Woodfuel Integrated Supply/Demand Overview Mapping – WISDOM: a geographical representation of woodfuel priority areas

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A new planning tool combines geographic information about woodfuel production and consumption to identify "hot spots" where action to ensure the sustainability of fuelwood use is urgently needed

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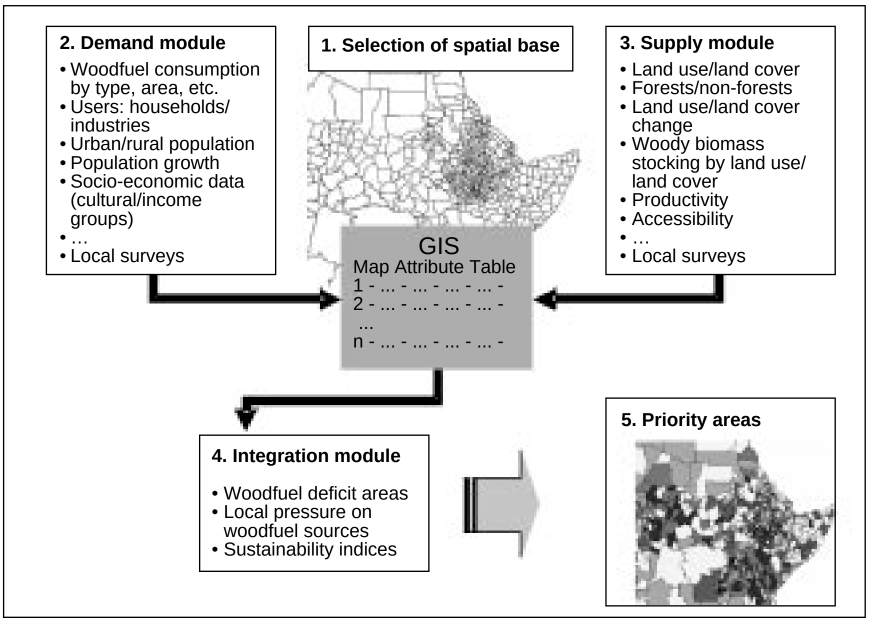
The patterns of woodfuel production and consumption and the associated social, economic and environmental impacts are complex and site specific. Broad generalizations about woodfuel use and availability at the regional, national and even subnational levels still commonly lead to biased assumptions and consequently to poor planning and ineffective action. Thorough local studies of woodfuel flows have sometimes been implemented, but they are expensive and time consuming, and they fail to provide the national perspective needed for the design of effective national policies.

There is therefore a need for methodologies and tools that provide country-wide synoptic views of local wood energy supply and demand patterns based on the consistent integration of data and information. Thus FAO, in cooperation with the Institute of Ecology of the National University of Mexico (UNAM), is currently developing Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM), a spatially explicit method for visualizing woodfuel priority areas or "hot spots". Although it is still largely in the formulation phase, WISDOM has been applied in a case study in Mexico and will soon be tested in other countries. It is based on geographic information system (GIS) technology, which offers new possibilities for combining, or integrating, statistical and spatial information about the production (supply side) and consumption (demand side) of woodfuels (fuelwood, charcoal and other biofuels). This accessible, user-friendly technology makes it possible to display the results of spatial analysis in easily understandable ways to public officials and private citizens as well as to the scientific community (Marble, 1998). Multi-scale analyses make it possible to show local situations throughout an entire country or region.

WISDOM is intended as a strategic planning tool, rather than an operational one. Its purpose is to integrate existing, currently dispersed information to obviate the need for costly collection of new data. WISDOM must adapt case by case to the available information, whether it be direct (woodfuel consumption and trends; sustainable woodfuel productivity) or indirect (proxy variables related to woodfuels demand and supply).



1
WISDOM steps

STRUCTURE

The use of WISDOM involves five main steps (Figure 1).

Selection of the spatial base

WISDOM is flexible and can be used for studies at the national, regional or subregional level.

For national-level studies, which are best suited to promote policy formulation, the analysis should be carried out at the lowest administrative level for which demographic, social and economic parameters are available, i.e. the municipality. The subnational level of analysis is an essential feature of WISDOM as it helps to avoid the aggregations and generalizations that so negatively affect wood energy studies.

Many countries have digital data sets for their administrative units, which facilitate the analysis. Census and other socio-economic information is increasingly provided in digital form.

For regional or subregional studies, demographic information may be derived from the LandScan Global Population Database of Oak Ridge National Laboratory in the United States, which provides worldwide population density maps at 30” x 30” (arc-second) resolution.

