WHO). The nutritional status of children 0–5 and 5–10 is commonly assessed using the following three indices: weight-for-age; height-for-age; and weight-for-height. The prevalence of anthropometric deficits is usually expressed as the percentage of children below a specific cut-off point, such as minus 2 standard deviations (or z-scores) from the median value of the international reference data.

- **Underweight** – Low weight-for-age is commonly referred to as underweight. Weight-for-age reflects body mass relative to chronological age and it is primarily a composite index of both weight-for-height and height-for-age. Weight-for-age fails to distinguish tall, thin children from those who are short with adequate weight. This arises because this index ignores the child's height, and, at a given age, taller children tend to be heavier than their shorter counterparts. According to the WHO classification of malnutrition, if the prevalence of underweight in children 0–5 years old is <10 percent, it is considered to be low; between 10 and 19 percent it is medium; between 20 and 29 percent it is high; and ≥30 percent it is considered to be very high.
- **Stunting** – Height-for-age reflects achieved linear growth, and deficits indicate long-term, cumulative inadequacies of health and nutrition. Stunting is a commonly used term that reflects a process of failure to reach linear growth potential as a result of suboptimal health or nutritional conditions, or both. Stunting is frequently found to be associated with poor overall socio-economic status, or repeated exposure to adverse conditions such as illness and inappropriate feeding practices. A child is considered to be stunted if their height-for-age is below minus 2 z-scores (standard deviations) from the median of the reference curve of height-for-age. According to the WHO classification of malnutrition, if the prevalence of stunting in children 0–5 years old is <20 percent it is considered to be low; between 20 and 29 percent it is medium; between 30 and 39 percent it is high; and ≥40 percent it is considered to be very high.
- **Wasting** – Low weight-for-height indicates a deficit of tissue and fat mass compared with the amount expected in a standard child of the same height or length. Low weight-for-height – also referred to as wasting – reflects a recent and severe process that has led to significant weight loss, usually as a consequence of food shortage or infectious diseases. One advantage of this index is that it can be obtained without knowing age, which makes it useful in populations that do not record dates of birth or for whom this information is unavailable or unreliable. Very often, there are seasonal episodes of wasting related to variations either in food supply or in diseases prevalence. One of the main characteristics of wasting is that its prevalence can increase very rapidly, and under favourable conditions can rapidly be mitigated. According to the WHO classification of malnutrition, if the prevalence of wasting in children 0–5 years old is <5 percent it is considered to be acceptable; between 5 and 9 percent it is poor; between 10 and 14 percent it is serious.

FIVIMS THAILAND

Definition of “Vulnerable area” by provinces:

- **The Most Vulnerable Group (Provinces 1–5) –** Most vulnerable, due to the concomitance of various food insecurity and nutrition outcomes and vulnerability factors. These groups are also characterized by low or very low per capita income. Provinces 1 to 5 are included in this subgroup.
- **Vulnerable Group (Provinces 6–10) –** Vulnerable, but not to the same extent as that of the previous subgroup. Provinces 6 to 10 are identified in this subgroup. In general, in these groups, the per capita income is higher than among the previous subgroup.
- **Less Vulnerable Group (Provinces 11–13) –** Less vulnerable, but in which some particular food insecurity and nutrition outcomes or some vulnerability factors can be detected. All other groups are included in this category. Not surprisingly, the per capita income of these groups is significantly higher than the national average.

ANNEX 6

COUNTRY POPULATIONS IN 2000 CHARACTERIZED BY A COMBINATION OF WOOD ENERGY AND POVERTY-RELATED PARAMETERS

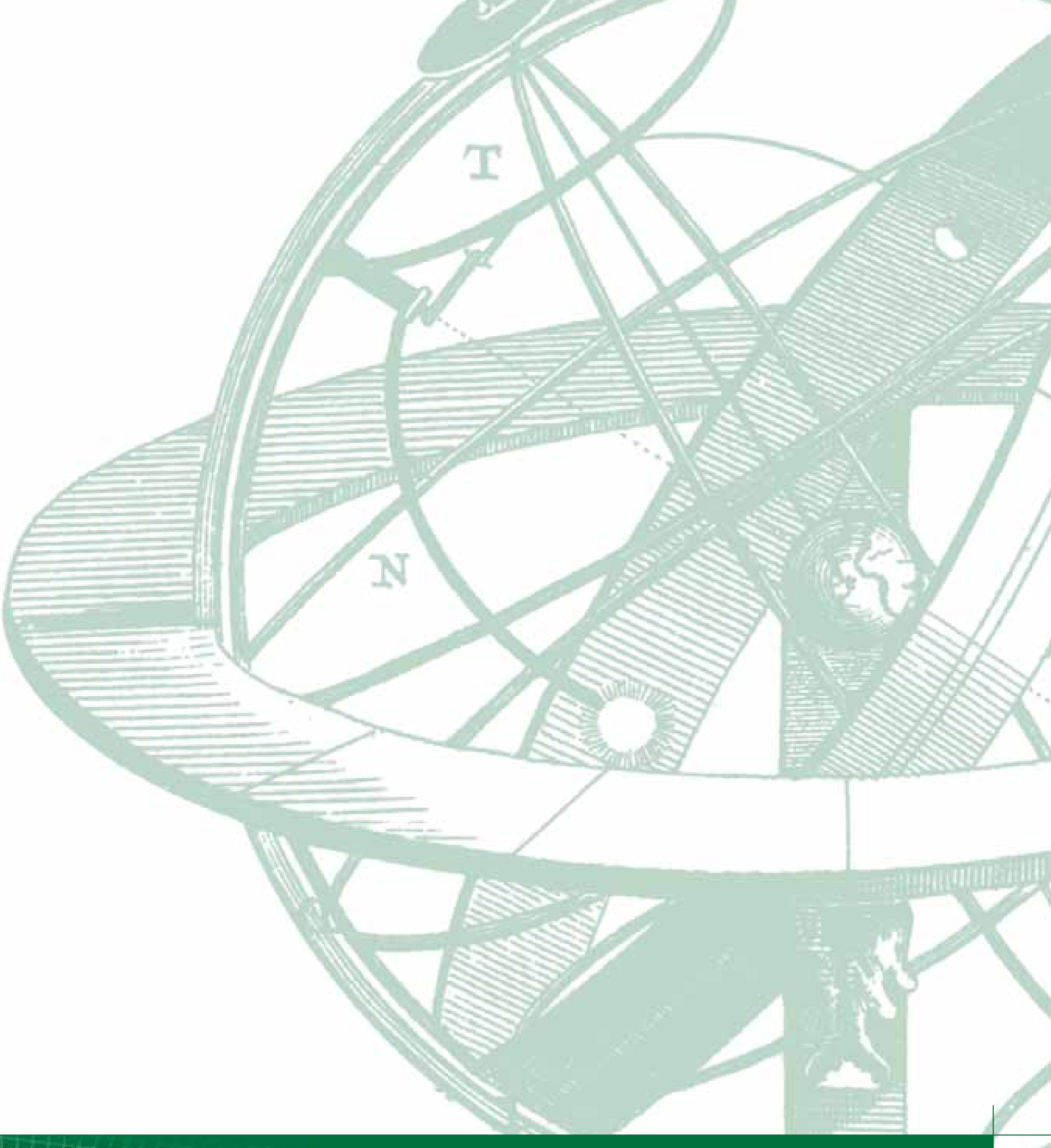


TABLE A6.1

Cambodia – population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1		8.6					8.6	"very serious conditions" total 25.3
very high deficit	2								
high deficit	3					16.8	8.4	25.3	
medium deficit	4					14.5	4.2	18.7	"serious" total 18.7
light deficit	5								
balanced	6		5.3					5.3	
light surplus	7					4.3		4.3	"serious"+ "very serious" = 44.0
	8					3.7		3.7	
	9				6.8	5.7	6.0	18.5	
	10				0.3	8.2	6.1	14.5	
very high surplus	11						1.1	1.1	
			14.0		**7.0**	**53.2**	**25.8**	**100**	

