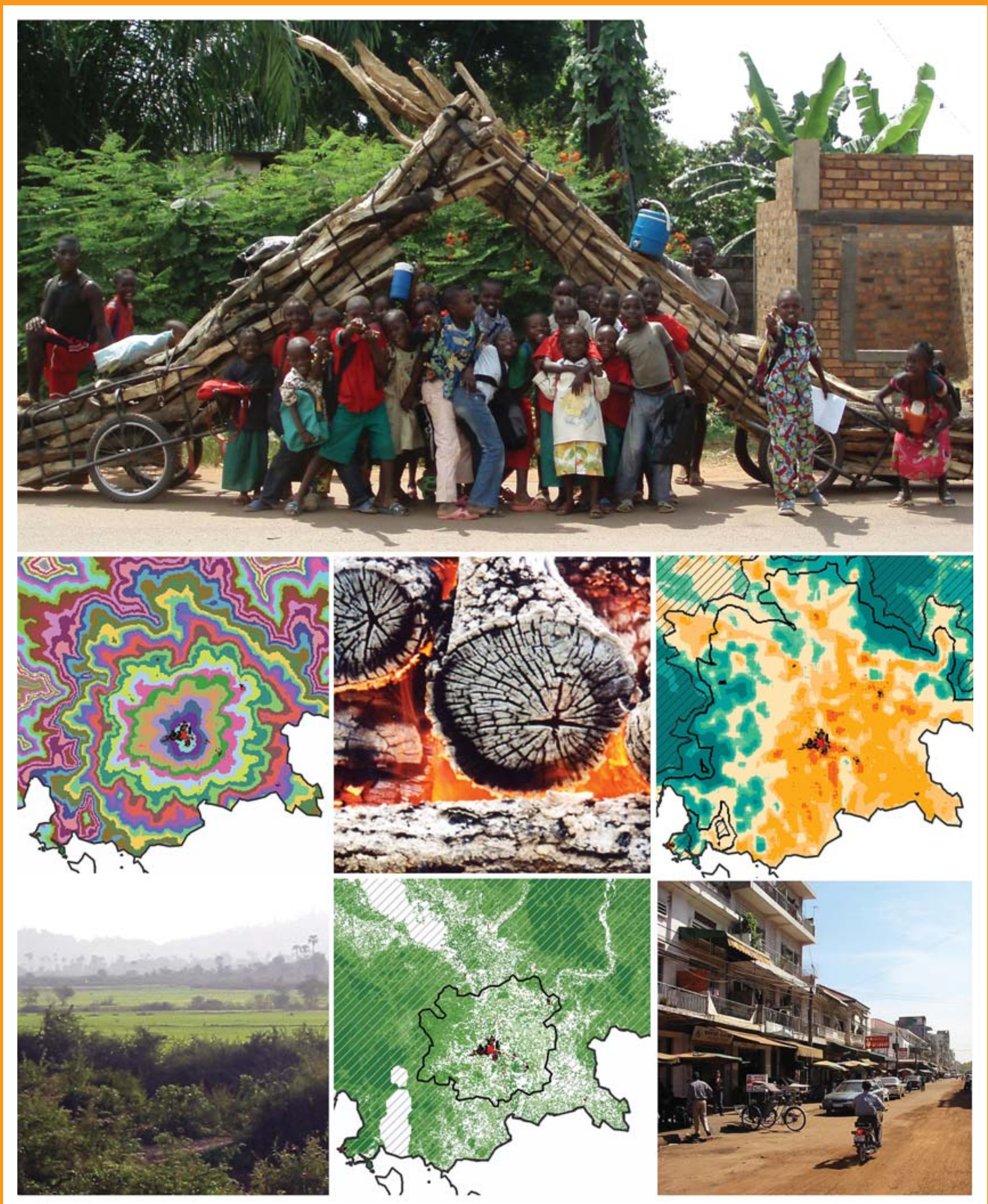
WISDOM for Cities

Analysis of wood energy and urbanization using WISDOM methodology

Woodfuels Integrated Supply/Demand Overview Mapping



FAO Forestry Department

Urban forestry – Wood energy

WISDOM for cities

Analysis of wood energy and urbanization using WISDOM* methodology

(*) Woodfuels Integrated Supply/Demand Overview Mapping (WISDOM)

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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Foreword

Forests and trees are the source of a myriad of products, services and functions (including income) for many people living in urban and peri-urban areas as well as for rural communities which earn their living by responding to urban demand. Over time, the impacts of urban areas have grown far beyond peri-urban boundaries, leading to, amongst others, forest degradation, deforestation and devegetation around cities. One major concern of forestry, energy and agriculture policy makers and urban administrators in African, Asian and Latin American countries, is how to mitigate negative impacts of urban centres on the surrounding environment, while at the same time enabling rural communities to take advantage of the opportunities available.

Historically, fuelwood has been viewed as the main contributor to degradation. In reality, the situation is considerably more complex. The main causes of the destruction of forests and trees around cities are the demand for land of ever-increasing populations and the unplanned use of resources and raw materials such as food, fodder, timber and fuels which are vital for the livelihoods of urban and peri-urban dwellers.

FAO's Forest Products Service and Forest Conservation Service joined forces to develop a tool to better assess and clarify the nexus between urban woodfuel (fuelwood and charcoal) consumption and natural supply capacities.

FAO's conventional Woodfuel Integrated Supply/Demand Overview Mapping methodology (WISDOM) was adapted to generate thematic maps describing the areas of influence of urban woodfuel demand. "WISDOM for Cities" has proved to be a useful tool for the mapping of sustainable resource potential and woodfuel consumption areas, identification of deficit and surplus areas and the pragmatic definition and visualization of areas influenced by the urban/peri-urban consumption of wood energy, as well as identification of priority areas for intervention.

As an analogy to "watershed", the concept of "urban woodshed" has been created to visualize, define and map the territory needed for the sustainable supply of the woody biomass demanded by cities.

We believe this study provides a useful tool for the analysis of woodfuel balances around cities, thus facilitating the development of comprehensive wood energy strategies and projects. We hope that "Wisdom for Cities" will stimulate dialogue amongst all concerned in the development of sustainable wood energy systems in order to better integrate the concerns of rural and urban areas, restore and rehabilitate tree and forest resources where necessary, and improve the livelihoods of poor communities.

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Abstract

This study reviews the nexus between rapid urbanization processes, poverty and woodfuel consumption trends in the urban and peri-urban areas of developing countries. It examines the environmental and socio-economic changes induced by rapid urban growth, such as the increase in charcoal consumption, and proposes conceptual and methodological tools to support urban wood energy planning and the establishment of sustainable wood energy systems.

Experiences and tools from various disciplines such as urban forestry and wood energy planning are here confronted with the threats and opportunities created by increasing woodfuel demand from more and more urban and peri-urban dwellers.

It is argued that urban administrators dealing with forestry, energy and urban development should give greater policy relevance to the wood energy sector and take responsibility for the impact that urban consumption has on forests and woodland, as well as on rural communities, beyond the city borders. It is recommended that urban, rural and forestry administrators of the same geographic region liaise and coordinate their efforts towards the implementation of sustainable wood energy systems at the regional level, since the woodfuel supply zone of a given city extends deeply into rural areas and forests and often overlaps with other cities' supply zones.

Similarly, it is argued that national forestry institutions should take up the challenge of putting charcoal production for the growing demand of urban and peri-urban populations on a more sustainable basis, if the current/potential benefits for poor charcoal producers are to be consolidated and if irreversible environmental damages are to be avoided.

In order to support urban wood energy planning and policy formulation, analytical methods and planning tools aiming at a sound and objective definition of urban/rural interaction are defined. Consideration is given to two planning levels: i) a strategic planning level focused on the overall national context and on the definition of priority areas of intervention; and ii) an operational planning level focused on the woodfuel flow within a specific urban woodshed.

To support strategic planning, the WISDOM methodology[1] is reviewed and adapted to map woodfuel surplus and deficit areas in terms of local supply/demand patterns and to outline the potential sustainable woodfuel supply zones of major cities (here termed urban woodsheds in analogy with the familiar geographic concept of *water*sheds).

The WISDOM methodology and the additional urban woodshed module are applied to selected cities in East Africa (Dar-es-Salaam, Arusha-Moshi, Kampala and Khartoum) and Southeast Asia (Phnom Penh, Battambang, Vientiane and Luang Prabang), using the WISDOM analyses recently carried out for these subregions as reference. The studies reveal how deeply the supply zones extend into rural areas and forests, with woodfuels often travelling several hundred kilometres to reach urban consumers, and highlight the essential contribution of wall-to-wall analysis in the definition of the zones of influence of individual cities.

To support operational wood energy planning within priority areas defined at the strategic level, the study presents the features and parameters to be collected for accurate woodfuel flow analysis and discusses best practices in urban and peri-urban land management for the integration of woodfuel production in multifunctional urban forestry.

[1] The WISDOM methodology has been applied by FAO at the country level in Mexico, Slovenia, Senegal and Argentina and at the subregional level in East Africa and Southeast Asia.

Acknowledgements

Given the interdisciplinary and intersectoral character of the study, many people have contributed specific information and competent advice, either directly or indirectly. In particular, the authors wish to express their gratitude to:

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Contents

Acronyms

30 arc-sec	30" × 30" latitude × longitude grid (approximately 0.9 × 0.9 km pixel size)
5 arc-min	5’ x 5’ latitude x longitude grid (approximately 9 × 9 km pixel size)
BAU	Business as usual (scenario)
ESMAP	Energy Sector Management Assistance Program (World Bank)
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Corporate Database for Substantive Statistical Data (FAO)
FIVIMS	Food Insecurity and Vulnerability Information and Mapping Systems
FOI	Forest Products and Industry Division (FAO)
FOIP	Forest Products Service (FAO)
FRA	(Global) Forest Resources Assessment (FAO)
GDP	Gross domestic product
GFPOS	Global Forest Products Outlook Study (FAO)
GIS	Geographic Information System
GLC	Global land cover
ICRAF	World Agroforestry Centre (formerly International Centre for Research in Agroforestry)
IEA	International Energy Agency
IUCN	The World Conservation Union (formerly International Union for the Conservation of Nature and Natural Resources)
i-WESTAT	Interactive Wood Energy Statistics (FAO)
IS	International system of units
LandScan	Worldwide population database compiled on a 30" × 30" latitude × longitude grid of the Oak Ridge National Laboratory (ORNL) Global Population Project
LCCS	Land Cover Classification System (FAO, 2005c)
LEAP	Long-range Energy Alternatives Planning
LPG	Liquefied petroleum gas
MDG(s)	Millennium Development Goal(s)
NGO	Non-governmental organization
Pixel	("picture element") The smallest unit of a raster map
ppp	Purchasing power parity
SWOT	Strengths, weaknesses, opportunities and threats (analysis)
UBET	Unified Bioenergy Terminology
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-Habitat	United Nations Human Settlement Programme
UPF	Urban and peri-urban forestry
WB	World Bank

WCMC	World Conservation Monitoring Centre
WE	Wood energy
WHO	World Health Organization
WISDOM	Woodfuels Integrated Supply/Demand Overview Mapping (methodology)
WSSD	World Summit on Sustainable Development

Executive summary

THE ISSUE

The new millennium has been defined as the “urban millennium”. The rapid growth in urban development is slowing down in the industrialized countries of North America, Europe and Oceania while there is a considerable increase in the urban population of developing countries. The growth of cities in developing countries and the consequent shift from rural to urban societies are linked to a complex set of factors but result in the so-called urbanization of poverty. In fact, the main reason why people from rural areas migrate to towns is linked to the expectation, very often a mirage, of better livelihoods and security. Wars, intranational conflicts and natural disasters are also frequent factors of forced urbanization.

Cities are thus confronted in the new millennium with the problem of accommodating the rapidly growing urban populations, providing them with adequate resources and basic urban services, such as housing, water and energy, while ensuring environmental sustainability and enhancing economic growth and development.

Focusing on the energy issues and recognizing that woodfuels (charcoal and fuelwood) still represent the only affordable fuel for most urban dwellers in developing regions, policies and decision-making on the urban environment and land use and on urban/rural interaction become crucial issues.

Woodfuel consumption statistics provide an indication, if not evidence, of the growth of urban woodfuel demand, especially charcoal, associated with rapid urbanization, as compared with a general decrease in the use of fuelwood. The shift from fuelwood to charcoal has severe environmental and socio-economic implications because charcoal comes almost exclusively from forests and dense woodlands and through commercial channels, while fuelwood comes mainly from farmlands, agricultural and forestry residues and by-products, deadwood collection and through informal means. In Africa, for instance, according to the *Global Forest Products Outlook Study* (GFPOS) (FAO, 2001a), charcoal consumption is expected to increase by 111 percent over the period 2000–2030, reaching one third of the total wood used for energy, which implies a substantial additional pressure on forest resources.

Increased consumption of charcoal and fuelwood by city dwellers has a high impact on forest resources, in terms of sustainability and degradation threats, and on farmers and poor decentralized communities, as present or potential income opportunity. In tropical Africa and in many other developing areas presenting this situation there is an urgent need to make charcoal and fuelwood production primary sustainable forest management objectives in order to reduce forest degradation processes and to convert occasional and often illegal income opportunities into dependable assets for poverty alleviation and sustainable development in poor rural and peri-urban communities.

CHALLENGES OF URBAN WOOD ENERGY PLANNING

It is evident that the environmental and economic nexus linking urban and rural areas is far-reaching and urban administrators must recognize the powerful influence that growing metropolitan areas exert on ever-expanding territories and social segments. Cities can no longer maintain a passive role regarding the *source* of woodfuel and *how* their needs for the resource are satisfied. It is clear that the role and responsibility of cities should be active rather than passive and that woodfuel and bioenergy supply should be considered in advance in urban development plans. Planning for supply should include internal elements, i.e. actions within the urban and peri-urban context based on land management options and best practices, and external elements, i.e. actions outside the urban and peri-urban context oriented towards the establishment of rational, sustainable and equitable interactions with rural woodfuel producers.

But urban wood energy planning is not a trivial matter because it does not refer to a self-contained and delimited sector and nor does it present a well-defined responsible institutional structure. It rather sits at the intersection of many different sectors, disciplines and institutional competences, each of which has its specific folder of responsibilities and planning tools but none of which perceives a direct responsibility for the development and monitoring of sustainable wood energy systems in cities. A critical challenge in urban wood energy planning is to overcome the fragmentation of competences and responsibilities that characterize the sector and to achieve an adequate level of integration and collaboration among the different sectors involved.

To support policy formulation and operational planning it is necessary to analyse consumption patterns and supply capacities on a geographic basis and to create an analytical context where socio-economic aspects can be integrated.

Two planning levels can be identified: i) a strategic planning level focused on the overall national context, on the supply zones of major cities (here termed "urban woodsheds" in analogy with the familiar geographic concept of *water*sheds) and on the definition of priority areas of intervention; and ii) an operational planning level focused on the woodfuel flow within a specific urban woodshed.

STRATEGIC PLANNING LEVEL: WISDOM METHODOLOGY WITH THE URBAN WOODSHED MODULE

The WISDOM methodology,[2] specifically adapted to the urban perspective, is here proposed as a strategic planning tool integrating woodfuel demand and supply aspects and supporting a comprehensive but spatially discrete analysis of cities' woodfuel consumption and their supply zones in a wide territorial context. In synthesis, the methodological steps of the analysis include the following.

Baseline WISDOM analysis

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

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

Additional urban woodshed module

Further focusing of the analysis for the delineation of urban woodsheds, i.e. supply zones of specific urban and peri-urban areas, requires additional analytical steps that may be summarized as follows.

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

The WISDOM methodology and the additional urban woodshed module were applied to selected cities in East Africa (Dar-es-Salaam, Arusha-Moshi, Kampala and Khartoum) and Southeast Asia (Phnom Penh, Battambang, Vientiane and Luang Prabang), using as reference the WISDOM analyses recently carried out for these subregions. The studies revealed how deeply the supply zones extend into rural areas and forests, with woodfuels often travelling several hundred kilometres to reach urban consumers, and they highlighted the essential contribution of wall-to-wall analysis in the definition of the zones of influence in individual cities.

In addition to cartographic and statistical outputs presented for each study site, the following conclusions may be highlighted.

- The theoretical supply zones of a given city may vary considerably because of the quantity and quality of woody biomass sources in surrounding areas. The sources of "commercial" woodfuels suitable for urban markets are only a fraction of "total" woodfuel sources. Excluded from the commercial circuit are the sparse vegetation types and most farm trees and shrubs, which are important for local consumption but

[2] WISDOM is the fruit of collaboration between FAO's Wood Energy Programme and the Institute of Ecology of the National University of Mexico. At the national level, the WISDOM approach has been implemented in Mexico (FAO, 2005e; Masera *et al*., 2006), Senegal (FAO, 2004b) and Slovenia (FAO, 2006a). At the subregional level, WISDOM was implemented over the eastern and central African countries covered by the Africover Programme (Burundi, Democratic Republic of the Congo, Egypt, Eritrea, Kenya, Rwanda, Somalia, the Sudan, United Republic of Tanzania and Uganda) and over the countries of Southeast Asia (Cambodia, Malaysia, Lao People's Democratic Republic, Thailand, Viet Nam and China, Yunnan Province).

unsuitable for commercial production. This implies that the “commercial” supply zone may be significantly greater than the “total” one.

- Another element that strongly influences the size of the theoretical sustainable supply zones is the local consumption of woodfuels in rural areas, settlements and other cities located within the zone itself. When the supply zone is confronted with all consumption (expanded zone) and not only that of the city itself (restricted zone), its size increases considerably.
- The combination of the two aspects above has a paramount influence on the size of the nominal supply zone of a city, which underlines the necessity and importance of a wall-to-wall analysis such as the WISDOM baseline for the definition of urban woodsheds. In order to highlight the influence of these aspects on the size of urban woodsheds, four theoretical supply zones were determined for each study site, i.e. restricted-total zone, restricted-commercial zone, expanded-total zone and expanded-commercial zone, the latter being the most comprehensive and probably the most realistic.

The issues mentioned above with regard to the mapping of urban woodsheds or theoretical sustainable supply zones should not be considered as trivial or simple technicalities. The urban woodshed delineation determines the future project area and is a fundamental prerequisite for the identification of stakeholders to be involved in the formulation of participative planning and policies. A wrong definition of urban woodsheds would heavily undermine the effectiveness of project action and the sustainability of the derived urban wood energy systems.

CONCLUSIONS FROM SELECTED SOUTHEAST ASIAN AND EAST AFRICAN WISDOM CASE STUDIES

The case studies on urban woodshed delineation conducted over selected urban centres of Southeast Asia and East Africa (discussed in Section 5.2 for methodology and presented in Section 5.3 for results) represent the first testing of the WISDOM approach adapted to an urban perspective. The analyses of selected cities were largely based on previous studies and accessible information sources, without additional country-level data collection or field verification. As such, they are limited to what is called a “strategic knowledge base”, a diagnostic level meant to support the formulation of strategies rather than operational planning for which a field-level approach is needed.

The cities selected to exemplify urban woodshed analyses (Figure 1), are:

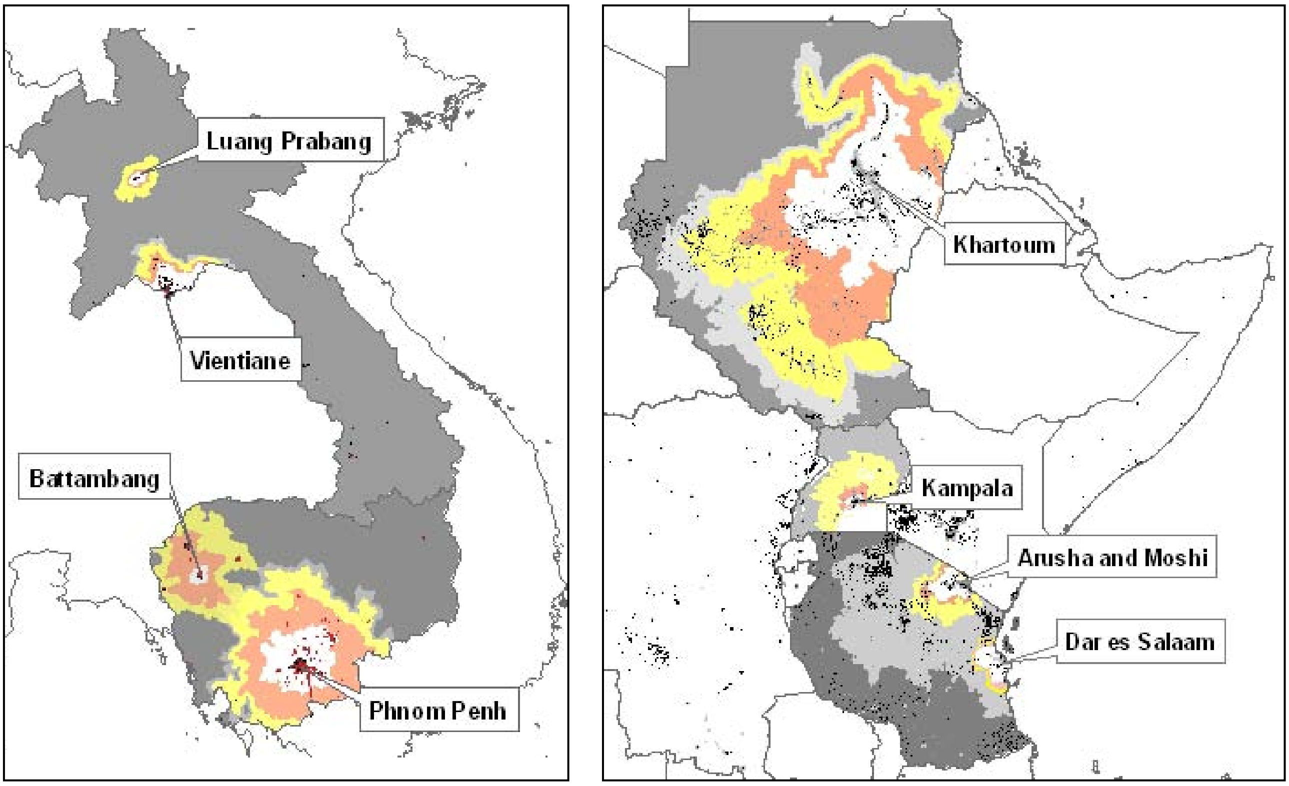
- Southeast Asia – Phnom Penh and Battambang in Cambodia; and Vientiane and Luang Prabang in the Lao People’s Democratic Republic.
- East Africa – Dar-es-Salaam, Arusha-Moshi in the United Republic of Tanzania; Kampala in Uganda; and Khartoum in the Sudan.

Findings from each case study are presented and discussed in Section 5.3. The most relevant and specific conclusions derived from the analysis of the urban woodsheds in these cities are described below.

- The urban woodshed in Phnom Penh, in its most comprehensive delineation (expanded-commercial supply zone), was estimated in 2000 to cover over 70 000 km^2, or 39 percent of Cambodia. This area is expected to grow to some 51 percent of the country by 2015, according to likely woodfuel consumption scenarios and trends in land use change. This huge area is a combination of woodfuel consumption in the city itself, i.e. some 500 000 tonnes of wood in 2000, and that of surrounding rural and urban areas with a combined consumption of over 4 million tonnes. The Phnom Penh woodshed hosts over 10 million people, half of whom are represented by sparse rural communities. Compared with other parts of the country, these communities have a high incidence of malnutrition according to World Health Organization (WHO) data, which is a clear indication of extreme poverty. Woodfuels represent the only affordable fuel for them and the production of charcoal and fuelwood for distant urban markets is an essential source of income. In this situation, woodshed delineation can play an important role in the selection of priority areas of intervention for the adoption of poverty alleviation measures, such as the creation of rural markets, associated with sustainable resource management.
- The expanded-commercial urban woodshed of Dar-es-Salaam has a relatively small supply zone because of the proximity of dense forests and woodlands, i.e. some 30 000 km^2 or 3 percent of the United Republic of Tanzania. However, the analyses centred on Arusha-Moshi revealed that, given the population density of the northeastern part of the country and the paucity of wood resources, the expanded-commercial zone of these cities extended over some 460 000 km^2 or as much as 52 percent of the country surface, and included Dar-es-Salaam itself.

- The Arusha-Moshi case study shows that a combination of factors outside the city strongly influences the size and shape of the urban woodshed, even at a considerable distance. It also stresses the benefits of urban woodshed analysis for several cities in a country, in order to achieve a comprehensive vision of urban/rural interaction.
- The Kampala case study highlighted the difficulties that Uganda faces in woodfuel supplies. In fact, the analysis of potential sustainable supply zones revealed that commercial supply sources from dense forests and woodlands are not sufficient to satisfy urban consumption levels even when the entire country area is considered (the expanded-commercial supply zone always remains negative). This means that lower and fragmented vegetation types are probably exploited for urban woodfuel markets and not only for local consumption, which implies a strong and widespread risk of overexploitation and protracted degradation of natural resources on the one hand and, on the other, subsistence energy shortages for poor rural and peri-urban communities.
- The Khartoum study revealed the huge supply zones theoretically needed to produce the woodfuel consumed in the capital. Assuming a sustainable supply from dense formations and bearing in mind all consumption from other rural and urban areas, Khartoum's expanded-commercial supply zone covers over 1.5 million km^2 or 62 percent of the country.

FIGURE 1



Cities selected for urban woodshed analysis in Southeast Asia (left: Cambodia and the Lao People's Democratic Republic) **and in East Africa** (right: the Sudan, Uganda and the United Republic of Tanzania).

OPERATIONAL PLANNING LEVEL: IN-DEPTH WOODFUEL FLOW ANALYSIS AND LAND MANAGEMENT

In order to guide policy decisions and determine operational action for a specific urban area and its woodshed, it is recommended that a detailed analysis of current and potential sustainable woodfuel flows be undertaken. This level of investigation calls for accurate data since its aim is to support operational wood energy planning and urban/rural land management. The main limitation to the implementation of woodfuel flow analyses is the cost of field data collection. In fact, the important contribution of the previous strategic planning phase is to circumscribe the areas requiring additional investments in data collection to the priority areas where such investment is justified.

The parameters to be studied in order to allow in-depth woodfuel flow analysis for operational urban woodshed planning are described in *A guide for woodfuel surveys* (FAO, 2002a), which also gives basic survey methods for their collection. They are grouped by broad categories: woodfuel demand, supply and provision (production, transportation and marketing).

Other aspects to be analysed include the definition of legal and physical accessibility to supply zones and the impact of woodfuel extraction on neighbouring areas in terms of reduction in woody biomass productivity as a result of excessive and non-sustainable fuelwood extraction and charcoal production for urban consumption. To this end, it is recommended that land cover monitoring be undertaken within the urban woodshed by means of a methodology that guarantees the most reliable analysis of land cover changes and the best inference on the underlying cause-effect mechanisms.

Land management and good practices may contribute substantially to optimizing the production of woodfuels in urban and peri-urban contexts and, more widely, to the sustainable supply of woodfuel for urban demand. They include i) the identification and promotion of tree species and management prescriptions that guarantee woody biomass production together with other environmental and social benefits; ii) the promotion and integration of agroforestry practices in urban and peri-urban farming systems in order to increase woody biomass production; iii) the definition of urban development standards that, together with minimum green area prescriptions for recreation and other environmental benefits, set a minimum "woody biomass productivity" quota for new urbanized areas; and iv) the recovery of all woody biomass from tree care and management of street trees and urban parks. Several actions should look at the integration of urban/rural planning and include good practices such as the establishment of formal agreements between urban authorities and peri-urban and rural associations for the continued and sustainable supply of fuelwood and charcoal.

MAIN RECOMMENDATIONS

Strategic planning

- Urban administrators and planners should acknowledge the policy relevance of urban wood energy.
- Since the woodfuel supply zone of a given city extends deeply into rural areas and forests and often overlaps with other cities' supply zones, it is recommended that urban, rural and forestry administrators of the same geographic region liaise and coordinate their plans and action.
- It is essential that city administrators clearly define the area of influence of urban woodfuel demand in environmental and socio-economic terms.
- To support energy planning at the regional level, it is recommended that each city's urban woodshed be mapped objectively and the relative social, economic and institutional stakeholders identified.
- Energy planning in the urban and peri-urban context should give special attention to the negative impact that rapid and massive substitution of woodfuel by other fuels (kerosene, liquefied petroleum gas [LPG] or electricity) may have on poor rural and forest communities representing the weakest link in the chain and that depend, permanently or seasonally, on woodfuel production for their livelihoods.
- Urban and national authorities should implement or strengthen consumption-reduction policies through dissemination of efficient conversion technologies and sustainable substitution programmes and, at the same time, undertake policies oriented towards the sustainable and equitable supply of woodfuel to urban users and to reducing the negative impact of unregulated forest exploitation.
- National, regional and international forestry authorities should give relevance to charcoal in their forestry policies and raise the production of charcoal to a primary sustainable forest management objective.
- National and urban authorities should develop and implement clear policies on:
    - the recognition of clear rights and responsibilities regarding land tenure and forest exploitation;
    - formal supply agreements between urban authorities and peri-urban and rural communities (e.g. smallowners' associations) that guarantee direct woodfuel producers' access to the urban consumer market;
    - fair pricing and transparent taxation systems; and
    - coherent land use planning and urban development programmes.
- Urban administrators should undertake specialized and participatory planning at both the strategic and

operational level in order to optimize multifunctional land management and environmental sustainability.

Operational planning

With regard to land management and best practices aiming to mitigate the negative impacts of urban and peri-urban wood energy the following is highly recommended.

- Implementation of programmes to promote and facilitate access to high-efficiency stoves.
- Formulation and implementation of policies favouring the integration of other energy sources and dedicated price policies.
- Promotion of programmes of plantations and management of urban and peri-urban forests with multiple functions but where the wood energy supply is considered at the design and planning level.
- Research on the suitability of native tree species, plantation schemes and management styles.
- Implementation of training and extension programmes on silvicultural and pruning techniques oriented towards the optimal and sustainable management of woody biomass resources in urban and peri-urban areas as well as in the rural/forest areas of the urban woodshed.
- Promotion of the sustainable and efficient use of woodfuels as a legitimate renewable energy source that ensures energy security and autonomy while contributing to sustainable rural development and poverty alleviation.

Methodological aspects

Given the interdependence among urban, peri-urban and rural people and factors in urban wood energy systems, it is recommended that an analysis of woodfuel demand and supply factors be integrated at urban/peri-urban and rural levels; for this exercise the WISDOM methodology appears to be highly suited. Two levels of analysis, supporting two different planning phases, may be identified:

- a *strategic knowledge base* that integrates existing data to support strategic planning and priorities; and
- an *in-depth woodfuel flow analysis* based on accurate field data to support operational planning within selected priority urban woodsheds.

Strategic knowledge base

To define the urban woodsheds of selected cities objectively and to contextualize the analysis within a country it is recommended that the analysis be carried out in two steps.

Step 1 *WISDOM baseline*. An overview of the entire country (or broad geographic region) that, from existing data and maps, provides a geographic representation of woodfuel supply/demand balance based on woody biomass supply potential and fuelwood/charcoal consumption patterns.

Step 2 *Urban woodshed analysis*. An outline of the potential sustainable supply zones of selected cities in terms of urban/peri-urban woodfuel consumption and potential sustainable woodfuel production suitable for and accessible to urban markets.

In-depth woodfuel flow analysis

- In order to guide policy decisions and determine operational action for a specific urban area and its woodshed it is recommended that a detailed analysis of current and potential sustainable woodfuel flows be undertaken.
- The recommended methodological aspects and parameters to be collected/analysed are those described in detail in *A guide for woodfuel surveys* (FAO, 2002a).

PART I

OVERVIEW OF URBAN AND PERI-URBAN FORESTRY AND WOOD ENERGY IN DEVELOPING COUNTRIES

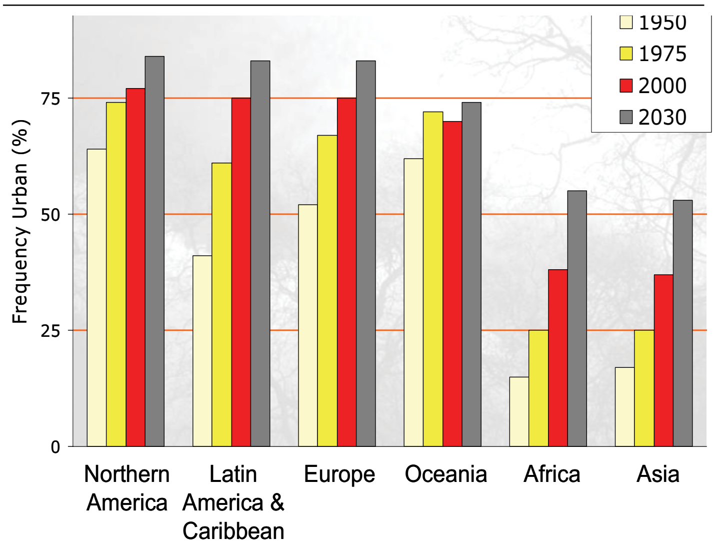
1 Introduction

1.1 BACKGROUND

The new millennium has been defined as the “urban millennium” (Box 1). The rapid growth in urban development is slowing down in the industrialized countries of North America, Europe and Oceania while there is a contemporary tremendous increase in the urban population of developing countries and countries in transition in Latin America, Africa and Asia (Figure 2).

The origin of the new urbanized society is often linked to a desperate search for a basic livelihood by people coming from poverty conditions, who frequently lose the sense of ”dwellership and social identity” in the harsh and inhospitable conditions of the growing cities. To date, urbanization and poverty have often been twinned words: over the last 20 years the world population living below the poverty line in urban areas has increased from 47 to 64 percent. Access to food and fuelwood for basic survival is increasingly becoming a prior concern for the governance of future cities and particularly in peripheral zones or neglected centres where the concentration of poverty is higher.

FIGURE 2
Percentage of urban dwellers in the total population from 1950 to those forecasted in 2030 (*source*: UN)



Woodfuel consumption statistics provide an indication, if not evidence, of the growth of urban woodfuel demand, especially charcoal, associated with rapid urbanization, as compared with a general decrease in the use of fuelwood. The *Global Forest Products Outlook Study* (GFPOS) (FAO, 2001a), estimated that globally, the total woodfuel consumption of charcoal increased from 9 percent in 1980 to 15 percent in 2000 and is expected to increase further to 23 percent in 2030. In Africa, where the link between urbanization and the shift from fuelwood to charcoal is greater, charcoal consumption increased from 18 percent in 1980 to 24 percent in 2000 and will increase to 34 percent in 2030. This is a substantial increase, considering that fuelwood consumption is estimated to grow as well, although at a slower rate. The shift from fuelwood to charcoal consumption, which is probably the most relevant change resulting from the process of urbanization in tropical developing countries, brings significant risks but also promising opportunities for the environment and for the sustainable development of the regions and communities involved in charcoal production. It implies a greater impact on supply sources as a result of the energy lost in the carbonization process and the fact that charcoal is produced almost exclusively from natural forests and woodlands, while fuelwood is often a by-product of farming systems. It offers opportunities of income and employment to communities involved in the production of charcoal located far upstream.

Urban forestry has often been seen as an important opportunity to better the quality of life of urban dwellers by providing a wide set of social, economic, ecological, health and psychological benefits. According to the definition given by Miller (1997), the urban forest can be intended as "the sum of all woody and associated vegetation in and around dense human settlements, ranging from small communities in rural settings to metropolitan regions". Urban forestry is the whole of disciplines, styles and techniques dealing with the sustainable management, design and planning of urban forests and trees. It includes the ecological, social and economic aspects characterizing cities and their ecosystems, and also concerns the impact generated by urban societies on trees and forests.

The consumption of woodfuels (fuelwood and charcoal) by growing cities in many developing countries has an impact on land much further away from the city borders, influencing the type of use and management of wood resources. This impact concerns trees and forests that are sources of woodfuels as well as communities directly or indirectly involved in woodfuel production, whose economic, social and behavioural character is often shaped and affected by urban influence.

BOX 1
The urban revolution

The city is a great success of human beings: it comprehends the highest knowledge in a physical landscape having an extraordinary complexity, power and splendour and, in parallel, summarizes social forces carrying the capacity of the most amazing sociotechnological and political innovation. But the city is also the place of the squalid existential failure, lightning rod of desperate dissatisfaction, arena of political and social conflicts (Harvey, 1989). As quoted by Ponting, 1991 (in Konijinendijk *et al*., 1993), Thoreau considered cities to be places where “millions of people are feeling lonely together”, while others have praised cities as centres of better life innovation and learning, transmitting accumulated knowledge on which future achievements can be built (Girardet, 1992).

In geographic and economic terms, the concept of "city" refers to a place of relatively dense settlement – so dense that city residents cannot grow their own food or provide entirely for their requirements in resources and facilities. In ecological terms, it is not a self-sufficient system and is highly dominated, in space and time, by the human population. A city population, therefore, is always dependent upon its "hinterlands" to provide it with food and resources: the external energy supply is a key factor in the survival and development of the city.

At the turn of the millennium more than half of the world’s population lives in cities and towns, or in growing dense settlements, and are thus classified as “urbanized”; and this figure is increasing rapidly.

During the 1990s, despite a reduced growth in metropolitan areas in developed countries, it appeared dramatically clear that urbanization had become a worldwide phenomenon, particularly with regard to traditionally rural societies. The concentration of people in urban settings reached extremely high percentages in the second half of the twentieth century: by 1950, more than 50 percent of the population of northern America, Europe and Oceania were urban and in 2000 this figure had reached about 75 percent of the total population (Figure 2). But the rapid growth in urban development is slowing down in these parts of the world, while there is a contemporary tremendous increase in the urban population of developing countries and countries in transition. The implications of global urban development are much more than a simple concentration of people in cities. Urbanization is a process that has physical and geographic implications, as well as social, cultural, behavioural and psychological impacts. Urbanization of consciousness and lifestyle is foreseen as a keystone of the urban millennium (Kuchelmeister, 1998).

Urbanized settings in developing countries are expected to represent at least 90 percent of forecasted world population growth according to projections towards 2030. The most explosive urban growth is expected in Africa and Asia; the latter will have the largest urban population in the world (UN, 2004).

1.1.1 Urban wood energy in the international agenda

Many factors converge in making sustainable and affordable energy a key component and a viable opportunity in the struggle towards the achievement of the Millennium Development Goals (MDGs). Although the sustainable access to energy is not treated as a priority in itself in the MDGs, most of them have a direct energy implication, particularly Goal 1 (Eradicate extreme poverty and hunger) and Goal 7 (Ensure environmental sustainability) (Box 2).

Specific reference to bioenergy was made at the 2002 World Summit on Sustainable Development (WSSD), where energy was high on the agenda. According to the WSSD Johannesburg Declaration, energy must be considered a human need on a par with other basic needs (clean water, sanitation, shelter, health care, food security and biodiversity) (Box 3).

There is a deeply rooted interrelation between poverty, access to energy and environmental sustainability.

BOX 2
Millennium Development Goals

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Urban wood energy is a key aspect also for the United Nations Human Settlement Programme (UN-Habitat). Specific initiatives that may benefit from the implementation of in-depth studies on sustainable urban wood energy systems are the following.

- The Sustainable Cities Programme (SCP), which is a joint UN-Habitat/United Nations Environment Programme (UNEP) facility established in the early 1990s to build capacities in urban environmental planning and management. The programme targets urban local authorities and their partners. It is founded on broad-based stakeholder participatory approaches.
- Local Agenda 21, which is a capacity-building programme that started in 1995 as a response to Chapter 28 of Agenda 21 whereby local authorities are called upon to undertake participatory processes to develop and implement "Local Agendas 21" for and with their communities. The Programme offers multiyear support to local authorities and their partners to undertake Local Agenda 21 processes in order to contribute locally to the implementation of Agenda 21 and the Habitat Agenda. Programme support specifically targets secondary cities that often lack capacities and are usually forgotten by international support programmes.

BOX 3
WSSD Plan of Implementation

The World Summit on Sustainable Development (WSSD) in Johannesburg specifically addressed the wood energy issue in several parts of the WSSD Plan of Implementation (PI), emphasizing that "access to energy facilitates the eradication of poverty". The pertinent PI paragraphs are the following.