In this step, spatial and statistical data are linked through a “map attribute table”, which has a database structure and contains the basic geographic attributes and identifiers of all individual elements of the digital map (identity codes and names, area, perimeter, coordinates, etc.). The table can be expanded as needed by the addition of thematic attributes referring to the same set of map elements. A salient feature of the WISDOM methodology is the progressive expansion of the table to include all available information directly or indirectly related to woodfuel demand and supply.

Demand module

The demand module portrays the spatial distribution of woodfuel consumption, disaggregated, if possible, by fuel type (fuelwood, charcoal, others), by sector of users (households, industrial, others) and by area (rural, urban). It is also used to identify those areas showing distinctive consumption dynamics (e.g. increasing woodfuel needs). The main sources of information in developing this module are statistics on demography and other socio-economic parameters collected and maintained by national statistical services, and studies and surveys that contain information on unit consumption by type of user, for example.

Several criteria can be set to determine priority areas in terms of woodfuel demand. For example, one might be interested in areas that show:

- high woodfuel consumption;
- high density of woodfuel users;
- high growth rates of woodfuel consumption or users, either by households or industrial users;
- high resilience of woodfuel demand.

The precise criteria, and the corresponding prioritization of areas, will depend on the specific objective of the study. For example, the study may be intended to identify places with large potential market opportunities for new technologies or places where there are major health impacts.

Table 1 shows potential variables that can be used in the analysis. A number of variables can be used for different criteria.

Whenever possible, it is important to assess the demand by woodfuel commodity (fuelwood, charcoal, black liquor, pyrolytic oil, etc.), since each has a different impact on sources and sustainability of supply, calling for separate lines of analysis.

The development of the demand module usually implies the integration of consumption data from surveys – normally covering only part of the country – with sociodemographic variables obtained from census information. The main challenge in this module is to find either direct or proxy variables, available at the minimum subnational unit, that can be used to estimate consumption levels and their spatial distribution.

Supply module

To the extent allowed by the existing information, the supply module provides a spatial representation of all natural and planted woodfuel sources (including not only natural forests but also plantations, trees outside forests, woodlands, shrubs and any other main source of woodfuels), their stocking capacity, their change over time and their productive capacities. Realistically speaking, the main, and often the only, sources of information for developing this module are national forest inventories, since detailed surveys of biomass stocking and productivity covering non-forest land use classes are still rare. In most cases, stocking and productivity for non-forest woodfuel sources (shrubs, agricultural plantations, agroforestry practices, etc.) will be inferred or “guessti-

TABLE 1. **Potential variables to be used in the demand module**

Variable	Desired breakdown
Woodfuel consumption by households Woodfuel use per capita Number of users at time *t*	Fuel type (fuelwood, charcoal, etc.) Urban/rural population Combination of fuels Minimum administrative unit of analysis
Woodfuel consumption by industrial users Woodfuel use per unit of product Number of users at time *t*	Type (and size) of industries Minimum administrative unit of analysis
Density of users Saturation (% of users) Users by km^2	Urban/rural Household/industrial Woodfuel exclusive/multiple fuel users
Average annual growth rate of consumption/users	Urban/rural Household/industrial Woofuel exclusive/multiple fuel users
Resilience of consumption Relevant cultural groups Income levels	Ethnic groups Income groups within urban/rural population

TABLE 2. **Potential variables to be used in the supply module**

Variable	Desired breakdown	Possible sources of information
Land use/land cover class	All land use/land cover classes must be considered	National studies, e.g. AFRICOVER mapping in Africa using FAO's Land Cover Classification System (FAO, 2000)
Land use/land cover change	Crude deforestation rates should be avoided; land cover transitions (i.e. using land use transition matrices) are well suited for this type of analysis	National monitoring studies; large-scale studies such as FAO's Global Forest Resources Assessment remote-sensing survey (FAO 1996, FAO 2002); TREES II high-resolution survey (Achard *et al.*, 2002)
Woody biomass stocking by land use/land cover	Biomass stocking for all land use/land cover classes including croplands, shrublands, etc.	Forest inventory data (volume expanded to total biomass); inference and extrapolation from detailed studies
Average biomass production by land use/land cover class	Productivity indices for all land use/land cover classes	Forest inventory data (yield expanded to total biomass); inference and extrapolation from detailed studies; agro-ecological zoning
Accessibility	Areas inaccessible for legal reasons (i.e. protected areas) and for physical reasons (slope, distance)	National or international maps of protected areas, such as those of the World Conservation Union (IUCN); (physical) terrain models (e.g. products derived from the Digital Chart of the World [ESRI, 1993])

mated". Given the paucity of data on non-forest classes, the development of this module will rely on local studies, even if of limited coverage, and expert opinions.

As with the demand module, it is essential to use disaggregated statistics referring to small units rather than aggregated averages.