TABLE A6.2

Lao PDR – population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1								"very serious conditions" total 6.8
very high deficit	2					4.7		4.7	
high deficit	3					2.1		2.1	
medium deficit	4					3.9	1.4	5.3	"serious" total 5.3
light deficit	5								
balanced	6						2.5	2.5	
light surplus	7								"serious"+ "very serious" = 12.1
	8						5.5	5.5	
	9			1.0		4.0	5.0	10.0	
	10			3.7	9.9	8.3	35.2	57.1	
very high surplus	11			1.7	0.4	3.2	7.5	12.9	
				6.3	**10.4**	**26.3**	**57.0**	**100**	

TABLE A6.3

Malaysia – population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1								"very serious conditions" total 0
very high deficit	2								
high deficit	3			6.8				6.8	
medium deficit	4								"serious" total 6.8
light deficit	5								
balanced	6								
light surplus	7								"serious"+ "very serious" = 6.8
	8								
	9								
	10			6.4	0.3			6.7	
very high surplus	11			75.8		10.7		86.5	
				89.0	**0.3**	**10.7**		**100**	

TABLE A6.4

Myanmar – population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1		8.1					8.1	"very serious conditions" total 7.9
very high deficit	2		1.6	1.1	0.9	0.5		4.1	
high deficit	3		6.1	9.3	6.4			21.9	
medium deficit	4		3.6	6.4	3.1	0.3		13.4	"serious" total 20.2
light deficit	5								
balanced	6		0.0	2.2	0.9			3.1	
light surplus	7			0.6	0.7			1.3	"serious"+ "very serious" = 28.0
	8		1.0	1.7	1.7			4.3	
	9		2.4	2.4	1.7	3.3		9.8	
	10		2.2	13.3	7.8	4.5		27.8	
very high surplus	11			2.3	0.8	3.2		6.3	
			25.0	**39.1**	**24.0**	**11.9**		**100**	

TABLE A6.5

Thailand – population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1	10.3						10.3	"very serious conditions" total 0
very high deficit	2	3.3						3.3	
high deficit	3	2.2	3.0					5.2	
medium deficit	4				6.0			6.0	"serious" total 9.1
light deficit	5	1.4	0.3	1.0	2.2			4.9	
balanced	6	2.2	0.5	1.8	6.8	0.9		12.2	
light surplus	7				2.6			2.6	"serious"+ "very serious" = 9.1
	8	0.4	6.0	1.1	7.6	0.7		15.8	
	9	0.8	1.0	8.0	3.7	2.9		16.5	
	10		8.6	8.9	1.0			18.5	
very high surplus	11		3.1	1.7				4.8	
		20.5	**22.6**	**22.5**	**29.9**	**4.5**		**100**	

TABLE A6.6

Viet Nam – population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1	3.3						3.3	"very serious conditions" total 22.8
very high deficit	2	6.8	2.4	2.2	12.6			24.0	
high deficit	3			6.6	10.2			16.7	
medium deficit	4		2.7	4.7	1.3	3.7		12.4	"serious" total 23.0
light deficit	5					4.5		4.5	
balanced	6		0.9		0.0			0.9	
light surplus	7		2.1					2.1	"serious"+ "very serious" = 45.8
	8	0.0			1.2	1.1		2.3	
	9				2.6	13.5	0.9	17.0	
	10		1.1		8.9	3.5	3.4	16.9	
very high surplus	11								
		10.0	**9.2**	**13.5**	**36.8**	**26.3**	**4.3**	**100**	

TABLE A6.7

Yunnan (Prov. China) – population distribution by woodfuel balance categories and malnutrition levels (percent)

Woodfuel supply/demand balance		Malnutrition (or vulnerability)							
		low	mid-low	mid-high	high	very high	critical		
		1	2	3	4	5	6	Total	
critical deficit	1								"very serious conditions" total 0
very high deficit	2								
high deficit	3								
medium deficit	4						1.8	1.8	"serious" total 9.5
light deficit	5						7.7	7.7	
balanced	6						2.4	2.4	
light surplus	7						3.6	3.6	"serious"+ "very serious" = 9.5
	8						12.8	12.8	
	9						28.6	28.6	
	10						42.1	42.1	
very high surplus	11						1.1	1.1	
							100.0	**100**	

ANNEX 7

LAND COVER CHANGE REFERENCES

FRA 2005 NATIONAL FOREST AREA STATISTICS

TABLE A7.1

National forest area change statistics for the period 2000–2005, published by the FAO Forest Resources Assessment 2005 (FRA 2005)

Country	Forest						
	Area			Annual change rate			
	1990	2000	2005	1990-2000		2000-2005	
	'000 ha	'000 ha	'000 ha	'000 ha/yr	percent	'000 ha/yr	percent
Cambodia	12 946	11 541	10 447	-141	-1.09	-218.8	-1.90
Lao PDR	17 314	16 532	16 142	-78	-0.45	-78	-0.47
Malaysia	22 376	21 591	20 890	-79	-0.35	-140.2	-0.65
Myanmar	39 219	34 554	32 222	-467	-1.19	-466.4	-1.35
Thailand	15 965	14 814	14 520	-115	-0.72	-58.8	-0.40
Viet Nam	9 363	11 725	12 931	236	2.52	241.2	2.06
Total	**117 183**	**110 757**	**107 152**	**-643**	**-0.55**	**-721**	**-0.65**
China	157 141	177 001	197 290	1 986	1.20	4 058	2.20

Source: FAO FRA Web site.

TABLE A7.2

Change rates applied for the estimation of forest resources in 2015 (see Table A7.2A for Yunnan data, and Section A7.3 for comments on the Viet Nam situation)

Country	Change 2000–2005	Annual rate 2000–2005	Annual percent 2000–2005	Compound rate 2000–2005	RS rate 1990–2000[1]	Forest area 2015	Change 2000–2015	Percent change 2000–2015
Cambodia	-1,094	-218.8	-1.90	0.9802788		8 560	-2 981	-25.8
Lao PDR	-390	-78	-0.47	0.9952367		15 389	-1 143	-6.9
Malaysia	-701	-140.2	-0.65	0.9934205		19 556	-2 035	-9.4
Myanmar	-2 332	-466.4	-1.35	0.9861224		28 020	-6 534	-18.9
Thailand	-294	-58.8	-0.40	0.9959989		13 949	-865	-5.8
Viet Nam	1,206	241.2	2.06	1.0197738		15 728	4 003	34.1
Viet Nam	Tentative estimate based on 4 sampling units 1990–2000				0.993442	10 623	-1 102	-9.4
Total Se Asia	-3 605	-721	-0.65	0.9934038		100 290	-10 467	-9.5
China	20 289	4057.8	2.29	1.0219411		245 112	68 111	38.5

Note: [1] Compound rate for the period 1990–2000 estimated using the remote sensing survey results (see page 104).