Chapter II (Poverty eradication)
Para. 9(b) Improve accesses to modern biomass technologies and fuelwood sources and supplies and commercialize biomass operations, including the use of agricultural residues, in rural areas and where such practices are sustainable.
Para. 9(c) Promote a sustainable use of biomass and, as appropriate, other renewable energies through improvement of current patterns of use, such as management of resources, more efficient use of fuelwood and new or improved products and technologies.
Para. 20(g) Develop and utilize indigenous energy sources and infrastructures for various local uses and promote rural community participation.
Chapter IV (Protecting and managing the natural resource base of economic and social development)
Para. 45 "Forests and trees cover nearly one-third of the Earth's surface. Sustainable forest management of both natural and planted forests and for timber and non-timber products is essential to achieving sustainable development as well as a critical means to eradicate poverty, significantly reduce deforestation, halt the loss of forest biodiversity and land and resource degradation and improve food security and access to safe drinking-water and affordable energy."

Avoiding deforestation and forest degradation derived from unsustainable woodfuel production, promoting renewable energy systems and reducing fossil fuels share are all effects of sustainable urban wood energy systems that contribute to the reduction of greenhouse gas emission and to climate change mitigation measures. As such, they actively contribute to the achievement of the objectives of the United Nations Framework Convention on Climate Change (UNFCCC).

1.2 RATIONALE AND OBJECTIVES

In countries where the use of woodfuels remains an important source of household energy for poor urban dwellers, it is essential to develop information bases and planning tools adapted to the sustainable management of urban woody biomass demand and supply. The issues at stake are numerous and include the following.

- A growing number of poor urban and peri-urban dwellers need access to basic energy services (and there is often no short-term alternative to traditional biofuels).
- The proper valuation of woody biomass resources economically accessible to urban markets can offer viable alternatives for sustainable resource management and clean and affordable energy options. It can also benefit poor upstream communities with employment and income.
- Appropriate land management can play a significant role in the urban wood energy issue in terms of woodfuel production, social consciousness and institutional and community capacity building.
- Policy-makers need well-adapted information bases and planning tools for the definition of possible policy alternatives.
- Analytical and planning tools exist for specific energy, forestry or urban planning aspects but methodologies integrating all these aspects are rare. The WISDOM methodology, which combines

forestry and energy aspects, may effectively support urban wood energy planning, if suitably reviewed and adapted to the urban perspective.

The WISDOM methodology has been applied to date in national and subregional contexts (Mexico, Slovenia and Senegal; in East-Central Africa and Southeast Asia), proving its adaptability to diverse data and policy priorities. In the Southeast Asian study the analysis included poverty indicators, which enabled priority areas to be identified and communities to be targeted with regard to woodfuel scarcity and poverty. Follow-up actions to the WISDOM case studies are summarized in Box 4. The WISDOM approach, based on the spatial and statistical data already produced, can be further refined to focus on the urban wood energy demand and its influence (negative and positive) on communities and land resources within its supply area.

BOX 4
Follow-up actions to WISDOM case studies

Mexico. The results of the Mexico study – in terms of the identification of priority areas or fuelwood “hot spots” – have been incorporated into the projects of the National Forestry Commission, which plans to launch a programme of efficient wood stoves and multipurpose energy plantations directed at those areas.

Slovenia. Follow-up actions included i) the development of a tailored WISDOM analysis for five municipalities interested in developing pellet production and district heating systems in their territory; ii) the definition of a proposed national wood energy strategy in the context of the National Forestry Programme and the National Programme for Rural Development; and iii) the preparation of the Slovenian Wood Biomass internet portal to guarantee easy access to state-of-the-art information on all aspects of wood energy in the country.

Senegal. In the framework of the “Systèmes d’information energétiques – SIE-Afrique” project, supported by the Institute de l’energie et de l’environnement de la francophonie, the case study contributed to an analysis of the wood energy component for Senegal. An updated WISDOM analysis for the country is foreseen as soon as the ongoing consumption survey is completed.

The recent WISDOM studies for East Africa (2005) and Southeast Asia (2006) contributed to regional biomass assessment and wood energy outlook and to the Poverty Mapping Project. The analysis of urban woodsheds presented in Chapter 4 may be considered the first follow-up to these studies.

The general objective of this paper is to contribute to the identification and development of tools and analytical methods supporting policy-makers and planners in the formulation of urban wood energy strategies and operational planning. Primarily, the analytical approach is focused on methods to assess the relationship between wood energy (needs, consumption and supply) and the management of forest and tree cover in and around cities, with attention to poverty alleviation in the urban and rural context. The aim is also to reduce the negative effects of irrational fuelwood and charcoal production around cities.

The major immediate objectives of this paper are i) to review and adapt the WISDOM methodology to in-depth studies aiming at supporting woodfuel management in the urban forestry context and poverty alleviation initiatives; and ii) to conduct preliminary analyses in selected locations in East-Central Africa and Southeast Asia.

A correlated objective is to highlight the potential contribution of urban and peri-urban forestry, as a multisectoral and transdisciplinary approach, to wood energy issues in cities.

2 Urban forestry in developing countries

2.1 RAPID URBANIZATION AND POVERTY

Urbanization[3] has profound effects on the ecology and economy of a region; the process of urbanization, and ultimately urban development, brings about substantial and dramatic changes to the landscape, a new hierarchy in land use, and an abrupt shift in the arrangement of spatial and time patterns in living conditions and use of resources.

The growth of cities in developing countries and the consequent shift from rural to urban societies are linked to a complex set of factors but result in the so-called urbanization of poverty. In fact, the main reason why people from rural areas migrate to towns is linked to the expectation, very often a mirage, of better livelihoods and security. Sadly, wars, intranational conflicts and natural disasters are also frequent factors of forced urbanization.

An analysis of the trend towards megacities[1] shows (Figure 3) how the urbanization process at its most extreme concerns more and more low-income developing countries. At the beginning of the twentieth century there were no cities in low-income countries exceeding 1 million inhabitants. Towards the end (1995) of the century some 47 percent of these so-called megacities (i.e. metropolitan areas exceeding 10 million inhabitants) were found in developing countries and in just five years the figure increased to 55 percent and is forecasted to reach 61 percent by 2015. By then, nearly 250 million people will live in megacities of low-income countries, whereas ten years previously they numbered around 80 million. This means that 14 metropolitan areas in low-income countries will need to provide livelihood resources, housing and job opportunities to a population equivalent to the number of people living in France, Spain, Italy and Germany combined.

But urbanization is a much wider issue than megacities alone. A dramatic example of booming urbanization of poverty comes from Africa. Up to 1970 no more than 25 percent of Africans lived in cities, while in 2006 the urban population was estimated to overtake 50 percent of people in the continent. The annual urban growth rate in sub-Saharan Africa is almost 5 percent (twice as high as in Latin America and Asia). The area also houses the world's largest proportion of urban residents living in slums, which today are home to 72 percent of urban Africa's citizens, representing a total of almost 190 million people. As more and more people seek a better life in towns and cities, the urban slum population in Africa is projected to double every 15 years. African cities are thus confronted in the new millennium with the problem of accommodating the rapidly growing urban populations, providing them with adequate resources and basic urban services, while ensuring environmental sustainability and enhancing economic growth and development.

It is evident that the question of urban poverty is intimately linked to access to livelihood resources and job opportunities and, in an ultimate assumption, to the potential quality of life that can be achieved in urban areas. The threatening issues in urban areas can be summarized as:

- uncertain employment;
- precarious housing;
- difficult or almost impossible access to property of the land;
- high costs versus scarce accessibility to primary livelihood needs (drinking-water, food, solid fuel, health, services, transport, education);
- severe health and sanitation problems;
- physical and social insecurity, criminality;
- shortage and discontinuity of energy supplies;
- lack or shortage of land for self-sustaining economic activities;
- lack of sense of belonging, spirit of the place, and frustrating living and working environments;
- limited physical, social and environmental infrastructures, i.e. places for recreation, socialization and outdoor activities at every stage of life.

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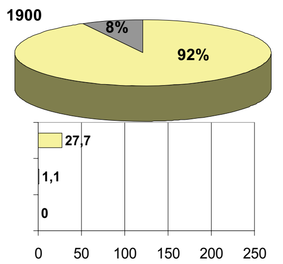
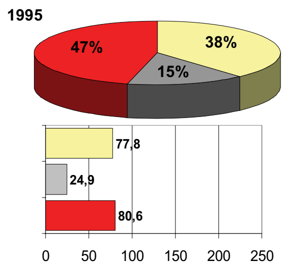
[3] See Annex 1 for definitions of terms such as *urbanization, city*, *urban agglomeration*, *megacities*, etc.

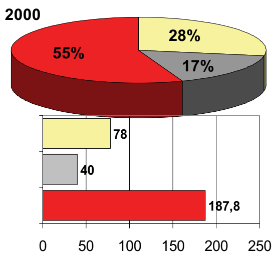
FIGURE 3

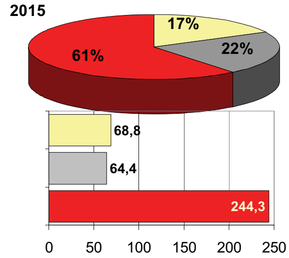
Trends in megacities in the twentieth century and projections to 2015 (various sources)

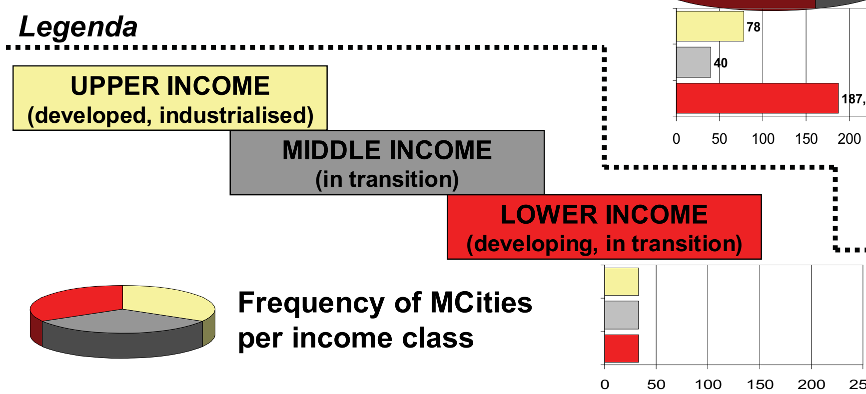
1900	10^{6}res	1995	10^{6}res	2000	10^{6}res	2015	10^{6}res
London, UK	6,6	Tokyo, Japan	26,9	Tokyo, Japan	26,9	Tokyo, Japan	27,0
New York, USA	4,2	Mexico City, Mexico	16,6	Dhaka, Banghladesh	21,1	Mumbai, India	26,2
Paris, France	3,3	São Paulo, Brazil	16,5	Karachi, Pakistan	19,2	Lagos, Nigeria	23,2
Berlin, Germany	2,4	New York, USA	16,3	Delhi, India	17,3	Dhaka, Bangladesh	21,1
Chicago, USA	1,7	Mumbai, India	15,1	Jakarta, Indonesia	17,3	São Paulo, Brazil	20,4
Wien, Austria	1,6	Shangai, China	13,6	Manila, Philippines	16,8	Karachi, Pakistan	19,2
Tokyo, Japan	1,5	Los Angeles, USA	12,4	Mexico City, Mexico	16,6	Mexico City, Mexico	19,2
S. Petersbou., Russia	1,4	Culcutta, India	11,9	São Paulo, Brazil	16,5	Calcutta, India	17,3
Philadelphia, USA	1,4	Seoul, South Korea	11,6	New York, USA	16,3	Jakarta, Indonesia	17,3
Manchester, UK	1,3	Beijing, China	11,3	Mumbai, India	15,1	Delhi, India	17,3
Birmingham UK	1,2	Osaka, Japan	10,6	Buenos Aires, Argentina	14,1	New York, USA	17,0
Moscow, Russia	1,1	Lagos, Nigeria	10,3	Cairo, Egypt	13,8	Manila, Philippines	16,8
Beijing, China	1,1	Rio de Janeiro, Brazil	10,2	Shangai, China	13,6	Shangai, China	14,8
				Los Angeles, USA	12,4	Los Angeles, USA	14,2
				Beijing, China	12,3	B. Aires, Argentina	14,1
				Calcutta, India	11,9	Cairo, Egypt	13,8
				Rio de Janeiro, Brazil	11,9	Istanbul, Turkey	12,5
				Seoul, South Korea	11,8	Beijing, China	12,3
				Osaka, Japan	10,6	Rio de Janeiro, Brazil	11,9
				Lagos, Nigeria	10,3	Tianjin, China	10,7
						Osaka, Japan	10,6
						Hyderabad, India	10,5
						Bangkok, Thailand	10,1











Observing the phenomenon from a combined geographic and ecological perspective, it can be seen how the urban sprawl and the need to accommodate and provide facilities for incoming people modify the environment where urban development takes place. Housing, industrial or commercial blocks, and infrastructures are often to be found on former rural land or already neglected and reclaimed areas. The fast growth of many cities means that land may be appropriated before any planning initiative by local or regional authorities can begin. Speculation on the price of land where new residential or productive settlements are built can be seen as a driving force in the impoverishment of new urban dwellers, as well as a powerful impediment to any planning activity and policy for the sustainable future of urban areas.

The combination of the issues mentioned above highlights the need for concrete action to avoid or reduce major threats and provide better living conditions and livelihoods for new urban people. Ensuing policy, planning and socio-economic problems in general are the following.

- Urban and environmental planning is often ignored or is ambiguous and weak. Landscape changes are caused by corruption, lack of decision-making and a power hierarchy on land tenure rather than by principles of sustainability. The results are often dramatic in terms of new urban environments.
- Urbanization has influences extending well beyond city boundaries; its impact is often not acknowledged and may even be ignored by many urban decision-makers.
- Harmonization and continuity between political strategies at the local, national and regional levels are

often lacking; communication and reciprocal capacity building are ignored.

- Participation and social involvement are frequently absent.
- There is little specific public financial support for greening, agriculture, forestry and agroforestry within cities or in urban development areas.
- The legitimacy of local people and land tenure is weak.
- There is no link between rural and urban planning. The development of cities is often not linked to their landscapes.

Focusing on the energy issues and assuming that woodfuel and charcoal still represent the only affordable fuel for a great number of urban dwellers in developing regions, policies and decision-making on urban environment and land use and on urban/rural interaction become crucial issues.

2.1.2 Poverty issues

"*The locus of global poverty is moving to the cities, a process now recognized as the 'urbanization of poverty'. Without concerted action on the part of municipal authorities, national governments, civil society actors and the international community, the number of slum dwellers is likely to increase in most developing countries. And if no serious action is taken, the number of slum dwellers worldwide is projected to rise over the next 30 years to about 2 billion*" (UN-Habitat, 2003, from the foreword by Kofi Annan, Secretary-General, United Nations.)

In the urban millennium, the words city and poverty appear to be twinned. The multiple faces of poverty are a dramatic part of *urbanscapes* in many regions of the world. The modernistic dream of a city as a living environment where poverty can not only be reduced but overcome seems far from the present status of urban areas. "Recent evidence shows that the wealth generated by cities does not automatically lead to poverty reduction: on the contrary, intracity inequalities are on the rise, particularly in the cities of Africa, Latin America and Asia" (UN-Habitat, 2006). The expected economic growth and development as a result of urbanization have not happened in many developing countries. In sub-Saharan Africa, where the highest urban growth rate is taking place, economic growth is low and is not expected to improve significantly in the near future. Yet some rapidly developing economies, such as India, in parallel with fast economic development, have also experienced exploding urbanization and the pace of urban growth has been really dramatic: Mumbai, Calcutta and Delhi are expected to be the second, eighth and tenth urban agglomerations in the world respectively, with a proportion of poor people rising to more than 70 percent (Bhasin, 2001).

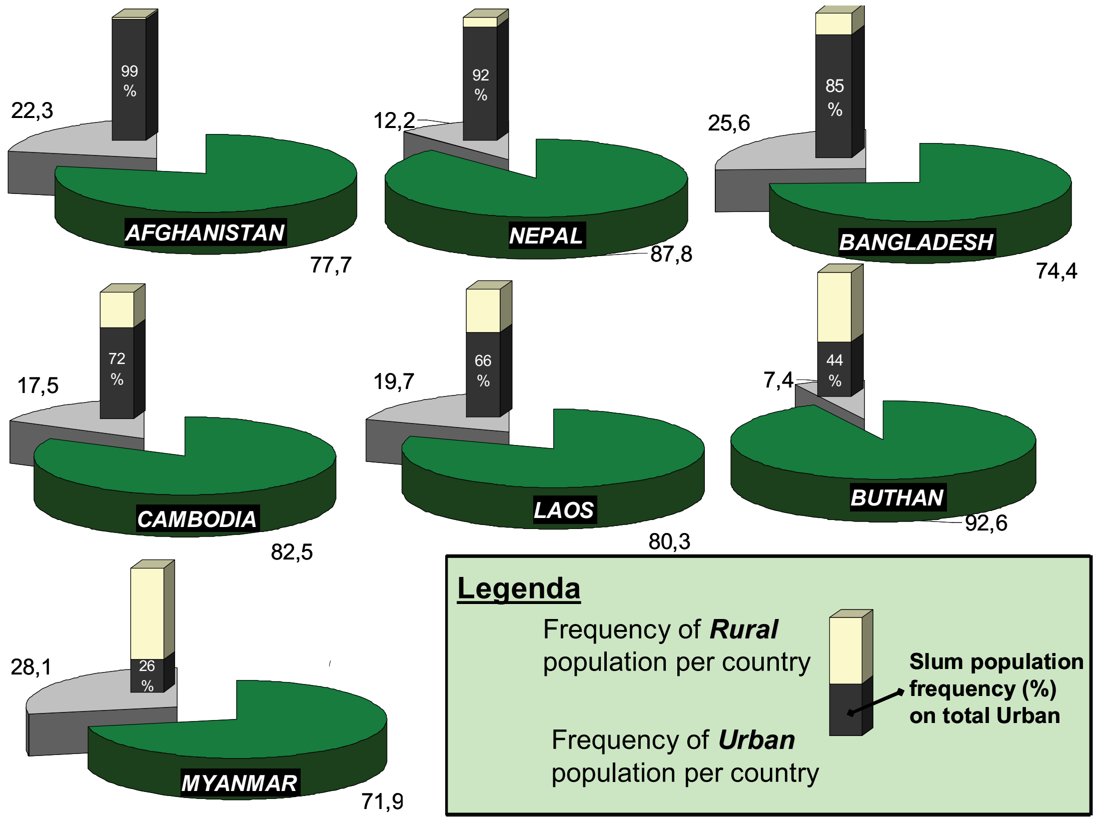
The dimensions of urban poverty include inadequate and unstable income, inadequate public infrastructure, limited or absent safety nets, inadequate protection of rights, voicelessness and powerlessness, and inadequate access to basic services.

In the latter dimension, the provision of energy for cooking (and boiling water), heating and housing facilities, is not often reported. However, if urban poverty issues are viewed through the lens of key aspects quoted by official sources (UN-Habitat 2004; 2006), and particularly water and food quality, sanitation and health, it is evident that the scarcity of energy supply is a further vehicle for other dramatic problems affecting both the rural and urban poor. The primary reason for guaranteeing an adequate supply of cooking fuel is to ensure that food is properly cooked. Many basic foods are not fully digestible unless they are cooked sufficiently; this is especially true of semi-liquid foods for babies, young children, the ill and wounded and the elderly. Cooking fuels also contribute to safe drinking-water and better health conditions through heating and boiling systems. Despite positive statistics on improved water supply in urban areas, the problem of water quality, linked to major recurrent diseases, remains (UN-Habitat, 2006). In India, 65 percent of hospital patients are treated for water-related diseases. In sub-Saharan Africa, people below the poverty line spend on average one third of their income to treat these diseases. The availability of wood energy could help to overcome this aspect of poverty, especially in urban slums where guaranteed water supplies are more scarce or lacking altogether as compared with other urban areas.

Slums represent one dimension of urban poverty and constitute a multiscale phenomenon: not all the poor are poor in the same way. The incidence of slum population is relatively more significant in lower-income countries worldwide, as shown for countries of south central and southeastern Asia in Figure 4.

FIGURE 4

Urban population rate per country and incidence of slum population in the least developed countries of south central and southeastern Asia (UN-Habitat, 2003)



Another dimension of poverty, both in peri-urban slums and squatter areas of urban centres, is related to the multiethnic composition of globalized urban societies, which often generate conflicts and create barriers among ethnic groups, reducing the effectiveness of poverty reduction efforts.

The causes of the links between poverty and urbanization are multiple, determined primarily by the harsh livelihoods and poverty conditions in rural and fringe areas that force people to migrate to the towns with the prospect of better living conditions. This traditionally explains the massive exodus, emphasized also by the need for profit-based economies to have low-cost labour forces available in urban areas. Yet there are other insidious driving forces. The so-called silent conflicts, often ignored by the media, are forcing epochal movements of entire populations. One in three African countries is experiencing armed conflict and a consequent decline in incomes (UN-Habitat, 2004), with increased poverty and inequality. There are also internal conflicts between groups of different provenance. The peripheral areas of towns host both refugees and internally displaced persons suffering from eradication and extreme misery.

There are more people in slums in those African countries with recent or ongoing conflicts than in cities of countries without conflicts (UN-Habitat, 2004). A particularly dramatic outcome of poverty is that of millions of displaced people in refugee camps, often in peri-urban zones. Africa hosts 30 percent of refugees in the world (UN-Habitat, 2004), with critical areas where refugee camps are reduced to ghost cities often lacking in basic supplies. While the association between fuelwood and urban poverty is apparently not considered a fundamental issue, or in any case is rarely covered in urban poverty surveys, in the agendas and reports regarding refugees the energy question is critical (Box 5).

The environmental impact of fuelwood supply is obviously less relevant than the paramount and immediate goal of saving human life. Yet over time, subsistence energy supplies in long-term refugee camps become inferior and may even cease, causing serious threats for both refugees and the surrounding populations. The provision of a subsistence energy supply to refugees should be planned with care in both the medium and long term. It seems that refugees often move from the gas and kerosene supplies provided back to woodfuels, either because supplies of these “modern” fuels run out or because woodfuels are better known and preferred as a result of traditional cooking practices and cultural identity.

BOX 5
Refugee camps

The majority of refugees today are to be found in the arid and semi-arid areas of the poorest countries in the world. The concentration of large populations in these areas puts a tremendous strain on the fragile environment and meagre resources. Moreover, these environments are hostile to refugees and can affect their health and well-being. Under normal circumstances, populations are free to move in search of more environmentally friendly areas. In the case of refugees, such freedom of movement is not usually possible. It is within this particular environmental confinement that refugees must be cared for and assisted (GTZ/UNHCR, 1992).

"It is a familiar story. In the developing world where biomass – in the form of woodfuel and charcoal – is the primary cooking fuel for most households, forest resources in and around the most heavily urbanized regions have been depleted to meet the demand for traditional cooking fuels. This phenomenon is no different from the situation in which large concentrations of refugees collect fuelwood for cooking and wood for construction in the immediate surroundings of their settlements or camps.

Unfortunately, humanitarian assistance providers have not become sufficiently aware of the necessity to meet the cooking fuel needs of recipients in emergency situations as an integral part of `first phase' emergency programming. … When humanitarian assistance providers do formulate plans to meet the cooking fuel requirements of the recipients of aid, these same providers seem to be aware neither of the health implications of their choice of fuel nor of the provisions of UN General Assembly Resolution 46/182 which affirms that international disaster assistance should serve long-term preventive, as well as relief, functions. In particular, the resolution states that emergency assistance should be provided in ways that will be supportive of recovery and long-term development**.**

Refugees cooking in the Congo

Refugees in the Sudan

Source: http://www.refugees.org/

2.1.3 Landscape modification and land use changes

Demographic factors, including population growth, density, fertility, mortality, and the age and sex composition of households, lifestyles and societal structures, are known to have an important influence on changes in land cover and use. Human migration, including shifts from rural to urban areas, movements between countries for economic or political reasons, and large-scale planned resettlements also significantly affect land cover and use.

As urban areas expand, they often encroach upon surrounding agricultural lands and, to a lesser extent, upon forested areas. Urban expansion into agricultural areas in developing countries results in the conversion of nearly 500 000 ha of arable land annually (Rosegrant *et al*., 2001). However, urban and developed areas currently cover only 2–4 percent of the Earth's land surface. As a result, some researchers argue that land lost to urbanization will not threaten global food production in the foreseeable future (Rosegrant *et al*., 2001)**.** Nevertheless, urban expansion frequently takes prime agricultural land out of production, making it increasingly necessary to use marginal lands for cropland and pastures. A key problem is that the concentration of people in cities necessitates a major increase in the production of food and energy. Severe losses of peri-urban agricultural land through urban expansion have been reported in Jakarta (Indonesia), Buenos Aires (Argentina), in several Colombian cities and in many African ones**.**

Evidence of the continuing impact of recent urbanization on landscapes, land use and management requires an understanding of the multiple spatiotemporal scale of urban growth. In particular, the evolutionary processes of urbanization include patterns of suburbanization, exurbanization, peri-urbanization (the shift of urban populations from more dense to less dense areas), multinucleation (the clustering of populations around several centres, rather than just one, in the same region) and even counterurbanization (the return to more urban areas). Thus, the “urban” concept expands, implying that the rural/urban distinction is a continuum, rather than a dichotomy; people increasingly live not simply in urban settings, but in highly differentiated ones.

The landscape and land use changes associated with urban expansion can be evaluated in terms of the following.

Intensification

Intensified landscape and land use changes occur on the urban fringe or the urban/rural interface, following settlement pressures and the need for space to be used for residential and productive (industrial and commercial) purposes (Figure 5A, B). The result is a general intensification of functions within narrow boundaries and in an uprooted landscape, very often unplanned. In terms of agriculture and forestry serving urban societies, this leads to monoculture systems and a general depletion in multiple resources. Land tenure is often not guaranteed and prices increase rapidly according to the expected profits of both land and urban activities. Intensification replaces former agriculture, grazing and forest activities with modern farming systems and plantation programmes.

Modification

Linked to intensified land use for urban development is the fundamental change in land use in peri-urban areas that are often oriented towards “industrialized” agriculture where a monoculture system prevails. This causes extensive loss of forests as well as modifications in landscape patterns. The sudden change in land property results in high prices and restructured property and farming patterns. In terms of wood energy resources, intensification and modification may represent a reduction in woodfuel supplies or an increase whenever the change includes dedicated plantations.

In turn, rapid urbanization caused by the mass migration of internal displaced persons may result in significant modifications in land use and landscape in the areas abandoned by these groups, far from urbanized zones.

Fragmentation

Fragmentation is a scale-dependent process with different spatial arrangements caused by general/local interests, cultures and strategic policies (e.g. transport infrastructure, urban development and creation of protected areas) (Figure 6A). The disaggregation of landscape patterns results from the impact of (urban) structures and infrastructures as well as from changes in land property or land management. The loss in connectivity of habitat and landscape units has both ecological and socio-economic implications. The former results in a changing pattern of behavioural, reproductive and feeding opportunities for both animal and plant species; the latter leads to limitations in human access to resources. Landscape fragmentation is strongly associated with urban development and leads to a loss of the rural/urban interface and to an increasing distance between urban dwellers and rural people.

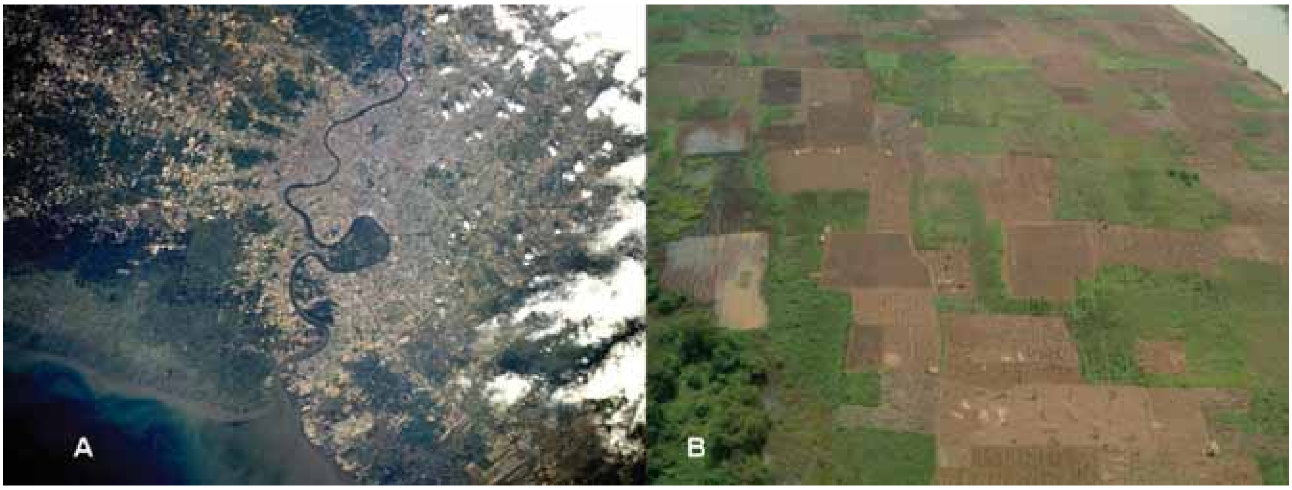
Abandonment

The vicinity of cities often causes changes in lifestyles and types of employment. The result is the progressive depopulation of rural areas and/or the neglecting of traditional land use practices. An associated phenomenon is the daily commuting from the rural suburbs to industrial/commercial occupations in cities. The household may still be in peri-urban or rural areas but people are not actively employed where they live, which results in the abandonment of traditional activities and micro and macro modifications in landscape patterns. The effects of abandonment on wood energy resources are various. The abandonment of agriculture and grazing practices in the absence of other land uses gives rise to secondary processes leading to an increased availability in wood resources. Management, however, usually requires strategic initiatives to form the social contexts to use the resources (e.g. education, definition of property rights, cooperation and participation, and marketing in a sustainable fashion).

FIGURE 5
Urbanization in Port Harcourt, Nigeria
A. Modification of land use caused by urban expansion. B. Intensification of urban landscapes by slums in informal settings in peri-urban areas

Photos: Salbitano, 2004.

FIGURE 6
Landscape modifications on a large scale
A. Urban expansion encroaching upon agricultural land in Bangkok, Thailand. B. Intensification of farming systems in southeast Nigeria



Photos: Salbitano, 2004.

Homogenization
Neglect of traditional land use can lead to a simplification in landscape patterns, resulting in a depletion of landscape diversity in the medium and long term. Substantial changes also affect the use of tree species, e.g. plantations for timber and fuelwood constitute new land use forms that need to be carefully designed to meet landscape and ecological requirements. Finally, the overexploitation of land for urban needs may lead to a homogenized modification of the landscape where desertification and deforestation go hand in hand.

2.2 URBAN FORESTRY

2.2.1 Concept and domain of urban and peri-urban forestry (UPF)

The definition of urban forest given by Miller (1997), i.e. the sum of all woody and associated vegetation in and around dense human settlements, ranging from small communities in rural settings to metropolitan regions, leads to the definition of its related discipline, urban forestry, as "an integrated, city-wide approach to the planting, care and management of trees in the city to secure multiple environmental and social benefits for urban dwellers" (Miller, 1997).

These definitions refer to the physical location of urban forests and trees in urban and peri-urban areas. From a different perspective that privileges "urban influence" over "urban context", an urban forest or woodland might be described as "a forest ecosystem (or rather, an area of land dominated by tree vegetation) in or near a specific urban area, of which the use and related decision-making processes are dominated by urban actors and their interests, values and norms" (Konijnendijk, 1999).

The urban forest potentially comprises a great variety of habitats (streets, parks, derelict corners, woodlands, etc.) where trees provide an extensive range of both benefits and problems (Grey and Deneke, 1986). In its broadest sense, urban forestry embraces a multimanagerial system that includes *municipal watersheds*, *wildlife habitats, outdoor recreation opportunities, landscape design, recycling of wood and of municipal wastes, tree care in general and the production of woodfuels, charcoal and wood fibre*. The possibility of producing woodfuels and timber is not ruled out, although it is unlikely that this will be a primary aim, at least in developed countries where urban forestry was first defined.

In technical and practitioners' terms, urban forestry is a *specialized branch of forestry* that has as its objective the cultivation and management of trees for their present and future contribution to the physiological, sociological and economic well-being of urban society. It comprehends, in scientific, technical and strategic ways, the range of activities carried out in the city centre, suburban areas and the "urban fringe" or interface area with rural land. Forestry activities can differ significantly according to the area. In dense built-up areas, the potential for significant new urban forestry efforts is relatively limited. It is mainly an issue of maintaining or replacing trees planted long ago. In suburban areas, more scope exists for tree planting, as land availability is greater than in the city centre but the legal, social and economic frameworks are more critical.

Urban forestry has strong links with community forestry, i.e. "a forest owned and generally managed by a community, the members of which share its benefits – see communal forest, social forest". Community forestry has been defined as "any form of social forestry that is based on the local people's direct participation in the production process, either by growing trees themselves or by processing tree products locally" (Raintree, 1991).

A fundamental concept of UPF is that a city, in order to be sustainable, needs to develop as an element of, and in harmony with, the landscape and ecosystem around it.

2.2.2 Benefits of urban forestry

The economic, sociocultural and environmental benefits provided by UPF are reported in Figure 7 but the network of potential benefits is much more complex, as illustrated in Figure 8.

The debate on the needs of urban societies and the required and released benefits that UPF supplies, leads to a common vision of the role that UPF plays (or, better, could play) in all urban contexts worldwide. However, particular benefits and functions capture varying attention according to socio-economic peculiarities, current and prospective policies and legislation characterizing the cities, and the embedded or adopted design and management styles. It follows that the woodfuel supply function, i.e. the object of the present issue, needs to be seen in itself but also as related to the other benefits expected from each single tree, hedgerow, park or urban and peri-urban forest/woodland. This implies the elaboration of UPF planning, design and management strategies that are specific for the various urban societies, as well as the adoption of clear policies and legislation that guarantee the maintenance of an adequate tree cover and environmental quality in the long term. However, a major impediment to UPF planning and design that deserves mentioning is linked to the high price of land and property in urban and peri-urban areas.

FIGURE 7
The economic, sociocultural and environmental benefits provided by UPF

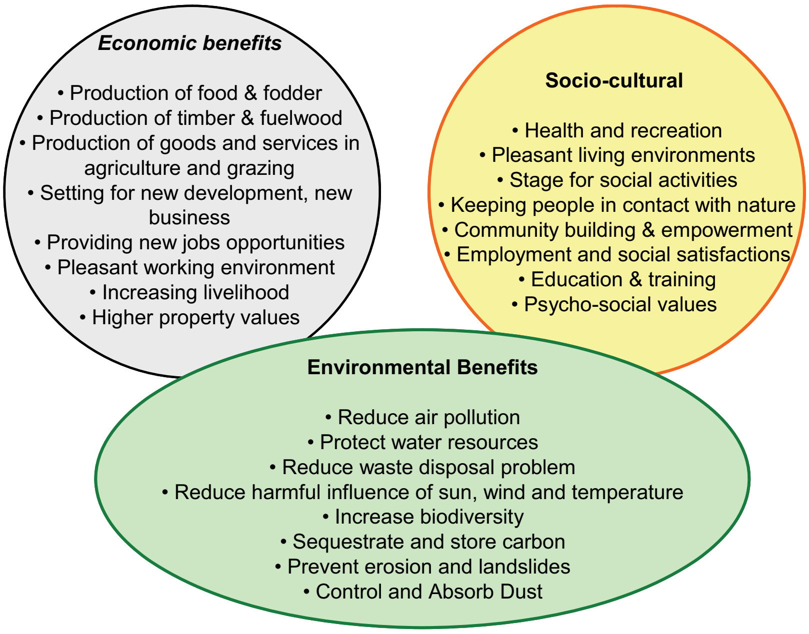
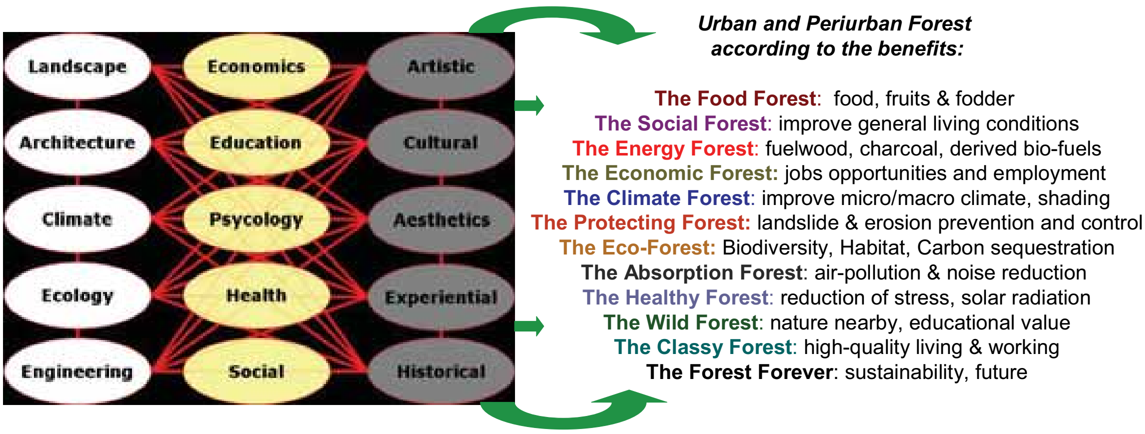


FIGURE 8
The network of benefits provided by UPF and the potential types and functions (Konijnendijk, pers. com.)



2.2.3 How can urban forestry contribute to wood energy supply?

In spite of the expansion of electricity and gas, and because of several economic and cultural factors, woodfuels remain a primary source of energy for a large fraction of urban households in developing countries, either as fuelwood or charcoal (see Section 3.6 and Chapter 4). Most woodfuel is provided by peri-urban areas and beyond. A small proportion of the wood consumed is obtained within the city area, sometimes as an emergency solution that runs the risk of rapidly exhausting wood resources. Small twigs and leaves are commonly used as fuel by the poorest.

Yet the role of urban and peri-urban trees extends far beyond the provision of the occasional bundle of fuelwood, twigs and leaves. A review of the roles and opportunities offered by UPF is essential to:

- understand the pattern of woodfuel supply sources serving the cities;
- define good management practices of tree-based systems for sustainable multiple uses where the

supply of wood energy is adequately integrated;

- outline the potentialities of urban forestry for creating employment and providing incomes in the context of wise management of urban and peri-urban tree-systems;
- check the performance of efficient mechanisms (legal, policy and economic) oriented towards maintaining optimum tree cover in and around cities and limiting the irrational use of tree systems in both cities and the entire woodfuel “catchment” area;
- formulate strategies oriented towards harmonizing urban/rural land and resource management.

The key question is: How and to what extent can urban forestry respond to urban wood energy needs? Related questions are the following.

- How can trees and forests be used for wood energy in the urban environment and by urban stakeholders?
- How can trees and forests be preserved from degradation and encroachment by built-up areas and infrastructures, and be sustainably managed in relation to urban development?
- Which policies and strategies favour the sustainable management of land around cities, adapting the city to its environment?
- What are the direct and immediate impacts of emergency situations (e.g. conflicts, natural disasters, shortage of gas/oil as sources of energy) on the tree cover because of fuelwood needs?

The energy demand generated by urban societies means looking beyond urban and peri-urban trees and forests, in the knowledge that these can cope only partially with the woodfuel needs of city dwellers. Forests and people located further away but under dominant and direct urban influence should be taken into account.

Although UPF can respond only in part to woodfuel demand, it plays a fundamental role in planning a sustainable urban wood energy system. In collaboration with urban development agents, UPF may trigger a virtuous planning process and provide good management practices aiming to deal with urban requirements through sustainable and responsible interaction with rural areas and communities well beyond the city boundaries.

2.3 TOWARDS A BROADER ROLE FOR UPF: A WORKING CONCEPT

Expanding on the definitions given above and specifically on the inclusion of trees and forests that are far from cities but whose finality and management are “dominated by urban actors and interests”, it can be seen that the prerogatives and responsibilities of UPF include areas and processes taking place far beyond the urban and peri-urban contexts.