Table 2 shows the potential variables to be used for the development of the supply module. In general terms, it may be assumed that woodfuel supply capacity (WSC) is a function of several factors which include, among others, land use/land cover and relative changes, biomass stocking, biomass productivity and accessibility.

Again, different criteria can be used to analyse woodfuel supply and to identify priority areas. For example, if the aim is to identify areas with potential woodfuel shortages, then the study could look for areas that show:

- rapid depletion rates of forests and woodlands as a result of land use changes or high pressure;
- low biomass productivity;
- poor accessibility.

Alternatively, areas with larger potential for sustainable woodfuel production will be those showing accessible woody vegetation with good stocking and productivity.

The quantitative WSC value is extremely difficult to determine with precision, not only because reliable information is lacking, but also because the capacity of agricultural farming systems to produce woodfuels depends also on the level of demand and on the accessibility of alternative sources.

However, as mentioned earlier, the scope of WISDOM is not operational planning, for which quantitative precision is essential. Thus, with the scope of identifying priority areas where the demand-supply balance reveals a possible deficit, the supply module may concentrate mainly on land use and land use change, and may use indicative biomass productivity indices based on ecological characteristics.

Integration module

After development of the demand and supply modules in the GIS, the next step is to develop variables that integrate the information from the two modules. The integration is done through the combination of the variables related to woodfuel consumption and supply that have been systematized for each minimum administrative unit of analysis. Several variables or indicators can be designed to analyse the combined impact of woodfuel supply and demand. The selection of indicators is decided case by case, depending on the availability and accuracy of the data. Potential indicators include:

- woodfuel deficit = [woodfuel supply – woodfuel demand] < 0;
- potential pressure on woodfuel sources = [woodfuel demand ÷ total accessible woodfuel sources].

Strictly speaking, woodfuel deficit areas are those with negative values. However, since it is difficult to obtain precise information on both supply and demand, different thresholds could be defined so that woodfuel deficit areas could include those with a range of values around zero.

Potential pressure on woodfuel sources (natural and planted) is given in tonnes (or cubic metres) per hectare per year and thus gives an idea of the average local wood productivity needed to cope with the existing woodfuel demand. If the demand is higher than the usual range for wood productivity in the area, then a large pressure on wood sources may be assumed.

Identification of woodfuel hot spots

The final step is the identification of those areas where action is urgently needed in terms of demand, supply or both (i.e. woodfuel "hot spots"). Departing from previous approaches based entirely on a quantitative measure of woodfuel deficits (e.g. the fuelwood gap model), WISDOM aims at identifying areas showing a distinctive woodfuel situation and dynamics. To do so, common multivariate statistical procedures

– data grouping techniques, factor analysis, cluster analysis, indexing and others – could be used. Alternatively, the final grouping of subnational areas in terms of their priority could be done using an overall woodfuel priority index (O.R. Masera, R. Drigo and M.A. Trossero, in preparation) that reflects the key aspects of the areas of analysis in terms of both woodfuel demand and supply.

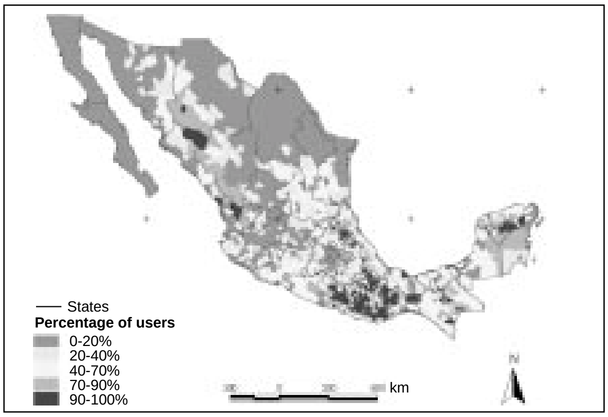
CASE STUDY: IDENTIFYING HOT SPOTS FOR HOUSEHOLD FUELWOOD CONSUMPTION IN MEXICO

A detailed case study carried out in Mexico illustrates the WISDOM approach (O.R. Masera, R. Drigo and M.A. Trossero, in preparation). Spatial information from detailed local surveys on fuelwood consumption (Figure 2) was integrated with sociodemographic historical series and land use/land cover statistics (Figure 3). The analysis helped to identify 273 counties where action to ensure the sustainability of fuelwood use is urgently needed (Figure 4).