TABLE A7.2A

Change rates applied for the estimation of forest resources in 2015 – data for Yunnan Province, China

Country	Change 1990–2005	Annual rate 1990–2005	Annual percent 1990–2005	Compound rate 1990–2005	Forest area	Change 2000–2015	Percent change 2000–2015
China	40 149	2676.6	1.70	1.0152844	229 605	52 604	29.7

DATA BASED ON REMOTE SENSING

A Remote Sensing Survey was conducted in the framework of FRA 1990 and FRA 2000, and the results, for continental SE Asia for 1990–2000 are summarized in Table A7.3. The result consists of a transition matrix which can be represented in form of a biomass flux diagram.

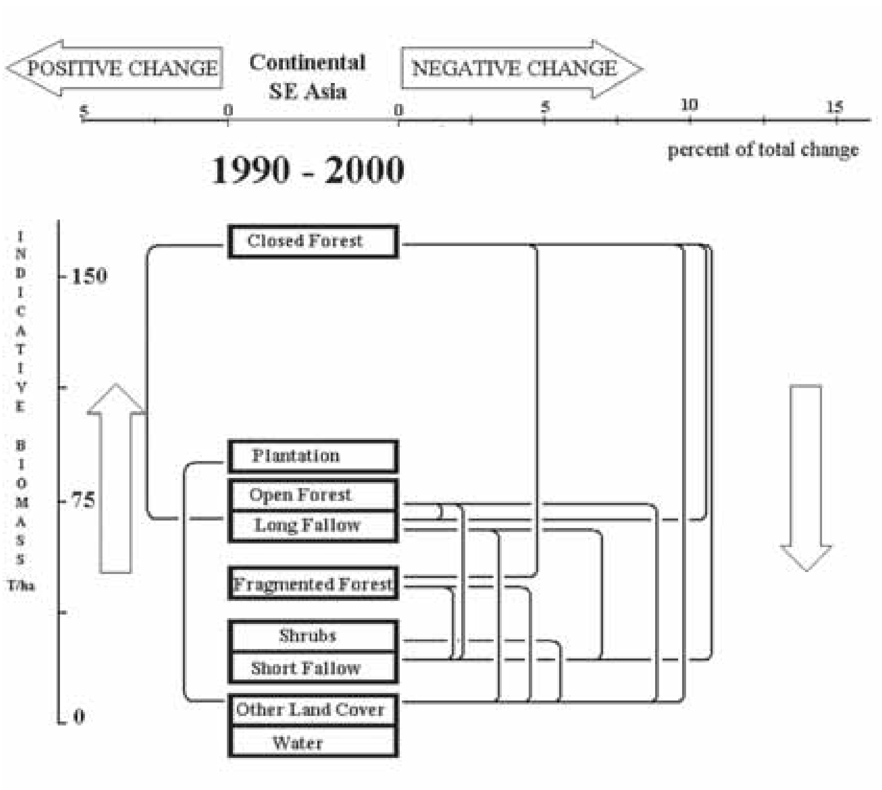
TABLE A7.3

Estimated 1990–2000 transition matrix expanded to the entire continental Southeast Asia subregional area. Area in '000 ha

	Classes in 2000									
Classes in 1990	**Closed forest**	**Open forest**	**Long fallow**	**Fragmented forest**	**Shrub**	**Short fallow**	**Other land cover**	**Water**	**Manmade woody veg.**	**∑ 1990**
Closed forest	**57 572**	142	1027	475	41	1061	952	107	22	**61 399**
Open forest	80	**10 994**	150	37	112	215	863	7	0	**12 458**
Long fallow	272	0	**17 193**	18	9	677	346	34	0	**18 549**
Fragmented forest	49	28	88	**5 766**	1	173	448	0	18	**6 571**
Shrub	39	17	16	10	**4 906**	94	552	26	14	**5 674**
Short fallow	43	1	108	28	11	**5 895**	550	15	0	**6 651**
Other land cover	114	84	61	40	114	94	**66 435**	61	145	**67 148**
Water	15			5	13		53	**868**		**954**
Manmade woody veg.	4						31		**6 762**	**6 797**
∑ 2000	**58 188**	**11 266**	**18 643**	**6 379**	**5 207**	**8209**	**70 230**	**1 118**	**6 961**	**186 201**

FIGURE A7.1

Continental Southeast Asia biomass flux diagram



CONSIDERATIONS ON VIET NAM FOREST CHANGE RATES

FRA 2005 estimates give a very consistent increment for natural forest area of 112 000 ha/year for 2000–2005 (128 000 ha for 1990–2000) in addition to the plantation rates of 108 000 ha/yr for 1990–2000 and 129 000 ha/yr for 2000–2005.

For the sake of reference is represented by the four sampling units located in Viet Nam (covering some 7.8 million ha, or almost one-quarter of the country) that report deforestation in all locations and an overall forest change rate of -0.66 percent for the F2 definition (that best matches the FRA forest definition), that lessens to -0.64 percent if increasing plantations are considered. This rate is about two-thirds of the subregional mean without Viet Nam (-0.97 percent/yr).

The FAO projections of agricultural areas in 2015 indicate a significant increase in cropland in the whole subregion, and particularly in Viet Nam, Cambodia and Lao PDR, which strengthens the hypothesis of a decrease in the Vietnamese forest area.

In the light of sample results and projected cropland, FRA 2005 statistics appear rather unrealistic and this might reflect the data collection method, which was probably based on independent periodic assessments and on progressively revised definitions, rather than on a direct and consistent estimation of forest cover dynamics.

Therefore, as one possible hypothesis for scenario development, the rate of -0.64 percent/yr was applied to project the 2015 forest area.

TABLE A7.4

Viet Nam sampling units

		Forest definition F2[1]	
	Year	Absolute forest cover '000 ha	Relative forest cover as percent of land area
4501 Central Viet Nam	1980	1013.4	72.0
	1990	1007.2	71.5
	2000	983.5	69.9
4502 South Viet Nam	1980	1589.4	72.5
	1990	1489.3	68.0
	2000	1412.6	64.5
4503 South Viet Nam	1980	1654.2	73.7
	1990	1394.6	62.1
	2000	1216.0	54.2
4509 North Viet Nam	1980	616.3	25.1
	1990	566.4	23.0
	2000	551.6	22.4

Note: [1] Results relative to F2 definition of forest, which was the best match for FRA definition of forest (FAO, 1996a).
Source: TEMS database. http://www.fao.org/gtos/tems/mod_fra.jsp?FRA_PAGE=body/fra_tree.jsp&EXPAND_SUBREGION=45.

CONSIDERATIONS ON CHINA FOREST CHANGE RATES

The FRA 2005 China data shows a very high forest area increment in both natural forest (+2.5 million ha/yr) and plantations (+1.5 million ha/yr) in the 2000–2005 period. If projected to 2015, this rate will imply a very substantial increase in forest area, namely 38.5 percent.