In this perspective, urban forestry should extend its responsibility towards extraurban resources and socio-economic processes dominated by urban influence (FAO, 2001c). The first task in this expanded role would be to disclose the nature, in terms of environmental and socio-economic sustainability and impacts, of the relation between growing urban needs, on the one hand, and the resources and processes that provide commodities and services on the other. This expanded area of influence may be termed the urban woodshed.

Foresters need to understand and assess the direct and indirect responsibilities that cities have towards areas and communities beyond their strict territories and act as a liaison between urban planners, conventional forestry and rural development actors.

Urban forestry thus has a fundamental role in bridging disciplines, aiming to connect with and participate in the responsibility that a city has for the whole territory that responds to and is influenced by urban needs. This is a key ethical and political issue that involves the constant participation of stakeholders both at urban and rural levels and includes the activation of communication flows and capacity-building initiatives.

Urban forestry and all its related silvicultural, economic, sociocultural and political aspects, becomes a means by which cities, urban dwellers and institutions can take responsibility for urban needs and resources. Shared responsibility for land use, and namely for forest and trees, involves a range of stakeholders and practitioners, from town planners and policy-makers to urban dwellers and producers, from non-governmental organizations (NGOs) to associations of wood buyers and sellers.

3 Wood energy in urban areas of developing countries

3.1 IMPLICATIONS OF RAPID URBAN GROWTH ON WOOD ENERGY

Urbanization in developing countries, represented mainly by rural households moving to urban and peri-urban areas, brings considerable changes to subsistence energy supply/demand patterns. These changes are the result of diverse factors, including distances from supply sources that limit direct fuelwood collection, increased purchasing power, greater dependence on marketed fuels, high dwelling density limiting open-air cooking, and cultural pressures imposing urban ways and marginalizing rural practices and traditions.

With consequent increases in income, households migrating from rural to urban areas initially change over from fuelwood to charcoal and subsequently to LPG and/or kerosene and electricity. This fuel "ladder" is not upwards only. The decrease in fuelwood use is apparent, as is the slow increase in the use of more modern fuels, but the role of charcoal is stable and dominant. In most poor cities it is the main household fuel, gaining consumers not only from newly urbanized households but also from urban dwellers pushed down the fuel ladder by increasing oil prices, economic recession or sociopolitical unrest.

For example, in the case of Maputo, Mozambique, a comparison between the 1992 and 2000 consumption pattern, shown in Table 1, confirmed a significant shift in the types of fuel used, excluding charcoal, which remained equally important in both 1992 and 2000 (CHAPOSA, 2002).

TABLE 1
Proportion of fuel types used by households in Maputo, 1992 and 2000

Fuel	**1992** (%)	**2000** (%)	**Significance** (alfa: 0.05)
Firewood	78	22	Significant
Charcoal	76	75	Not significant
Paraffin	14	44	Significant
Gas	12	21	Significant
Electricity	12	26	Significant
Total	**952**	**208**	

Source: Brouwer and Falcão, 2001 (in CHAPOSA, 2002).

Rapid urbanization by the rural poor and an inherent change in the "choice" of household fuels have had considerable effects on the exploitation of woody biomass resources. Table 2 lists some of the main differences between fuelwood use, dominant in rural households, and that of charcoal, dominant in urban households.[4]

The massive and continuing shift from fuelwood to charcoal caused by rapid urbanization presents a serious risk of environmental degradation but also provides significant opportunities for sustainable development in peri-urban and decentralized rural communities, i.e. rural and forest communities located far from the periphery of the urban woodshed. By moving from the informal and ubiquitous gathering of fuelwood towards the structured production of commercial woodfuels, the wood energy issue increases its forestry character. The higher reliance on forests and relatively dense woodlands as sources of woody material boosts the sustainability issue and should receive full attention from the forestry sector and benefit from its tools and best practices such as sustainable forest management and participatory approaches.

[4] There are notable exceptions to this urban/rural characterization such as, for instance, Bangui in the Central African Republic where urban households consume far more fuelwood than charcoal.

TABLE 2
Urbanization and associated change from fuelwood to charcoal energy systems

	Main features and implications of energy systems
Migration from rural situation dominated by use of fuelwood	• **Fuelwood** • By-product of agricultural crops; gathering of deadwood and green wood from farmlands, woodland and forests; by-product of shifting cultivations and land use changes • Mainly non-commercial procurement; producer and user often the same • Relatively high production efficiency (use of residues and by-products) and low impact in respect of woody biomass resources • Generally low energy conversion efficiency • Relatively high impact on living conditions (gathering time, hardness, indoor health conditions) of women and children in poorest households
To: urban situation with wider energy mix dominated by charcoal	• **Charcoal** • Product of exploitation of forests and woodlands through high intensity selective and/or clear felling • Fully commercial supply; producer and user always different • Relatively low production efficiency (due to energy loss in carbonization) and high impact on denser forests and woodland formations • Generally medium-high energy conversion efficiency (offsetting some energy loss in the carbonization process) • Relatively low impact on living conditions • impact on household economy (more than fuelwood)

From a forestry perspective, sustainable charcoal production represents a major challenge. Arnold *et al.* go so far as to say that “perhaps the single most important issue for forestry is that of continuing to try to put the large and growing charcoal production and trading systems that feed large urban markets, on a more sustainable basis” (Arnold *et al*., 2003).

It is essential for forestry to take up the challenge, in collaboration with rural development and energy actors, and find the tools and means to turn threats into opportunities.

3.2 URBAN AND PERI-URBAN CONSUMERS OF WOODFUELS

Just as urban and peri-urban areas house a high and diverse concentration of productive sectors, in addition to their obvious residential function, so woodfuel is consumed by an equally varied typology of end users. In developing countries the residential sector is the prime consumer of fuelwood and charcoal, but several other sectors use woodfuels as their sole source of energy or in combination with other fuels and energy sources.

Besides the residential sector, woodfuels are consumed in the agricultural, industrial, trade and services and institutional sectors, as described briefly below (FAO, 2002a). A more extensive listing by productive sector is given in Annex 7.

In the *residential sector*, urban and peri-urban households use fuelwood and charcoal mainly or exclusively for their own needs – cooking, boiling water, heating, laundering and preparing livestock feed. The main distinctions between rural and (peri-)urban households are that the latter purchase the woodfuels they need, rather than directly collecting or producing them, and that in the urban context there is a relatively higher consumption of charcoal.

In the *agricultural sector*, i.e. peri-urban and urban agriculture, charcoal or fuelwood may be used for heating greenhouses and poultry sheds.

In the *industrial sector,* woodfuels are used for processing raw materials. Examples of industrial activities using woodfuels are charcoal plants and brick and tile works; and for coffee drying and roasting, bakeries, sugar mills and fish smoking.

In the *trade and services sector,* woodfuels are used for a variety of commercial activities that are engaged in buying and selling goods or providing services, such as bakeries, hotels, restaurants and laundries.

In the *institutional sector,* users include educational establishments, hospitals and police and military establishments that rely on woodfuels for heating, cooking, laundering, etc.

3.3 THE CHARCOAL ISSUE

The many aspects of charcoal production, trade and consumption in Africa have been the subject of detailed field analyses in several recent projects. Of particular interest is the "Charcoal potential in southern Africa" research project (CHAPOSA, 2002), which analysed trends in deforestation and forest depletion in areas supplying three urban centres in sub-Saharan Africa: Lusaka in Zambia, Dar-es-Salaam in the United Republic of Tanzania and Maputo in Mozambique and which contributed to an understanding of the reasons for the "success" of charcoal in African cities.

The following highlights from this research provide an excellent insight into the role of charcoal from a stakeholder perspective, charcoal production systems and the progressive impact of charcoal on forests and woodlands.

3.3.1 Stakeholder perspective

These highlights (CHAPOSA, 2002) from the perspective of users, traders and producers help to understand why charcoal is such a successful fuel in the cities of developing countries.

- Retailers have a preference for selling charcoal: "it sells well, it doesn't go rotten and children don't steal it" (Fernandes, 1995, from Maputo market survey in CHAPOSA, 2002).
- People use charcoal in combination with paraffin and, to a lesser extent, electricity and/or gas. When incomes rise, the two latter tend to replace woodfuels but not completely; if the cost of modern fuels rises, the charcoal share in the domestic energy mix increases.
- Fuelwood is typically a fuel of the poor. It is used by extended families in the poorer income strata. Charcoal is also used by relatively large households but can be found among the higher income classes as well.
- The system for producing, transporting and marketing charcoal employs large numbers; it is widely operated as a market system with limited interference from the authorities.
- Charcoal production has become one of the main sources of income for poor people in rural areas; in production areas this income can be more important than that from other sources such as agriculture.
- It is mostly men who are engaged in charcoal production.
- Charcoal production is (or could become) a means to reduce poverty among rural people, on their own and without external support.
- It is also a means of improving the conditions of the urban poor, by providing a reliable, convenient and accessible source of energy for cooking at all times and at a surprisingly stable cost. The study has shown that charcoal prices (in "real" terms) have been stable over at least the last ten years.
- The charcoal trade provides income opportunities for many people in urban areas, through small-scale retail businesses (Figure 9), where women are predominantly employed.
- Electricity infrastructure is insufficient and unreliable, petroleum fuel prices fluctuate widely because of changes on the world market and in domestic policies. The indigenous renewable woodfuels prevail.

FIGURE 9
Bags of charcoal for sale in Bangui, Central African Republic (Photo: Salbitano)

3.3.2 Charcoal production systems

As regards the main features of charcoal production systems, the CHAPOSA project highlighted the following aspects.

- The charcoal production system manifests several traits of a free market system. This ought to ensure that resources are put to best use.
- Many actors work the system, more or less independently of each other.
- Information on market features is essentially free and the entrance fee to the market is affordable even for the poor. It usually constitutes personal labour.
- The exception to the above is in the transportation sector, especially for long-distance transport, where vehicles, roads and fuel are needed. Yet the profit level in charcoal transportation is not very high, as evidenced by the use of old and dilapidated vehicles.
- The end result is a widespread consumer product.
- Basic resources for the whole production system are trees in forests and woodlands (unlike fuelwood supply sources that include trees outside forests, wood industry residues, etc.).
- Net present value calculations of the basic resource shows that it is perfectly rational to cut trees for charcoal production under existing forest resource regimes, rather than saving them for other future uses or expending money and labour on management for higher-quality wood.
- At present, the whole value of the wood resource is the commercial value it can attain at harvesting. This value is limited in terms of charcoal (a mature tree yields about five bags of charcoal which, at the producer stage, is US$15–20 in monetary terms). Obviously there is no interest rate so low that this value would be positive in a net present value calculation over the 30 to 50 years it takes a tree to mature. This implies that market forces work only towards felling trees, not protecting them.
- There should be other than commercial values ascribed to wood resources, which necessitates an authority to uphold them. The government could be such an authority, especially since in all three countries investigated in Africa (United Republic of Tanzania, Zambia and Mozambique), the state owns substantial parts of (or all) forest resources. However, in all cases, the government is a poor owner of wood resources. Even if policies exist to protect forests for certain reasons, resources assigned to enforcing these policies are woefully inadequate.
- Even the role of management that directly yields income to the treasury is inadequate, and the rules and regulations are complicated and less than transparent. Thus, in the Maputo area it was estimated that only about 1 percent of fees and licences was actually collected for the woodfuel sector. In Zambia the estimate was about 10 percent and in the United Republic of Tanzania 25 percent.
- Forests are almost like an open access resource. Those who cut the forest reap the rewards and care little for future users (or rightful owners). This is in spite of state ownership of the forest resource and instated rules and regulations. The state is usually ill equipped to bear the responsibilities of an owner and to enforce the rules of government.
- However, if the situation has not developed into total resource depletion in favour of investors’ profit it is because protection and production policies do have some effect. The risk of policy enforcement, more than actual enforcement, obviously inhibits larger investments for a more rapid and efficient exploitation of the resource.
- The charcoal industry remains dispersed and ill developed; little capital is channelled towards it. Those entering the industry do so with little more than their own labour as input. This attracts poor people in search of a means to make a living.
- The ultimate effect is that a source of income is created for many poor people in rural areas, contributing to the provision of an essential commodity for the poor in urban areas: an affordable, convenient and accessible energy source at relatively stable prices.

3.4 IMPACTS OF URBAN WOOD ENERGY

The impacts of urban wood energy practices are effective at multiple levels. The first is the impact at *ecosystem level*, both urban and forest/rural, where wood resources are found. Here, the impacts generated by wood energy supply/consumption depend on i) the size and population of cities; ii) their energy and land policies; iii) the traditional and changing lifestyles; iv) the existing or forecasted price policies; v) the security of energy supply; and vi) the character of the urban, peri-urban and rural/forest landscape. The combination of these factors determines the amplitude, recurrence and timing of impacts at the ecosystem level. A second level concerns the *socio-economic* implications of wood energy production, trade and use as compared with other energy. These include impacts on the economy of rural communities involved in woodfuel production; on urban and peri-urban dwellers involved in transportation and trade; on health problems and air-quality characteristics, both indoor and outdoor, linked to conversion technologies; and other economic and behavioural aspects.

Another way of looking at the potential and/or real impacts of urban wood energy practices is to define aspects directly impacting ecosystems and societies (*directly* linked to the wood energy chain, such as the degradation of forest ecosystems or the pollution effects of charcoal and woodfuel burning in low-efficiency stoves) or *indirectly* affecting, in time and space, urban and rural dimensions, such as the land use changes induced by recurrent exploitation of wood resources and the impact on personal development because of the time spent in gathering fuelwood.

Impacts can also be classified as *positive* and *negative*. The *positive* impacts are income and employment generation for decentralized communities and for poor farmers between crops; the creation of rural markets and induction of sustainable production (and management) systems to guarantee continuation of benefits; and affordable subsistence energy for the urban, peri-urban and rural poor. The *negative* impacts are low and uncertain incomes and resource depletion determined by undefined land tenure and exploitation rights; overexploitation resulting from marked inequality in revenue distribution because of the fragmentation of actors and a lack of clear supply agreements especially affecting the poorest link in the chain; unstable markets and low security in resource exploitation; erosion of tree/forest cover through wood energy crises; energy shortages; and bad or no management applied to tree/forest resources.

3.4.1 Impacts on urban and peri-urban ecosystems

The term *ecosystem* applied in the urban context generated a fairly heated debate over the last decades in relation to the fact that a city cannot be considered a real ecosystem, according to ecological theories and practice; the population of the biocoenosis of a city or metropolitan region has very little chance of being self-sufficient in terms of food and energy. This consideration leads to the assumption that, even if the concept of ecosystem in the urban dimension is accepted, it has to be looked at as a fragile and relatively unstable system in space and time. Energy, particularly wood energy, is together with food the best example of this fragility.

The direct impacts of woodfuel production on urban/peri-urban ecosystems are constrained by the obvious fact that tree and forest resources are often scarce in and around cities. Nonetheless, the chopping of branches and even entire trees for fuelwood is a common sight along city roads in many poor countries (Figure 10A, B). This direct exploitation of urban trees and forests may increase considerably whenever the shortage of energy supply becomes dramatic (Box 6).

BOX 6
Case study: Sarajevo urban forest

"Global ReLeaf Sarajevo" is the first project of the "Plant It Green" programme in partnership with American Forests. Global ReLeaf Sarajevo is a tree-planting initiative to help restore the war-devastated urban forests of the host city of the 1984 Winter Olympics. During the four-year siege of Sarajevo, residents cut trees for heating and cooking fuel, and consequently deforested the hillsides. The devastation of the urban forests created a major risk of landslides. Debbie Armstrong, gold medallist at the 1984 Winter Olympics, has joined the effort to help Sarajevo to restore its urban forests.

FIGURE 10
Fuelwood production from urban trees

A. Heavy tree pruning for fuelwood in Bangui, Central African Republic (*Photo*: Salbitano)

B. Fuelwood bundle from city trees (*Photo*: Salbitano)

3.4.2 Impacts on rural and forest ecosystems

Charcoal and fuelwood are frequently secondary products of various land uses and forestry regimes, rather than their primary objectives. Similarly, they tend to be the by-products of deforestation and land use changes rather than the direct cause, although charcoal production, for example, may sometimes be a direct cause of degradation (Pancel, 1993). Fuelwood, in particular, is a secondary product of timber harvesting, shifting cultivation processes, orchard and farm tree management, etc.

In many cases, among a multiplicity of factors with an established result, such as a permanent loss of forest cover, it is difficult to point out with precision a single cause or quantify the contribution of a single factor. Logging roads (or simply new access to forest areas), new settlements, the demand for new farmland and woodfuel needs are often concomitant causes in the process of forest depletion.

It is now generally accepted that woodfuel extraction is less destructive than had been assumed in the 1980s and early 1990s (Arnold *et al*., 2003) and far less responsible for forest depletion than agricultural expansion. It is also true, however, that unsustainable charcoal production for urban markets, which is fairly frequent, has a much greater impact on forests and woodlands than fuelwood collection (Arnold *et al*., 2003).

Under normal conditions, forest clearings for charcoal production revert to secondary forest as a result of coppice growth and regeneration but intense production may lead to forest degradation and, where there is high population pressure, indirectly to permanent deforestation. As stated in the final report of the “Charcoal potential in southern Africa” project (CHAPOSA, 2002), charcoal production in forests and woodland has several ecological implications, depending on the intensity and intervals of the exploitation but permanent impacts, such as loss of tree and shrub cover, are usually a result of agricultural expansion following charcoal production. Research carried out in the United Republic of Tanzania, Zambia and Mozambique highlighted the following progressive impacts and phases.

- Initially, there is a depletion of mature trees favoured for charcoal production. As these species become scarce, less favoured trees are used.
- When no mature trees remain, charcoal production can no longer be sustained. The fate of the area will depend on external factors.

- If the population has increased in the area, some of the previous woodland will be used for cultivation; if this is shifting cultivation, the land will eventually be abandoned and left to regenerate as shrubland or woodland; if the cultivation is permanent, stumps will be cleared and the land will remain cleared indefinitely. The same will occur if the land is used for heavy grazing.

- In areas where the land cleared for charcoal production is abandoned, regeneration takes place, initially mostly from coppice, since charcoal producers generally leave the stumps of trees felled. Hence the species composition will remain essentially similar to composition before charcoal production.
  - However, under heavy pressure for charcoal production, regrowth is again cut before the trees reach maturity.
  - Under a sustainable management regime, regeneration can be improved by fire control (early burning), selective cutting of non-viable coppice and protection from grazing.

Results of the land cover change analysis carried out by the CHAPOSA project around Dar-es-Salaam provided evidence of considerable degradation in the region as a result of charcoal production. For a significant fraction of closed and open woodlands around the city the change observed between 1991 and 1998 was so intense that it qualified as “deforestation” (change to bushland or grassland) even in the absence of agricultural activities. The report itself, however, considered that in the majority of cases the permanent impact of deforestation was primarily a result of increasing demand for cropland while the most frequent impact of charcoal production was degradation with loss of tree density and of charcoal-suitable species, particularly along roads.

3.4.3 Impacts on urban and peri-urban dwellers

The rapid growth of urban populations and the concentration of woodfuel use in the urban context cause a series of impacts, both negative and positive, on the health, well-being and economic and social aspects of urban dwellers.

Negative impacts

Dense agglomeration and intensive housing imply a significant increase in emissions for energy needs. The use of woodfuels determines changes in the urban environment with potential effects on human health. Especially in the poverty context, where the technologies applied to woodfuel use are low, the increase in emissions is massive, together with derived smoke and high particulate matter. This can give rise to a range of human pathologies, from respiratory diseases to cancer.

Overexploitation for wood energy production alters the quality of *urbanscapes*. Reducing or exhausting the urban and peri-urban tree cover modifies the microclimate, particularly solar radiation, relative humidity and particulate absorption. Such changes can indirectly cause health and well-being problems. The reduction (or absence) of tree cover also means a decrease in the potential for outdoor activities, both leisure (sport, recreation, etc.) and economic (trade, open-air markets) and is therefore an indirect cause of deterioration in living conditions.

Whenever the sources of wood biomass are depleted, a negative effect will be an uncertain or insufficient subsistence energy supply.

The prevailing use of wood energy requires more room for storage at retailer and domestic levels as compared with other energy sources such as gas and electricity.

Positive impacts

The use of wood energy is intimately linked to popular tradition and culture. Wood and charcoal are visible and tangible materials, part of the daily life and landscape of many places in the world (Figure 11).

Woodfuels impact on cultural identity by being part of the traditional way of cooking in most developing countries; they are always on the market even when other energy sources are available. Their familiarity gives urban dwellers a sense of belonging, with no dependency on external forces.

Woodfuels are an essential commodity for poor people in urban areas since they represent convenient and accessible sources of energy at affordable and relatively stable prices.

The woodfuel chain supports a wide range of income-generating activities with a low initial investment. Wood energy systems have a positive impact on diffused employment in and around cities. Of all energy sources, woodfuels have the highest employment rate per released unit of energy.

Woodfuels are safe energy options in comparison with insufficient and unreliable electricity or fluctuations of oil prices on the world market.

FIGURE 11
Fuelwood and schoolchildren in Bangui, Central African Republic, where wood energy systems are an integral part of daily life and culture (Photo: Salbitano)

3.4.4 Impacts on rural and forest communities

There are a considerable number of people involved in one way or another in the chain of activities that constitutes urban wood energy systems. Together with the traders, retailers and transporters in urban and peri-urban areas, there are even more rural and forest dwellers involved, albeit sometimes temporarily, in fuelwood collection and charcoal production. For "decentralized" people living on the periphery of the urban woodshed, woodfuel production is the main source of income or, as in the case of many poor farmers, it is an important addition to their primary agricultural revenue.

Negative impacts

Among the serious negative social and economic impacts of unregulated fuelwood extraction and charcoal production are the degradation and loss of communal resources through overexploitation of forests and woodlands traditionally under customary laws. This is the effect of uncertain land tenure and ambiguous rights of exploitation of forests and woodlands by rural and forest communities. The situation not only prevents the development of long-term benefits and sustainable production for villagers but also facilitates the dealings of unscrupulous traders who are interested only in fast profits and can impose low wages. Under these conditions unregulated fuelwood and charcoal production may lead to:

- degradation of the village environment and the loss of woodfuel resources for villagers' own use;
- a massive transfer of wealth from rural communities to a few urban-based traders;
- inequitable revenue distribution among producers and traders;
- traders operating in quasi-monopolistic conditions and unilaterally deciding upon exploitation sites on a short-term profit basis;
- increased levels of corruption;
- impoverishment of rural areas;
- an acceleration of the rural exodus.

Positive impacts and opportunities

As discussed above, it is evident that urban woodfuel demand must be taken extremely seriously by city planners as well as by forestry, agriculture, rural development and energy agencies in view of its many social, economic and environmental implications. There are solutions whereby negative impacts can be mitigated and opportunities exploited in support of sustainable development. Key factors are clear land tenure and exploitation rights, participatory approaches and sustainable resource management.

Senegal's Sustainable and Participatory Energy Management (PROGEDE) project (1997–2004), supported by the World Bank and the Government of the Netherlands, is one such positive case. On the supply side, the project focused on the implementation and monitoring of 300 000 ha of environmentally sustainable community-managed forest resource systems in the Tambacounda and Kolda regions of Senegal. It also dealt with important practical issues regarding woodfuel demand, capacity building and institutional strengthening of institutions.

Box 7 gives a summary of important lessons learned from the PROGEDE project and its achievements that are also relevant and promising for other countries facing similar problems.

BOX 7

PROGEDE project

Lessons learned

- Production and marketing of biomass fuels can not only be stabilized and made sustainable, while arresting deforestation and contributing to ecological conservation, but can become a highly effective social and economic rural development strategy.
- While demand management is important and needs to be pursued – especially through dissemination of improved end-use technologies and practices – this alone cannot resolve existing problems. It is an element of particular relevance, in view of the considerable distance between urban demand and production sites.
- The establishment of environmentally and socially sustainable woodfuel supply systems can only be achieved through the introduction of integrated community-based forestry and natural resources management schemes. Governments generally lack the financial and human resources and the incentive to do this, while the private sector is not interested because of the long payback period, inherent risks and low profit margins.
- A minimum policy platform is therefore required, which should include i) clear and legally enforceable forest resource and land tenure rights and responsibilities; ii) a transparent decentralized fiscal and taxation system; iii) a clear and fair pricing system; and iv) guaranteed access for woodfuel producers to final consumer markets.
- Investments in women's activities (rural vegetable gardens, microcredit, etc.) result in the most significant and tangible poverty alleviation, especially in terms of health, nutrition and education of the beneficiary population, particularly children.

Achievements of particular relevance

- ✓ Sustainable community-managed forest systems were established over an area of 378 161 ha.
- ✓ Rural communities and NGOs in project regions implemented participatory management modules and produced and marketed woodfuels and other potential wood and multiple non-wood products.
- ✓ Community-based microenterprises were established, including beneficiary-operated improved carbonization units, apiculture cooperatives, collective (women) and individual agricultural/livestock diversification units/systems.
- ✓ A sustainable income-generating base (wood and non-wood products) was established.
- ✓ Some 20 percent of Senegal's current energy supplies are now derived effectively from renewable resources.
- ✓ The urban charcoal trade was reorganized and modernized to establish long-term supply agreements (contracts) between rural communities and urban traders.
- ✓ Existing charcoal traders were helped to diversify their economic activities.
- ✓ Interfuel (kerosene and LPG) substitutions were supported as was the distribution of improved stoves by the private sector and the NGO community.
- ✓ A permanent energy sector digital database and information system were established.
- ✓ Urban and peri-urban "energy boutiques" were designed and established.
- ✓ The Forest Service was transformed into a technical assistance and capacity development agency with a participatory vocation and significantly improved governance.
- ✓ Traditional social institutions and their natural management resource roles and responsibilities were revitalized and strengthened, as were women's groups and associations.
- ✓ Charcoal traders within the project zone went from being "enemies" of the rural communities to becoming actual commercial partners – legal contracts helped make this change.

Source: World Bank, 2006 (based on World Bank, 2005).

3.5 URBAN DEMAND AND RURAL SUPPLY: EVOLVING SPATIAL AND SOCIO-ECONOMIC INTERACTION

3.5.1 Expanding supply zones

From the geographic angle, it is evident that the area of woodfuel demand by cities in developing countries is growing rapidly. Urban woodsheds tend to include vast portions of the national territory, as a result of increasing demand arising from the combination of urbanization and poverty and reduced resources because of land use changes and overexploitation. Woodfuel supply areas may be far from cities, especially in the case of charcoal, which may be produced several hundred kilometres away from consumption sites (such as in Dakar, whose charcoal supply sources are at the opposite side of Senegal, in Casamance).

Furthermore, it is important to remember that woodfuel supply areas are often degraded, especially woodlands and forests exploited for charcoal production. These processes of degradation are the result of overexploitation and short rotation periods that do not allow enough time to recreate the original stocking level, together with changes in land use resulting primarily from the growing need for farmland and pastures. Consequently, actual supply areas are often insufficient and “nominal” supply areas in sustainable regimes need to be larger than current ones.

When analysing urban woodshed areas and their spatial evolution over time following urban demand projections, it is vital to consider *actual* supply zones and the impact upon them, as well as to delineate the *nominal* or *potential* sustainable supply zones. In turn, knowledge about the availability, or otherwise, of potential sustainable supply areas should influence development policies and priorities in urban forestry and energy.

3.5.2 The socio-economic chain

In socio-economic terms, the urban woodshed includes several categories of consumers, extended chains of producers, traders and retailers who represent a fundamental dimension of wood energy systems. Fuelwood and charcoal production, trading and commercialization provide employment, both temporary and permanent, and income for a large number of people often located outside urban areas.

Among other conventional and renewable energy options, bioenergy is the most labour-intensive technology and has the highest employment-creation potential in both developing and industrialized countries (IEA Bioenergy, 2005). This is particularly true for wood energy systems in developing countries and their high employment rates, as compared with other energy systems, as shown in Table 3, which gives an estimation of local employment potential of different household fuels per standard unit of consumed energy (FAO, 2003c). The values in Table 3 resulted from estimates of local employment from the production and distribution of different fuels, taken from studies undertaken in developing countries (UNDP/WB-ESMAP, 1992). Of the various household fuels, fuelwood and charcoal production and trade provide the greatest employment per standard unit of energy consumed, and petroleum fuels have the least effect on employment.

Applying standard fuelwood and charcoal conversion factors (Annex 1) to the employment rates of Table 3, employment rates per tonne of woody biomass (oven dry) for fuelwood and for charcoal have comparable values, with average values of 2.7 and 2.3 workdays, respectively. These values are indicative only and subject to major local variations but they are useful in defining the order of magnitude of the employment potential of wood energy systems.

Given the concentrated and increasing demand for woodfuels, particularly charcoal, by large cities in developing countries, it is easy to imagine the growing amount of people outside the cities dependent on this resource for their livelihood.

Town administrators, planners and policy-makers need to be aware of this dependence and its environmental and socio-economic interactions. Growing cities have responsibilities for the management of resources exploited for their needs and for those communities that depend upon them. Urban forestry can play an essential bridging role in this respect by assisting in the definition and mapping of urban woodsheds and the associated geography of stakeholders.

In order to act in response to this expanded responsibility town planners and policy-makers must be informed about these environmental and socio-economic interactions and urban forestry can play an essential bridging role in this respect by assisting in the definition and mapping of urban woodsheds and the associated geography of stakeholders.

TABLE 3
Estimated local employment potential of different household fuels per standard unit of energy consumed (UNDP/WB-ESMAP, 1992)

Fuel type	Amount of fuel per TJ	Employment per TJ energy in workdays[1]
Kerosene[2]	29 kl	10
LPG	22 m^3	10–20
Coal[3]	43 tonnes	20–40
Electricity[4]	228 MWh	80–110
Fuelwood[5]	62 tonnes	100–170
Charcoal	33 tonnes	200–350

1 Employment covers growing, extraction, production, transmission, maintenance, distribution and sales, including reading of meters. It excludes employment generated outside the country for fuels that are imported in a semi-finished state.
2 This assumes that crude oil (for refining), kerosene and LPG are imported.
3 This varies according to the capital intensity of the mine, seam thickness, energy value of the coal and distance from demand centres.
4 This varies according to production methods, ranging from hydro to traditional oil/coal-fired units and the efficiency of electricity generation, transmission and distribution.
5 This depends on the productivity of the site, efficiency of producers and distance from markets.

3.6 SWOT ANALYSIS OF URBAN WOOD ENERGY

It is evident that urban wood energy is at the crossroads of different sectors (forestry, agriculture, energy, urban and rural development), with an important influence on the environment and the economies of urban and rural areas and communities, and at scales ranging from individual households to national or even international contexts.

In order to see the many aspects that characterize urban wood energy and its environmental and socio-economic influence in urban and rural contexts, an analysis of strengths, weaknesses, opportunities and threats (SWOT) is given in Table 4.

TABLE 4
SWOT analysis of urban wood energy systems

	URBAN- PERI-URBAN context				RURAL context			
	Strengths	**Weaknesses**	**Opportunities**	**Threats**	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**
General	Expertise and methodologies in (urban) forestry, energy and agriculture sectors are adequate to cope with wood energy system	Information on the entire chain from production to final users is weak	Integration of (urban) forestry, energy, agriculture and political will can improve urban and rural environments and quality of life through sound intersectoral policies and actions	The lack or absence of information may be an impediment to the understanding and formulation of sound policies	Expertise and methodologies in (urban) forestry, energy and agriculture sectors are adequate to cope with wood energy system	Information on the entire chain from production to final users is weak	Integration of (urban) forestry, energy, agriculture and political will can improve urban and rural environments and quality of life through sound intersectoral policies and actions	The lack or absence of information may be an impediment to the understanding and formulation of sound policies
Environ-mental	Biomass is a renewable resource Integration with other benefits and services (multipurpose land management) Landscape restoration/ improvement Quality of air, water and soil Substitution of non-renewable fuels Improve urban ecosystem Increased biodiversity in urban environment	Emissions with low technologies Smoke and high particulate matter Storage space at domestic and retailer level	Lower emissions with more efficient technologies Evolution to bioenergy Substitution of non-renewable fuels Improvement, in the long term, of urban environment Increase in urban forestry activities can encourage a comprehensive and participatory management of urban environment	Degradation and depletion of urban/peri-urban trees because of increasing energy needs by urban poor Land degradation through inappropriate techniques Inadequate institutional capacity and political recognition may cause unsustainable management and environmental degradation Floods/landslides caused by deforestation, degradation of watersheds, etc.	Valorization of marginal forests and forest residues Maintenance of forest cover (through sustainable forestry techniques) Maintenance of water resources	Forest and land degradation through inappropriate techniques Rapid increase in charcoal demand and derived profit opportunity encourages unsustainable "mining" of forest/woodlands	Promotion of a sustainable forest management Enhanced profitability of sustainable forestry Community forestry and participation enhance sustainability Increase in charcoal demand requires and encourages a stronger approach to comprehensive and participatory forest management	Irreversible forest/land degradation, desertification, Increase in charcoal demand (compared with fuelwood) puts higher pressure on forest resources Inadequate institutional capacity and political recognition may cause unsustainable management and forest depletion Floods/landslides caused by deforestation, degradation of watersheds, etc.

(*continued*)

	URBAN – PERI-URBAN context				RURAL context			
	Strengths	**Weaknesses**	**Opportunities**	**Threats**	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**
Socio-economic	Lower dependency on external fuel market Energy security Reduction of external bills Local and regional employment chain High employment rate Commodity appreciated by retailers and users (charcoal) Integration with alternative energy sources Stable economic value (charcoal) Women retailers Affordable entrance to woodfuel business chain Widespread demand Adequate planning and decision-making guarantee suitability for creation of community-based microenterprises Urban (community) forestry and participation enhance sustainability	Use of fuelwood considered an indicator of poverty in terms of social status Limited use (cooking and heating) as energy resource with traditional technologies Price of land for activities of small urban forest producers Lack of knowledge and scarce silvicultural techniques Urban forest and wood energy are neglected sectors at the political level and not part of the agenda of national/international energy/environment agencies	Expanded uses as energy resource with improved technologies Involvement of small urban forestry producers and stakeholders enhances the sense of belonging Increased energy security because of lower dependence from imported fuels Reduction of foreign bills and debt	Inadequate institutional capacity and political recognition may generate social inequality, illegality and corruption Rapid increase in land value in peri-urban areas may threaten urban forestry projects that need medium-/long-term investment	Option for combating poverty in rural areas High employment rate Refuge source of revenue in agricultural crisis period Suitable for creating community-based microenterprises Community forestry and participation enhance sustainability	Transport dependent Inequality of added income among those involved, from producers to retailers, in the absence of pricing policies and with an uncontrolled market Market forces work only towards felling trees and not protecting them, because of low product output Rapid increase in charcoal demand and derived profit opportunities lead to depletion of communal resources benefiting urban operators but impoverishing rural communities	Creation of small producers' cooperatives Establishment of long-term supply agreements between rural communities and urban traders	Disproportionate transfer of wealth from rural communities to few urban traders Impoverishment of rural communities in the absence of policies, regulations, participation Acceleration of rural exodus Increasing urbanization caused by the impoverishment of rural/forest communities whose communal resources have been depleted Inadequate institutional capacity and political recognition may engender social inequality, illegality and corruption

PART II

WOOD ENERGY DATA AND METHODOLOGIES FOR URBAN AND PERI-URBAN WOOD ENERGY PLANNING

4 Wood energy data and planning tools

4.1 WOODFUEL CONSUMPTION STATISTICS

Determining current woodfuel consumption at the global, regional or national level and estimating possible future scenarios are complex tasks mainly because of the lack of adequate wood energy information in international databases and within countries themselves. This situation, common to both developed and developing countries, is a consequence of insufficient institutional awareness of the importance of wood energy for local, regional and national economies. The different “forestry” or “energy” perspectives adopted by estimating agencies, which lead to wide discrepancies in data sources, are some of the greatest problems (FAO, 2005a).

Much remains to be done in order to establish reliable wood energy statistics, but important steps have recently been taken in this direction, showing that there is hope in the future for this generally neglected sector. Significant improvements include:

- the international process promoted by FAO, leading to an established set of terms and definitions related to wood energy and bioenergy (FAO, 2004a);
- the development, in the framework of the Global Forest Products Outlook Study (GFPOS), of multivariate modelling of fuelwood and charcoal consumption based on reliable field data, used to fill in data gaps in FAO country statistics (FAO, 2001a);
- the review of existing national and international sources of wood energy information and statistics and the creation of a consultable multisource database (FAO, 2005a).

Most existing statistics on fuelwood and charcoal consumption are limited to country totals, with some breakdown by household and other sectors but rarely by urban and rural areas.

Given the lack of systematic statistics on urban woodfuel consumption, the role and dynamics of urban wood energy are inferred from the time series and projections of charcoal consumption, with the assumption that charcoal is consumed prevalently in urban contexts while fuelwood is consumed prevalently in rural ones.

4.2 GFPOS FUELWOOD AND CHARCOAL CONSUMPTION PROJECTIONS

In order to utilize the most complete set of statistics on past and projected fuelwood and charcoal consumption, all figures and statistics given here are derived from estimates at country level in the framework of GFPOS (FAO, 2001a), which cover the whole world from 1960 to 2030. This data set is the only one to attempt projections for all countries worldwide and, notwithstanding some limitations and approximations through lack of reliable field data, offers a consistent and realistic vision of likely wood energy scenarios.

Although other sources may be considered more reliable than GFPOS in a country by country analysis, at regional and global levels it appears to provide realistic and reliable aggregated estimates.

4.2.1 Global fuelwood and charcoal consumption scenario

Global trends in woodfuel consumption, shown in Figure 12, illustrate the marked increase of charcoal in all regions, especially Africa and Latin America, and the decrease of fuelwood, with the notable exception of Africa, where fuelwood demand is expected to increase until 2025.

In Asia and Africa the woody biomass used for charcoal production is at present a fraction of the amount used directly as fuelwood, while in Latin America charcoal is expected to equal fuelwood by 2030. In Africa the growth in charcoal demand primarily as a result of urbanization is extremely high and is expected to double by 2030.

4.2.2 African scenario

The consumption levels and expected trends of fuelwood and wood for charcoal in African subregions are shown in Figure 13. Charcoal consumption levels and trends are highest in tropical subregions: East Sahelian, West Moist, Tropical southern and Central Africa.

The increasing importance of charcoal consumption in tropical Africa as compared with that of fuelwood is shown in Figure 14. According to GFPOS estimates, wood used for charcoal in 2030 will correspond to half the wood used for fuelwood, with an increment of some 111 percent since 2000, compared with the 27 percent increment expected for fuelwood. In 2030 the wood used for charcoal will represent one third of the total wood used for energy.

What is most relevant, however, is that this will come almost exclusively from forests and dense woodlands and via commercial means and channels, while the majority of fuelwood will come from farmlands, agricultural and forestry residues and by-products, deadwood collection and via informal and non-commercial channels. The impact of charcoal production on forest resources is significant today but is likely to increase in the future.

It is imperative to recognize the dominant role and inherent challenges of charcoal production in forest management and to convert potential threats into development opportunities for decentralized and peri-urban communities.