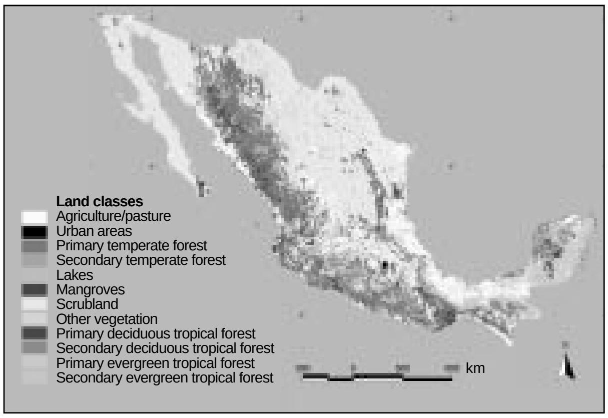
The demand for woodfuels in Mexico is concentrated on fuelwood, primarily in rural areas. Most fuelwood is either collected or bought from local markets. Most fuelwood comes from forest areas (little from agricultural areas). Most demand comes from households.

In the analysis, hot spots were defined as those areas showing high fuelwood demand, high density and growth of fuelwood users, high resilience of fuelwood consumption (in terms of social and cultural aspects) and few or insufficient woodfuel resources. The analysis focused on fuelwood, households and fuelwood-exclusive users.

- ***Spatial base.*** The unit chosen was the *municipio* (county), of which the country has a total of 2460. The spatial base was a country-wide georeferenced database available from the Mexican National Bureau of Statistics (INEGI).
- ***Demand module.*** The two main sources for the development of the module were the National Population Censuses of 1980, 1990 and 2000 and a comprehensive collection of local, regional and national surveys on energy use in the household sector.
- ***Supply module.*** Land use/land cover statistics were obtained from the National Forest Inventory 2000, which was conducted at a 1:250 000 scale over the whole country. The original 69 land use/land cover classes were aggregated into seven major



2
Saturation of fuelwood users at the municipio *(county) level, Mexico, 2000*



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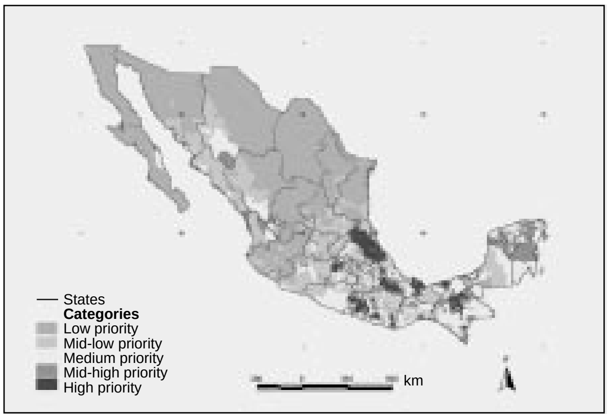
Simplified vegetation map for Mexico, 2000



4
Priority municipios *(counties) requiring action related to fuelwood use and availability of fuelwood resources, Mexico, 2000*

classes (Palacio-Prieto *et al.*, 2000). Average biomass productivity was assumed for each land use/land cover class.

- ***Integration module.*** The GIS database included information on fuelwood demand and supply for each of the 2460 *municipios*. Variables designed to integrate supply and demand included pressure on woodfuel resources, potential deficit of woodfuels and others.
- ***Identification of priority areas.*** *Municipios* were grouped into five main categories (high, mid-high, mid, mid-low and low) for each of a set of uncorrelated variables (e.g. consumption). A simple indexing of all the variables and a further grouping was conducted to rank the *municipios* into five classes of priority.

CONCLUSIONS

WISDOM is an iterative tool for wood energy planning and policy development. It makes possible spatial analyses of woodfuel supply and demand to show local situations throughout an entire country or region. The identification of woodfuel hot spots can help decision-makers and governments set priorities. Additional studies can then help to identify ways to overcome the main problems and to develop interventions.

WISDOM is a modular, open tool, adaptable to the heterogeneous information collected by the many sectors concerned with wood energy – forestry, energy, agriculture, social affairs, etc. WISDOM does not reduce the need to collect local data, but rather emphasizes this need since its reliability is influenced by the quantity and quality of the data available. Local data also help to define the specific information gaps that disrupt the analysis. Repetitive applications of WISDOM over the years should be able to help progressively enhance the consistency of wood energy analysis.

The main benefits of using WISDOM can be summarized as follows.

- It allows a holistic vision of the wood energy sector over the entire country or region and helps to determine priority areas for intervention and new wood energy initiatives.
- It contributes essential information for the promotion of sustainable management of forests, other wooded lands and trees outside forests.
- It can be used to promote the development of wood energy as a locally available and environmentally friendly source of energy.
- It helps to clarify the true role of the forest and agricultural sectors in supplying woodfuels. It is hoped that in so doing, it will favour a clearer allocation of responsibilities and promote synergies.
- It allows the identification of critical data gaps.
- It combats the fragmentation of information and responsibility that so heavily limits the development of the sector.
- It enables concentration of actions on circumscribed targets and thus helps optimize the use of available human, institutional and financial resources. ◆

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