An independent reference is represented by the four sampling units located in Viet Nam (covering some For the sake of caution, the change rate applied was that of the wider period 1990–2005, which, extrapolated to 2015, implied an increase in forest area, with respect to 2000, of 29.7 percent.

This rate was in part supported by the FAO projections of agricultural areas in 2015, which indicate a significant decrease in cropland.

BUFFERS WITHIN FOREST AREAS USED TO ALLOCATE THE PREDICTED 2000–2015 CHANGE

The predicted change in woody biomass stocking due to the predicted change in forest area was spatially distributed according to (i) distance from forest edge and (ii) distance from high consumption areas, based on the premise that closer to forest edges and closer to high demand sites the probabilities of change are higher. Table A7.5 lists the buffer thresholds used and the change rates finally applied in each buffer combination for each country.

TABLE A7.5

General weighting values applied for forest edge proximity and for distance from high demand sites

Forest edge buffers		High consumption sites buffers		
Distance from forest edge "fordistance"	Fraction of overall change rate	Consumption buffers: distance from high consumption sites	Weight applied to change rate	Exceptions
1: 1 pixel (0.9 km)	0.1	1: < 75 km	1.25	Malaysia (1.0) and Viet Nam (1.15)
2: 2–5 pixels	0.4	2: 75–150 km	1	not Viet Nam (0.85)
3: 6–10 pixels	0.8	3: >150 km	Remaining change	
4: >10 pixels	1.6			

TABLE A7.6

Development of change rates adjusted for forest edge proximity and for distance from high demand sites

	Estimated forest change 2000–2015 ('000 ha)				areas of "exploitable" forest by combined buffers ('000 ha)				Change rate of combined buffers		
	Consumption buffers				Consumption buffers				Consumption buffers		
Cambodia											
Fordistance	total	1	2	3	total	1	2	3	1	2	3
1	-1 050	-229	-346	-476	2 130	371	701	1 058	-0.62	-0.49	-0.45
2	-676	-53	-255	-368	2 396	151	903	1 341	-0.35	-0.28	-0.27
3	-91	-2	-47	-42	577	9	301	267	-0.20	-0.16	-0.16
4	-10	0	-4	-5	285	3	128	154	-0.04	-0.03	-0.03
Total	-1 827				5 387						
Lao PDR											
Fordistance		1	2	3	total	1	2	3	1	2	3
1	-265	-10	-38	-217	2 255	67	324	1 864	-0.15	-0.12	-0.12
2	-115	-2	-10	-103	1 885	32	164	1 689	-0.08	-0.06	-0.06
3	-9		-1	-8	280		23	257		-0.03	-0.03
4					6			6			-0.01
Total	-389				4 427						
Malaysia											
Fordistance		1	2	3	total	1	2	3	1	2	3
1	-934	-934			4 025	4 025			-0.23		
2	-636	-636			8 042	8 042			-0.08		
3	-136	-136			3 313	3 313			-0.04		
4	-21	-21			2 095	2 095			-0.01		
Total	-1 727				17 474						
Myanmar											
Fordistance		1	2	3	total	1	2	3	1	2	3
1	-2 694	-1 107	-780	-807	8 875	2 917	2 569	3 388	-0.38	-0.30	-0.24
2	-1 758	-631	-454	-674	11 553	3 317	2 980	5 257	-0.19	-0.15	-0.13
3	-159	-51	-30	-78	2 095	536	393	1 166	-0.09	-0.08	-0.07
4	-7	-1	-1	-5	342	56	33	252	-0.03	-0.02	-0.02
Total	-4 619				22 865						

see next page

TABLE A7.7

Development of change rates adjusted for forest edge proximity and for distance from high demand sites

	Estimated forest change 2000–2015 ('000 ha)				Areas of "exploitable" forest by combined buffers ('000 ha)				Change rate of combined buffers		
		Consumption buffers				Consumption buffers			Consumption buffers		
Thailand											
Fordistance		1	2	3	total	1	2	3	1	2	3
1	-433	-86	-159	-188	3 771	598	1 388	1 785	-0.14	-0.11	-0.11
2	-207	-29	-76	-102	3 228	362	1 186	1 681	-0.08	-0.06	-0.06
3	-11	-1	-4	-6	264	23	96	145	-0.05	-0.04	-0.04
4	0		0	0	30		1	30		-0.01	-0.01
Total	-651				7 294						
Viet Nam											
Fordistance		1	2	3	total	1	2	3	1	2	3
1	-385	-257	-107	-20	2 401	1 396	789	217	-0.18	-0.14	-0.09
2	-216	-151	-64	-2	2 628	1 594	910	124	-0.09	-0.07	-0.01
3	-13	-8	-4	0	295	169	109	17	-0.05	-0.04	-0.02
4	0	0	0	0	23	13	7	3	-0.01	-0.01	-0.01
Total	-614				5 347						

TABLE A7.8

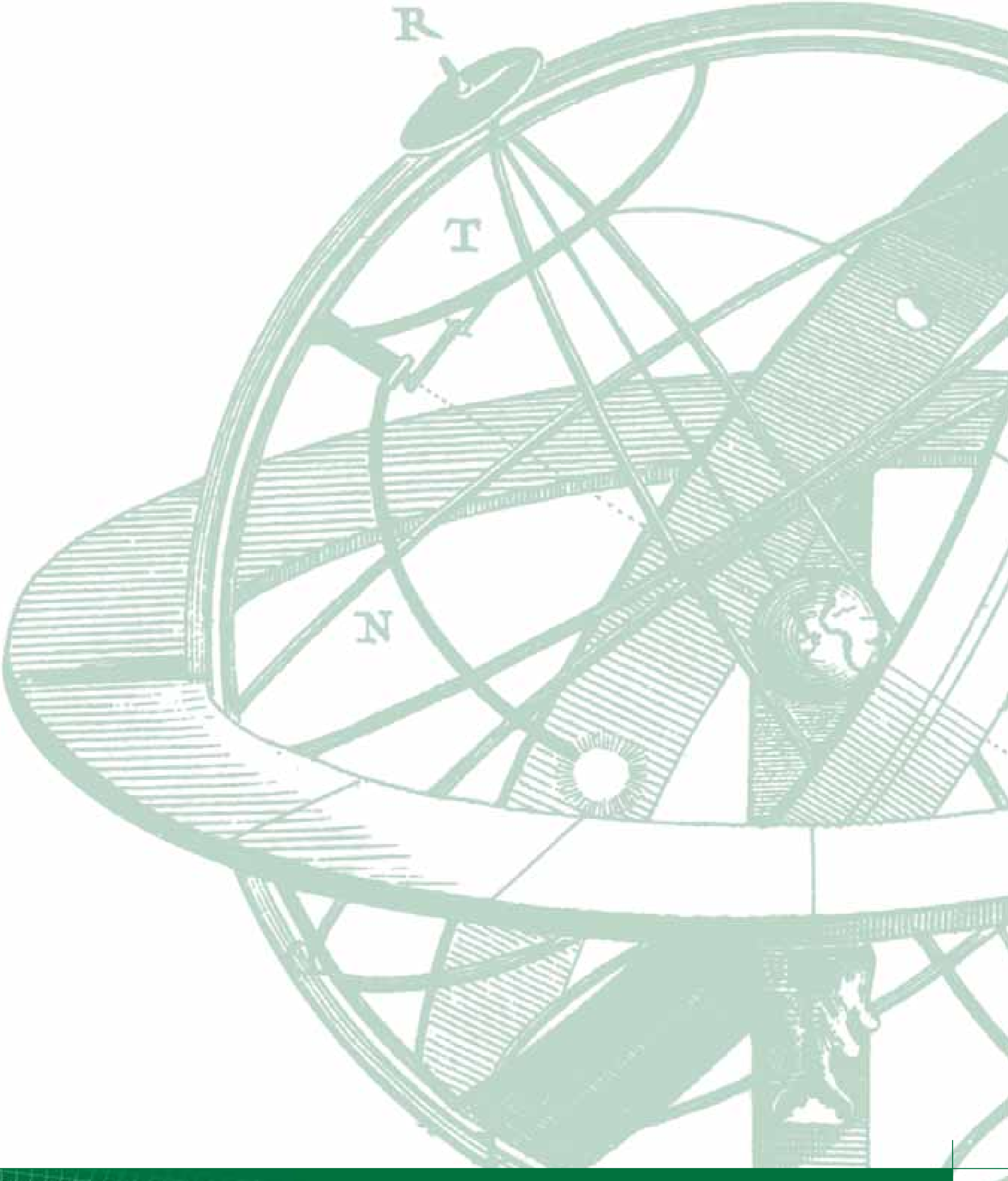
Estimated average fraction of exploitable woody biomass from forest classes (including stem, bark and branches) used for other, non-energy uses