FIGURE 12
Global fuelwood and charcoal consumption by region, 1970–2030 (FAO, 2001a)

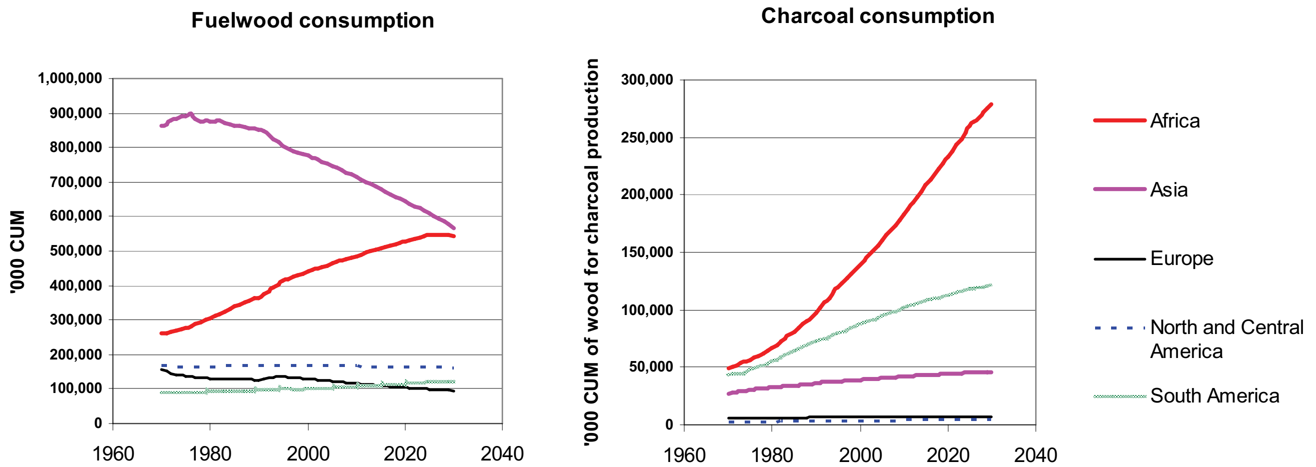


FIGURE 13
African fuelwood and charcoal consumption by subregion, 1970–2030 (FAO, 2001a)

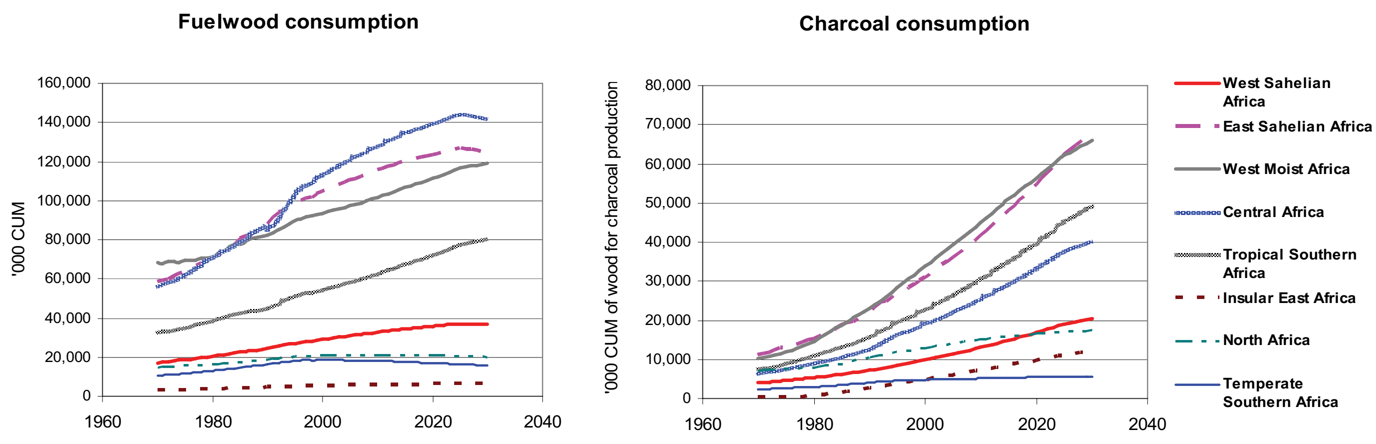
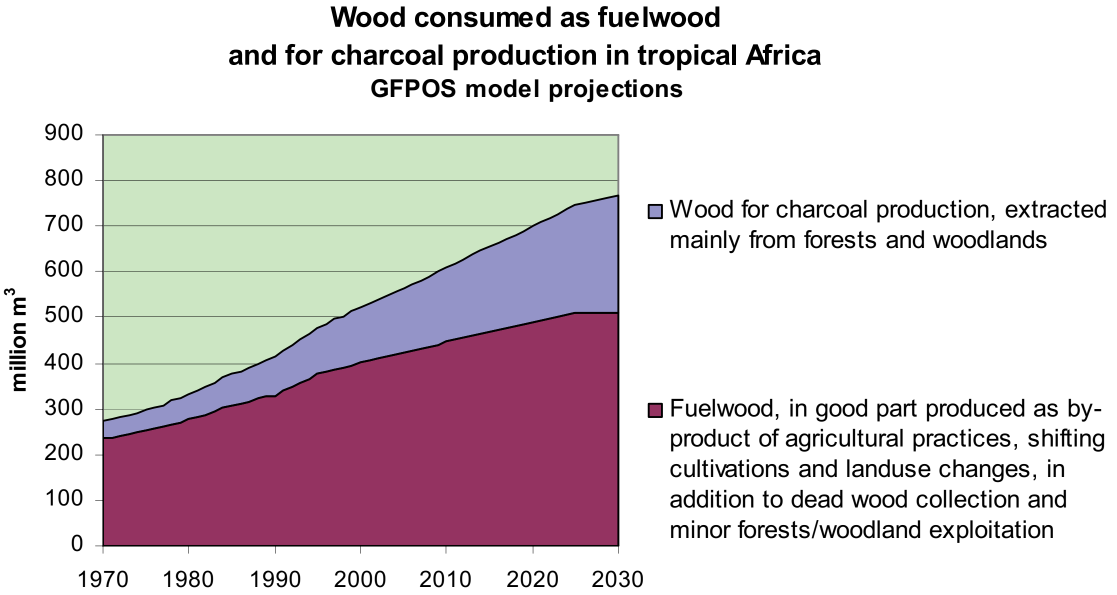


FIGURE 14
Consumption of wood for energy in tropical Africa, 1970–2030 (FAO, 2001a)



4.3 PLANNING TOOLS FOR POLICY-MAKERS

Urban wood energy is not a self-contained and delimited sector and does not have a well-defined institutional structure responsible for planning and controlling it. It rather sits at the intersection of many different sectors, disciplines and institutional competences, each of which has its specific set of responsibilities and planning tools but none of which takes direct responsibility for the development and monitoring of sustainable wood energy systems for cities. Table 5 provides a synthetic overview of the main sectors that contribute to sustainable urban wood energy planning.

A critical challenge in urban wood energy planning is to overcome the fragmentation of competences and responsibilities that characterize the sector and to achieve an adequate level of integration and collaboration among the sectors involved.

In the energy sector there are several planning tools that include wood energy elements, such as the Long-range Energy Alternatives Planning (LEAP) system (FAO, 1998a; SEI, 2000), but these are analysed mainly from the consumption perspective, omitting most of the issues related to woodfuel supply sources and production sustainability.

Forest management tools, on the other hand, deal with production sustainability (FAO, 2002b), but focus mainly on timber concessions and industrial roundwood production rather than woodfuel production, in spite of the paramount importance of woodfuels among forest products. Moreover, forest management is limited to forest formations, while a significant part of all consumed woodfuels is produced outside forests and other wooded lands (i.e. shifting cultivation areas, land use conversions, agroforestry, farmlands, etc.) or from harvesting and industrial forestry residues.

Specific wood energy problems are commonly dealt with by means of detailed local studies, such as the area-based woodfuel flow analysis (FAO, 1997a; 1998b; 2000; 2001b), where results support local planning or are expanded at national level to guide energy action and interventions. Many local studies and projects, if not most, were focused on specific cities and on their fuelwood and charcoal supply zones, with the specific scope of supporting sustainable resource management and the continued supply of woodfuels (Bertrand, Konandji and Madon, 1990; ESMAP, 1993; Chaposa, 1999).

Although these studies give adequate information and effectively support the formulation of sound policies, they are expensive and time consuming. Their cost makes them limited in coverage and sporadic, thus failing to provide the necessary national overview for the formulation of policies in respect of renewable energy potential, forestry and energy planning, inventories of greenhouse gases, and so on.

Moreover, these studies confirmed the local heterogeneity of wood energy situations and helped to specify the fundamental characteristics of wood energy systems, which may be summarized as follows.

Geographic 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, 2003a). 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 or domesticated landscapes, such as shrublands, farmlands, orchards and agricultural plantations, agroforestry, tree lines and hedges, contribute substantially to fuelwood and, to a lesser extent, to row material for charcoal production.

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

TABLE 5
Sectors involved in sustainable urban wood energy planning

Sector	Main perceived focus by sector management	Potential role of the sector in urban wood energy planning
Urban forestry	Multipurpose management of urban forests, trees and green recreational areas	Promotion of suitable woodfuel species, biomass production practices and participatory management approaches in urban and peri-urban areas; bridging forestry and urban development
General forestry	Conservation of forest resources and sustainable forest management (prevalently oriented towards timber products and industrial forestry)	Participatory sustainable management of forests and woodlands for fuelwood and charcoal production within the urban woodshed; bridging rural and urban development
Urban development	Development of residential, commercial/industrial areas and infrastructure	Inclusion of woody biomass production function in land management of urban and peri-urban areas; optimization of tree cover
Urban energy	Expansion of electricity grid and gas distribution network in urban and peri-urban areas	Analysis of woodfuel demand by urban and peri-urban dwellers and its evolution over time; establishment of supply agreements with rural/forest communities
General energy	National energy policy oriented mainly towards oil-derived products, electricity and “modern” renewables	Surveying of woodfuel consumption patterns and trends; promotion of efficient energy technologies
Agriculture	Food production	Bioenergy crops, woody biomass production through woodlots of fast growing species; charcoal production to complement farmers’ income
Rural development	Sustainable development; rural communities; farmers’ associations; governance and equity; gender; poverty alleviation	Development of rural markets for woodfuels; recognition of communal rights; promotion of fuelwood and charcoal producers’ associations

Given the multisectoral and geographic character of urban wood energy, the first planning phase should therefore integrate data from different sectors and provide a comprehensive overview of the main issues, risks and opportunities from an open and spatially discrete perspective.

4.3.1 Woodfuels Integrated Supply/Demand Overview Mapping (WISDOM) methodology

In order to cover the various dimensions of wood energy systems, the FAO Forest Products Service (FOIP) has developed and implemented the WISDOM methodology, which is a spatially explicit planning tool for highlighting and determining woodfuel priority areas or woodfuel hot spots (FAO, 2003b). WISDOM is the fruit of collaboration between the FAO Wood Energy Programme and the Institute of Ecology of the National University of Mexico. At the national level, the WISDOM approach has been implemented in Mexico (FAO, 2005e; Masera *et al*., 2006), Slovenia (FAO, 2006a) and Senegal (FAO, 2004b). At subregional level, WISDOM has been implemented over the eastern and central African countries covered by the Africover Programme[5] (FAO, 2006b) and the countries of Southeast Asia[6] (FAO, in press).

The WISDOM methodology was preferred to other approaches, such as the LEAP model (FAO, 1998a; SEI, 2000), for its thematic specificity (woodfuels rather than generic energy or forestry planning) and for its open framework (i.e. not a package), which allows a high degree of flexibility and adaptability in the heterogeneity and fragmentation of data related to the production and consumption of woodfuels. With respect to the definition of urban supply zones generally applied in field projects (Bertrand, Konandji and Madon, 1990; ESMAP, 1993; CHAPOSA, 1999), the WISDOM approach has the advantage of considering the entire demand and supply context, including consumption in peri-urban and rural areas, which supports a consistent and possibly a more objective definition of urban woodsheds.

WISDOM, especially when applied at the regional level, does not replace a detailed national biomass demand/supply balance analysis for operational planning, but rather it is oriented towards supporting 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, in the highest possible spatial detail, areas deserving urgent attention and, if needed, additional data collection. In other words, WISDOM serves as an assessing and strategic planning tool to identify sites for priority action.

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

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

Additional urban woodshed module. Further focusing of analysis for the delineation of urban woodsheds, i.e. supply zones of specific urban and peri-urban areas, requires additional analytical steps that may be summarized as follows.

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

Figure 15 gives an overview of the main steps in the WISDOM methodology. After a countrywide analysis that is essential for defining broad issues and priority urban woodsheds with objectivity, WISDOM can be further refined in selected priority areas by using specific woodfuel flow data and thence developed into an operational planning tool, as discussed in greater detail in Chapter 5.

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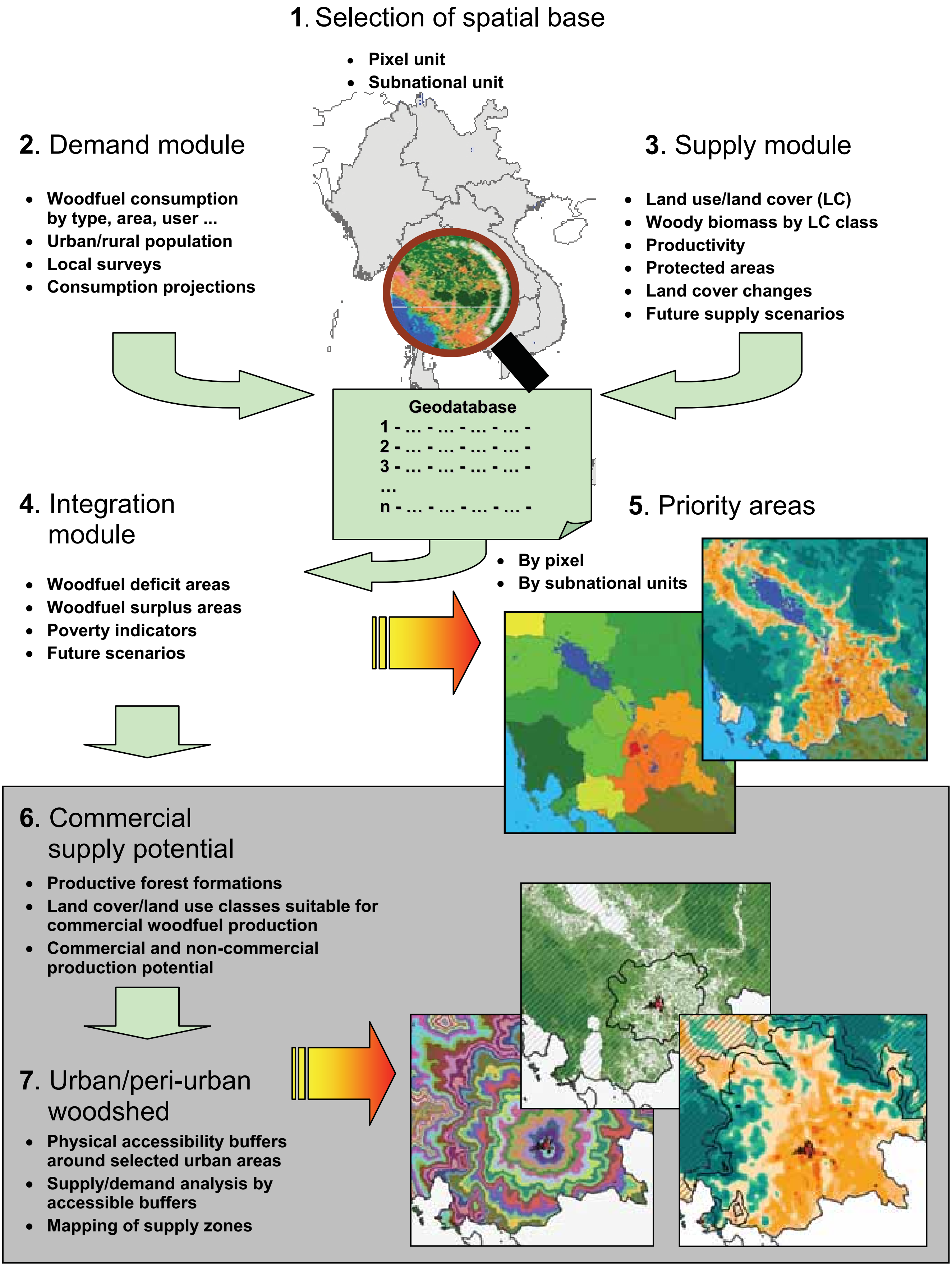
[5] Burundi, Democratic Republic of the Congo, Egypt, Eritrea, Kenya, Rwanda, Somalia, the Sudan, United Republic of Tanzania and Uganda.

[6] Cambodia, Malaysia, Lao People's Democratic Republic, Thailand, Viet Nam and China, Yunnan Province.

FIGURE 15
WISDOM analytical steps with the additional urban woodshed component (grey frame)



5 Wood energy scenarios in urban areas of East Africa and Southeast Asia

In this chapter woodfuel (fuelwood and charcoal) consumption in urban centres of selected countries of East Africa and Southeast Asia is analysed with the support of the Geographic Information System (GIS) data set produced by recent studies based on the WISDOM methodology in ten East and Central African countries (FAO, 2006b) and in the countries of Southeast Asia (FAO, in press).

Two levels of analysis are presented: a general overview of fuelwood and charcoal consumption in urban and rural areas, and the likely trends and case studies of spatial analysis of urban woodsheds, or areas of influence of woodfuel consumption, in selected African and Asian urban areas.

5.1 URBAN WOODFUEL CONSUMPTION IN EAST AFRICA AND SOUTHEAST ASIA IN 2000

The demand modules of WISDOM in East Africa and Southeast Asia were developed upon best estimates of national fuelwood and charcoal consumption. These reference values were chosen from national and international sources on the basis of the estimation methods (when reported) and on source competence/reliability. Country-level estimates were converted into per capita consumption levels in rural, rural village and urban contexts and then “spatialized” through population distribution maps (FAO, 2005b) with reference year 2000 and, for Southeast Asia only, 2015 (FAO, 2006b; FAO, in press).

Figures 16 and 17 show the marked difference between urban and rural areas with regard to fuelwood and charcoal consumption in the countries of East and Central Africa and Southeast Asia covered by the studies. In most of these countries there is a clear distinction between rural and urban woodfuel consumption patterns, which helps to understand and assess the major implications derived from the rapid processes of urbanization.

The exceptions to the general trend appear to be Eritrea and Thailand for which the most reliable references report a high charcoal consumption also in rural areas (FAO, 2006b; FAO, in press). In Yunnan Province, China, the consumption of charcoal is considered negligible (FAO, in press).

In addition to the clear dominance of charcoal in urban woodfuel consumption shown in the East African and Southeast Asian figures, it is probable that the rural fraction of charcoal consumption is in villages rather than in sparsely populated rural areas. Consequently, in these studies rural areas were further subdivided into rural settlements (more than 2 000 inhabitants/km^2) and sparsely populated areas (fewer than 2 000 inhabitants/km^2), with the assumption that in the first case, the land is occupied prevalently by housing, commercial buildings and infrastructures while, in the second, agricultural land uses prevail, as indicated by a study conducted by the International Institute for Applied Systems Analysis (IIASA) in China and Bangladesh (FAO, 2005b).

In rural settlements, woodfuel consumption was assumed to have a pattern somewhere between the urban and average rural levels, i.e. with higher charcoal and lower fuelwood consumption than in average rural conditions. Consumption in the sparsely populated rural areas was derived from the remaining “unallocated” consumption and resulted in a higher fuelwood and lower charcoal consumption than in average rural conditions (FAO, 2006b; FAO, in press).

5.1.1 Southeast Asian consumption scenarios, 2000–2015

As part of the Southeast Asian WISDOM study, woodfuel consumption in subregional urban and rural areas was projected to the year 2015, according to the national fuelwood and charcoal consumption trends shown by the GFPOS study and the business as usual (BAU) scenario (in which per capita consumption was kept stable and variations determined only by rural and urban population growth). These 2000–2015 consumption trends are shown in Figures 18 and 19. The reduction in woodfuel consumption predicted by the GFPOS study is clear, compared with the increase in the BAU scenario, and is primarily a result of the expected economic growth in Southeast Asia and consequent substitution of traditional fuels by “modern” ones such as LPG, kerosene and electricity. Nonetheless, even in an economically positive perspective the demand for woodfuels will remain high in both the urban and rural context.

FIGURE 16
Urban and rural fuelwood and charcoal consumption in East African countries, 2000

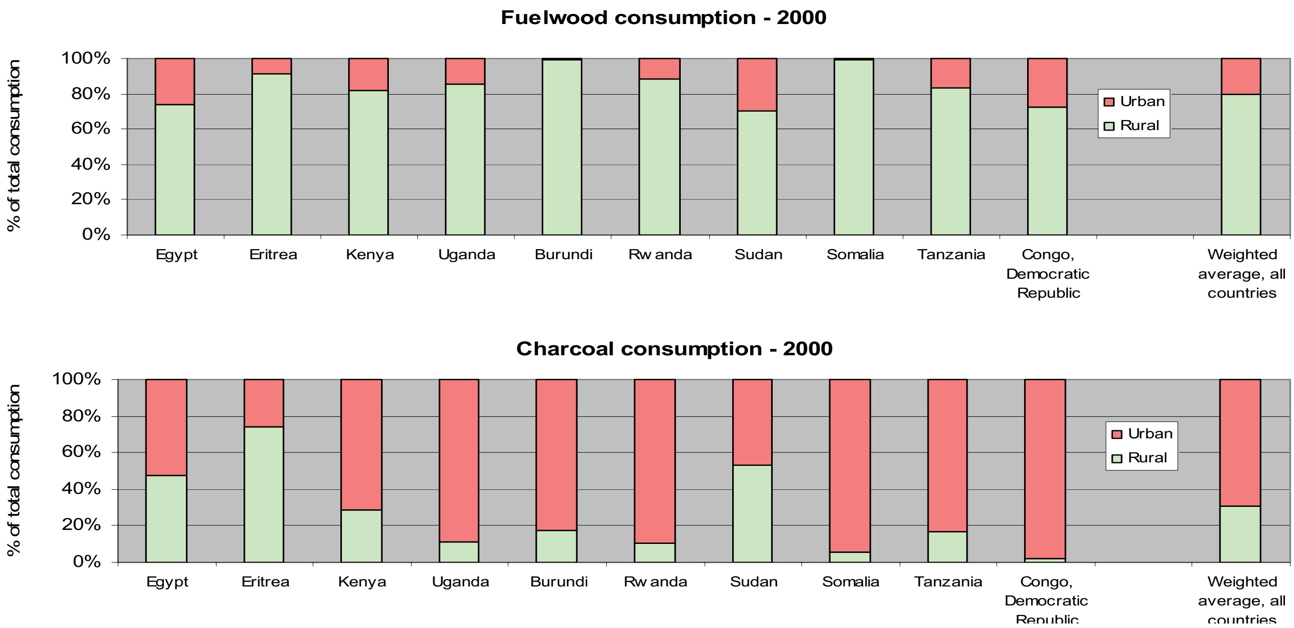


FIGURE 17
Urban and rural fuelwood and charcoal consumption in Southeast Asian countries, 2000

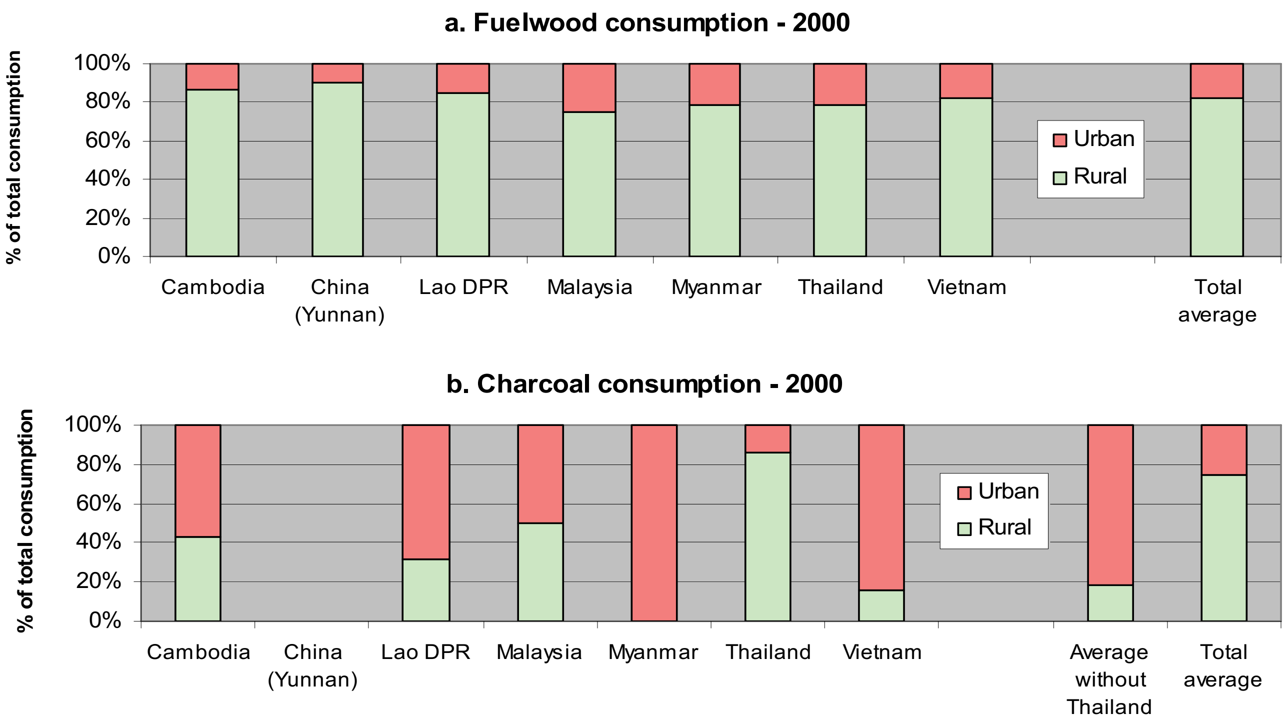
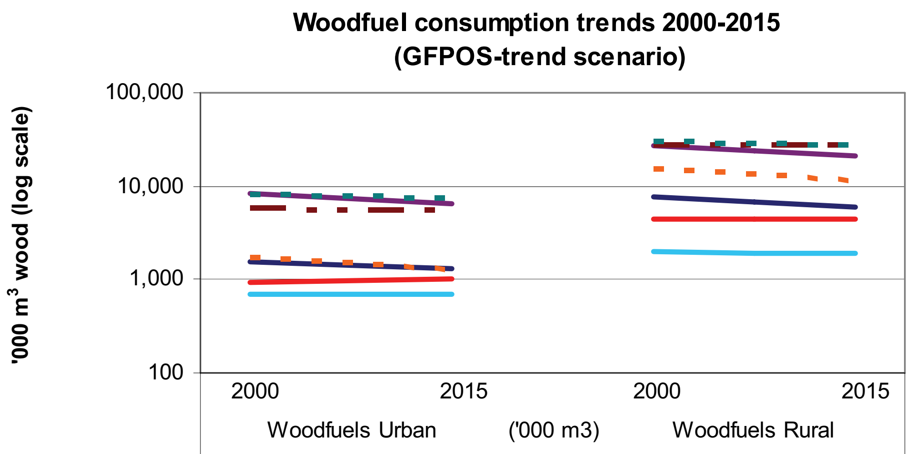


FIGURE 18

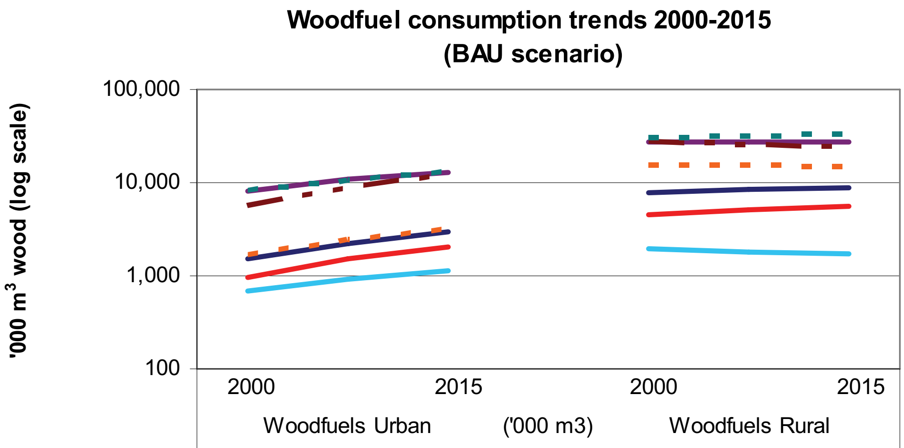
Woodfuel consumption trends in Southeast Asia (GFPOS scenario), 2000–2015



	Woodfuels Urban 2000	Woodfuels Urban 2015	Woodfuels Rural 2000	Woodfuels Rural 2015
Cambodia	1,520	1,307	7,745	5,927
China (Yunnan)	1,679	1,257	15,111	11,316
Lao DPR	952	1,003	4,501	4,508
Malaysia	696	688	1,961	1,886
Myanmar	8,282	6,533	26,902	21,372
Thailand	5,623	5,442	26,770	27,460
Vietnam	8,060	7,469	29,583	26,858

FIGURE 19

Woodfuel consumption trends in Southeast Asia (BAU scenario), 2000–2015



	Woodfuels Urban 2000	Woodfuels Urban 2015	Woodfuels Rural 2000	Woodfuels Rural 2015
Cambodia	1,520	2,935	7,745	8,960
China (Yunnan)	1,679	3,048	15,111	14,794
Lao DPR	952	2,037	4,501	5,558
Malaysia	696	1,115	1,961	1,700
Myanmar	8,282	13,021	26,902	26,866
Thailand	5,623	11,938	26,770	24,116
Vietnam	8,060	12,611	29,583	31,908

5.2 URBAN WOODSHED ANALYSIS OF SELECTED URBAN AREAS

In these paragraphs, the urban woodshed, or theoretical area of influence of fuelwood and charcoal consumption in selected urban areas, is analysed, based on estimated woody biomass production capacities and woodfuel consumption in the legally and physically accessible areas around cities.

The case studies analysed were all concerned with selected urban areas of East Africa and Southeast Asia in order to benefit from the recent WISDOM studies in these regions (FAO 2006b; FAO, in press). The geodatabases created for the regions, which provided spatially discrete parameters related to woodfuel consumption and production potential, as well as local-level supply/demand balance, provided an appropriate analytical setting for the delineation of hypothetical urban woodfuel supply zones.

5.2.1 Urban woodshed module of WISDOM studies in East Africa and Southeast Asia

As described briefly in Section 4.3.1, and depicted in Figure 15, the standard WISDOM methodology can be extended with an additional urban woodshed module designed for the analysis and delineation of the basin of provision of a preselected consumption site such as a single city of wide urban agglomerations. This additional phase necessitates a definition of the share of the local woodfuel productivity that may be suitable for a commercial circuit, plus a definition of resource accessibility from a legal and physical perspective. The following sections describe the conceptual and methodological steps undertaken in the analysis of urban woodsheds of selected locations in East Africa and Southeast Asia. Further details on the analysis procedure and reference data used are given in Annex 4.

Definitions of urban woodfuel supply zones

The area of influence or supply zone referring to the woodfuel consumption of a specific urban area was determined from diverse perspectives, each delimiting a different area. Two basic aspects were considered in the definition of theoretical supply zones – the supply sources of woody biomass (total and commercial only) and the inclusion, or otherwise, of local supply/demand balance in the estimation of resources available for urban consumption, as shown in Table 6.

TABLE 6
Definition matrix of urban woodfuel supply zones based on supply sources considered and estimation procedures

		Estimation elements	
		Woodfuel consumption in selected urban area only	**Woodfuel supply/demand balance within supply zone**
Woodfuel supply sources		**(restricted estimation system)**	**(expanded estimation system)**
All woodfuel sources	(“total” supply potential)	restricted-total	expanded-total
Woodfuel sources suitable for commercial production	(“commercial” supply potential)	restricted-commercial	expanded-commercial

The main distinction between the restricted and the expanded approach is that only urban woodfuel demand is considered in the first, while in the second the local supply/demand balance and therefore the demand outside the selected city is also taken into account. Consequently, in the expanded approach deficit cells around the selected urban area have the effect of further expanding the area of influence, which will “close” only when wood resources (total or commercial) are sufficient to balance the urban demand as well as other deficit areas around the city.

Listed by increasing area of influence, the definitions given below were adopted.

Restricted total supply zone. This is the area around the city where the total potential sustainable and accessible woodfuel production capacity equals the woodfuel consumption of the city itself. All woody biomass productivity is accounted for, including that of sparse and degraded vegetation types and farmlands. Woodfuel consumption outside the city is not considered.

Restricted commercial supply zone. This is the area around the city where the potential sustainable, accessible and economically viable woodfuel production capacity equals the woodfuel consumption of the city itself. Only the woody biomass productivity of denser forest and woodland formations is accounted for, since sparse and fragmented formations are not suitable for commercial fuelwood and charcoal production. Woodfuel consumption outside the city is not considered.

Expanded total supply zone (based on local balance and total surplus). This is the area around the city in which the balance between total woodfuel demand and supply (from all biomass sources) achieves stability. Consumption outside the city is taken into account. The estimation procedure is two-phase.

1. The supply/demand balance is estimated at the local level, i.e. within cells of 10 x 10 km, in which all accessible wood productivity is considered.
2. The area around the city is progressively expanded until total demand (counting not only the city but also all consumption from urban and rural areas progressively included) is counterbalanced by total productivity.

Expanded commercial supply zone (based on local balance and commercial surplus). This is the area around the city in which the balance between total woodfuel demand and "commercial" supply achieves stability. Consumption outside the city is taken into account but the surplus woody biomass (local productivity higher than local consumption) is limited to the "commercial" share, i.e. derived from dense forest and woodland formation. The estimation procedure is three-phase.

1. The supply/demand balance is estimated at the local level, i.e. within cells of 10 x 10 km, in which all accessible wood productivity is considered. The result is a countrywide map of deficit and surplus areas.
2. Surplus areas are reviewed in relation to the "commercial" or "non-commercial" character of surplus resources, depending on the density of forests and woodlands. The result is a countrywide map of "commercial" surplus potentially available and economically accessible for urban woodfuel markets.
3. The area around the city is progressively expanded until total demand (counting not only the city but also all consumption from urban and rural areas progressively included) is counterbalanced by "commercial" surplus.

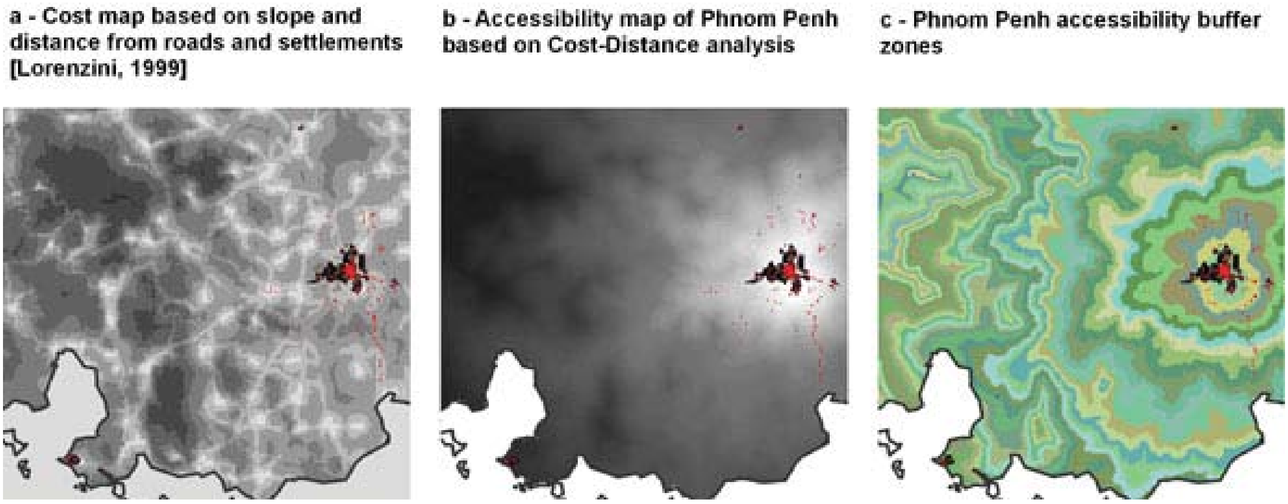
The idea of determining four different and progressively increasing supply zones is to show the complex and far-reaching urban/rural interface in both geographic and socio-economic terms. It is definitely not recommended that the role and impact of cities be analysed without an understanding of the human and environmental context as a whole, including both urban and rural environments.

Accessibility

The issue of physical accessibility, which was largely neglected in the WISDOM studies on East Africa and Southeast Asia because of the focus on local supply/demand situations, acquires particular relevance in urban wood energy systems where the transportation of fuelwood and charcoal has an essential role.

In order to visualize the main methodological steps in the present study, the accessibility of potential woodfuel resources from selected urban areas was determined by cost maps (Figure 20a), based on slope and distance from roads and settlements (Lorenzini, 1999a, pers. com.); the production procedure is described in Annex 3. Country-level cost maps were then used to determine accessibility buffers around selected urban centres (Figure 20b, c) within which woodfuel consumption and potential accessible supply were analysed, as described in Annex 4.

FIGURE 20
Example of accessibility mapping from cost map to accessibility buffers in Cambodia (Phnom Penh as urban area of cost-distance calculation)



Note: These maps show only the elements of physical accessibility. Legal accessibility factors, such as protected areas with limited access rights are not shown, although included in the estimation of resources actually accessible.

The accessibility buffers delineated in the study were based on relatively coarse digital elevation data[7] and on rather outdated maps of roads and settlements,[8] all available at the global level. Although useful for preliminary analyses they would be inadequate for local operational studies for which detailed and up-to-date information on actual transportation networks and economic evaluation of transportation costs are essential.

Urban woodshed analysis in selected East African locations

Analysis of urban woodsheds for selected urban areas in East Africa was based on digital thematic maps and statistics produced as part of the East African WISDOM study.

The reference year of the study, determined by demographic and land cover reference data, was 2000. The spatial resolution of the supply module, based on Land Cover Classification System (LCCS) maps, was relatively high, with original scales between 1:100 000 and 1:200 000. The resolution of local supply/demand balance analysis (integration module) was much lower, i.e. 5 arc-min cell size or 9.2 x 9.2 km at the equator.

The cities, selected arbitrarily to exemplify urban woodshed analyses, included Dar-es-Salaam and Arusha-Moshi in the United Republic of Tanzania; Kampala in Uganda; and Khartoum in the Sudan.

The features and methodological background of the East African WISDOM study are given in the published documentation (FAO, 2006b). The analytical work on the definition and mapping of urban woodsheds is shown in Figure 21 and described in greater detail in Annex 4.

The thematic maps resulting from these analyses are discussed in Section 5.3.2.

Urban woodshed analysis in selected Southeast Asian locations

The methodology of analysis for the Southeast Asian WISDOM data set was similar to that applied for East Africa, apart from the following aspects.

- The spatial resolution of the Southeast Asian WISDOM study was 30 arc-sec, i.e. 0.92 x 0.92 km at the equator (rather than 5 arc-min).
- Legal accessibility factors were already accounted for in the original WISDOM study.
- The original study included an analysis for the year 2000 as well as for 2015, giving several

[7] Global 30 arc-sec GTOPO30 digital elevation model of the Eros Data Center (1997).
[8] Digital Chart of the World. version 1999, which reported road networks and settlements in the late 1980s.

supply/demand scenarios. This meant that probable evolutions of urban woodsheds to 2015 could be analysed (limited to the Phnom Penh case study).

- Subnational maps of malnutrition indicators estimated for the year 2000 (mainly stunting growth in children under five) enabled the nutritional conditions of the population living within the urban woodshed areas to be analysed, as a proxy for poverty conditions.

The analytical work on the definition and mapping of urban woodsheds for the selected Southeast Asian study sites presented several differences compared with those in East Africa. The analytical steps are shown in Figure 22 and described in greater detail in Annex 4.

The cities selected for urban woodshed analyses were Phnom Penh and Battambang in Cambodia; and Vientiane and Luang Prabang in the Lao People's Democratic Republic.

The urban woodshed maps resulting from the analyses of these sites are discussed in Section 5.3.1.