Country	GFPOS industrial roundwood production model[1] ('000 m^3 VOB_{10} [stem only])			Extrapolated value	Fraction of exploitable VOB_{10} produced for other uses from forest classes	Fraction of exploitable woody biomass from forest classes used for other uses	Fraction of exploitable woody biomass from forest classes available for energy uses
	2000	2005	2010	2015	2015	2015	2015
Cambodia	806	950	1014	1 078	0.16	0.060	0.940
China	112 575	129 431	151 582	173 733	0.34	0.127	0.873
Lao PDR	984	1 062	1 212	1 362	0.15	0.060	0.940
Malaysia	37 382	37 567	37 910	38 253	0.44	0.281	0.719
Myanmar	3 329	3 715	3 975	4 235	0.11	0.044	0.956
Thailand	8 159	8 729	9 734	10 739	0.93	0.364	0.636
Viet Nam	4 859	5 412	6 106	6 800	0.69	0.279	0.721

Note: [1] GFPOS industrial roundwood production model from FAO, 1998b.

ANNEX

8 WOODFUEL CONSUMPTION PROJECTIONS



GFPOS MODEL PROJECTIONS

The FAO Global Forest Product Outlook Study (GFPOS) produced fuelwood and charcoal consumption projections up to year 2030 for all countries of the world based on existing survey data and modelling techniques (FAO, 2001a). Country estimates were based on national, regional or global models, depending on the data available.

Key parameters in most models were:

- per capita GDP purchasing power parity in 1997 US$;
- forest area per capita;
- urban proportion of the population;
- 1997 oil production in barrels per capita per year;
- national land area in thousands of hectares;
- temperature; and
- dummy variables determined for each country.

In order to check the validity of modelling assumptions, the GDP growth rates used in the GFPOS study were compared with current World Bank statistics. World Bank data available for Cambodia, Lao PDR and Viet Nam for the period 1994–2004 confirmed that GDP growth rates for these countries did not differ significantly from that projected in GFPOS. It was concluded that GFPOS model predictions of fuelwood and charcoal consumption were still valid, and therefore their trends for the period 2000–2015 were used to project from the 2000 baseline values forward to 2015, as reported in Tables A8.1 and A8.2.

TABLE A8.1

Estimated total charcoal consumption in 2000 and 2015 and reference values from the GFPOS study used for consumption projections

Country	Fuelwood ('000 m^3)				GFPOS compound rate	Fuelwood model type[2]
	Phase 1	Phase 2	GFPOS			
	2000	2015	2000	2015	2000-2015	
Cambodia	8 651	6 581	9 931	7 555	0.981 93	HH: Regional; non-HH: continental
Yunnan (Prov. China)	16 790	12 574	216 721[1]	162 300[1]	0.980 91	HH: National; non-HH: continental
Lao DPR	5 250	5 229	5 770	5 747	0.999 73	HH: Regional; non-HH: continental
Malaysia	3 185	2 396	3 187	2 398	0.981 22	HH: Regional; non-HH: continental
Myanmar	34 332	26 830	17 863	13 960	0.983 70	HH: Regional; non-HH: continental
Thailand	13 634	10 308	13 262	10 027	0.981 53	HH: Regional; non-HH: continental
Viet Nam	35 593	32 279	26 029	23 606	0.993 51	HH: Regional; non-HH: continental

Notes: [1] GFPOS values refer to entire China. [2] HH = household consumption model. non-HH = consumption model for all non-household sectors.

TABLE A8.2

Estimated total charcoal consumption in 2000 and 2015 (as wood used for charcoal production) and reference values from the GFPOS study used for consumption projections

Country	Charcoal ('000 m^3 of wood used for charcoal production)				GFPOS compound rate	Charcoal model type
	Phase 1	Phase 2	GFPOS			
	2000	2015	2000	2015	2000-2015	
Cambodia	547	653	188	225	1.011 89	Global
Yunnan (Prov. China)	0[1]	0	10 788	10 085	0.995 52	Global
Lao DPR	202	282	102	141	1.022 29	Global
Malaysia	159(2)	177	159	177	1.007 38	Global
Myanmar	852	1 075	852	1 075	1.015 62	National
Thailand	18 759	22 594	7 290	8 780	1.012 48	National
Viet Nam	2 050	2 048	656	656	0.999 94	Global

Notes: [1] No Charcoal consumption assumed in Yunnan. [2] GFPOS was used as main reference source.

Two scenarios were considered: one "business-as-usual" (BAU) in which per capita consumptions were maintained constant (high-consumption scenario), and another one with decreasing per capita consumption, as projected by the GFPOS model (low-consumption scenario). The results are summarized in Table A8.3.

TABLE A8.3

Summary by country for the total estimated woody biomass consumed in 2000 and the consumption predicted in 2015 according to both the BAU scenario and the GFPOS trend scenario

	Consumption of woody biomass for energy ('000 t oven-dry biomass)		
	2000 Baseline	2015 BAU	2015 GFPOS trend
	2000	2015	2015
Cambodia	5 407	6 969	4 262
Yunnan (China)	9 874	10 487	7 381
Lao DPR	3 097	4 271	3 132
Malaysia	1 996	2 089	1 429
Myanmar	20 012	23 212	16 226
Thailand	18 887	21 027	19 219
Viet Nam	21 834	26 038	19 963