FIGURE 21
Flow chart of main analytical steps, East African WISDOM data set
(resolution = 5 arc-min, i.e. 9.2 x 9.2 km at the equator)

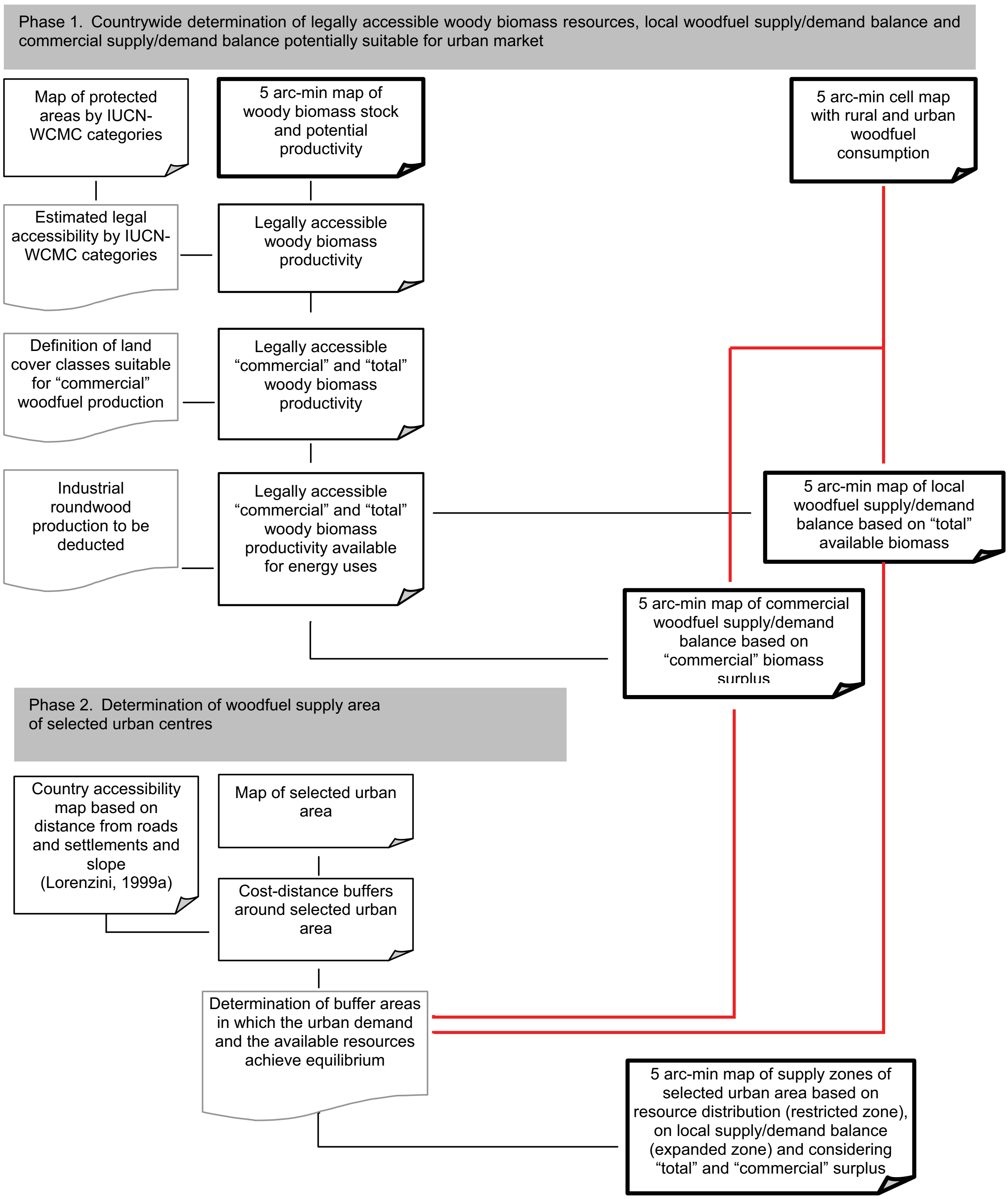
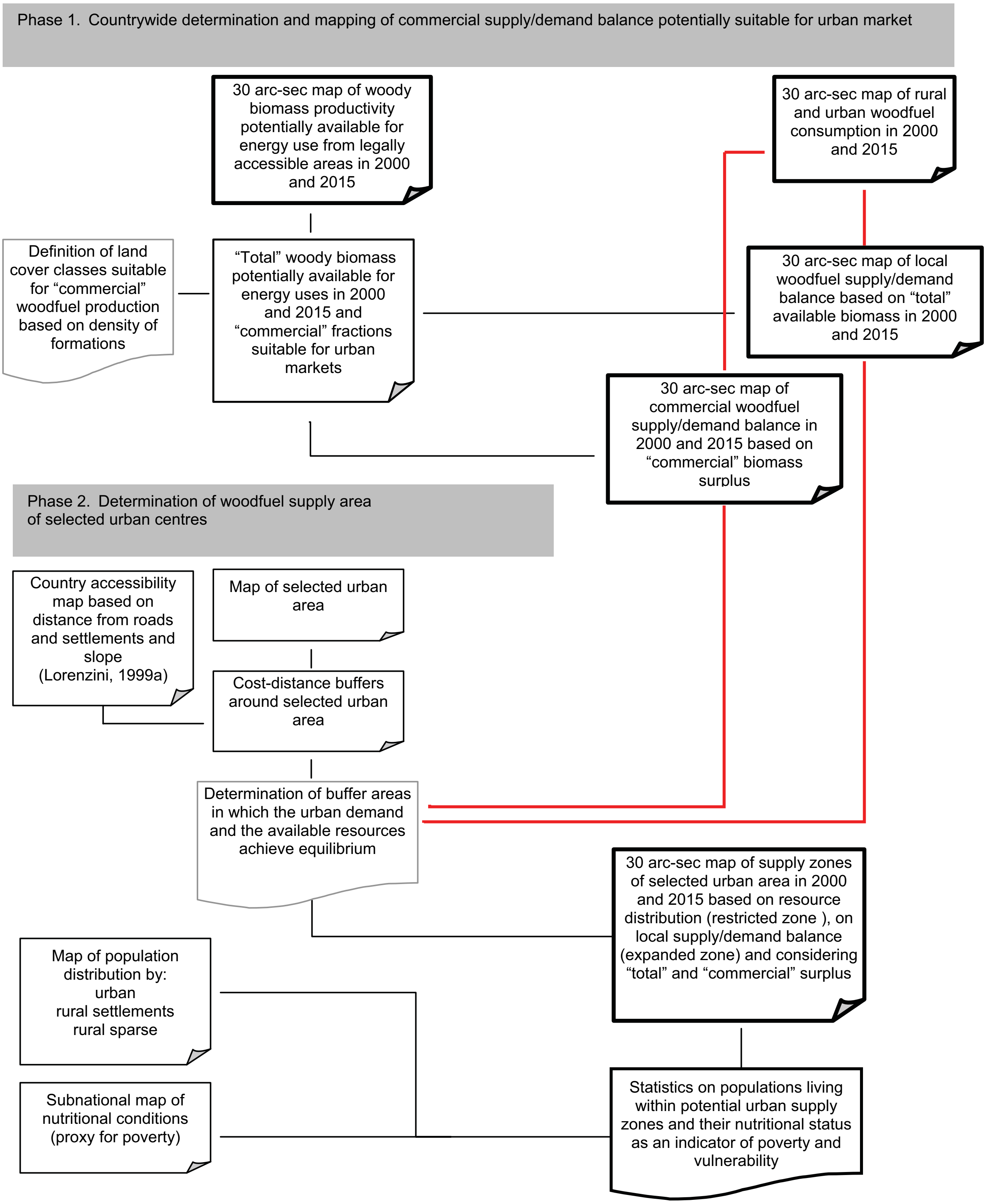


FIGURE 22
Flow chart of main analytical steps, Southeast Asian WISDOM data set
(resolution = 30 arc-sec, i.e. 0.92 x 0.92 km at the equator)



5.2.2 Data limitations

Regional analysis based on global and regional data sets may present several inaccuracies when observed at the local level, as in the case of urban woodshed analysis, because of the relatively coarse resolution of reference maps. Such approximations concern the following.

- Spatial population maps and consequent spatialization of woodfuel consumption, as a result of the population distribution algorithms, which are particularly weak in Africa (FAO, 2005b); in addition, population data within 5 arc-min cells present major problems along coastal areas of the East African data set (it is therefore recommended that the analysis at the original 30 arc-sec resolution be reviewed in order to avoid the coastal area problem).
- Woody biomass distribution and productivity, resulting from coarse land cover maps (as for Southeast Asia) and limited field measurements of volume and productivity, especially for open and degraded forest formation and non-forest woody biomass sources.
- Quantity and sources of wood assortments used by timber industries and other non-energy applications; in the present study total industrial roundwood was assumed to come from dense formations (the same sources assumed suitable for commercial woodfuel production). A more precise identification of industrial wood sources would enhance the definition and location of woody biomass actually available for energy uses (see Annex 4).
- Definition of "commercial" woodfuel sources; these were tentatively defined from land cover class descriptions and limited to woody formations with high density, assuming that they would be more suitable for charcoal and fuelwood production from a commercial perspective (see Annex 4).
- Per capita consumption rates in urban areas, rural settlements and sparse rural areas, which were often inferred because of limited and contradictory reference data.
- Accessibility ranking, which was based on relatively coarse terrain models and probably outdated road network and settlement maps (see Annex 3).
- Several other assumptions concerning the commercial versus non-commercial woodfuel sources, identification of industrial roundwood sources, limited access within protected areas, etc.

The mapping of urban woodsheds presented in the following section was carried out by segmentation of the territory according to accessibility buffers, and the limit of a supply zone was determined by the buffer whereby the cumulative supply exceeded consumption. Consequently, the limits of the supply zones are not the exact place where the "non-negative" balance condition was achieved but rather that of the buffer within which such condition occurred. It is useful to bear this in mind with regard to the summary woodshed statistics.

The examples should be considered as "first-level" delineations meant to provide a visual support to the methodological discussion rather than as accurate woodshed analyses. Regional and national-level analyses can best express their potential in the preliminary phase of urban woodshed analysis by providing i) a comprehensive overview; ii) a rapid delineation of specific woodsheds; and iii) an objective definition of priority areas for operational action in which additional investment in data collection and analysis may be justified and cost effective.

5.3 SELECTED URBAN WOODSHED ANALYSES: RESULTS AND FINDINGS

The following maps depict the supply zones of selected urban centres in East Africa and Southeast Asia delineated according to total and commercial supply potential (restricted zones) and to estimated surplus resources after deduction of local woodfuel demand (expanded zones).

The cities, selected arbitrarily to exemplify urban woodshed analyses, in Southeast Asia were those of Phnom Penh and Battambang in Cambodia; and Vientiane and Luang Prabang in the Lao People's Democratic Republic. In East Africa, they were Dar-es-Salaam and Arusha-Moshi in the United Republic of Tanzania; Kampala in Uganda; and Khartoum in the Sudan.

In order to exemplify the analysis methodology, the Southeast Asian woodsheds are presented first because the baseline data available for this subregion allowed the inclusion of additional elements related to poverty and to the possible evolution of the situation to 2015, elements that were not available for East Africa.

5.3.1 Selected Southeast Asian urban woodsheds

Phnom Penh, Cambodia, 2000

Figure 23 shows the delineation of the restricted woodshed supply zones, with the background of the relevant woody biomass resources. The top map shows the restricted-total supply zone, which is the area necessary for providing the amount of woodfuel consumed in Phnom Penh on account of sustainable woody biomass productivity (available for energy use) from all sources and according to accessibility determined by roads, settlements and slope.

The bottom map shows the restricted-commercial supply zone and considers only consumption in Phnom Penh city. On the supply side it relates only to the sustainable productivity of dense forest and woodland formations considered more suitable for commercial woodfuel production for urban markets. The difference between these two zones is great, because woody biomass resources in the proximity of the city are mostly composed of open, fragmented and degraded formations and trees outside forest in agricultural landscapes, as was deduced from the land cover map used in the regional WISDOM analysis. These resources play an important role in the local context but may be uneconomic from a commercial perspective.

Figure 24 shows the delineation of the expanded supply zones, with the background of the relevant woodfuel supply/demand balance data. The delineation of the supply zones in these cases took into account not only consumption in Phnom Penh but also that of the other areas progressively included until the overall equilibrium between demand and supply was achieved.

The top map shows the expanded-total supply zone, which took into consideration the entire local surplus (shaded green) from all possible sources, including sparse and fragmented areas.

The bottom map shows the expanded-commercial supply zone, and considers only the surplus from denser formations more suitable for commercial woodfuel production for distant urban markets. The commercial balance map, background to the second image, shows the same deficit areas (shaded red) as the first but with a smaller surplus area (shaded green) and a greater "balanced" area, because of the exclusion of those resources that, although important in a localized supply/demand context, are less significant for the provision of distant cities.

With an urban population of approximately one million, Phnom Penh influences the environment and socio-economics of a considerable part of the national territory. As shown in Table 7, the different Phnom Penh supply zones range from some 14 000 km^2, home to 4.7 million people, to over 70 000 km^2 and 10 million people. Of particular relevance from the perspective of sustainable development and poverty alleviation, these zones include numerous communities, here accounted for under sparse rural population, which could be the major beneficiaries of sustainable wood energy systems created to provide woodfuels for cities and other large settlements. Their number varies between 1.6 million for the restricted-total zone to some 5.5 million for the expanded-commercial one.

FIGURE 23
Phnom Penh restricted woodshed zones

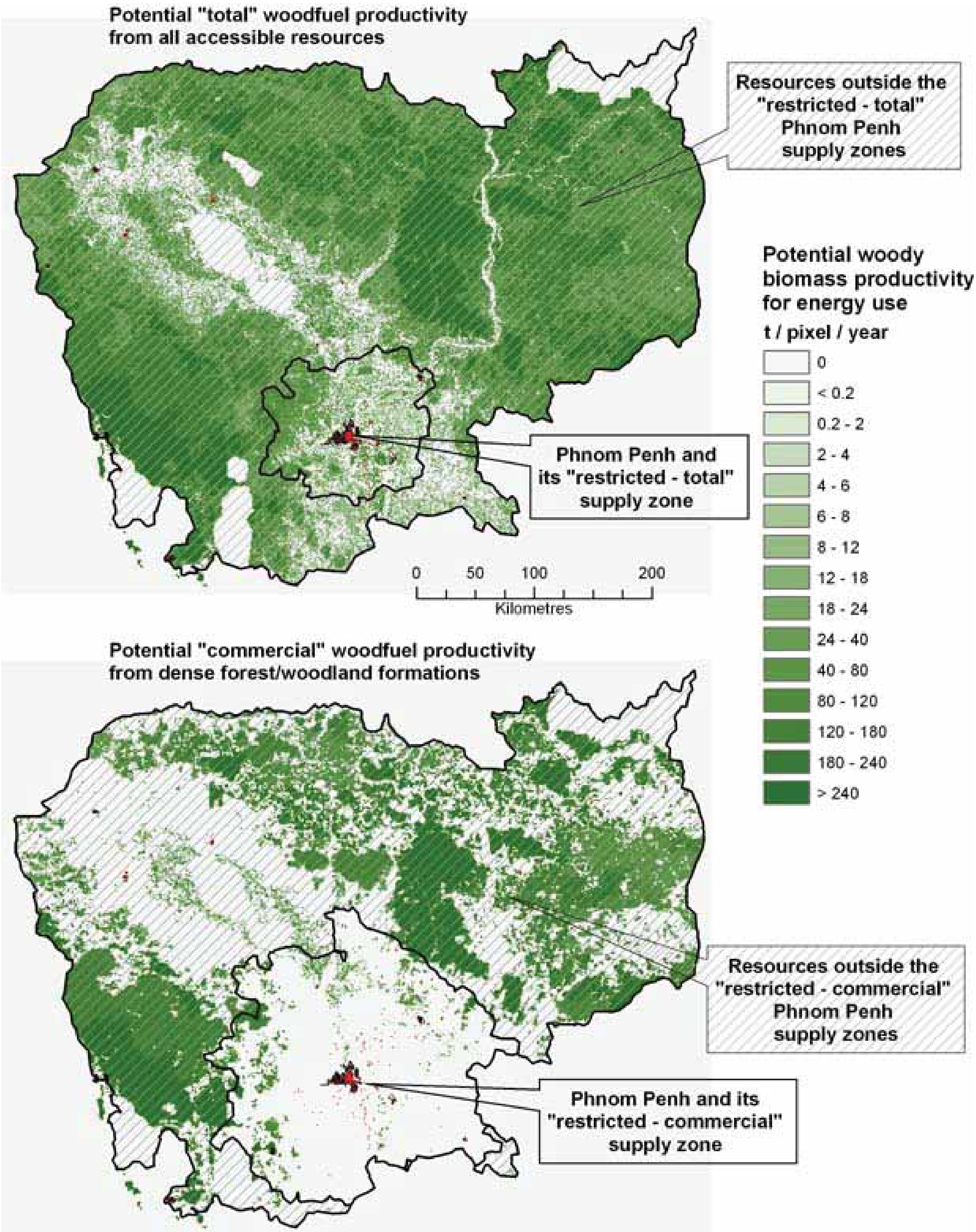


FIGURE 24
Phnom Penh expanded woodshed zones

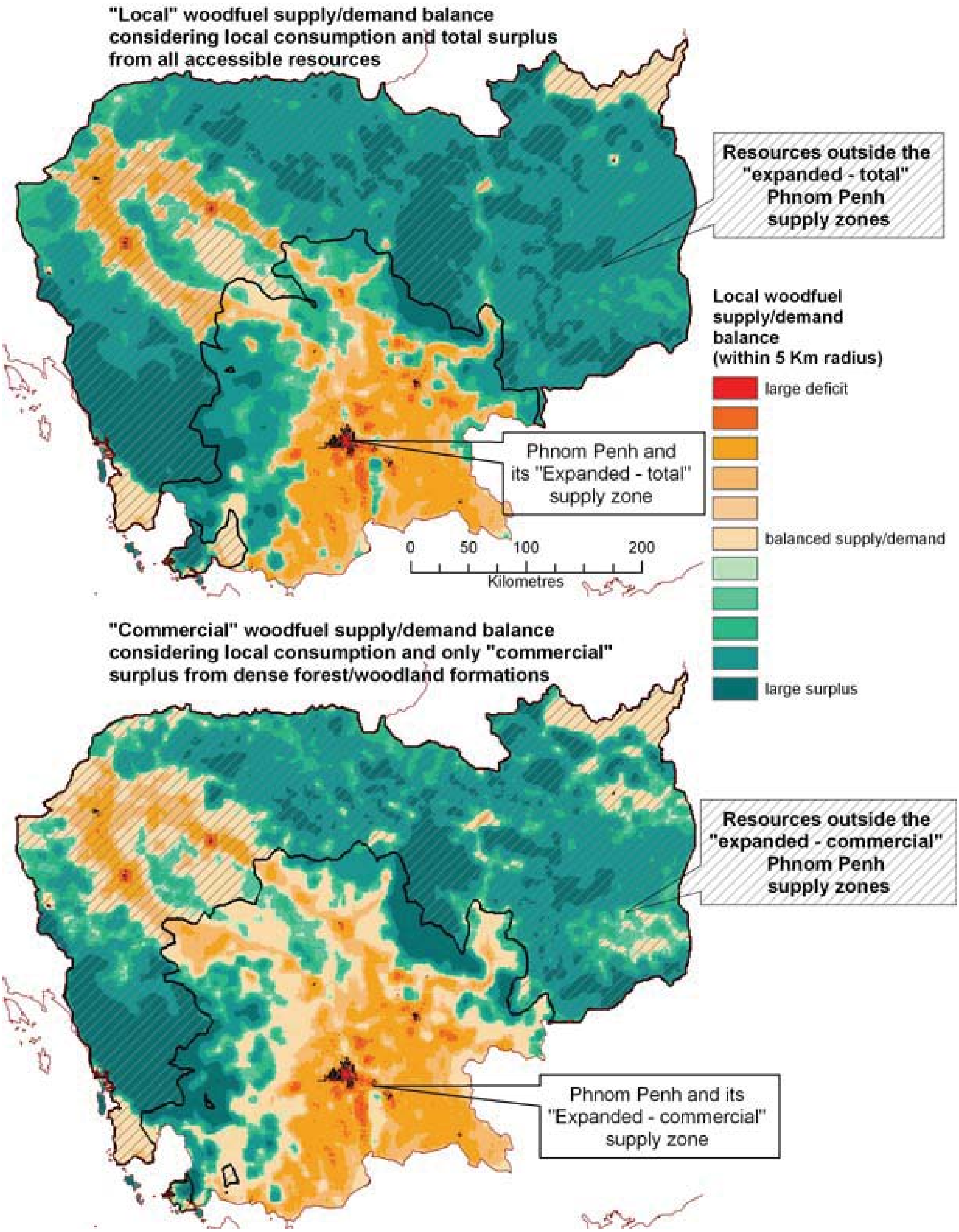


TABLE 7
Main statistics for Phnom Penh woodshed zones

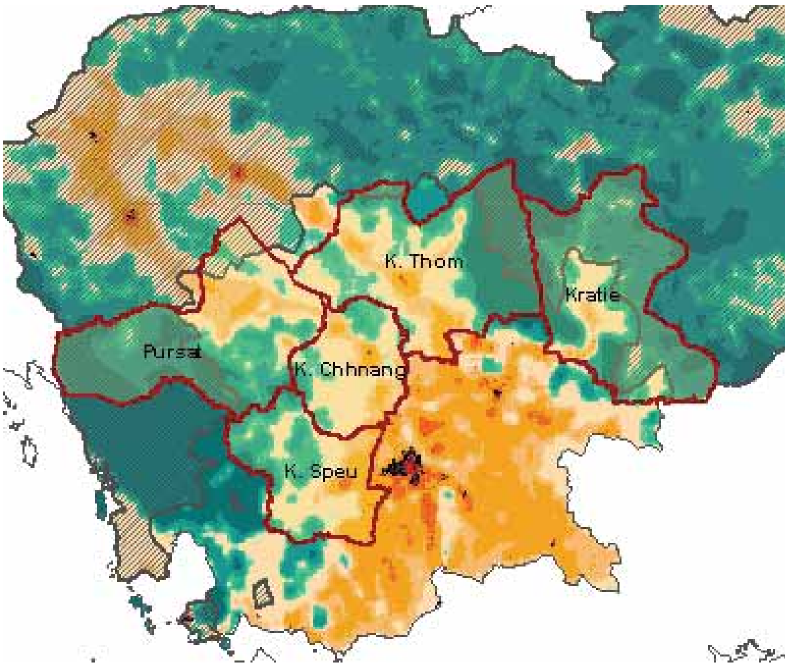
		Phnom Penh supply zones			
		Restricted		Expanded	
		Total	Commercial	Total	Commercial
Area of supply zone	km^2	13 900	39 900	60 100	70 400
Annual consumption (2000)	$t*yr^{-1}$	461 300	461 300	4 012 600	4 185 500
Potential annual supply or surplus	$t*yr^{-1}$	514 600	552 200	4 282 400	4 288 700
Population ('000 inhabitants)					
Urban		1 856	1 975	1 999	1 999
Rural settlements		1 223	2 445	2 655	2 672
Sparse rural		1 613	4 128	5 132	5 461
Total population		4 693	8 548	9 786	10 131

The results of the Phnom Penh urban woodshed are supported by the study carried out in 1998 on the city's woodfuel flow in the framework of the Regional Wood Energy Development Programme in Asia (FAO, 1998b). According to this study, fuelwood and charcoal come from forested areas in Kratie, Kampong Thom, Kampong Speu, Pursat and Kampong Chhnang. As shown in Figure 25, these provinces overlap with the expanded-commercial supply zone estimated for the year 2000.

The study reports that, since 1970, forested areas have been greatly reduced because of war, agricultural clearance, construction and logging concessions. Communities within the supply areas reported that forest loss and degradation have been most rapid over the last few years, and the reasons given for this include agricultural clearance and firewood collection. The provision of wood energy is often associated with forest loss, but involvement in the wood energy trade is often a secondary factor and cutting trees to obtain land for agricultural use is the primary factor (FAO, 1998b).

In addition, confirming the need to differentiate between local and commercial woodfuel sources, the study reports that within rural areas, most wood for local consumption is collected from agricultural land, such as paddy dykes, which suggests that the supply for commercial urban markets has the greatest impact on forests. A main issue in these areas is that of landownership, since it is mainly those without land who are engaged in the trade (FAO, 1998b).

FIGURE 25
Provinces supplying woodfuels to Phnom Penh
(expanded-commercial woodshed in the background)



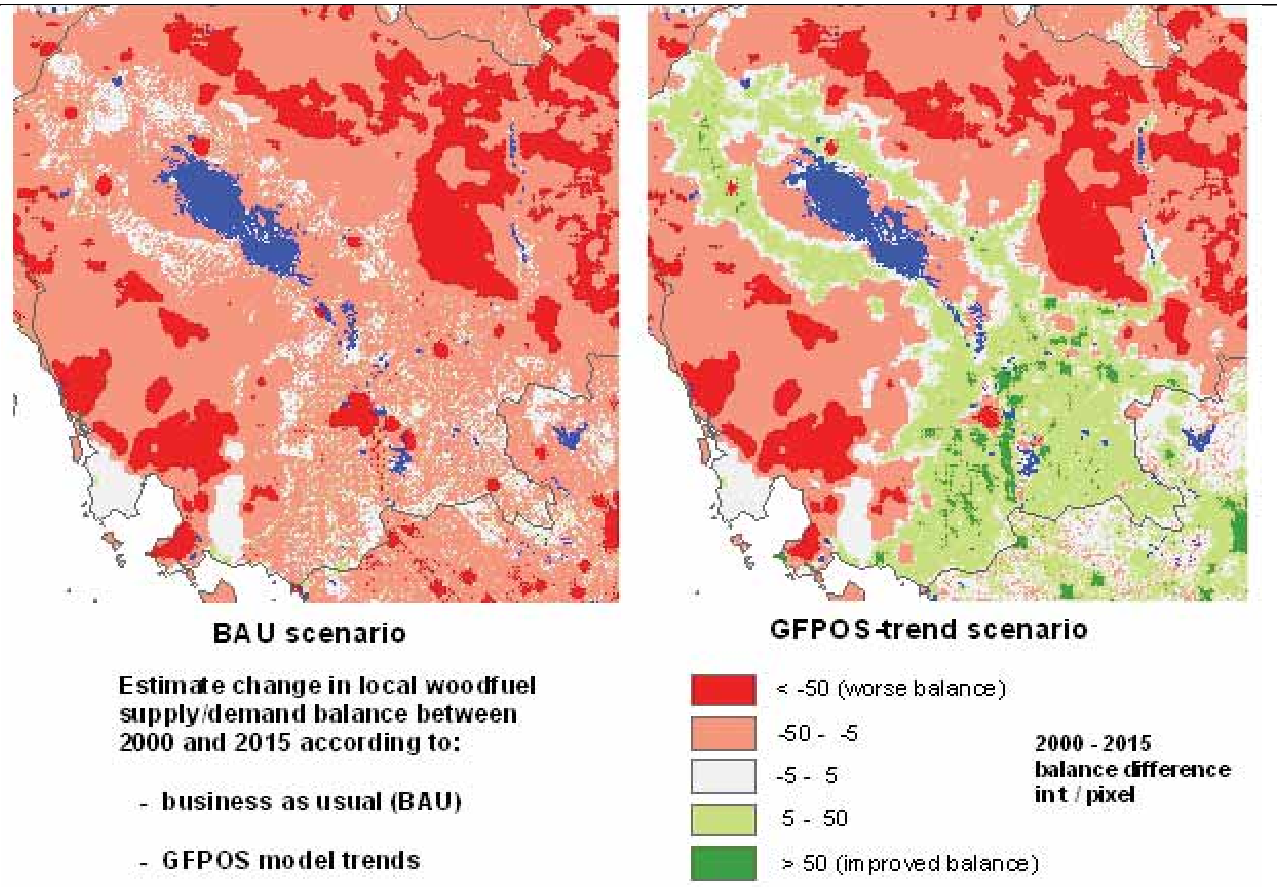
Phnom Penh to the year 2015

The possible evolution of the Phnom Penh woodshed to the year 2015 was tentatively outlined on the basis of the 2015 woodfuel supply/demand balance predicted in the Southeast Asian WISDOM study using spatialized population projections and land cover change rates (FAO, in press).

The changes in supply/demand balance over the period 2000–2015 according to both the BAU and the GFPOS scenario are shown in Figure 26. While the BAU scenario depicts a homogeneous negative trend simply as a result of population growth, the GFPOS scenario offers a more composite situation resulting from expected economic growth and fuel substitution trends.

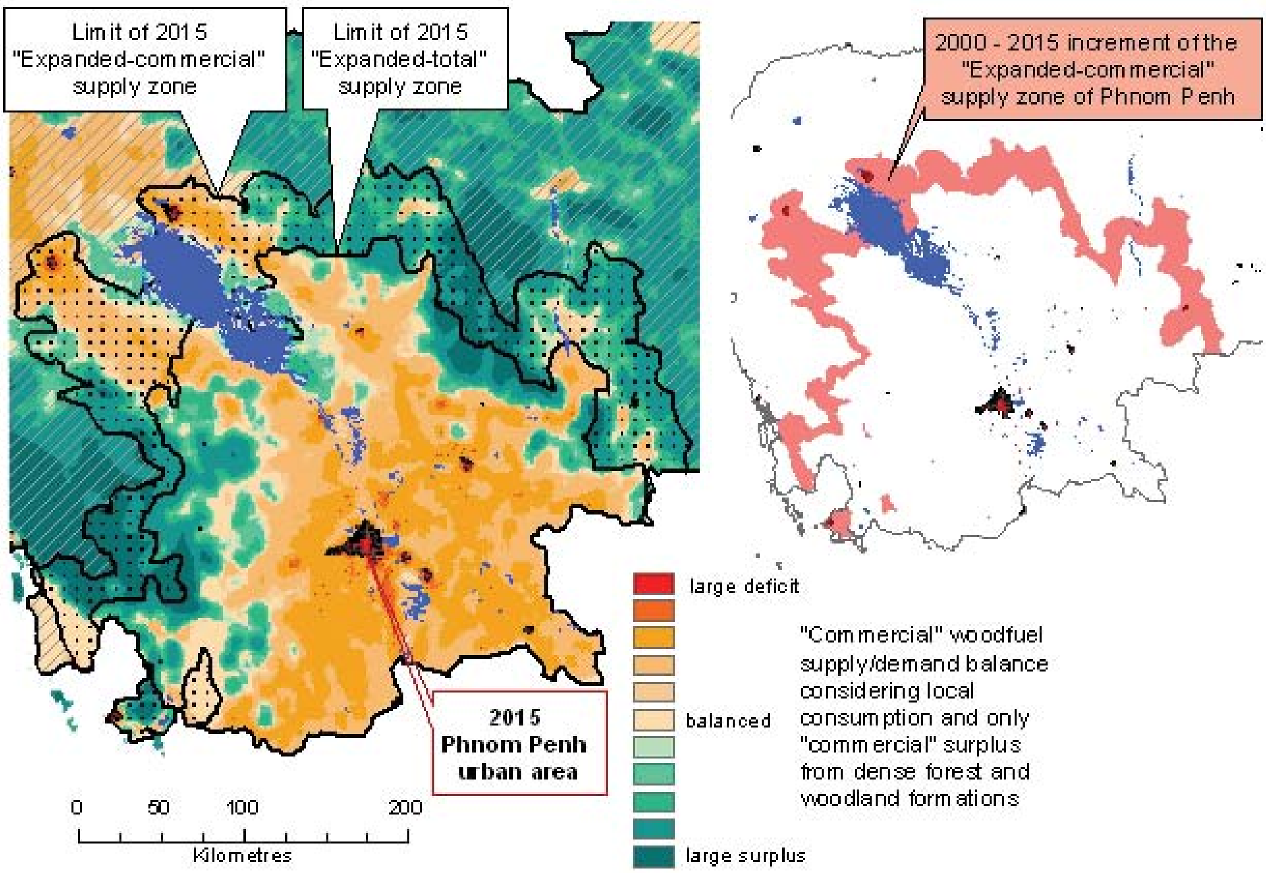
The woodshed evolution in 2015 was based on the GFPOS scenario, which appears more realistic and optimistic than that of BAU.

FIGURE 26
Projected woodfuel supply/demand balance in 2015 and possible changes with regard to the 2000 baseline balance



The results of the 2015 projection are shown in Figure 27, which gives the limits of the expanded-commercial and expanded-total supply zones as well as the net increment of the former in the period 2000–2015. In spite of the overall reduction in woodfuel demand predicted by the GFPOS model, there is a significant increase in supply in the expanded-commercial zone, which may be explained by the relative increase in charcoal consumption in urban areas and the projected deforestation rates, with consequent reduction in dense forest formations that are sources of “commercial” biomass.

FIGURE 27
Phnom Penh expanded woodshed zones in 2015 (GFPOS-trend scenario) and 2000–2015 woodshed area expansion



Battambang, Cambodia

The woodshed analysis for Battambang, the second-largest city in Cambodia, resulted in the supply zones shown in Figure 28. Here the four zones were overlaid on the estimated woody biomass productivity (restricted zones) and the commercial balance (expanded zones).

The urban woodshed areas of Battambang are far less extensive than Phnom Penh, primarily because of the smaller size of the city. Here the area of the restricted-commercial supply zone is roughly equal to the expanded-total supply zone, since the reduction in local consumption of the expanded zone is offset by the non-commercial supply sources.

The main statistics of the supply zones are summarized in Table 8. In Battambang, the sparse rural population located within the area of influence and potentially involved in woodfuel production varies between 0.4 and 1.8 million, depending on the supply zone considered. However, the expanded zones, which account also for local consumption outside the city, are much more realistic. What appears difficult to determine, given the lack of field data, is the distinction between the woody biomass used exclusively for local consumption and that suitable for commercial woodfuel production, which establishes the size of the expanded-commercial zone.

FIGURE 28
Battambang woodshed zones

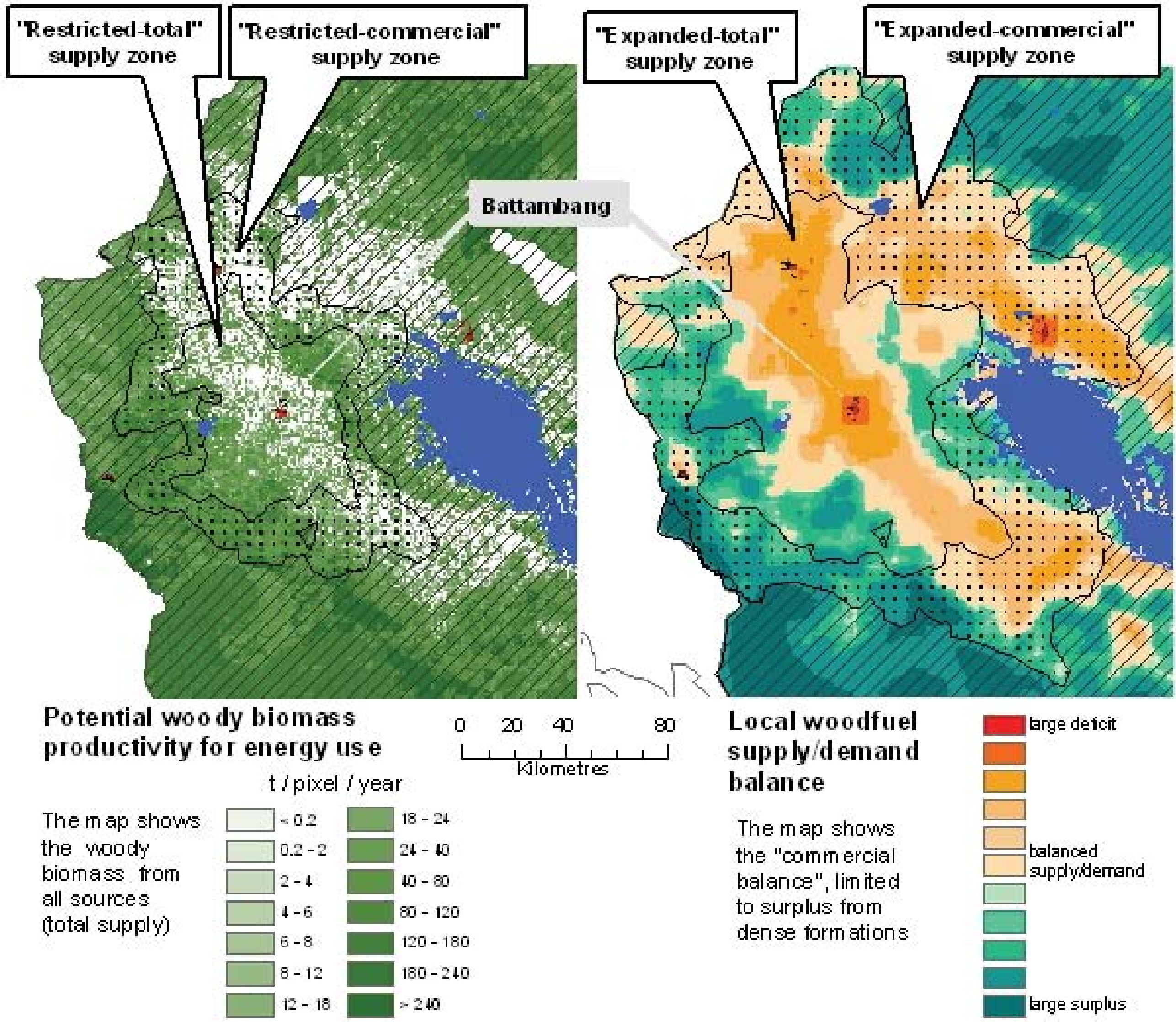


TABLE 8
Main statistics for Battambang woodshed areas

		Battambang supply zones			
		Restricted		Expanded	
		Total	Commercial	Total	Commercial
Area of supply zone	km^2	4 200	10 900	10 900	27 500
Annual consumption (2000)	$t*yr^{-1}$	125 000	125 000	416 000	546 000
Potential annual supply or surplus	$t*yr^{-1}$	185 000	214 000	457 000	635 000
Population ('000 inhabitants)					
Urban		91	116	116	232
Rural settlements		262	334	334	440
Sparse rural		431	861	861	1 843
Total population		784	1 311	1 311	2 515

The expanded-commercial zones of Phnom Penh and Battambang overlap each other over a limited area, as visible in Figure 29. This means that the potential supply for each city in this area is reduced and that the entire supply zone of each city should be increased accordingly.

Nutritional conditions within the Phnom Penh and Battambang woodsheds

As discussed previously, the relation between poverty and wood energy is multifold, with important implications not only for urban and rural users but also for woodfuel producers, who may depend on wood energy systems for their livelihoods. From this perspective, the establishment of sustainable urban wood energy systems may have considerable sustainable development and poverty alleviation effects for decentralized rural communities.

Mapping poverty is an ongoing challenging task and a comprehensive thematic map is not yet available (FAO, 2002c; 2003d). The main poverty-related spatial data set available at the time of analysis was an indicator of malnutrition, i.e. a map of the incidence of stunt growth in children under five, as a percentage, by subnational administrative units (FAO, in press). This parameter is one of the best indicators of poverty, as indicated by WHO. The incidence of stunting within the Phnom Penh and Battambang woodsheds is shown in Figure 29 and summarized in Table 9.

FIGURE 29
Nutritional conditions within the Phnom Penh and Battambang woodsheds

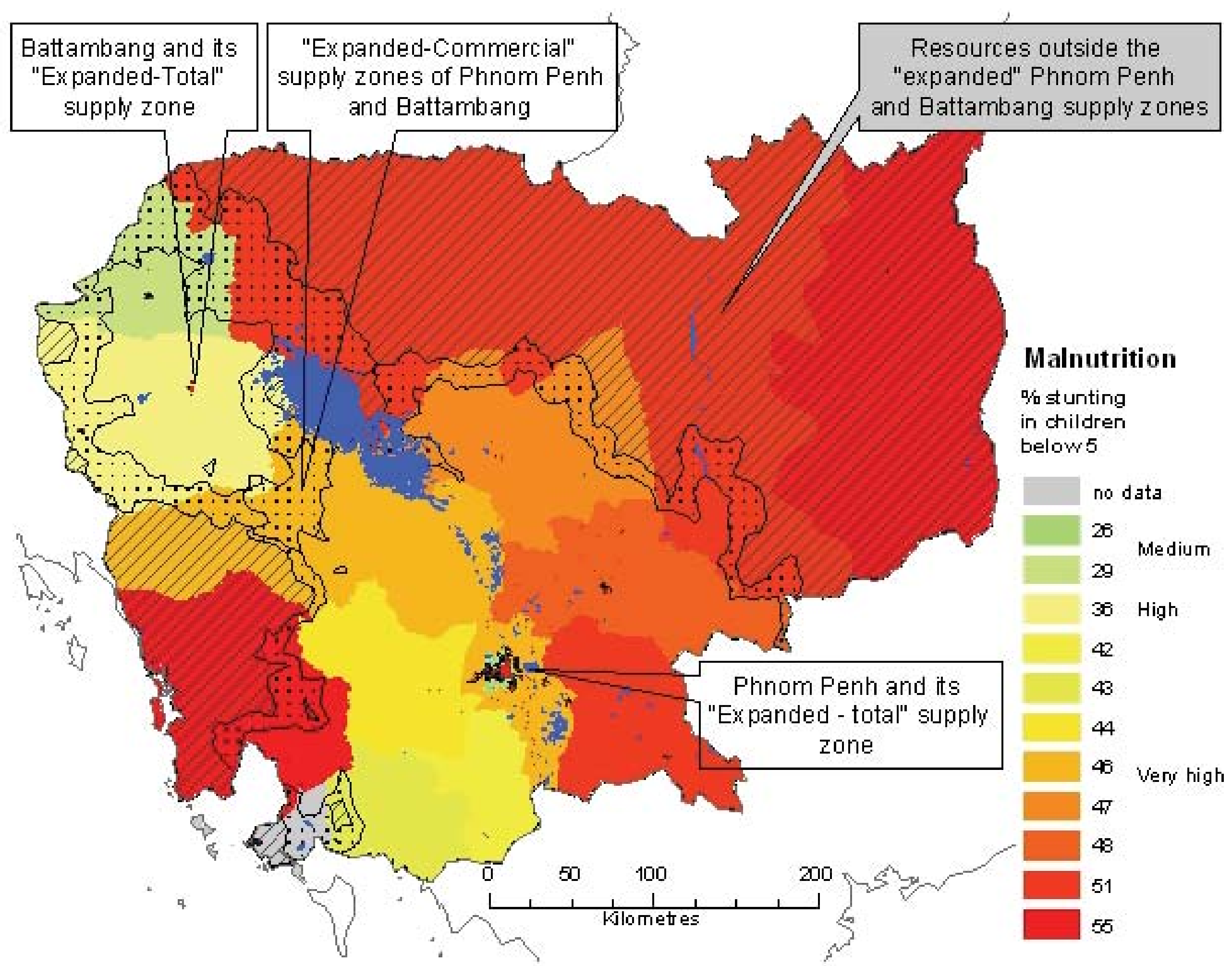


TABLE 9
Population and nutritional statistics within the Phnom Penh and Battambang woodsheds

		Battambang supply zones				Phnom Penh supply zones				Cambodia country total
		Restricted		Expanded		Restricted		Expanded		
		Total	Comm.	Total	Comm.	Total	Comm.	Total	Comm.	
Area	km^2	4 200	10 900	10 900	27 500	13 900	39 900	60 100	70 400	180 836
Population	('000)									
Urban		91	116	116	232	1 856	1975	1 999	1 999	2 308
Rural settlements		262	334	334	440	1 223	2 445	2 655	2 672	3 143
Sparse rural		431	861	861	1 843	1 613	4 128	5 132	5 461	7 659
Total		784	1 311	1 311	2 515	4 693	8 548	9 786	10 131	13 109
Malnutrition										
Stunting*	%	36	35	35	38	43	45	45	45	46

* Percentage of children under five showing stunt growth.
WHO categories: <20% = low; 20–29% = medium; 30–39% = high; ≥40% = very high.

According to the thresholds indicated in the WHO classification of malnutrition, stunting conditions are ranked as very high (incidence **≥**40 percent), high (30–39 percent), medium (20–29 percent) and low (<20 percent). With reference to these thresholds the situation in Cambodia appears to be extremely serious, with a national average of 46 percent. But the situation is not homogeneous, as shown in Figure 28; the conditions within the Phnom Penh and Battambang woodsheds are significantly different, with a stunting incidence of "only" 35–38 percent in the latter and 43–45 percent in the former. This factor plays an important role in the selection of priority areas of intervention, especially when these imply the creation of rural markets and the adoption of poverty alleviation measures.

Vientiane and Luang Prabang woodsheds

The situation in the woodshed areas of Vientiane and Luang Prabang in the Lao People's Democratic Republic is quite different (Figure 30). As shown in Tables 10 and 11, the urban populations within the supply zones of these two cities are much smaller than in Cambodia. Although the precision of these figures is limited, because of the process of spatialization and the fairly subjective definition of rural/urban conditions in reference sources (FAO, 2005b), the order of magnitude they provide is consistent.

Given the relatively low population density also in peri-urban and rural areas, the factor that most influences the size of the zones is the type of supply, i.e. total versus commercial, rather than the inclusion or exclusion of consumption outside the cities (restricted-expanded). In the case of Luang Prabang, for instance, the suburban and rural consumption is so low that the restricted-commercial and expanded-commercial supply zones are roughly the same (see Section 5.2.2).

FIGURE 30
Vientiane and Luang Prabang woodshed zones

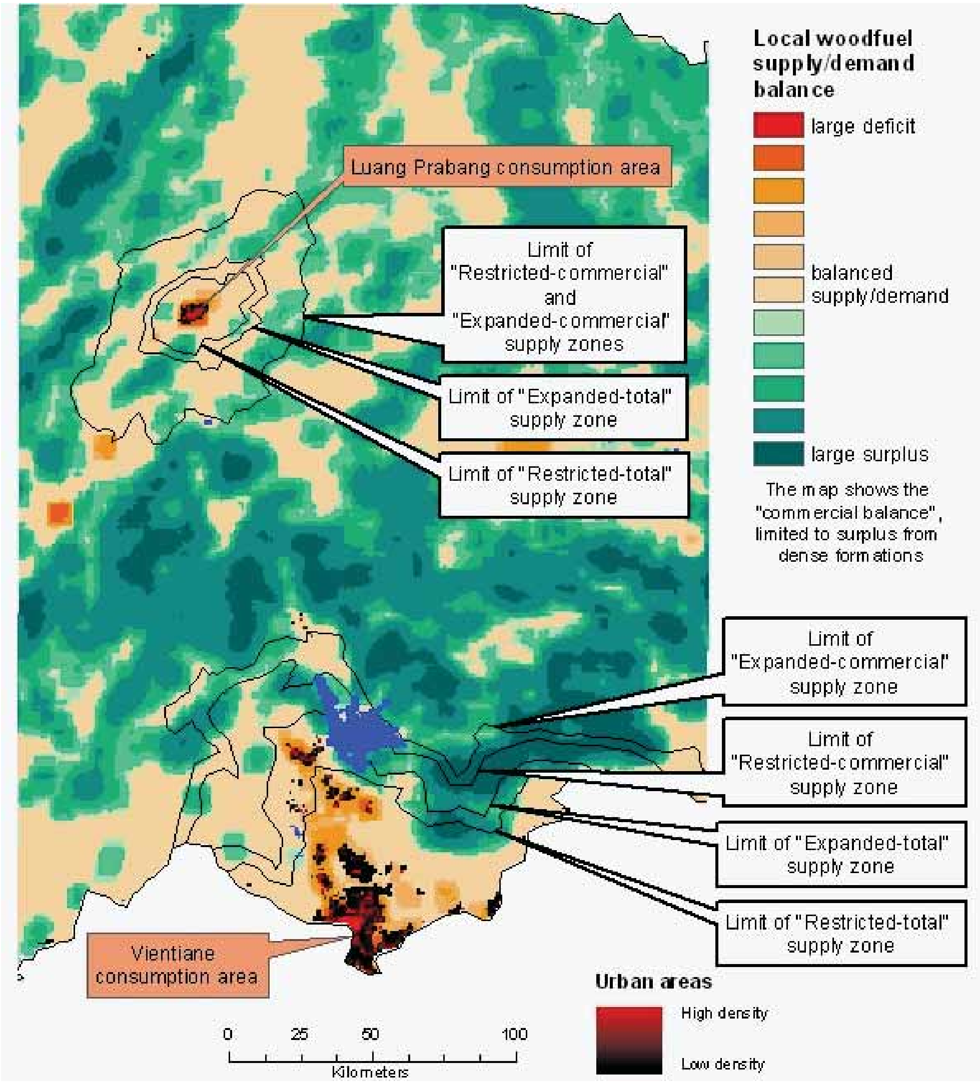


TABLE 10
Main statistics for Vientiane woodshed zones

		Vientiane supply zones			
		Restricted		Expanded	
		Total	Commercial	Total	Commercial
Area of supply zone	km^2	3 600	7 700	5 100	9 500
Annual consumption (2000)	$t*yr^{-1}$	259 000	259 000	473 100	500 200
Potential annual supply or surplus	$t*yr^{-1}$	321 100	268 300	545 500	551 000
Population ('000 inhabitants)					
Urban		570	620	620	630
Rural settlements		50	70	70	80
Sparse rural		150	210	190	230
Total population		770	900	880	940

TABLE 11
Main statistics for Luang Prabang woodshed zones

		Luang Prabang supply zones			
		Restricted		Expanded	
		Total	Commercial	Total	Commercial
Area of supply zone	km^2	800	4 400	1 300	4 400
Annual consumption (2000)	$t*yr^{-1}$	53 600	53 600	73 500	101 600
Potential annual supply or surplus	$t*yr^{-1}$	65 900	73 300	112 400	107 700
Population (‘000 inhabitants)					
Urban		70	70	70	70
Rural settlements		10	20	20	20
Sparse rural		20	80	40	80
Total population		100	170	130	170

5.3.2 Selected East African urban woodsheds

The East African WISDOM geodatabase presents several differences with regard to that of Southeast Asia, which influence the delineation of urban woodsheds. These differences include i) a higher resolution of woodfuel supply maps that were based on Africover vector maps (Africover Web site) with minimum mapping units of 200–300 m (below 100 m width for linear features), compared with the 0.9 km pixel size (30 arc-sec) of the Southeast Asian maps; and ii) a lower resolution of the woodfuel supply/demand balance maps, for which a cell size of approximately 9 x 9 km (5 arc-min) was used, compared with the Southeast Asian pixel size, which was 0.9 km. The result is that the mapping of supply sources is more detailed, while the spatial definition of the supply zones, based on the 5 arc-min data set, is coarser.

Dar-es-Salaam and Arusha-Moshi, United Republic of Tanzania

Given the comparatively high concentration of wooded landscapes (woodlands and bushlands) in the proximity of the city, the urban woodshed of Dar-es-Salaam is relatively small, as shown in Figure 31 and summarized in Table 12, with all supply zones within some 150 km from the city, including the expanded-commercial zone.

Findings from the land cover change study conducted by the CHAPOSA project (CHAPOSA, 2002) to assess the impact of charcoal production around Dar-es-Salaam show considerable degradation of woodlands and shrublands over an area that is roughly as big as the restricted-total supply zone in Figure 31. This may indicate that the sustainable supply zone should be larger, in order to allow longer rotations and enough time for exploited woodland to recover. It may also indicate that the sustainable productivity assumed in the WISDOM study is optimistic and should be lower. In any case, this confirms the need to proceed with field-level investigations and verification after the nationwide WISDOM analysis and the first delineation of urban woodshed zones.

In Dar-es-Salaam, the sparse rural population located within the area of influence and potentially involved in woodfuel production varies between 0.6 million for the restricted-total supply zone and 0.9 million for the expanded-commercial one.

A totally different situation results from an analysis of the urban woodshed of Arusha-Moshi in the Kilimanjaro region (Figure 32 and Table 13). The combination of i) the high population density (and woodfuel demand) of the northeast and central regions of the country; and ii) the scarce woody biomass resources of the area generates a much wider expanded-total supply zone and an expanded-commercial zone that covers half the country.

FIGURE 31
Dar-es-Salaam woodshed zones

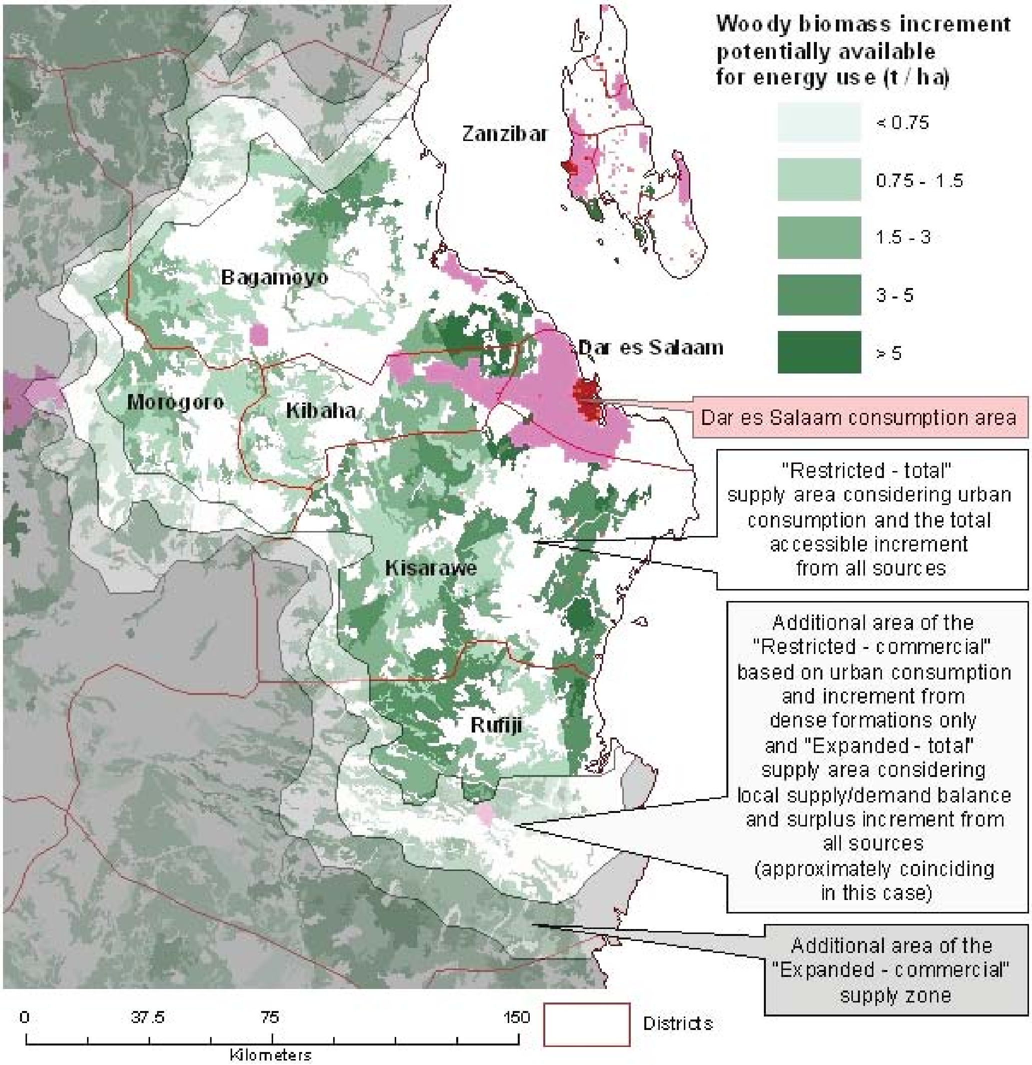


TABLE 12
Main statistics for Dar-es-Salaam woodshed zones

		Dar-es-Salaam supply zones			
		Restricted		Expanded	
		Total	Commercial	Total	Commercial
Area of supply zone	km^2	19 000	24 000	24 000	30 000
Annual consumption (2000)	$t*yr^{-1}$	2 200 000	2 200 000	2 500 000	2 600 000
Potential annual supply or surplus	$t*yr^{-1}$	2 800 000	2 500 000	2 800 000	2 900 000
Population (‘000 inhabitants)					
Urban		2 090	2 090	2 090	2 180
Rural settlements		0	0	0	0
Sparse rural		580	710	710	860
Total population		2 670	2 800	2 800	3 040

FIGURE 32
Arusha-Moshi woodshed zones

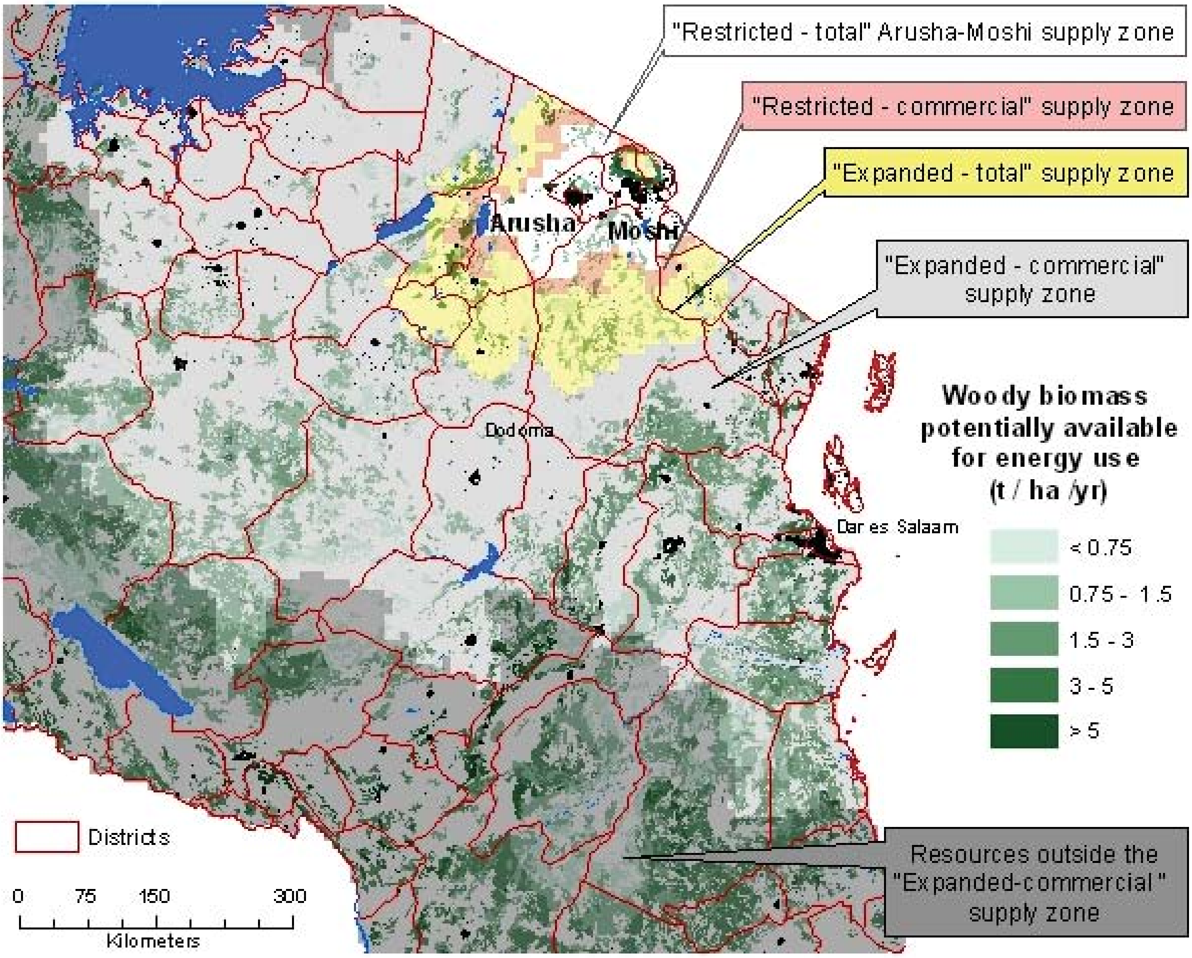


TABLE 13
Main statistics for Arusha-Moshi woodshed zones

		Arusha-Moshi supply zones			
		Restricted		Expanded	
		Total	Commercial	Total	Commercial
Area of supply zone	km^2	22 000	32 000	73 000	459 000
Annual consumption (2000)	$t*yr^{-1}$	1 000 000	1 000 000	3 300 000	16 700 000
Potential annual supply or surplus	$t*yr^{-1}$	1 100 000	1 000 000	3 400 000	16 900 000
Population (‘000 inhabitants)					
Urban		1 190	1 240	1 400	5 010
Rural settlements		0	0	0	0
Sparse rural		920	1 220	2 240	14 450
Total population		2 110	2 460	3 640	19 460

Even Dar-es-Salaam is included in the expanded-commercial supply zone of Arusha-Moshi, as an effect of the progressive inclusion of additional buffers, for which both potential supply and local consumption are added, until cumulative consumption and supply balance out. The Arusha-Moshi case study shows the importance of backing the analysis of the urban woodshed of a particular city with a wall-to-wall WISDOM analysis. In fact, the combination of factors outside the city strongly influences the size and shape of the urban woodshed, even at considerable distance. It also stresses the benefits of undertaking urban woodshed analysis for several cities in a country, in order to achieve a comprehensive vision of urban/rural interaction and to fine-tune the urban woodshed of interest.

Kampala, Uganda

At the time of writing, there is a report in the press that “Wood scarcity hits Kabale”, a district in southeast Uganda, detailing that households have resorted to cooking with coach grass and crop residues because of the scarcity of fuelwood. Until recently, the report says, there were plenty of trees on the hilltops but with a growing population, most trees have been felled to create land for cultivation. Unsurprisingly, the district was listed among the subnational units of Uganda with the highest woodfuel deficit in the East African WISDOM study (FAO, 2006b).

The scarcity of woody biomass for household energy in Uganda is a well-recognized problem and this is reflected also in the urban woodshed analysis of Kampala. The supply zones, shown in Figure 33 and summarized in Table 14, are very large considering that Kampala has a population of “only” 1.2 million.

What emerges clearly from the analysis is that the sources of woody biomass are prevalently fragmented, degraded and of low density, which explains the large difference between the restricted-total and the restricted-commercial supply zones. The remaining dense formations, which are more suitable for commercial woodfuel production, are scarce and distant, extending the restricted-commercial supply zone to some 200 km from the city.

The situation is more serious when accounting for local consumption outside the city. The expanded-total zone covers some 91 000 km^2 with distances over 200 km from the city, while from the expanded-commercial perspective there is a debit balance even if the supply zone includes the whole country.

It should be borne in mind that supply zone definitions are theoretical, always assuming sustainable exploitation regimes. In this respect, the situation in Uganda indicates a strong risk of overexploitation and protracted degradation of natural resources.

Khartoum, the Sudan

The larger city of Khartoum, with the nearby urban areas of Rufaa and Wad Medani, has almost 5 million inhabitants and there is consequently a tremendous demand for charcoal and fuelwood for household energy, according to recent consumption studies.

Given the high demographic concentration in the central Sudanese regions and the relative scarcity and low productivity of wood resources, supply zones are extremely large, as shown in Figure 34 and summarized in Table 15. Woodfuel supply zones reach a considerable distance: up to 500 km for the restricted-total zone, and a need to reach the biomass-rich southern provinces over 1 000 km away for the expanded-commercial one.[9]

The production of fuelwood and charcoal represents a source of income for large numbers of sparse rural communities living in these areas.

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[9] Note that the shape of the supply zones in Figure 33 is based exclusively on resource distribution and physical/legal accessibility parameters, not accounting for the certain (but undefined) impact exerted by the conflict that opposes the southern part of the country, rich in forests and woodlands, to the central part where most of the woodfuel demand is concentrated.

FIGURE 33
Kampala woodshed zones

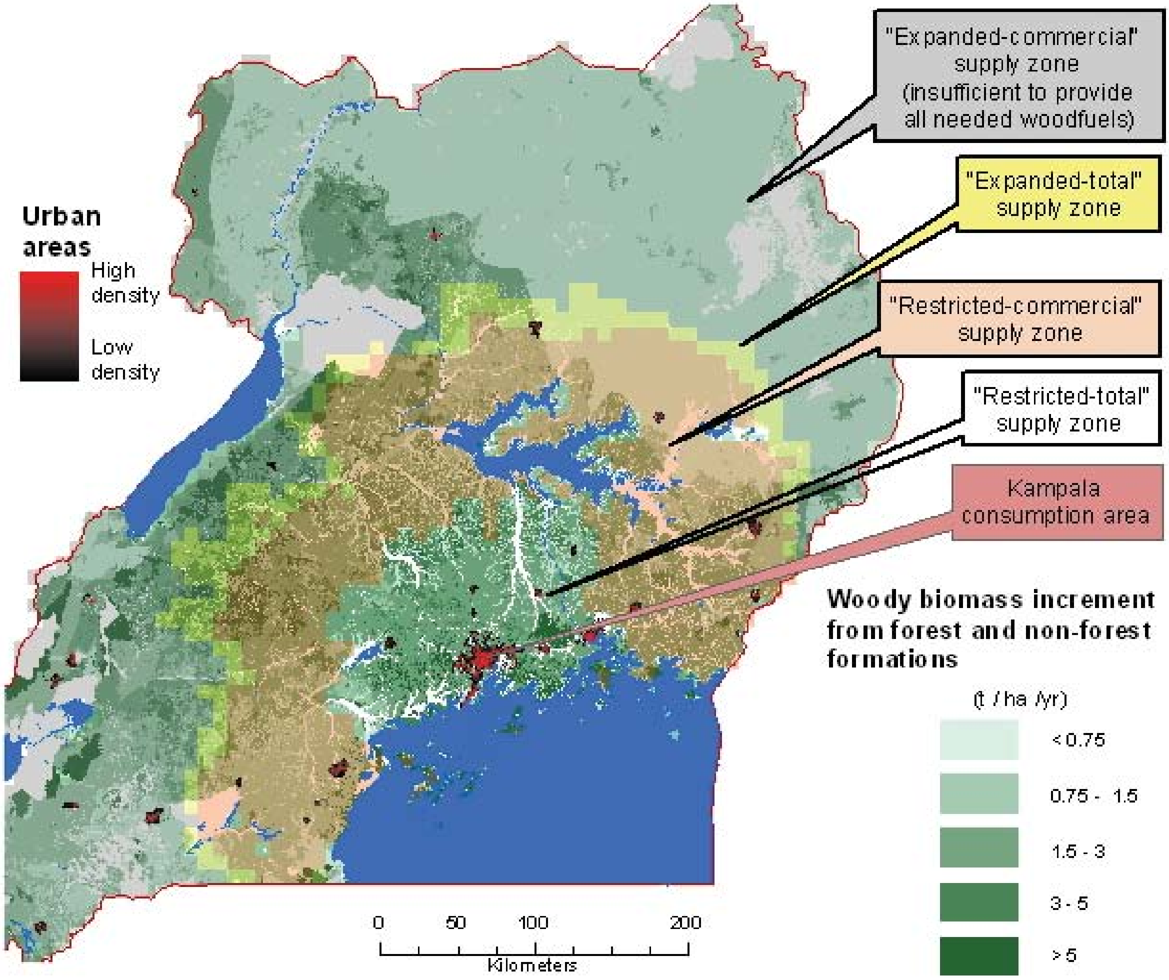


TABLE 14
Main statistics for Kampala woodshed zones

		Kampala supply zones			
		Restricted		Expanded	
		Total	**Commercial**	**Total**	**Commercial ***
Area of supply zone	km^2	19 000	78 000	91 000	202 000
Annual consumption (2000)	$t*yr^{-1}$	2 600 000	2 600 000	11 500 000	**17 600 000**
Potential annual supply or surplus	$t*yr^{-1}$	3 100 000	2 600 000	11 900 000	**13 700 000**
					-3 900 000
Population ('000 inhabitants)					
Urban		2 340	2 820	2 840	3 270
Rural settlements		520	2 100	2 180	3 080
Sparse rural		2 120	8 290	9 170	16 540
Total population		4 980	13 210	14 190	22 890

*The expanded-commercial supply zone appears insufficient to provide the needed woodfuel even if extended over the entire country. The potential supply from the commercial surplus (13.7 million tonnes) is less than the total estimated consumption (17.6 million tonnes).

FIGURE 34
Khartoum woodshed zones

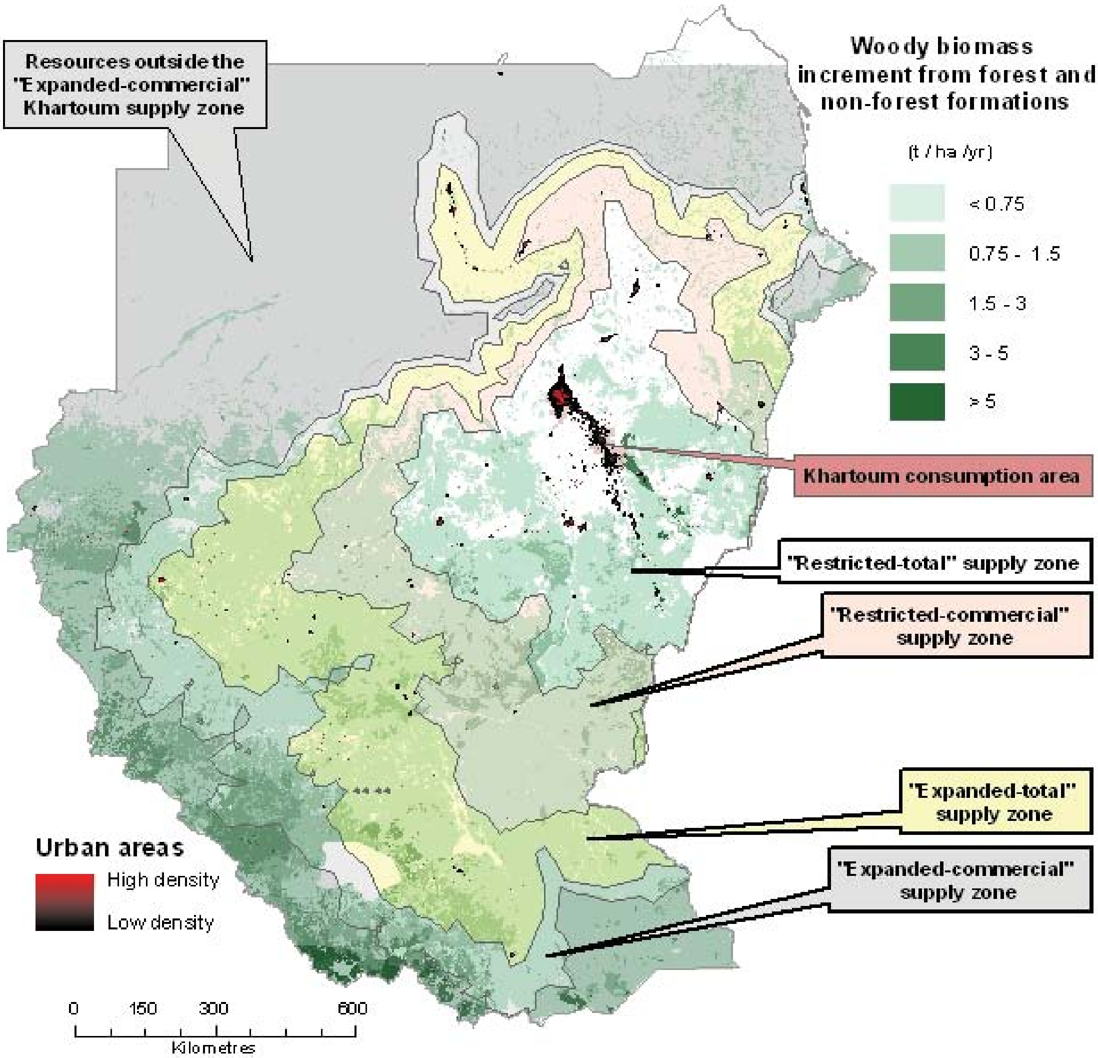


TABLE 15
Main statistics for Khartoum woodshed zones

		Khartoum supply zones			
		Restricted		Expanded	
		Total	Commercial	Total	Commercial
Area of supply zone	km^2	399 000	760 000	1 260 000	1 550 000
Annual consumption (2000)	$t*yr^{-1}$	3 900 000	3 900 000	1 636 900 000	1 814 300 000
Potential annual supply or surplus	$t*yr^{-1}$	4 000 000	3 900 000	1 637 400 000	1 815 200 000
Population (‘000 inhabitants)					
Urban		8 060	9 010	10 280	11 000
Rural settlements		0	0	0	0
Sparse rural		7 130	10 340	14 720	16 710
Total population		15 190	19 350	25 000	27 710

6 Planning sustainable urban wood energy systems

6.1 STRATEGIC AND OPERATIONAL PLANNING LEVELS

The challenges of the booming energy demand in urban areas of countries in tropical Africa, Asia and Latin America, combined with the poverty conditions of many urban and peri-urban dwellers, require a renewed and strengthened commitment by policy-makers together with adequate planning tools.

Two main planning levels can be identified: a *strategic* planning level, aiming at the formulation of national-level policies and strategies, and an *operational* planning level, aiming at the implementation of these policies in a local context.

To support strategic planning, it is necessary to have a comprehensive spatial knowledge of woodfuel consumption levels and sustainable supply capacities, which may be called a "strategic knowledge base". This holistic view of the wood energy sector should cover the entire country and show the geographic variability of demand and supply patterns.

The aim of this strategic knowledge base is to integrate all available spatial and statistical information on (or related to) woodfuel consumption and production capacities of a country, or broad geographic region, in order to create a geographically discrete overview of woodfuel demand/supply patterns and to determine the potential sustainable supply zones of selected urban areas. The main objectives of this geostatistical database may be summarized as follows:

- identifying and outlining woodfuel surplus and deficit areas, i.e. areas with a positive or negative woodfuel supply/demand balance, for an entire country (or broad geographic region);
- identifying administrative units and populations affected by subsistence energy shortages (deficit areas) as well as those with high bioenergy potentials (surplus areas);
- outlining the potential sustainable supply zones of major, or selected, urban areas with regard to urban/peri-urban woodfuel consumption and suitable/accessible production capacities;
- supporting strategic planning and policy formulation aiming at the establishment of sustainable wood energy systems;
- defining objectively priority areas of intervention (e.g. vulnerable regions and/or communities, urban woodsheds) within which in-depth studies and operational planning should be given precedence.

To support operational planning and sustainable resource management within specific urban woodsheds, it is necessary to undertake local studies, such as in-depth woodfuel flow analyses, providing reliable parameters.

The objectives of in-depth studies on urban wood energy and its implications on urban forestry, on the urban/rural interface and on sustainable resource management may be outlined as follows:

- guiding policy- and decision-makers to address energy demand in urban and peri-urban environments as it relates to the sustainable management of landscapes, forests and other woody resources;
- supporting the sustainable management of urban and peri-urban tree cover and other woody biomass resources;
- supporting the sustainable management of forests and other wood resources beyond peri-urban areas in response to woodfuel demand.

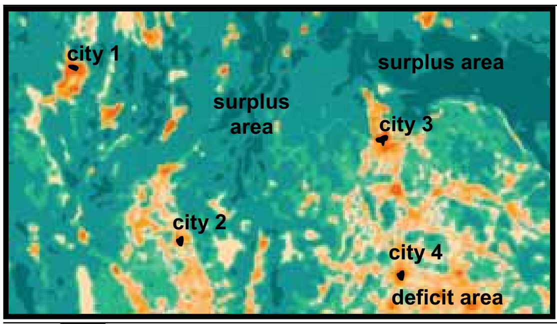
6.2 ADAPTATION OF THE WISDOM METHODOLOGY TO URBAN AND PERI-URBAN WOOD ENERGY

From a WISDOM methodological perspective, the creation of a strategic knowledge base implies comprehensive analysis of the WISDOM baseline and urban woodshed delineation for all major urban centres in a country.

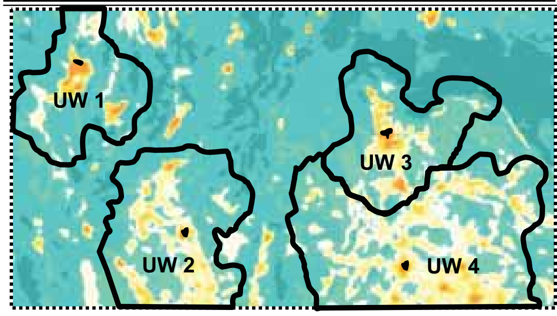
An in-depth analysis for operational planning represents a subsequent and more detailed level of investigation that may be limited to selected woodsheds. The main aims of these analytical steps are summarized in Figure 35.

FIGURE 35
Levels of analysis in support of urban wood energy planning (thematic maps are merely symbolic)

Strategic knowledge base

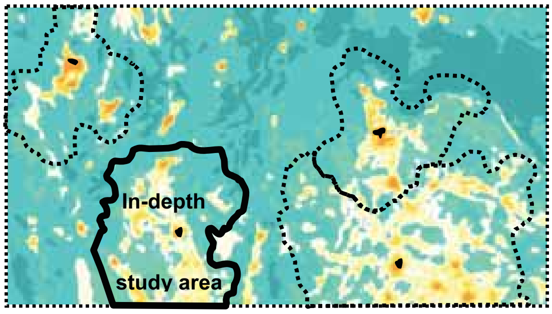


1. **WISDOM baseline**. An overview of the entire country (or broad geographic region) that, based on existing data and maps, provides a geographic representation of woodfuel supply/demand balance based on woody biomass supply potential and fuelwood/charcoal consumption patterns. This overview can be produced by using the standard WISDOM approach. The key features are wall-to-wall coverage; definition of deficit and surplus areas; categorization of administrative units; support to strategic planning and policy formulation, etc.



2. **Urban woodshed (UW) delineation**. A delineation of the supply zones of selected cities is undertaken using the WISDOM baseline data and additional parameters related to the commercial character of woodfuel sources and to accessibility factors. This analysis constitutes the additional urban woodshed module of the WISDOM methodology (see Sections 4.3.1 and 5.2), based mainly on existing data and maps. The aim of this module is to support strategic planning and to identify the priority areas of intervention, where additional investment in data collection and analysis is justified.

In-depth woodfuel flow analysis for operational planning



3. **In-depth study within priority urban woodsheds**. A detailed analysis of current and potential sustainable woodfuel flow with reference to a specific urban area and its urban woodshed, and with the aim of guiding policy decisions and operational action. This level of investigation requires accurate data since it seeks to support operational planning.

The WISDOM methodology, with the additional urban woodshed module that creates the strategic knowledge base, is described in detail in Section 4.3.1. The method was applied in the selected case studies described in Chapter 5. These analyses were based on relatively coarse thematic maps that were drawn for subregional analysis (FAO, 2006b; FAO, in press) but proved useful for the delineation and description of potential sustainable supply zones from different perspectives. The approach proposed is extremely flexible and can be adapted to the information already existing within countries or, as in the case of the East African and Southeast Asian studies, in regional and global data sets.

For operational woodshed planning the generic parameters of the overview are no longer sufficient. Consumption and supply data may need to be reviewed, except in the rare cases where recent surveys have produced reliable and location-specific information, and additional socio-economic parameters directly related to the woodfuel flow within the study area must be collected.

At this level of analysis a more detailed WISDOM is recommended, with additional parameters collected through woodfuel flow analysis methods, as described in woodfuel survey guidelines (FAO, 2002a; Zakia *et al.*, 1992) and applied in several case studies (FAO, 1997a; 1998b; 2000; 2001b). The parameters to be estimated in detailed woodfuel flow studies are summarized in the following paragraphs.

6.3 KEY PARAMETERS OF IN-DEPTH WOODFUEL FLOW ANALYSIS FOR OPERATIONAL URBAN WOODSHED PLANNING

The main parameters to be studied in order to allow local-level planning are briefly described here. Significant variables, their usefulness and practical survey methods may be found in *A guide for woodfuel surveys* (FAO, 2002a) to which the reader is referred for additional details.

6.3.1 Woodfuel demand

The determination and mapping of current woodfuel demand and the prediction of likely future scenarios are essential to understand people's needs and to define other thematic elements such as supply and provision. Table 16 gives a list of the main variables to be considered in the course of local woodfuel demand studies.