ANNEX 9

2015 SUPPLY/DEMAND SCENARIOS

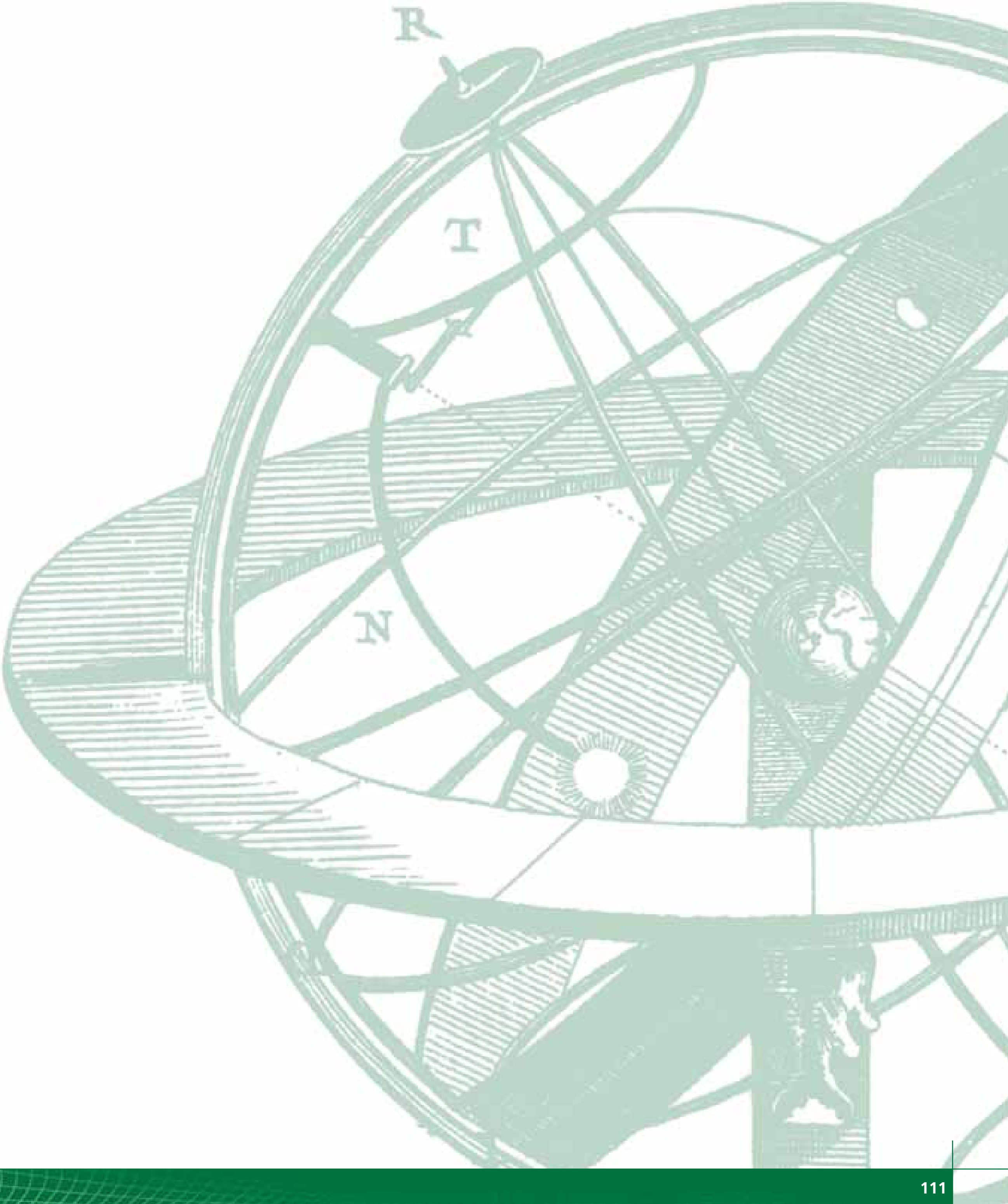


TABLE A9.1

Overall supply/demand balance aggregated at national level ('000 t of woody biomass) for three productivity supply levels within two consumption scenarios

	GFPOS-trend consumption scenario			BAU consumption scenario		
Supply	Mean productivity	Minimum productivity	Maximum productivity	Mean productivity	Minimum productivity	Maximum productivity
Cambodia	11 319	101	26 277	8 612	**-2 607**	23 570
Yunnan (China)	43 472	6 858	92 290	40 366	3 752	89 184
Lao DPR	31 706	6 623	65 151	30 567	5 484	64 012
Malaysia	107 664	29 117	212 392	107 003	28 457	211 732
Myanmar	78 388	10 266	169 216	71 401	3 280	162 230
Thailand	24 351	**-7 020**	66 179	22 544	**-8 827**	64 372
Viet Nam	10 990	**-11 296**	40 705	4 915	**-17 371**	34 630

TABLE A9.2

Balance thresholds used in the definition of balance categories. Threshold values are supply <minus> consumption by 30 arc-sec pixel in kg (the threshold values are quintiles of the 2000 balance values)

Threshold	Code	Balance category
< -67 676	1	high deficit
-67 676 – -31 204	2	medium-high deficit
-31 204 – -6 889	3	medium deficit
-6 889 – 5 267	4	balanced
5 267 – 29 582	5	medium surplus
29 582 – 53 897	6	medium-high surplus
> 53 897	7	high surplus

TABLE A9.3A

Areas by woodfuel balance categories expressed as percentage of a country's area under different supply/demand balance conditions in the GFPOS-trend consumption scenario

	High deficit	Medium-high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Mean productivity							
Cambodia	4.2	7.0	7.2	8.6	9.2	12.8	50.9
Yunnan (China)	0.3	1.3	2.4	2.3	8.4	13.4	71.8
Lao DPR	0.8	0.8	1.4	1.2	3.4	7.0	85.5
Malaysia	0.1	0.1	0.1	1.3	0.6	0.6	97.2
Myanmar	4.3	5.9	5.5	2.4	4.5	6.1	71.3
Thailand	3.8	7.3	11.0	10.1	15.7	14.5	37.6
Viet Nam	13.8	6.9	6.9	4.4	9.9	13.7	44.3
Total area	**4.0**	**4.5**	**5.4**	**4.3**	**7.7**	**9.6**	**64.5**
Minimum productivity							
Cambodia	12.1	8.9	9.2	13.3	38.5	14.1	3.9
Yunnan (China)	3.5	6.3	12.9	13.0	42.5	18.4	3.4
Lao DPR	2.4	3.0	5.6	6.2	45.2	25.0	12.8
Malaysia	0.6	0.4	0.6	2.1	3.6	9.7	83.1
Myanmar	9.8	7.6	7.0	5.2	29.8	27.4	13.2
Thailand	7.5	13.5	20.6	16.8	29.9	9.3	2.4
Viet Nam	23.1	11.1	12.3	10.7	28.4	12.4	1.9
Total area	**8.4**	**7.8**	**10.4**	**9.5**	**30.2**	**17.3**	**16.3**
Maximum productivity							
Cambodia	2.8	4.8	5.3	7.4	6.3	5.5	67.9
Yunnan (China)	0.1	0.5	0.9	0.8	2.5	4.0	91.2
Lao DPR	0.5	0.3	0.4	0.4	1.2	1.8	95.3
Malaysia	0.1	0.0	0.1	1.2	0.3	0.3	98.1
Myanmar	2.7	4.3	4.4	2.1	3.1	2.8	80.5
Thailand	2.0	3.2	5.1	6.5	10.9	10.3	62.0
Viet Nam	10.0	4.0	4.2	2.7	5.5	6.4	67.2
Total area	**2.6**	**2.7**	**3.2**	**3.0**	**4.5**	**4.7**	**79.4**