TABLE 16
Most significant variables to be analysed in detailed woodfuel demand surveys (FAO, 2002a)

General variables	Breakdown and explanation
End users Urban residential, rural residential, agricultural, industrial, trade and services, institutional sectors	By Size (number of users, households, establishments), geographic distribution (usually census subdivisions), form of provision
Specific variables	
Source of provision	Direct, indirect and recovered (see Section 6.3.2)
Saturation or penetration	Fraction of a given sector making use of woodfuels
Multiple fuel use	Families or establishments making alternative or contemporaneous use of two or more energy sources
Substitution	Amount of woodfuel replaced by a unit of alternative fuel
End uses	The needs that the user satisfies through the use of woodfuels
Activities	Major unitary operations that can characterize an end use
Fuel-burning means	Installations or appliances: stove, hearth, oven, boiler, lamp, etc. Simple fuelwood burning methods still in use in Bangui, Central African Republic, are shown in Figures 36 and 37
Consumption	Total consumption Specific consumption = amount of fuel consumed per consumer, unit of time, activity, unit of product obtained or unit of raw material processed

FIGURE 36
Simple improved stove in the market at Bangui, Central African Republic

FIGURE 37
Traditional three-stone system still common in households in Bangui, Central African Republic

Photos: Salbitano

6.3.2 Woodfuel supply

When considering woodfuel supply it is important to differentiate between *actual supply* (i.e. effectively available) and *potential supply*, which is what could be made available through sustainable management of wood resources and without compromising the normal production levels of other wood.

Since woodfuels are not normally stored for a long time, it may be assumed that *actual supply* is equal to *consumption* and consequently its estimated volume can be based on estimates of actual consumption.

On the other hand, *potential supply* requires the identification and measurement of all potential woodfuel sources, the estimation of legally and physically accessible productivity under sustainable management regimes and the deduction from such value of other wood products consumed under normal conditions.

Table 17 gives a list of the main variables related to woodfuel consumption to be considered in the course of local woodfuel supply studies.

TABLE 17
Most significant variables to be analysed in detailed woodfuel supply surveys (FAO, 2002a)

General variables	Breakdown and explanation
Woodfuel sources	Direct sources (trees and woody shrubs) Indirect sources (charcoal producers, sawmills, cellulose plants, furniture factories, tannin, resin and vegetal oil extraction plants) Sources of recovered woodfuels (residues of wood industries, discarded building or packaging material)
Specific variables	
Stocks	Total woodfuels from direct sources present in a unit area of a given resource at a given time. Not applied to indirect sources and recovered woodfuels
Productivity	Direct sources Total woodfuel productivity = net annual above-ground wood growth suitable for energy use, i.e. the increase of above-ground woody biomass in live trees and bushes, including stems and branches (excluding twigs and leaves) Accessible and available woodfuel productivity = total woodfuel productivity minus fraction of wood growth destined for other uses and not accessible because of legal and physical constraints
	Indirect sources Charcoal estimates are made from saturation and consumption studies For wood processing industries, it is possible to calculate supply by applying coefficients of by-product generation
	Recovered woodfuels Estimated on the basis of production statistics for wood derivatives, applying empirical or estimated recovery coefficients

The most common, and usually the only, sources of information on wood productivity are forest inventory reports and forest management documentation, but these are usually focused on timber assortments, rather than on woody biomass. They are limited to “productive” forest formations, while woodfuel sources are often open and degraded formations, trees and shrubs from farmlands, orchards, etc.

While woodfuel productivity values from inventory data of productive forests can be derived with reasonable approximation (FAO, 1997b; Brown and Lugo, 1984), acquiring data on the sustainable productivity of hybrid formations is far more complex and uncertain. Fully fledged surveys on sparse and heterogeneous landscapes are unlikely, but remote sensing data of adequate resolution and minimal field sampling can prove helpful and provide a first-level assessment of wood resources in non-forest landscapes, as was done in the framework of the Slovenia WISDOM study (FAO, 2006a).

Supply sources in the urban woodshed context

Woody biomass sources within the urban area. *Direct* sources are from pruning and thinning of green areas such as parks, gardens, road and shade trees (Figures 38 and 39).

Indirect and recovered woodfuel sources are by-products and residues of wood industries, and wood fractions of urban waste, discarded building material, etc.

FIGURE 38
Fuelwood from city park management in Bangui, Central African Republic

FIGURE 39
Twigs and leaves collected for fuel in Bangui, Central African Republic

Photos: Salbitano

Woody biomass sources in the immediate surroundings (urban development area). *Direct* sources are orchards, woodlots and farm trees, short rotation forestry and land conversion by-products related to urban expansion.

Indirect and recovered woodfuel sources are by-products and residues of wood industries.

Woody biomass sources within the actual supply area (current sources). The actual supply area can be outlined, with some approximation, on the basis of declarations by informed persons (fuelwood/charcoal retailers and traders, forestry officers, rural authorities, etc.).

It is important to distinguish between the sources of woody biomass suitable, and used, for woodfuel production destined for the urban market, which may be called “commercial” resources, and other sources that are suitable, and used, for local demand only. This distinction enables the theoretical area for the sustainable production of the necessary woodfuel to be mapped out.

Woody biomass sources within the potential supply area (potential supply sources under sustainable management). Once current and projected woodfuel consumption levels and the “commercial” productivity of main land use, land cover types and other sources have been determined, it is possible to revise the theoretical supply area, assuming a sustainable supply regime.

This new delineation based on detailed local information will help to update the urban woodshed zone determined during the first phase of the study. Enhanced productivity values collected in one location can thus improve the general overview and allow more reliable assessment of supply/demand balance analyses and more accurate delineation of other urban woodsheds.

6.3.3 Woodfuel provision (production, transport and marketing)

Woodfuel provision relates to the totality of processes and activities whereby woodfuels move from their place of origin to the end user. If the users themselves are responsible for production and transport, this is termed self-provision but if paid third parties are involved, the provision is referred to as commercial.

Table 18 gives a list of the main variables related to woodfuel production, transport and marketing to be considered in the course of local woodfuel flow studies. Several aspects of the fuelwood trade in and around Bangui, Central African Republic, are shown in Figure 40.

TABLE 18

Most significant variables to be analysed in detailed woodfuel flow studies (FAO, 2002a)

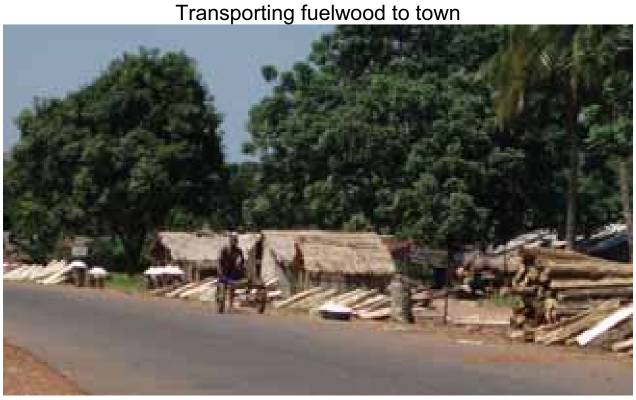
General variables	**Breakdown and explanation**
Woodfuel producers	Individuals or firms that harvest or recover woodfuel from their direct or indirect sources – loggers, farmers, charcoal burners, wood-based industries, wood recovery operators. These are subdivided by quantity, type (self-provision, commercial) and location
Transport operators	Individuals or firms that use any mode of transport (human, animal, mechanical) to take woodfuels from producers to traders and/or final consumers. These are subdivided by commercial transporters and self-providers
Commercial suppliers	Individuals or firms engaged partly or exclusively in buying and selling woodfuels. These are subdivided by quantity, size and location
Specific variables	
Type of provision	Self-provision Commercial provision
Periodicity of provision	
Cost of woodfuels	
Market network	Individuals and firms intervening in the commercial provision of woodfuels
Price setting for woodfuels	Price mark-ups during the passage from producer to end user via market supply chain or network
Woodfuel values	Exchange, use and existence values
Supplementary woodfuel variables	
Local units and their IS equivalents	
Specific weight	
Moisture content	
Heating value	

FIGURE 40

Transport and trade of fuelwood in Bangui, Central African Republic

Transporting fuelwood to town

Small-scale roadside fuelwood sales



Fuelwood and charcoal market in peri-urban area

Fuelwood log market

Photos: Salbitano

Accessibility zoning based on legal, physical and economic factors

The first two phases of analysis, the general overview and woodshed delineation, include a definition of the legal and physical accessibility of supply areas. This aspect is estimated tentatively on the basis of legal constraints (protected areas) and physical constraints (slope, distance from roads and settlements and distance from selected urban areas), as described in Section 5.2.1. See also Annexes 3 and 4.

During the implementation of in-depth studies, i.e. detailed investigation of woodfuel provision, additional elements and parameters should be collected to support the definition of real accessibility within the study area. These should include:

- elements of accessibility linked to land tenure and legal constraints;
- distance along roads and slopes within which woodfuel production is considered feasible and economical (under normal conditions);
- distance along roads, railways and rivers within which woodfuel transport costs are considered acceptable (under normal conditions).

Detailed accessibility parameters will help to revise further the urban woodshed delineated during the second phase of the study. Enhanced accessibility factors can thus improve the general overview and allow more accurate delineation of other urban woodsheds.

6.3.4 Analysis of the impact of urban woodfuel demand

The impact of urban wood energy has *n* dimensions, ranging from local and regional social, economic and environmental factors to global climate change in both negative and positive terms. The type of impact considered here is limited to the reduction in woody biomass productivity caused by excessive and non-sustainable fuelwood extraction and charcoal production for urban consumption.

Other types of impact will need to be considered when formulating long-term policies; however, they will be defined and discussed at a more detailed and circumscribed level of analysis.

Land cover monitoring

The perception of the relationship between woodfuel use and forest depletion has changed over time without achieving a stable and all-convincing position. The fears of the 1980s and 1990s of an epochal fuelwood crisis associated with forest destruction caused by excessive fuelwood exploitation have proved unrealistic (Arnold *et al*., 2003) and there is now a more pragmatic understanding of supply sources, which are often non-forest, and of adaptive mechanisms in case of fuelwood shortages. However, the issue of booming charcoal demand linked to rapid urbanization is of great concern at present and deserves close attention.

Continued and excessive exploitation for charcoal production will cause degradation of forests and woodlands although permanent impacts generally result from the combination with other factors such as population pressure and demand for cropland. In the presence of a multiplicity of factors it is difficult or even impossible to point to a single cause or the contribution of a single factor. Nevertheless, it is important to identify and quantify unsustainable practices and land cover change rates in order to take remedial action and determine future resource scenarios. To this end it is recommended that land cover monitoring within the urban woodshed be undertaken by means of a methodology that guarantees the most reliable analysis of land cover changes and the best inference on the underlying cause-effect mechanisms.

The optimal approach to assess land cover changes should be based on permanent sample plots, which would allow assessing more subtle changes such as phases of degradation and change in species composition. In fact, rather than carrying out ad-hoc surveys for woodshed analyses it would be preferable to deduct the needed information from national-level inventory data periodically collected and designed to respond to the needs here discussed.

In general, however, continuous forest inventories are rare and woodshed-level change analyses must be based on present-day in-situ observations and remote sensing data for present-historical comparison. Several approaches exist nowadays to remote sensing-based land cover monitoring, thanks to the advances in sensors characteristics and image processing software.

The choice of the best approach depends on a range of specific factors that includes, of relevance, the accessible human and technological resources and experience on GIS, image processing and interpretation. If such capacities are high, a wider range of options is available, including the multi-temporal segmentation approach (Desclée et al., 2006), which appears rather promising, although the method is yet to be tested on varied contexts. In a lower technological context, a suitable alternative is the monitoring methodology based on the interdependent interpretation of multitemporal remote sensing data (FAO, 1996; Drigo, 1995), which aimed to ensure a reliable identification of land cover modifications based, mainly on visual analysis by field-competent interpreters. Key recommended features of the monitoring methodology are described in Annex 5.

6.3.5 Social, economic and institutional context

Identification and mapping of stakeholders

A survey of woodfuel demand and provision enables the physical flow of woodfuels to be determined and the direct stakeholders of wood energy systems to be identified and located. These include not only woodfuel producers, traders, transporters, retailers and users but also institutional, legal and administrative stakeholders from the specific city and supply zones. These stakeholders must be clearly defined and be involved in the design of an operational project and in negotiations from the early stages.

In addition, after the delineation of the theoretical sustainable supply area, the forest and rural communities potentially involved in the expanded urban woodshed should be identified and included in the stakeholder map.

Analysis of stakeholders includes physical dimensions (volumes, numbers, distances) that are best analysed in a flow analysis, especially suitable for urban areas where consumption is concentrated (FAO, 2002a). Non-physical stakeholder dimensions, such as cultural and social, may be related to territorial competence, where this may be defined, or simply added as layers to the stakeholder map and as members of the decision-making process.

Analysis of social and economic dimensions

An analysis of the social and economic dimensions of woodfuel production, consumption, transport and trade (economic flows in and out of cities) includes the economic magnitude of commercial physical flows and can only be undertaken once these have been described and mapped.

Price chain analysis and the estimation of the contribution of each stage (producers, stockpilers, transporters, wholesalers and retailers) to final prices will help to formulate tax policies and social equity measures.

As stated in FAO's woodfuel survey guidelines, "An understanding of economic flows helps gauge and interpret the importance of woodfuels in the regional or national economy, their contribution to job creation and income generation, their potential for the creation of fiscal revenue and the impact of substitution of energy sources. This is very important for defining energy, social and natural resource management policy" (FAO, 2002a).

A socio-economic profile of users (income levels, elasticity) may be useful for projecting substitution rates according to economic growth trends and for defining likely demand scenarios also with regard to fluctuating oil prices.

In general, wood energy systems are characterized by a marked fragmentation of operators (producers, transporters, retailers) who tend to work in isolation on an individual or family basis. The sector is characterized by an almost complete absence of associations, such as those that group and strengthen farmers. Fragmentation leads to poor bargaining power and lack of job security especially for the weaker links in the chain – decentralized farmers and forest dwellers producing fuelwood and charcoal. In part, this is because fuelwood collection and charcoal production often take place out of formal legislative prescriptions and with the fear of illegality. Lack of formal rights to exploit communal areas, for instance, keeps the whole system extremely weak and damages the poorest operators and the environment. Compared with other rural and urban occupations, fuelwood collection and charcoal production are prerogatives of the poorest members of the community who, in general, have a low social profile.

As regards charcoal, traders and transporters' roles may dominate strongly over other operators (such as producers and retailers); they may often exert some kind of monopoly.

Formal recognition of customary rights over the exploitation of communal lands and contract agreements between producers and (urban) users of woodfuel would improve the equity of the system by enhancing and consolidating the role of decentralized communities and facilitating the sustainable management of forests and woodlands.

6.4 LAND MANAGEMENT OPTIONS AND BEST PRACTICES IN URBAN AND PERI-URBAN WOOD ENERGY PLANNING

The magnitude and complexity of the impact that recent urban booming has on landscape and land use require an understanding of the multiple spatiotemporal scales of urbanization versus land management (see Section 2.1.3). Moreover, city and regional, national and international policies demand more and more multifunctional benefits from the landscape in general and from forests in particular.

Matching multifunctional requirements with rapid urban development, preservation of landscape characteristics and environmental quality requires a great deal of prior planning with long-term perspectives and participatory approaches (FAO, 2005d). The importance of planning is illustrated by many case studies, such as that in Quito, Ecuador, which pointed out that many existing problems in the urban forest system could be easily resolved by a more universal commitment to planning at the strategic and negotiation level. The absence of sufficient prior planning often led to disastrous results. For example, planning efforts consistently underestimated the pace of growth of the metropolis (FAO, 1997c).

The ecological settings of cities have paramount influence on the typology and intensity of wood energy systems and their social, economic and environmental impacts. Similarly, there are no standard remedial actions or management solutions. Appropriate land management options and best practices must be identified on a case-by-case basis with relation to the ecological setting.

In general, land management and best practices for the production of woodfuels in urban and peri-urban contexts and, more widely, for the sustainable supply of woodfuels to satisfy urban demand may be oriented towards the following.

Broad strategic planning level

- The integration of urban, peri-urban and rural strategic planning must be a prerequisite for operational land management planning at this level and for the objective assessment of urban/rural interactions. This requires a preliminary evaluation of i) current woodfuel supply practices; and ii) potential sustainable supply capacities in a comprehensive analytical context, ideally covering the entire national territory and including eventual import/export fluxes. The baseline WISDOM analysis, which provides information on woodfuel deficit and surplus areas, appears particularly suited to this preliminary planning phase.

Urban and peri-urban planning level

- Tree species and management prescriptions must be identified and promoted to guarantee woody biomass production together with other environmental services such as protected areas; watershed protection forests; natural reserves and parks; and social, educational and recreational areas. Annex 6 lists the main pan-tropical fuelwood species and briefly describes the fuelwood species suitable for different land use systems and main environmental services.
    - Integration of fuelwood and charcoal production in multipurpose urban and peri-urban forestry.
    - Use of preferred fuelwood species with good coppicing capacities in water regime and soil protection plantations.
    - Local knowledge is valuable on suitable woodfuel species with a multifunctional character (since research on suitable species is extremely limited and often not oriented towards local solutions). When planting crops for fuelwood and charcoal production, preference should be given to indigenous species that are usually best adapted to local conditions and appreciated for their fuel quality. In silviculture, however, focus is often put on exotic species, since they grow quickly and provide good timber. But exotics may have detrimental effects in the long term; some indigenous species are equally fast-growing.
- The integration of agroforestry practices must be promoted in urban and peri-urban farming systems in order to increase woody biomass production.
- Urban development standards must be redefined that, together with minimum green area prescriptions for recreation and other environmental benefits, specify a minimum "woody biomass productivity" quota for new urbanized areas.[10]
- The recovery of all woody biomass from tree care and management of street trees and urban parks should be promoted.

[10] Using as reference the 9 m^2 of minimum per capita green area used in European urban development standards, it could be said that one or two trees per person could be dedicated to wood energy purposes; not enough, but certainly a significant contribution to per capita energy needs.

Integrated urban/rural planning level

- Formal agreements between urban authorities and peri-urban and rural associations (e.g. smallowners' associations) should be established, as well as other forms of alliance for the continued and sustainable supply of fuelwood and charcoal as part of urban planning.
- Contracts and guarantees on the wood energy chain should be under the responsibility and coordination of urban agencies or urban/rural consortia.
- Demonstration, education and extension events should be promoted for both urban and rural dwellers.

7 Conclusions and recommendations

7.1 GENERAL CONCLUSIONS ON URBAN WOOD ENERGY

For cities to be sustainable, they need to be understood, planned and developed as an element of the environment (watershed, landscape, ecosystem); trees and forests are critical productive and protective elements.

In most developing countries, woodfuels provide subsistence energy for a large percentage of urban and peri-urban dwellers as well as for industrial and commercial activities. Their role is expected to remain important or even increase as a result of rapid urbanization.

Wood energy systems, with the numerous processes and operations involved in the production, preparation, transportation, marketing and trade of woodfuels, provide employment and revenue for a large number of people (more than any other energy carrier) and constitute a strong socio-economic interface between urban and rural areas. This aspect must be considered carefully when planning rapid and massive substitution of woodfuels by other fuels (such as kerosene, LPG or electricity). The negative impact on poor rural communities (that would in any case be excluded from substitution benefits) may be extremely serious and deserves special attention at the planning and policy formulation phases.

Migration from rural to urban and peri-urban areas leads to many major changes in the typology and potential impact of woodfuel demand. One of these changes is the shift from fuelwood to charcoal, which comes almost exclusively from forests and denser woodlands and through commercial channels, while fuelwood comes mainly from farmlands, agricultural and forestry residues and by-products, deadwood collection and through informal means. Charcoal consumption is expected to increase in the coming decades. In tropical Africa, for instance, an increase of 111 percent is forecast by 2030, reaching one third of the total wood used for energy.

Increased charcoal consumption has a great impact on forest resources, in terms of sustainability and degradation threats, and on farmers and decentralized communities, as a present or potential income opportunity. In tropical Africa and in many other developing areas presenting this dynamic there is an urgent need to raise charcoal production to a primary sustainable forest management objective in order to convert potential threats into development opportunities for decentralized and peri-urban communities.

The environmental and economic nexus that links urban and rural areas is far-reaching and urban administrators must recognize the powerful influence that growing metropolitan areas exert on ever-expanding territories and social segments.

Whereas the management of urban wood energy demand, such as promoting efficient conversion technologies and energy-access policies, is important and deserves adequate emphasis, the problems of urban wood energy cannot be resolved without adequate consideration for supply sources, wherever they may be.

Cities can no longer maintain a passive role regarding the source of woodfuels and how they obtain them. Their role and responsibility must clearly change from passive to active and they should consider their woodfuel and bioenergy supply at a preliminary stage in urban development plans. These plans should include internal elements, i.e. actions within the urban and peri-urban context based on land management options and best practices, and external elements, i.e. actions outside the urban and peri-urban context oriented towards the establishment of rational, sustainable and equitable interactions with rural woodfuel producers.

To deal with the urban/rural interface and determine the urban woodshed, i.e. woodfuel provision basin, and to support policy formulation and operational planning it is necessary to analyse consumption patterns and supply capacities on a geographic basis and create an analytical context where socio-economic aspects can be integrated.

Urban woodshed analysis can efficiently support the identification of stakeholders among the rural and peri-urban communities that are at present involved in woodfuel production as well as those that will be potentially involved in the context of sustainable production regimes.

Urban and peri-urban wood resources can contribute only in part to the provision of woodfuels for urban consumption, whose main supply sources will remain those of surrounding forests and rural areas.

Nevertheless, urban wood energy planning will trigger a virtual planning and management process aiming to satisfy urban requirements through sustainable and responsible interaction with rural areas and communities well beyond city boundaries.

7.2 CONCLUSIONS ON WISDOM METHODOLOGICAL ASPECTS

The WISDOM methodology, purposely adapted to the urban perspective, can integrate geographic and statistical data related to urban woodfuel consumption and production capacities and thus effectively support the delineation of urban woodsheds.

The supply area of the woody biomass needed for urban woodfuel consumption (urban woodshed) can be assessed on the basis of the sustainable productivity of legally and physically accessible sources. Additional driving factors include the suitability of potential woodfuel sources for commercial exploitation and local consumption that reduce the resources available to urban consumers, limiting true obtainable amounts to commercially suitable surpluses. In conclusion, a realistic delineation of urban woodsheds requires considerable data and the integration of many spatially discrete thematic layers.

A clear and comprehensive perception of woodfuel supply and demand aspects over an entire country (or at least the broad region of interest in large countries), such as that provided by the standard WISDOM baseline approach, is an essential prerequisite for the estimation/delineation of urban woodsheds and, subsequently, for the selection of the urban areas of field-level intervention and operational planning on an objective priority basis.

From a methodological angle, the following conclusions may be highlighted.

- The theoretical sustainable supply zones of a given city may vary considerably on account of the quantity and quality of the woody biomass sources of surrounding areas. The sources of “commercial” woodfuels suitable for urban markets are only a fraction of “total” woodfuel sources. Excluded from the commercial circuit are the sparse vegetation types and most farm trees and shrubs, which are important for local consumption but less suitable for commercial production. This implies that the commercial supply zone may be significantly greater than the total one.
- Another element that strongly influences the size of the theoretical sustainable supply zones is the local consumption of woodfuels in rural areas, settlements and other cities located within the zone. When the supply zone is confronted with all consumption (expanded zone) and not only with that of the city (restricted zone), its size increases considerably.
- The combination of the two aspects above has a paramount influence on the size of the nominal supply zone of a city, which underlines the necessity and importance of a wall-to-wall analysis such as the WISDOM baseline for the definition of urban woodsheds. In order to highlight the influence of these aspects on the size of the urban woodsheds, four theoretical supply zones were determined for each study site: restricted-total zone, restricted-commercial zone, expanded-total zone and expanded-commercial zone, the latter being the most comprehensive and probably the most realistic.

The issues mentioned above relative to the mapping of urban woodsheds should not be considered trivial or mere technicalities. The urban woodshed delineation supports the formulation of strategies and policies, determines future field project areas and is a fundamental prerequisite for the identification of the stakeholders to be involved in participative planning and resource management. A wrong definition of the urban woodshed would heavily undermine the effectiveness of project action and the sustainability of the derived urban wood energy systems.

Operational planning of urban wood energy calls for detailed information, the collection of which may be limited to the urban woodshed areas delimited during the comprehensive analysis (WISDOM baseline and woodshed delineation). In this approach, the costs of field data collection can be kept to a minimum without compromising the contextual perspective.

7.3 CONCLUSIONS FROM SELECTED EAST AFRICAN AND SOUTHEAST ASIAN WISDOM CASE STUDIES

The case studies of urban woodshed delineation conducted over selected urban centres of East Africa and Southeast Asia (discussed in Section 5.2 for methodology and in Section 5.3 for results) represent the first testing of the WISDOM approach adapted to the urban perspective. The analyses carried out over selected cities were largely based on previous studies and on accessible information sources, without additional country-level data collection or field verification. As such, they are limited to the strategic knowledge base, a diagnostic level meant to support the formulation of strategies rather than operational planning for which a field-level approach is needed.

The cities selected for urban woodshed analyses in Southeast Asia were Phnom Penh and Battambang in Cambodia; and Vientiane and Luang Prabang in the Lao People's Democratic Republic. In East Africa, they were Dar-es-Salaam and Arusha-Moshi in the United Republic of Tanzania; Kampala in Uganda; and Khartoum in the Sudan. The most relevant and specific conclusions derived from an analysis of urban woodsheds in these cities include the following.

- The urban woodshed of Phnom Penh, in its most comprehensive delineation (expanded-commercial supply zone), was estimated to cover in 2000 over 70 000 km^2, or 39 percent of the entire country. This area is expected to grow to some 51 percent of the country by 2015, according to likely woodfuel consumption scenarios and trends in land use change. This huge area of influence results from the combination of woodfuel consumption in the city itself, i.e. some 0.5 million tonnes of wood in 2000, and that of surrounding rural and urban areas with a combined consumption of over 4 million tonnes. The woodshed hosts over 10 million people, half of whom are represented by sparse rural communities. Compared with other parts of the country, these communities present a high incidence of malnutrition, according to WHO data, which is a clear indication of extreme poverty. For these people, woodfuel represents the only affordable fuel and the production of charcoal and fuelwood for distant urban markets is an essential source of income. In this situation, woodshed delineation can play an important role in the selection of priority areas of intervention for the adoption of poverty alleviation measures, such as the creation of rural markets, associated with sustainable resource management.
- The expanded-commercial urban woodshed of Dar-es-Salaam has a relatively small supply zone because of the proximity of dense forests and woodlands, i.e. some 30 000 km^2, or 3 percent of the entire country. However, the analysis centred on Arusha-Moshi revealed that, given the population density of the northeastern part of the United Republic of Tanzania and the paucity of wood resources, the expanded-commercial supply zone of these cities extended over some 460 000 km^2, or as much as 52 percent of the country, and included Dar-es-Salaam itself.
- The Arusha-Moshi case study shows that a combination of factors outside the city strongly influences the size and shape of the urban woodshed, even at a considerable distance. It also stresses the benefits of urban woodshed analysis for several cities in a country, in order to achieve a comprehensive vision of urban/rural interaction.
- The Kampala case study highlighted the difficulties that Uganda faces with regard to woodfuel supplies. In fact, the analysis of potential sustainable supply zones in Kampala revealed that "commercial" supply sources from dense forests and woodlands are not able to satisfy urban consumption levels even when the entire country area is considered (the expanded-commercial supply zone always remains negative). This means that lower and fragmented vegetation types are most probably exploited for urban woodfuel markets and not only for local consumption, which implies a strong and widespread risk of overexploitation and protracted degradation of natural resources on the one hand and, on the other, subsistence energy shortages for poor rural and peri-urban communities.
- The case of Khartoum revealed the huge supply zones theoretically needed to produce the woodfuel consumed in the capital city. Assuming a sustainable supply from dense formations and bearing in mind all consumption from other rural and urban areas, the expanded-commercial supply zone covers over 1.5 million km^2, or 62 percent of the country.

7.4 GENERAL RECOMMENDATIONS

Given current and predicted consumption trends, it is strongly recommended that urban administrators and planners acknowledge the policy relevance of urban wood energy and invest resources to guarantee a regular and sustainable supply of woody biomass for urban and peri-urban communities. In this way, acceptable and affordable subsistence energy levels can be secured with the same determination as that dedicated to the supply of water and other essential goods and services.

Yet urban wood energy planning is not simply a city business. Since the woodfuel supply zone of a given city extends deep into rural areas and forests and often overlaps with the supply zones of other cities, it is recommended that urban, rural and forestry administrators of the same geographic region liaise and coordinate their plans and actions to promote and implement sustainable wood energy systems at the regional level.

Growing cities must take responsibility for their impact on surrounding territories and communities. As a first step in this direction, it is essential and highly recommended that city administrators define clearly the area of influence of urban woodfuel demand in environmental and socio-economic terms. By analogy with the *water*shed that defines a water supply basin, the area supplying woodfuels to a city has been termed the urban woodshed.

In order to support sustainable resource management and wood energy planning at the regional level, it is recommended that each city's urban woodshed be mapped objectively and the relative social, economic and institutional stakeholders identified, since these are essential prerequisites of integrated regional planning.

Considering the number of people who depend on the economic flow of urban wood energy, it is recommended that energy planning in the urban and peri-urban context give special attention to the negative impact that rapid and massive woodfuel substitution by other fuels (kerosene, LPG or electricity) may have on poor rural and forest communities that represent the weakest link in the chain and that depend, permanently or seasonally, on woodfuel production for their livelihoods.

Emphasizing that efficient wood energy policies must balance action towards both woodfuel demand and supply, it is recommended that urban and national authorities implement or strengthen consumption reduction policies through the dissemination of efficient conversion technologies and sustainable substitution programmes and, at the same time, undertake policies oriented towards the sustainable and equitable supply of woodfuel for urban users and reducing the negative impact of unregulated forest exploitation.

In order to mitigate the negative environmental impact of unregulated charcoal production and to consolidate and enhance the socio-economic benefits that an expanding charcoal market resulting from growing urban demand brings to decentralized communities, it is recommended that national, regional and international forestry authorities assign high relevance to charcoal in their forestry policies and raise charcoal production to a primary sustainable forest management objective.

To reduce the negative impacts of uncontrolled exploitation and to promote sustainable and equitable wood energy systems it is recommended that national and urban authorities develop and implement clear policies on:

- the recognition of established rights and responsibilities concerning land tenure and forest exploitation;
- formal supply agreements between urban authorities and peri-urban and rural communities (e.g. smallowners' associations) that guarantee direct woodfuel producers' access to the urban consumer market;
- fair pricing and transparent taxation systems; and
- coherent land use planning and urban development programmes.

In order to optimize multifunctional land management and environmental sustainability within urban woodsheds in response to rapid urban development and growing energy needs, it is strongly recommended that urban administrators undertake specialized and participatory planning at both the strategic and operational level.

7.5 RECOMMENDATIONS ON METHODOLOGICAL ASPECTS

Given the interdependence among urban, peri-urban and rural people and factors in urban wood energy systems, it is recommended that an analysis of woodfuel demand and supply factors at urban/peri-urban and rural levels be integrated, for which the WISDOM methodology appears well suited. Two levels of analysis, supporting two different planning phases, may be identified:

- a *strategic knowledge* base that integrates existing data to support strategic planning and priorities; and
- an *in-depth woodfuel flow analysis* based on accurate field data to support operational planning within selected priority urban woodsheds.

7.5.1 Strategic knowledge base

In order to adapt the WISDOM methodology to urban wood energy planning needs it is recommended that an additional urban woodshed analysis module be added. This includes an analysis of surplus wood resources suitable for commercial woodfuel production in the territories surrounding cities and their physical/legal accessibility.

For an objective definition of urban woodsheds in selected cities and to contextualize the analysis within a country it is recommended that it be carried out in two steps.

Step 1 *WISDOM baseline*. An overview of the entire country (or broad geographic region) that, from existing data and maps, provides a geographic representation of woodfuel supply/demand balance based on woody biomass supply potential and fuelwood/charcoal consumption patterns.

Step 2 *Urban woodshed analysis*. An outline of the potential sustainable supply zones of selected cities in terms of urban/peri-urban woodfuel consumption and potential sustainable woodfuel production suitable for and accessible to urban markets.

The aim of the strategic knowledge base is to define priority areas of intervention objectively (e.g. vulnerable regions and/or communities, urban woodsheds), within which in-depth studies and operational planning should be given precedence.

The specific recommended methodological steps in the WISDOM analysis for urban forestry energy planning are given in Section 4.3.1. The methodology and results of urban woodshed delineation for selected cities in Southeast Asia and East Africa are reported in Sections 5.2 and 5.3.

7.5.2 In-depth woodfuel flow analysis

In order to guide policy decisions and operational action for a specific urban area and its woodshed it is recommended that a detailed analysis of current and potential sustainable woodfuel flows be undertaken. This level of investigation requires accurate data since its aim is to support operational wood energy planning and urban/rural land management.

The recommended methodological aspects and parameters to be collected/analysed are described in Sections 6.3 and 6.4.

In order to achieve the widest social acceptance and equity of benefits, it is recommended that urban, peri-urban and rural stakeholders (communities and institutions) be involved in the formulation of strategies and policies oriented towards creating sustainable urban wood energy systems.

Among the many important actions concerning land management and best practices aiming to mitigate the negative impacts of urban and peri-urban wood energy the following is highly recommended.

- Implementation of programmes to promote and facilitate access to high efficiency stoves.
- Formulation and implementation of policies favouring the integration of other energy sources and dedicated price policies.
- Promotion of programmes for plantations and management of urban and peri-urban forests with multiple functions but where the wood energy supply is considered at the design and planning level.
- Research on the suitability of native tree species, plantation schemes and management styles.
- Implementation of training and extension programmes on silvicultural and pruning techniques oriented towards the optimal and sustainable management of woody biomass resources in urban and peri-urban areas as well as in the rural/forest areas of the urban woodshed.
- Promotion of the sustainable and efficient use of woodfuels as a legitimate renewable energy source to ensure energy security and autonomy while contributing to sustainable rural development and poverty alleviation.

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ANNEXES

Annex 1
Definitions and conversion factors

DEFINITIONS OF "CITY" AND OTHER RELATED TERMS

Defining a city seems, as a first step, a rather simple issue – a single political jurisdiction that contains the historical city centre. But immediately questions arise. Not all historical centres are core to the built-up areas we know as cities. The political jurisdiction of these areas extends far beyond a rather small historical centre. From a statistical approach, a number of countries (105) base their urban data on administrative criteria while another group (100) refers to size or population density. Thus, beyond the city definition and concept, in terms of livelihood and energy supply/demand, we should refer to *cities*, *urban agglomerations* and *megacities* as representing aspects of the same phenomenon. Cities are the reference unit in policy and institutional terms, while the urban agglomeration results from clusters of new and old settlements leading to a noticeable urban area not necessarily coinciding with the city boundaries.

The United Nations defines an urban agglomeration as a built-up or densely populated area containing the city itself, the suburbs and continuously settled commuter areas; in this sense it does not coincide with a *metropolitan* area, i.e. the term referring to a set of formal local government areas that normally comprise the urban area as a whole plus its primary commuter areas. Megacities represent continuous dense settlements with more than 10 million residents (sometimes called metacities or hypercities, referring to a number of residents exceeding 20 million).

Urbanscape, or urban landscape, refers to the complex of biotic organisms, abiotic factors and human-induced processes that interact over time in a landscape characterized by the prevailing presence of a city.

Urbanization refers to a process in which an increasing proportion of an entire population lives in cities and suburbs. It is defined as the increase in population density or extent of cities and towns over time, or a combination of these factors. With reference to a specific place, urbanization means increased spatial scale and/or density of settlement and/or business and other activities in the area over time. The process may occur either as a natural expansion of the existing population (usually not a major factor since urban reproduction tends to be lower than rural), the transformation of the peripheral population from rural to urban, incoming migration, or a combination of these factors. In all cases, urbanization has a considerable effect on the ecology of a region and on its economy; the process of urbanization and urban development implies substantial and dramatic changes affecting the landscape, a new hierarchy in land use and an abrupt shift in the arrangement of spatial and time patterns in living conditions and use of resources.

DEFINITIONS OF URBAN AND PERI-URBAN FORESTS AND FORESTRY

Urban forest	"the sum of all woody and associated vegetation in and around dense human settlements, ranging from small communities in rural settings to metropolitan regions" (Miller, 1997)
Urban forestry	"an integrated, city-wide approach to the planting, care and management of trees in the city to secure multiple environmental and social benefits for urban dwellers" (Miller, 1997)
Urban forest or **woodland**	"a forest ecosystem (or rather: an area of land dominated by tree vegetation) in or near a specific urban area, of which the use and related decision-making processes are dominated by urban actors and their interests, values and norms" (Konijnendijk, 1999)
City forest	"an area – thought of and managed as a forest – in or near a city, of which the use by the inhabitants of the city concerned is significantly greater than the use by others. A city forest is accessible and within reach for all inhabitants of the city concerned" (Konijnendijk and Vlasman, 1993)

DEFINITIONS OF SELECTED WOOD ENERGY TERMS

These definitions are taken from *Unified Bioenergy Terminology* (UBET) (FAO, 2004a).

Bioenergy	Energy from biofuels
Biofuel	Fuel produced directly or indirectly from biomass
Biomass	Material of biological origin, excluding material embedded in geological formations and transformed to fossil
Charcoal	Solid residue derived from carbonization, distillation, pyrolysis and torrefaction of fuelwood
Demolition wood	Used wood from demolition of buildings or civil engineering installations
Energy forest trees	Woody biomass grown specifically for its fuel value in medium- to long-rotation forestry
Energy plantation trees	Woody biomass grown specifically for its fuel value as short-rotation trees
Firewood	Cut and split oven-ready fuelwood used in household wood-burning appliances such as stoves, fireplaces and central heating systems. Firewood usually has a uniform length, typically in the range of 150–500 mm
Forest fuel	Woodfuel produced where the raw material has not previously had another use. It is produced directly from forest wood by a mechanical process
Fuelwood	Woodfuel where the original composition of the wood is preserved. This category includes wood in the raw and residues from wood-processing industries
Renewable energy	Energy produced and/or derived from sources infinitely renovated (hydro, solar, wind) or generated by combustible renewables (sustainably produced biomass); usually expressed in energy units and, in the case of fuels, based on net calorific values
Wood energy systems	All the (steps and/or) unit processes and operations involved in the production, preparation, transportation, marketing, trade and conversion of woodfuels into energy
Wood energy	Energy derived from woodfuels corresponding to the net calorific value of the fuel
Woodfuel	All types of biofuels originating directly or indirectly from woody biomass. This category includes fuelwood, charcoal and black liquor (the latter is not significant in the context of this study since its cycle is entirely within the paper industry)

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

Annex 2
GFPOS model projections 1970–2030

The FAO Global Forest Products Outlook Study (GFPOS) produced fuelwood and charcoal consumption projections for the period 1970–2030 for all countries of the world, based on existing survey data and modelling techniques (FAO, 2001a).

The broad aim of the modelling exercise was to supply best possible estimates of fuelwood and charcoal consumption to fill information gaps on forest products in the online Corporate Database for Substantive Statistical Data (FAOSTAT). It responded to concern over previous FAO estimation procedures, basically projecting woodfuel consumption on population growth, which were considered too simplistic.

GFPOS models were based on a range of independent explanatory variables, which included:

- per capita gross domestic product (GDP) purchasing power parity (ppp) in US$ (1997)
- forest area per capita
- urban proportion of the population
- oil production in barrels per capita (1997)
- national land area in thousands of hectares
- temperature
- dummy variables determined for each country.

Country estimates were based on national, regional or global models, depending on the data available. Seventeen models were developed – nine for fuelwood consumption (Table A2.1) and eight for charcoal consumption, belonging to two sets:

- one based only on FAOSTAT, limited to countries that supplied at least ten valid questionnaires, used to estimate and project total fuelwood and charcoal consumption;
- another based on all available information, including a relatively rich data set of national and subnational field surveys assembled for the purpose from "grey" literature and FAOSTAT, used to estimate household and non-household fuelwood consumption and total charcoal consumption.

TABLE A2.1
GFPOS model types of fuelwood consumption and countries of application

Fuelwood consumption models		
Model type		**Countries**
FAOSTAT 1	FAOSTAT model relating the log of total national fuelwood consumption to the log of GDP ppp in US$ (1997)	14
FAOSTAT 2	FAOSTAT model relating the log of total national fuelwood consumption to the log of population	12
FAOSTAT 3	FAOSTAT model relating the log of per capita fuelwood consumption to the log of per capita GDP ppp in US$ (1997)	20
FAOSTAT linear	F linear-FAOSTAT model relating total national fuelwood consumption to GDP ppp in US$ (1997)	2
FAOSTAT constant	F constant-constant total national fuelwood assumption	1
National household model + national non-household model		2
National household model + continental non-household model		11
Regional household model + continental non-household model		142
Regional household model + national non-household model		1

The FAOSTAT fuelwood consumption models were based on the fuelwood fraction of the broader FAOSTAT category “woodfuel including wood for charcoal”.

Beyond providing “gap filling” estimates, a promising additional application of GFPOS modelling is to serve as an adjustment function for short- and long-term consumption projections based on new reference data.

The data set collected and harmonized for model development includes data from over 160 countries on woodfuel consumption at national and subnational level, by sector and by area over the period 1960–1999. The data set is extremely heterogeneous in terms of representativity and reliability but nonetheless represents a valuable effort that deserves to be pursued.

TABLE A2.2
GFPOS model types of charcoal consumption and countries of application

Charcoal consumption models		
Model type		**Countries**
F1 FAOSTAT	FAOSTAT model relating the log of total national charcoal consumption to the log of GDP ppp in US$ (1997)	3
F2 FAOSTAT	FAOSTAT model relating the log of total national charcoal consumption to the log of population	1
F3 FAOSTAT	FAOSTAT model relating the log of per capita charcoal consumption to the log of per capita GDP ppp in US$ (1997)	1
F4 FAOSTAT	FAOSTAT model relating the log of per capita charcoal consumption to the urban proportion of the population	2
FAOSTAT linear	FAOSTAT model relating total national fuelwood consumption to the urban proportion of the population	6
FAOSTAT constant	Constant total national fuelwood assumption	1
Global total consumption model		180
National total consumption model		11

Annex 3

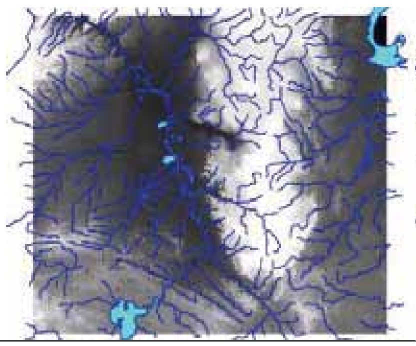
Cost maps as the basis for the assessment of physical accessibility

In order to simulate, as best possible, the efforts necessary to bring woodfuels from production sites to selected urban areas, and not simply the linear distance from their origin, the analysis procedure included the use of cost maps based on slope, derived from the digital terrain model, and on the distance from roads and settlements (Lorenzini, pers. com., 1999a). The production procedure for these cost maps is illustrated in Figure A3.1

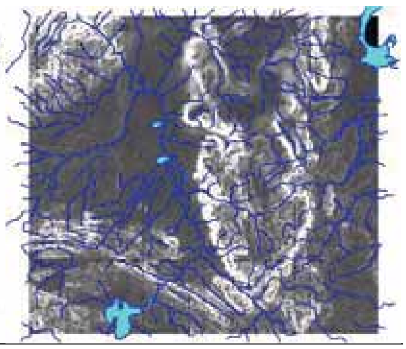
FIGURE A3.1
Cost map development procedure

Step 1. A slope map was generated from the global 30 arc-sec GTOPO30 digital elevation model of the Eros Data Center (ed: 1997), expressed as a percentage rise. The slope, varying from 0 (0°) to infinite (90°), was assumed to be the cost in crossing each specific cell of the slope raster map.

Digital elevation model (DEM)



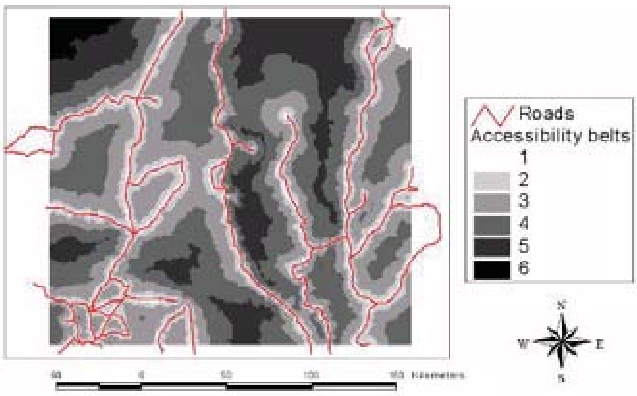
Slope map



Step 2. A raster map was generated as the least accumulative cost surface resulting from the function
sum(cost * distance_from_roads)
estimated from all the roads mapped in the Digital Chart of the World (DCW), as shown on the right.

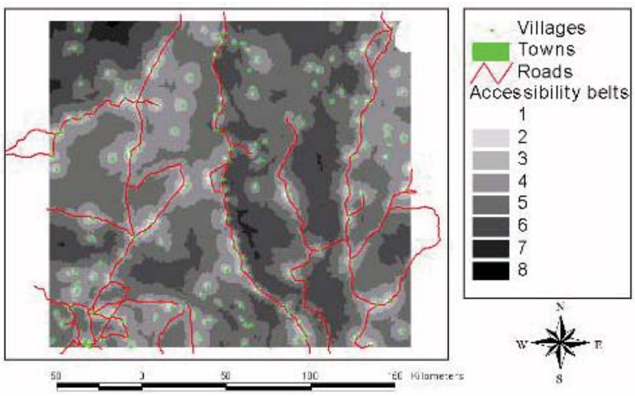
Step 3. A raster map was generated as the least accumulative cost surface resulting from the function
sum(cost * distance_from_villages/towns)
estimated from all the villages/towns mapped in the DCW.

Cost map based on distance from roads and slope



Cost map based on distance from roads, settlements and slope

Step 4. The final cost map, shown on the right, was produced by combining the two maps obtained during steps 2 and 3 with the following formula:
finalcost = int(ln(cost_urban*cost_road))+1



Source: Lorenzini, 1999b.

Annex 4

Main steps of urban woodshed analysis based on East African and Southeast Asian WISDOM data

A brief description is given of the analytical steps undertaken for the delineation of woodfuel supply zones (urban woodsheds) in selected urban centres in East Africa and Southeast Asia.

The cities selected from the East African data set are Dar-es-Salaam and Arusha-Moshi in the United Republic of Tanzania; Kampala in Uganda; and Khartoum in the Sudan. Those from the Southeast Asian data set are Phnom Penh and Battambang in Cambodia; and Vientiane and Luang Prabang in the Lao People's Democratic Republic.

TABLE A4.1
Available layers

East Africa	Southeast Asia
Woodfuel consumption data: estimated consumption of woody biomass in 5 arc-min cells (9 km at the equator) by urban, rural settlements and rural dwellers	Woodfuel consumption data: estimated consumption of woody biomass in 30 arc-sec pixels (0.9 km at the equator) by urban, rural settlements and rural dwellers
Potential sustainable productivity of woody biomass (high resolution Africover vector data and 5 arc-min cells) Total woody biomass stocking based on LCCS class definitions (FAO, 2005c) Estimated annual increment of woody biomass from high resolution LCCS vector data and field references	Potential sustainable productivity of woody biomass (30 arc-sec pixels) Total woody biomass stocking based on the Global Land Cover (GLC) map (2000). Tree cover percentage and field references (30 arc-sec) Estimated annual increment of woody biomass from high resolution LCCS vector data

ADDITIONAL GIS PROCESSING FOR WOODSHED ANALYSIS

Definition of accessibility restrictions based on legal factors (protected areas) for the East African data set

The main steps were the following.

- Downloading of latest IUCN WCMC protected area maps. Merging of IUCN area categories and other relevant non-IUCN designated areas into a single protected area map.

  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 "legal accessibility factor" was allocated to the protected areas on the basis of IUCN definitions of protected area management categories. On this basis, as for the Southeast Asian WISDOM study, 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; category VI allows even greater access, indicatively estimated at 75 percent.

- Intersecting protected area map and land cover and woody biomass data at the resolution of the original LCCS data set (FAO, 2005c) in order to assign the legal accessibility factor to land cover and biomass data.
- Recalculating stock and increment according to the new polygon areas.
- Calculating legally accessible increment according to protection level.

The analysis of legal accessibility was limited to East African countries since it was already available for Southeast Asia.

Definition of the share of woody biomass available for local consumption and for urban wood energy markets

Deduction of industrial roundwood production and estimation of woody biomass available for local consumption

Deduction of industrial roundwood was re-estimated for selected East African countries on the basis of the most recent FAOSTAT references, with the following results.

- The total Tanzanian production of industrial roundwood (all wood extracted except woodfuels) for the year 2000 was estimated at 2.3 million m^3, approximately 1.7 million tonnes (FAOSTAT, 2006). This amount was deducted entirely from the legally accessible dense forest formations (suitability class 1 in Table A4.2), whose energy-available increment was reduced by 6.3 percent.
- In Uganda, industrial roundwood for 2000 was estimated at 3.2 million m^3, approximately 2.3 million tonnes (FAOSTAT, 2006). This amount was deducted entirely from the legally accessible dense forest formations (suitability class 1 in Table A4.2), whose energy-available increment was reduced by 33.9 percent (factor 0.6613).
- In the Sudan, industrial roundwood for 2000 was estimated at 2.1 million m^3, approximately 1.6 million tonnes (FAOSTAT database ed. 2006). This amount was deducted entirely from the legally accessible dense forest formations (suitability class 1 in Table A4.2), whose energy-available increment was reduced by 28.7 percent (factor 0.713).

The woody biomass available for local consumption was estimated from all land cover classes from legally accessible areas, by application of assumed constraints to the exploitation of woody resources based on IUCN categories and deduction of industrial roundwood (amount deducted entirely from dense productive formations). An additional reduction of 10 percent was made on account of other non-energy uses (posts, poles, etc.) and of resources not accessible for other reasons.

This analysis was carried out for African countries only since the values originally used for Southeast Asia were up to date.

Estimation of woody biomass available and suitable for commercial charcoal and fuelwood production for urban markets

The basic assumptions are that:

- local consumption (within a few kilometres from the resource location) makes use of woody biomass growing in all land cover classes, including farmlands, degraded shrub formations, etc. while commercial fuelwood and charcoal production for distant urban centres takes place prevalently in dense tree formations;
- the resource available and suitable for commercial fuelwood and charcoal production was assessed according to the estimated productive capacities (restricted approach) as well as after deduction of the woody biomass needed to satisfy local needs (expanded approach). In this second approach, the resource available for urban centres was limited to surplus amounts resulting from local supply/demand balance.

The woody biomass available and suitable for commercial fuelwood and charcoal production for urban markets was limited to that in natural tree and woody formations of higher density, assuming that they would be more suitable from a commercial perspective in guaranteeing an acceptable return for the investment. A minimum stocking value for profitable charcoal production, if available, could be used to define the commercial/non-commercial threshold (*Question*: What is the minimum stocking/ha for economically viable charcoal production?)

This subset was determined on the basis of class description (denser tree and woody formations).

- For the East African data set, based on LCCS, the commercial sources were limited tentatively to the suitability classes ranked 1 to 3 in Table A4.2.
- For the Southeast Asian data set, based on GLC (2000), the commercial sources were limited tentatively to land cover classes 1 to 9, as shown in Table A4.3.

In the delineation of the expanded supply zones, the woody biomass available for urban markets was estimated considering the supply/demand balance and not only the accessible (total or commercial) productivity. For the expanded-total supply zone the estimate considered the entire surplus from local supply/demand balance.

For the expanded-commercial supply zone, the estimate considered that only the commercially suitable surplus would be available for urban consumption. In this case, a commercial balance (Comm_bal_t) was estimated. This implied the accounting of deficit conditions as such but, for surplus conditions, the available resource was limited to its potentially commercial share, as follows:

if Local balance (Loc_bal_t)	<= 0	(deficit or balanced condition),
		then Comm_bal_t = Loc_bal_t
if Local balance (Loc_bal_t)	>0	(surplus condition) and Comm_wbio_t < Loc_bal_t,
		then Comm_bal_t = Comm_wbio_t
if Local balance (Loc_bal_t)	>0	(surplus condition) and Comm_wbio_t > Loc_bal_t,
		then Comm_bal_t = Loc_bal_t

TABLE A4.2
Woody biomass resources by categories of suitability for woodfuel production for urban markets based on LCCS (FAO, 2005c)*

Rank	**Suitability for fuelwood and charcoal production for urban markets**	**Description**	**Legally accessible woody biomass increment**	**Woody biomass annually available for energy use after deduction of industrial roundwood and unproductive margin**	
			(t^6)	(t^6)	(%)
1	High suitability	Closed tree and/or woody formations, medium-high homogeneity	26.8	22.6	39
2	Medium suitability	Prevalently closed tree and/or woody formations, medium homogeneity	9.1	8.2	14
3	Low suitability	Open tree and/or woody formations, medium-high homogeneity	11.3	10.2	17
4	Marginal suitability	Open tree and/or woody formations, low homogeneity	8.2	7.3	13
5	Marginal suitability	Lower fraction of open tree and/or woody formations, low homogeneity	1.5	1.4	2
6	No unsuitability	Very open or unsuitable formations	9.9	8.9	15
	All	All	66.8	58.6	100

*Quantitative values refer to East African WISDOM data for the United Republic of Tanzania.

DETERMINATION OF THE AREA OF INFLUENCE AROUND SELECTED URBAN CENTRES

Accessibility buffers

In order to assess the efforts necessary to bring woodfuels from production sites to selected urban areas the procedure of analysis included the use of cost maps based on slope and on distance from roads and settlements (Lorenzini, pers. com., 1999a), as shown in Annex 3.

Country-level cost maps were used to determine accessibility buffers around the selected urban areas by means of the Environmental Systems Research Institute (ESRI) cost-distance function. The continuous cost-distance maps resulting from the process were then reclassified into discrete values in order to create cost buffers more suited to the subsequent geostatistical analysis.

Definition and delineation of urban supply zones

Different supply zones around the selected cities were determined according to the four definitions, i.e. restricted-total, restricted-commercial, expanded-total and expanded-commercial. The supply zone relative to each definition was determined by the number of accessibility buffers around the selected city whereby potential woodfuel production and consumption relative to each definition achieved equilibrium.

TABLE A4.3

Tentative distinction of woody biomass sources by suitability for commercial woodfuel production for urban markets based on GLC 2000 class description*

	Tentative estimate of mean productivity of above-ground woody biomass suitable for woodfuel production (t/ha/yr)	Tropical rain forest	Tropical rain forest Equatorial	Tropical mountain system Equatorial	Tropical mountain system	Tropical moist deciduous forest	Tropical dry forest	Tropical shrubland	Subtropical humid forest	Subtropical mountain system
	GLC 2000 class name	11-TAr	10-TAr_Eq	15-EqM	16-TM	12-TAwa	13-TAwb	14-TBSh	21-SCf	25-SM
Classes more suitable for commercial woodfuel production										
1	Tree cover, broad-leaved, evergreen	3.8	5.1	5.1	2.7	3.0	2.8	2.8	3.1	3.1
2	Tree cover, broad-leaved, deciduous closed	3.0			2.7	2.7	1.8	1.8	3.1	3.1
4	Tree cover, needle-leaved, evergreen	1.4			1.2	1.1			1.3	1.2
7	Tree cover, regularly flooded, freshwater	0.9	4.4	4.4			0.6	0.6		
8	Tree cover, regularly flooded, saline water	0.9	4.4	4.4		0.9	0.9	0.9		
9	Mosaic: tree cover/other natural vegetation	2.6	5.6	5.6	1.3	1.4	1.2	1.2	1.8	1.8
Classes less suitable for commercial woodfuel production										
11	Shrub cover, closed-open, evergreen	1.7	3.2	3.2	0.9	1.0	0.8	0.8	1.2	1.2
12	Shrub cover, closed-open, deciduous	1.7	3.2	3.2	0.9	1.0	0.8	0.8	1.2	1.2
13	Herbaceous cover, closed-open	1.1	2.0	2.0	0.6	0.6	0.5	0.5	0.8	0.7
14	Sparse herbaceous or sparse shrub cover	1.1	2.0	2.0	0.6	0.6	0.5	0.5	0.8	0.7
15	Regularly flooded shrub and/or herbaceous cover	1.1	2.0	2.0	0.6	0.6	0.5	0.5	0.8	0.7
16	Cultivated and managed areas	1.1	2.0	2.0	0.6	0.6	0.5	0.5	0.8	0.7
17	Mosaic: cropland/tree cover/other natural vegetation	2.1	4.0	4.0	1.1	1.2	1.0	1.0	1.5	1.5
18	Mosaic: cropland/shrub and/or grass cover	2.1	4.0	4.0	1.1	1.2	1.0	1.0	1.5	1.5
19	Bare areas	0.4	0.7	0.7	0.2	0.2	0.2	0.2	0.3	0.2
20	Waterbodies									
21	Snow and ice									
22	Artificial surfaces and associated areas	0.4	0.7	0.7	0.2	0.2	0.2	0.2	0.3	0.2
23	No data	1.7	3.2	3.2	0.9	1.0	0.8	0.8	1.2	1.2

*Quantitative values refer to average class productivity by ecological zone (Southeast Asian WISDOM, FAO, in press).

Annex 5

Monitoring land cover changes: key methodological aspects[11]

The study of land cover changes is no trivial task, for the driving factors behind change are complex and often highly location specific. The changes are elusive events that are difficult to predict and that defy generalization. They present a high statistical variance; are often small, compared with many other conventional mapping items; and suffer from less consistent estimation procedures than those commonly accepted for other more conventional purposes such as simple land cover mapping. These factors necessitate the use of rigorous methodologies in design and implementation monitoring initiatives. Thus, it may be useful to highlight a few important methodological aspects in the assessment of land cover changes based on high-resolution remote sensing data.

1. The **reliability** of the measurement of change depends primarily on the level of **coherence** in class delineation among all elements of the time series. Under an operative point of view the interdependent visual interpretation of multitemporal images (FAO 1996), nowadays carried out within GIS vector editing environments, is still the most used method because it can make full use of an analyst's experience and knowledge and, fundamentally, the recognition capacity of human brain. The **visual interdependent interpretation procedure** developed in the framework of the remote sensing component of the 1990 FAO forest resources assessment (Drigo, 1995; FAO, 1996) was designed to induce the highest level of thematic and spatial consistency among the classifications of the series of images covering the study areas.[12] A fundamental aspect of this interpretation procedure is that the class delineation of each image of the time series implies the consultation of all images in the series. This is an iterative process that eliminates the propagation of the types of error that are typical of independent image interpretation. The visual interpretation approach was considered appropriate and was preferred to automated change detection since it favours a critical and consistent interpretation of time-series data in spite of the common diversity among the images of a series due to seasonal characters, atmospheric disturbances, etc.. The distinction between a real land cover change and the effect of temporary seasonal or meteorological factors is often subtle and in this the human brain is by far more efficient and flexible than any numerical algorithm. Moreover, the visual approach proved more accessible to the interpreters whose main required competence was knowledge of specific field conditions, rather than remote sensing, GIS, or digital processing capacities.. In addition to thematic maps, key outputs of this procedure are consistent and highly informative change matrices.

   More recently, object-based methods have been proposed for forest change detection to combine the contextual analysis of visual interpretation with the quantitative aspect of pixel-based approaches (Desclée et al., 2006). The interest for object-based methods has increased with the improvements in image segmentation techniques and in the availability of commercial advanced software (the main one is eCognition, or Definiens Imaging as it is now commercially defined) (Baatz & Schäpe, 2000) specifically developed for such a task.

2. Other essential aspects that allow a more consistent evaluation of change are the following.
   - Simple **land cover classification schemes** based on distinct physiognomic classifiers that can be detected with acceptable confidence on remote sensing images. Given that a change is more reliable when there is a sharp contrast between the original land cover class and the final one (FAO, 1996), the presence of many classes with similar biomass densities separated by only small tonal differences may generate a cloud of low-reliability transitions, thereby enhancing the “noise” in the resulting transition matrices.
   - Time series composed of **compatible remote sensing data** (high resolution satellite or airborne imagery), with similar resolution or interpretability at the scale of interpretation.
   - **Common season** of image acquisition to limit to a minimum the chromatic variations linked to plant phenology.
   - **Clear interpretation responsibility**. The study in any given location must be carried out from A to Z by a single person with a good knowledge of local field conditions, land uses, common practices, etc.

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[11] Adapted from Drigo, 2005.

[12] A similar interpretation procedure was adopted in the study by Achard *et al*., 2002, where it was adapted to the visual on-screen interpretation of digital data, which guaranteed consistent results and simplified the digital mapping process considerably.

3. **Spatial and temporal scale aspects**. The study of land cover changes appears to be conducted most conveniently for intermediate-scale strategic planning purposes, e.g. over entire provinces, catchment areas (river basins) or, in this context, over urban woodsheds of a few million hectares, and over suitably long time intervals, to become cost effective. The methodology thus appears optimal at intermediate scales (ranging between 1:100 000 and 1:500 000) and over time intervals of more than five years. At more detailed levels, i.e. 1:50 000 and higher resolution, the analysis would become far more complex and expensive, since suitable historical satellite data would not be available, leaving as the sole alternative the use of historical aerial photographs, if accessible. Similarly, over very short time intervals the size of change would be too small to be detected with acceptable reliability.
4. **Cost**. The cost of this approach is relatively low, if based on high to medium resolution satellite data (i.e. Landsat TM series, MODIS 250m). Current pricing policies of remote sensing data, particularly those of the Landsat Programme and of the cost-free MODIS, and the availability of rich data archives, make the analysis of land cover changes relatively inexpensive. However, higher resolution analyses (below 20m pixel size) and elaborate image processing procedures may considerably increase the cost of the analysis.

URBAN WOODSHED APPLICATIONS

The monitoring methodology based on satellite time series is suitable for national and subnational applications where it may provide essential information for the development of local models and scenarios to support territorial resource planning initiatives. The spatial resolution of the remote sensing data used and thematic detail of this approach, i.e. land unit classification and change matrix analysis, are also suitable for local applications, for instance to study and describe the processes of change at a district, province or catchment level or, most relevant for the present context, for urban woodshed studies.

As regards the survey design for urban woodshed monitoring studies, complete coverage is the obvious and most convenient approach. In addition, in a local monitoring study it would be easier to relate the observed land cover changes to other territorial features such as drainage pattern, slope and soil characteristics, settlements and infrastructural developments such as roads or dams, as well as take socio-economic variations (both in space and time) into account. Knowledge of the processes of change occurring in a certain area, as well as their impacts and trends, adds significantly to simple statistics on available resources as derived from remote sensing and so facilitates the development of more realistic models and scenarios of land use change and inference on cause-effect mechanisms.

TRANSITION MATRICES AND BIOMASS FLUX DIAGRAMS

As an example of land cover change analysis, Table A5.1 and Figure A5.1 show the results of the analysis carried out over an area of approximately 1 million ha in the East Godavari district of Andhra Pradesh, India, from January 1973 to January 1995 (FAO, 1995). The table shows the transition matrix reporting land cover class areas in 1973 and 1995 and the individual class-to-class transitions.

Much information may be derived from the matrix. First, area totals for the two dates may be compared and the net change for each land cover class assessed. The *closed forest* class, for instance, changed from 238 900 ha in 1973 to 207 000 ha in 1995. But more can be learned from examining the inner part of the matrix. This provides, *inter alia*, along the diagonal all areas that remained stable during the period under consideration and, away from the diagonal, all individual class-to-class transitions. The light grey cells within the matrix identify negative transitions, implying a loss in biomass while the others identify positive ones, implying an increase.

The information on land cover dynamics contained in the change matrix can be represented efficiently, and in a more accessible manner, in the form of a so-called woody biomass flux diagram. This was conceived in order to express better the magnitude of the land cover changes through the allocation of biomass densities to the individual land cover classes (FAO, 1995). By including the biomass perspective, it is possible to visualize and understand more clearly the change processes, and even assess their environmental impact through the release (or sequestration) of woody biomass related carbon. A nominal biomass value for each class thus permits the estimation of the biomass changes related to each class transition. The flux diagram may be considered a kind of "signature", representing the dynamic character of a certain area over a certain period of time.

TABLE A5.1
Area transition matrix in the East Godavari district, Andhra Pradesh, India, 1973–1995

('000 ha)			**Land cover classes in 1995**								
Land cover classes in 1973	**State in 1973**	**% of land area**	**Closed forest**	**Open forest**	**Long fallow**	**Frag-mented forest**	**Shrubs**	**Short fallow**	**Other land cover**	**Water**	**Planta-tions**
Closed forest	238.9	23.7	204.1	5.8	4.6	0.8	2.1	9.9	8.7	0.8	2.1
Open forest	9.9	1.0		8.3			0.4	0.4	0.8		
Long fallow	14.5	1.4	2.5		8.3			2.9	0.4		0.4
Fragmented forest	5.4	0.5				4.6			0.8		
Shrubs	38.9	3.9					35.6		3.3		
Short fallow	9.1	0.9	0.4					7.9	0.8		
Other land cover	571.0	56.7							565.6	5.0	0.4
Water	116.4	11.5							1.2	115.1	
Plantations	3.3	0.3									3.3
State in 1995	**1007.4**		**207.0**	**14.1**	**12.8**	**5.4**	**38.1**	**21.1**	**581.8**	**120.9**	**6.2**
% of land area		**100.0**	**20.6**	**1.4**	**1.3**	**0.5**	**3.8**	**2.1**	**57.7**	**12.0**	**0.6**

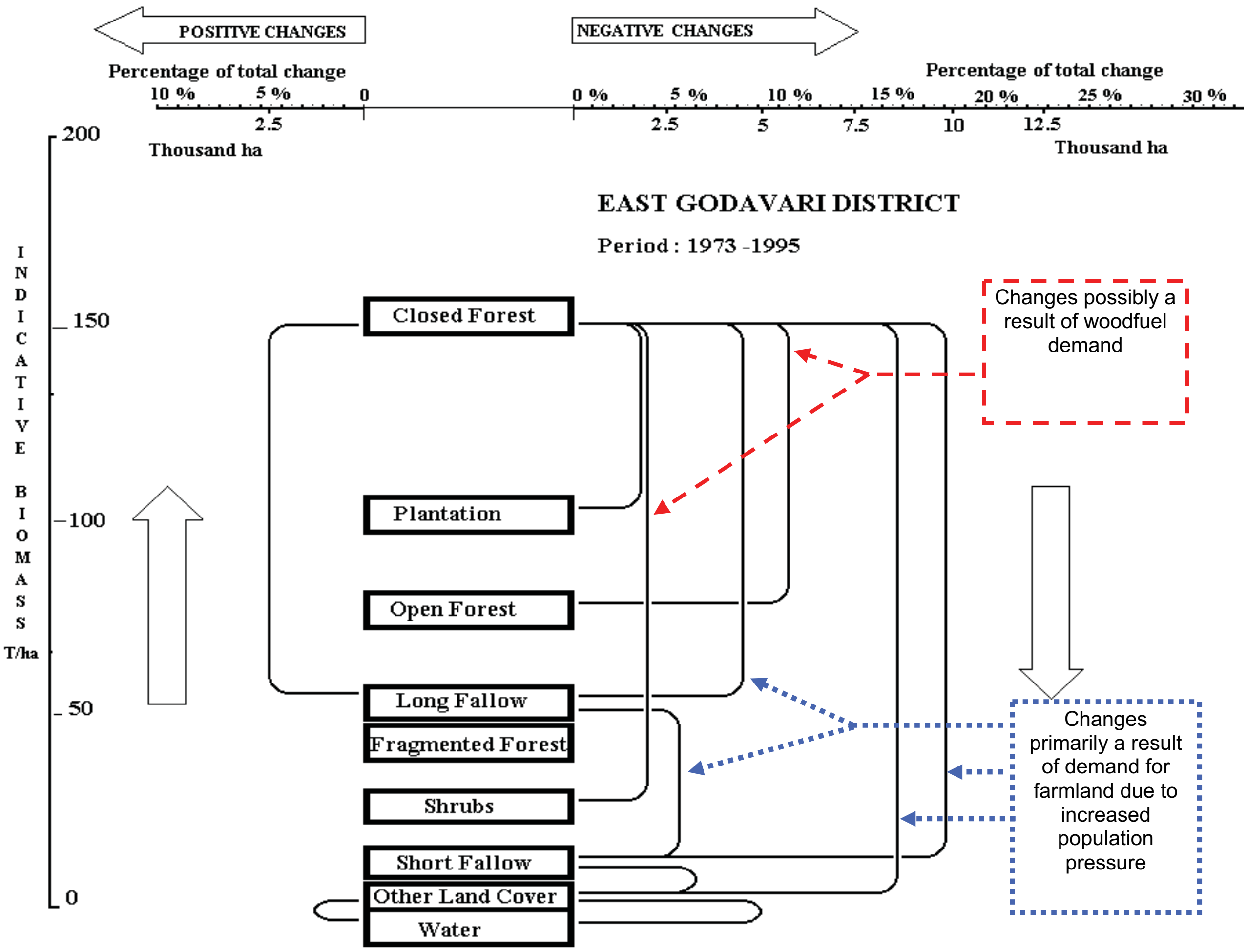
The woody biomass flux diagram in Figure A5.1, which combines the rates of change listed in Table A5.1 with estimated biomass values, is structured as follows.

- The Y-axis, with its indicative biomass values, shows the order of the classes by their estimated biomass per hectare.
- The X-axis shows the areas of class-to-class transition, divided into positive and negative changes. The left of the diagram represents the lower-left part of the matrix, showing the positive class transitions (the arrow pointing upwards indicates an increment in biomass), while the right-hand side represents the upper-right part of the matrix, showing the negative class transitions (the arrow pointing downwards indicates a loss of biomass).

The process here is fairly complex, involving the expansion of short fallow subsistence farming and permanent agriculture on closed forest areas; various phases of forest degradation (closed to open forest and closed forest to shrubs); and expansion of long fallow shifting cultivations in closed forest areas and regrowth of forest in previous long fallow areas, in a cycle that was common in the past but nowadays is very rare. The study was not carried out specifically to assess the impact of woodfuel production and it is not possible, without adequate auxiliary field data, to pinpoint the causes of change. A reasonable guess is that fuelwood collection may be responsible for forest degradation processes (*closed* to *open forest* and to *shrubs*) and may be a concomitant cause of the deforestation processes (*closed forest* to *short fallow* cultivation and to *other land cover*).

FIGURE A5.1

Woody biomass flux diagram in the East Godavari district, Andhra Pradesh, India, 1973–1995



Annex 6
Pan-tropical fuelwood species[13]

A brief description of the characteristics of fuelwood species for different land use systems and for main environmental services is given below. Tables A6.1, 2 and 3 list the main pan-tropical species suitable for fuelwood and charcoal production by broad ecological zones with an indication of their suitability in different land use systems and environmental services.

Silvopastoral systems

Silvopasture combines trees with pasture forage and livestock production. Trees with palatable foliage, pods and twigs may contribute to pastoral production, especially at the end of the dry season, when shortages of fodder occur. The trees can also provide shade for livestock but have to be tolerant to the impact of the animals and withstand damage to their root systems and bark. The leaves and fruits should not be poisonous for livestock and the crowns should be above their reach. A thin canopy is ideal because it allows transmission of light for pasture forage. Profuse production of pods and foliage is necessary.

Agroforestry

Agroforestry is a mix of agricultural crops with trees and shrubs. The latter provide farmers with fuelwood, fodder, mulch, fruit, green manure, nitrogen fixation and controlled shade for agricultural crops. Trees should not compete with crops for nutrients or for light. Deep-rooting systems are ideal. The tree canopy should allow acceptable light penetration for crops. Trees should not be damaged by the cultivation or harvesting of surrounding crops. In addition, they may produce marketable products.

Woodlots

Woodlots are small areas of land that people devote to trees. They provide not only fuelwood but also timber and poles. The trees in woodlots are generally fast growing and able to coppice or regenerate easily. Woodlots can bring steep slopes, river banks and other inaccessible land into production. If planted on a marginal site, trees should be tolerant to harsh conditions.

Large plantations near cities

To supply fuelwood for residents, extensive plantations are established for cultivation around settlements and cities. These plantations provide large amounts of fuelwood and charcoal for the convenience of city dwellers as well as for industrial purposes. They are set up with the species that are most in demand on the market, which should also be appropriate for charcoal production. Dense wood is preferable because wood is usually transported by lorry. Since the plantations are large, trees should be highly resistant to disease and fire.

Land rehabilitation

Some species can be used for rehabilitation on land that has been overgrazed, eroded or depleted of nutrients. Land rehabilitation aims at gradually increasing the production potential of the site. Tree species suited for rehabilitation can stand harsh conditions. Tolerant of drought, poor soils and neglect, the trees should be fast growing to establish a new environment and they should be deeply rooted in order to obtain water in dry conditions. They should be able to raise soil quality by nitrogen fixing and improve soil fertility by providing green manure and mulch. The latter implies the production of litter with a high nitrogen content that adds organic matter to the soil.

Erosion control

Trees protect against erosion if they impede soil migration. Erosion control species develop an extensive lateral root system to bind the soil. Development of root suckers makes a tree useful for erosion control (CABI, 2005). To protect against erosion, windbreaks also slow the wind entering the site.

Windbreaks

Windbreaks are valuable in agriculture because they raise productivity by sheltering crops from the velocity and drying effects of wind. The trees have to be low-branched and suitable for dense planting in at least double rows. Small shrub species mixed with larger species in between give rise to a more effective shelter

[13] Adapted from Van de Vreken, 2005.

against the wind. If the windbreak consists of just one species, branching has to extend to the ground. Trees in windbreaks need to have wind-firm root systems. The crown should be bushy and allow some wind penetration. The branches have to stand firm against the wind; they should be pliable and not easily breakable. The trees should not harbour pests from adjacent crops and the root system should not compete excessively for water with crops (Wilkinson *et al.*, 2000). If the windbreak is set up in coastal areas, the trees should be salt tolerant.

Living fences

Living fences serve to screen houses for privacy. They also enclose fields and meadows. Thorny branches are ideal to fence in livestock. Dense foliage is needed to impede visibility. The trees can stand being closely planted to form a fence. They should be able to tolerate frequent clipping.

Ornamentation

Ornamental trees are distinguished by their beauty, in that they have attractive flowers, lush foliage or a special crown. When used in cities or along avenues, resistance to air pollution is desirable. In addition, they should preferably provide shade.

Shade

A shade tree has dense foliage that persists throughout the hot season. The shade provided is useful for cities, gardens, pastures or fields, humans, animals and crops.

TABLE A6.1

Main fuelwood species of arid and semi-arid tropical regions and their suitability for different land uses and environmental services

Arid and semi-arid regions (rainfall <800 mm or <6 humid months)

	Silvopastoral systems	Agroforestry	Woodlots	Large plantations near cities	Land rehabilitation	Erosion control	Windbreaks	Living fences	Ornamentation	Shade
Acacia cyclops	x					x				
Acacia nilotica	x	x		x	x	x	x	x	x	
Acacia raddiana	x					x		x		x
Acacia senegal	x	x		x	x	x	x			
Acacia seyal	x	x								
Albizia lebbeck	x	x	x		x	x	x		x	x
Anogeissus latifolia	x				x	x				
Azadirachta indica		x	x	x	x	x		x		x
Balanites aegyptiaca	x		x				x	x		x
Cajanus cajan	x	x	x			x	x	x		x
Cassia siamea	x	x	x		x	x	x		x	x
Dalbergia sissoo	x	x	x	x	x	x	x	x		
Eucalyptus camaldulensis			x	x	x	x	x		x	x
Eucalyptus citriodora					x					x
Eucalyptus microtheca				x		x	x	x	x	x
Eucalyptus occidentalis			x		x	x	x		x	x
Parkinsonia aculeata	x				x	x	x	x	x	x
Pithecellobium dulce			x				x	x	x	x
Populus euphratica	x				x		x			
Prosopis alba	x				x	x	x		x	
Prosopis juliflora	x				x	x	x	x	x	
Sesbania sesban	x	x			x	x	x	x		x

TABLE A6.2
Main fuelwood species of humid tropical regions and their suitability for different land uses and environmental services

Humid tropics (rainfall >800 mm or >6 humid months)

	Silvopastoral systems	Agroforestry	Woodlots	Large plantations near cities	Land rehabilitation	Erosion control	Windbreaks	Living fences	Ornamentation	Shade
Acacia auriculiformis		x		x	x	x			x	x
Calliandra calothyrsus	x	x	x		x	x		x	x	x
Casuarina equisetifolia		x	x	x	x	x	x	x	x	
Eucalyptus brassiana				x						x
Eucalyptus deglupta						x			x	x
Eucalyptus pellita				x						
Eucalyptus urophylla				x	x					
Gliricidia sepium	x	x	x		x	x	x	x	x	x
Gmelina arborea		x		x					x	x
Guazuma ulmifolia	x				x			x	x	x
Hibiscus tiliaceus					x	x		x	x	
Leucaena leucocephala	x	x		x	x	x	x	x		
Mimosa scabrella	x	x		x	x				x	x
Muntingia calabura		x			x	x			x	x
Pinus caribaea		x		x	x	x			x	x
Sesbania grandiflora	x	x			x		x	x	x	x
Syzygium cumini	x		x		x		x	x	x	x
Tamarindus indica	x	x	x				x		x	
Terminalia catappa		x		x	x	x			x	x
Trema orientalis		x		x	x	x	x	x	x	x

TABLE A6.3
Main fuelwood species of tropical highlands and their suitability for different land uses and environmental services

Tropical highlands (above 1 500 m)

	Silvopastoral systems	**Agroforestry**	**Woodlots**	**Large plantations near cities**	**Land rehabilitation**	**Erosion control**	**Windbreaks**	**Living fences**	**Ornamentation**	**Shade**
Acacia decurrens		x	x		x	x	x			x
Acacia mearnsii		x				x				x
Alnus acuminata	x				x					
Eucalyptus globulus			x	x	x	x	x		x	x
Eucalyptus grandis		x		x	x	x			x	x
Eucalyptus robusta				x	x	x	x	x		x
Eucalyptus tereticomis				x	x	x				x
Gleditsia triacanthos	x	x	x		x	x	x	x	x	x
Grevillea robusta	x	x	x	x	x				x	x
Melaleuca quinquenervia					x	x			x	
Melia azedarach	x	x	x		x	x	x		x	x
Sapium sebiferum		x							x	

Annex 7

Sectors, subsectors, branches and sub-branches of woodfuel end uses

Productive sector	Subsector	Branch	Sub-branch	Woodfuel end use
Primary	Agriculture	Crop production	Grains and oilseeds	Drying of grains and oilseeds
			Tobacco	Tobacco curing
		Animal production	Pigs	Cooking feed
			Poultry	Poultry houses
			Other	Heating
				Other
Secondary	Manufacturing industry	Food and beverages	Sugar, granulated	Producing steam
			Sugar, brown	Evaporating cane juice
			Coffee	Drying, roasting
			Tea	Withering, drying
			Tobacco	Curing
			Herbs	Drying
			Oils	Producing steam
			Milk products	Steam
			Bread	Baking
			Confectionery	Cooking, sterilizing
			Maize tortillas	Nixtamalization
			Tapioca meal	Drying
		Metal minerals	Iron	Reduction, smelting
			Steel	Carbon restoration, blacksmithing
		Non-metal minerals	Lime	Calcination
			Chalk	Dehydration
			Cement	Clinkering
			Tiles and bricks	Firing, ceramization, glazing
			Pottery	Firing, glazing
			Salt	Evaporation-crystallization
			Kaolin	Drying
		Pulp and paper	Pulp and paper	Steam and power for processing

		Wood-based products	Wood	Wood drying
Tertiary	Commerce and services	Food and beverages	Restaurants	Food preparation
	Tourism and leisure		Hotels Camping sites	Heating, hot water, food preparation, laundering
	Public	Health	Hospitals Schools	Laundering Food preparation

Source: FAO, 2002a.