TABLE A9.3B

Areas by woodfuel balance categories expressed as percentage of a country's area under different supply/demand balance conditions in the BAU consumption scenario

	High deficit	Medium-high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Mean productivity							
Cambodia	9.5	6.5	5.9	7.9	8.4	12.1	49.6
Yunnan (China)	1.6	2.3	3.1	2.7	8.5	13.2	68.5
Lao DPR	1.4	1.1	1.5	1.2	3.4	7.1	84.2
Malaysia	0.3	0.1	0.1	1.3	0.6	0.7	96.9
Myanmar	7.3	5.7	4.5	2.1	4.2	5.9	70.3
Thailand	4.5	5.6	9.8	10.2	16.4	15.1	38.3
Viet Nam	17.3	6.6	6.6	4.0	9.2	13.1	43.2
Total area	**5.9**	**4.3**	**4.9**	**4.2**	**7.6**	**9.5**	**63.6**
Minimum productivity							
Cambodia	12.1	8.9	9.2	13.3	38.5	14.1	3.9
Yunnan (China)	3.5	6.3	12.9	13.0	42.5	18.4	3.4
Lao DPR	2.4	3.0	5.6	6.2	45.2	25.0	12.8
Malaysia	0.6	0.4	0.6	2.1	3.6	9.7	83.1
Myanmar	9.8	7.6	7.0	5.2	29.8	27.4	13.2
Thailand	7.5	13.5	20.6	16.8	29.9	9.3	2.4
Viet Nam	23.1	11.1	12.3	10.7	28.4	12.4	1.9
Total area	**8.4**	**7.8**	**10.4**	**9.5**	**30.2**	**17.3**	**16.3**
Maximum productivity							
Cambodia	7.2	5.0	4.6	6.6	5.4	4.9	66.2
Yunnan (China)	0.8	1.2	1.3	0.9	2.7	4.3	88.8
Lao DPR	0.9	0.5	0.6	0.5	1.3	1.7	94.6
Malaysia	0.2	0.1	0.1	1.2	0.3	0.3	97.9
Myanmar	5.4	4.3	3.8	1.8	2.7	2.5	79.5
Thailand	2.9	2.5	4.0	6.1	10.7	10.7	63.1
Viet Nam	13.0	4.2	4.0	2.5	5.1	5.9	65.3
Total area	**4.3**	**2.7**	**2.8**	**2.7**	**4.3**	**4.6**	**78.6**

TABLE A9.4

Population and woodfuel balance – percentage of country total populations living in different supply/demand balance conditions under the GFPOS-trend consumption scenario

	High deficit	Medium-high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Mean productivity							
Cambodia	46.5	21.7	12.1	4.8	6.3	4.1	4.6
Yunnan (China)	9.2	10.7	13.1	7.8	15.6	13.5	30.1
Lao DPR	29.1	6.9	8.0	4.2	9.1	9.9	32.8
Malaysia	20.8	5.8	6.2	2.3	5.9	4.7	54.4
Myanmar	50.0	18.9	10.3	3.3	5.0	3.6	8.8
Thailand	38.6	17.1	14.7	6.4	9.5	5.7	7.9
Viet Nam	67.4	10.8	6.7	2.9	4.5	3.4	4.3
Total area	**43.3**	**13.6**	**10.2**	**4.5**	**7.6**	**5.7**	**15.0**
Minimum productivity							
Cambodia	55.3	23.4	12.0	4.1	4.6	0.5	0.1
Yunnan (China)	15.8	23.7	24.5	13.4	18.0	4.1	0.5
Lao DPR	34.5	13.2	14.9	8.3	21.3	6.4	1.4
Malaysia	30.0	13.1	7.8	3.4	11.9	12.9	21.0
Myanmar	59.5	20.4	9.8	3.1	4.8	1.9	0.5
Thailand	50.1	25.5	15.0	4.5	3.7	1.0	0.4
Viet Nam	77.3	11.4	6.0	2.4	2.4	0.4	0.1
Total area	**52.7**	**18.6**	**12.0**	**4.9**	**6.8**	**2.7**	**2.2**
Maximum productivity							
Cambodia	39.0	17.7	12.0	5.4	7.7	5.4	12.7
Yunnan (China)	7.0	4.1	6.3	4.0	9.5	10.9	58.3
Lao DPR	24.4	4.5	3.8	2.7	6.2	7.1	51.2
Malaysia	14.0	4.2	2.8	2.2	4.3	4.5	68.1
Myanmar	41.6	16.4	10.2	3.9	5.7	4.2	17.9
Thailand	30.3	10.7	10.6	5.5	11.3	8.6	23.0
Viet Nam	57.8	9.0	6.7	2.8	5.5	4.6	13.6
Total area	**35.7**	**9.8**	**7.9**	**3.8**	**7.4**	**6.4**	**28.8**

TABLE A9.5

Percentage of country sparse rural populations (<2000 inh/km²) living under different supply/demand balance conditions – GFPOS-trend consumption scenario

	High deficit	Medium-high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Mean productivity							
Cambodia	16.7	26.4	20.0	8.2	11.6	7.9	9.2
Yunnan (China)	1.3	4.7	6.1	4.7	13.9	16.9	52.4
Lao DPR	4.2	5.5	8.5	5.5	12.3	13.8	50.3
Malaysia	0.1	0.2	0.2	0.6	0.9	1.7	96.3
Myanmar	21.9	26.4	16.2	4.8	7.7	5.9	17.0
Thailand	9.0	18.8	21.7	10.7	16.1	9.5	14.2
Viet Nam	35.6	14.4	11.9	5.7	10.5	8.9	13.0
Total area	**15.8**	**16.0**	**14.1**	**6.5**	**11.6**	**9.5**	**26.5**
Minimum productivity							
Cambodia	24.6	34.1	22.3	8.3	9.5	1.1	0.3
Yunnan (China)	4.0	12.0	22.4	18.6	33.4	8.7	1.0
Lao DPR	8.3	14.3	20.0	12.1	33.1	10.1	2.2
Malaysia	0.7	1.5	3.2	2.6	8.4	17.4	66.2
Myanmar	32.9	30.2	16.6	5.5	9.5	4.2	1.1
Thailand	19.3	35.8	26.4	8.4	7.2	2.0	0.8
Viet Nam	48.8	20.7	14.0	6.9	7.9	1.6	0.2
Total area	**24.7**	**24.6**	**19.2**	**9.0**	**13.3**	**4.6**	**4.5**
Maximum productivity							
Cambodia	10.4	19.1	17.0	8.2	12.2	9.0	24.0
Yunnan (China)	0.4	1.9	2.8	1.9	5.1	7.0	81.0
Lao DPR	1.8	2.3	3.1	2.5	6.3	8.7	75.2
Malaysia	0.0	0.0	0.1	0.4	0.2	0.4	98.9
Myanmar	13.5	21.1	15.5	6.0	8.3	5.9	29.7
Thailand	3.7	8.7	11.8	8.0	16.9	13.8	37.1
Viet Nam	26.2	9.4	8.3	4.5	9.0	8.5	34.1
Total area	**10.1**	**10.2**	**9.7**	**5.2**	**9.8**	**8.7**	**46.3**

TABLE A9.6

Population and woodfuel balance – percentage of country total populations living in different supply/demand balance conditions under the BAU consumption scenario

	High deficit	Medium-high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Mean productivity							
Cambodia	64.7	13.0	7.6	3.0	4.6	3.0	4.0
Yunnan (China)	24.5	12.5	9.6	5.7	11.5	10.5	25.7
Lao DPR	35.0	6.9	6.3	3.9	8.3	8.6	30.9
Malaysia	32.7	6.3	3.5	2.1	3.1	3.6	48.8
Myanmar	62.7	13.4	6.7	2.4	3.8	3.0	8.0
Thailand	42.4	12.7	13.5	6.9	10.2	6.0	8.3
Viet Nam	74.0	8.1	5.2	2.2	3.7	2.9	3.9
Total area	**52.7**	**10.7**	**7.9**	**3.8**	**6.4**	**4.9**	**13.5**
Minimum productivity							
Cambodia	71.1	14.5	7.1	3.0	3.7	0.5	0.1
Yunnan (China)	35.9	19.1	18.1	9.5	13.9	3.2	0.4
Lao DPR	40.8	12.2	13.2	7.1	19.5	5.9	1.3
Malaysia	44.2	6.3	6.2	3.8	10.2	11.7	17.6
Myanmar	70.2	14.2	6.8	2.5	4.1	1.8	0.5
Thailand	51.0	21.9	16.3	5.2	4.1	1.1	0.4
Viet Nam	81.9	8.6	4.9	2.0	2.1	0.4	0.0
Total area	**61.4**	**14.2**	**10.1**	**4.2**	**5.9**	**2.4**	**1.9**
Maximum productivity							
Cambodia	57.6	12.3	7.5	3.2	5.1	3.5	10.6
Yunnan (China)	16.1	9.0	6.7	3.4	7.5	8.0	49.4
Lao DPR	30.1	4.1	4.5	2.1	5.6	5.0	48.6
Malaysia	25.0	4.4	3.2	1.2	2.8	2.9	60.6
Myanmar	54.7	12.2	7.5	2.9	4.1	3.1	15.5
Thailand	35.9	7.6	8.3	5.3	10.6	9.0	23.2
Viet Nam	65.4	7.5	4.9	2.3	4.3	3.7	11.7
Total area	**44.9**	**8.4**	**6.3**	**3.2**	**6.0**	**5.3**	**25.7**

TABLE A9.7

Percentage of country sparse rural populations (<2000 inh/km²) living under different supply/demand balance conditions – BAU consumption scenario

	High deficit	Medium-high deficit	Medium-low deficit	Balanced	Medium-low surplus	Medium-high surplus	High surplus
Mean productivity							
Cambodia	36.1	21.3	13.7	5.6	8.9	6.2	8.2
Yunnan (China)	4.5	6.2	7.1	5.2	13.6	15.9	47.5
Lao DPR	8.0	6.9	7.8	5.2	11.6	12.4	48.0
Malaysia	0.2	0.2	0.4	0.6	1.3	2.1	95.2
Myanmar	35.3	21.6	11.5	4.0	6.5	5.2	15.8
Thailand	8.4	15.1	20.9	11.9	18.1	10.5	15.0
Viet Nam	42.9	12.7	10.3	4.8	9.1	8.1	12.1
Total area	**21.9**	**13.7**	**12.3**	**6.4**	**11.3**	**9.1**	**25.3**
Minimum productivity							
Cambodia	45.5	25.1	14.2	6.2	7.7	1.0	0.3
Yunnan (China)	9.7	15.1	23.6	16.1	27.6	7.0	0.9
Lao DPR	13.2	15.2	18.9	10.8	30.6	9.3	2.1
Malaysia	1.0	2.5	3.5	3.3	8.8	18.9	61.9
Myanmar	45.6	24.0	12.3	4.5	8.6	3.9	1.1
Thailand	16.6	32.3	29.6	10.1	8.3	2.3	0.9
Viet Nam	55.2	17.7	12.2	6.1	7.2	1.5	0.2
Total area	**30.5**	**21.8**	**18.5**	**8.5**	**12.1**	**4.4**	**4.3**
Maximum productivity							
Cambodia	27.9	17.7	12.4	5.7	8.9	6.8	20.5
Yunnan (China)	1.9	3.4	3.2	2.1	5.3	7.3	76.9
Lao DPR	4.3	3.4	4.1	2.2	6.8	7.0	72.2
Malaysia	0.0	0.0	0.1	0.4	0.2	0.4	98.8
Myanmar	25.4	18.8	12.5	4.4	6.4	5.0	27.6
Thailand	4.2	6.8	10.2	7.6	17.1	15.0	39.1
Viet Nam	32.8	9.2	7.4	4.0	8.0	7.4	31.4
Total area	**15.5**	**9.4**	**8.2**	**4.5**	**9.1**	**8.4**	**44.8**

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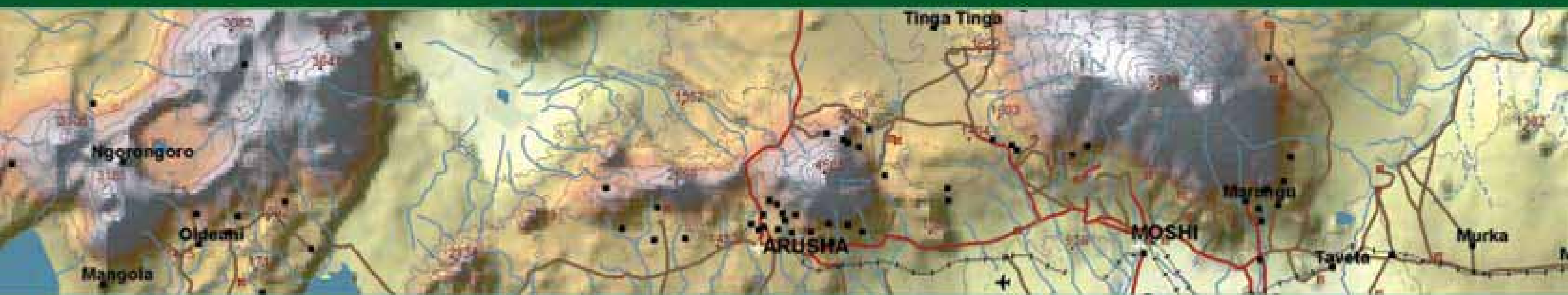
Current (2000) and projected (2015) woodfuel consumption patterns and supply potentials in continental Southeast Asia are analysed and mapped applying the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology. Combined with poverty data, the study helps define areas where poor rural and suburban populations that depend primarily on woodfuels for their subsistence energy supply are likely to suffer severe shortages, adding an indicator to the mapping of extreme poverty and a new tool for poverty alleviation policies and forestry and energy development planning.

Integrating several cartographic layers with multi-source field data provides maps of woody biomass stocking and potential sustainable productivity in 2000 and 2015 at a spatial resolution of less than 1 km. Woody biomass consumption maps matching the resolution of supply maps, coupled with likely population distribution in 2015 and model projections of woodfuel consumption, give future consumption scenarios. Combining these yields balance maps of woodfuel deficit and surplus areas. This study is a starting point for expanding work in the agro-energy sector, which can benefit from the approach, the GIS analytical environment, the additional thematic layers and the nexus with forestry, energy and poverty alleviation issues.



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