4. Identification of forests under fuelwood harvesting pressure within priority *municipios*: an accessibility analysis

The WISDOM analysis carried out for Mexico allowed the identification of 262 high priority *municipios*, distributed over several aggregated areas or "clusters of *municipios*". This procedure allows focusing policy action over those areas that require most attention for natural resource management and other social or economic concerns. However, in order to go from strategic planning to actual implementation on the field, more steps are needed. Specifically, from an environmental perspective, it is important to identify those forest areas within each *municipio* or "hot spot" that show more pressure from fuelwood harvesting. Specific actions such as forest restoration, multipurpose energy plantations and others, can be concentrated on these newly identified areas.

Accessibility analyses provide a valuable tool for identifying priority forest areas within the clusters and *municipios* identified by WISDOM. Assessing the accessibility to fuelwood sources due to physical restrictions (i.e. slope, distance) and legal restrictions (i.e. protected areas) may allow helping to recognize those fuelwood supply areas more critical in terms of the pressure exerted by people's demand. By considering the number of fuelwood users that can access limited portions of the whole forest area, accessibility studies may also help quantify the actual pressure on forest resources.

Determining the areas accessible to fuelwood harvesting is not a simple issue. Traveling costs considering the influence of slopes and land cover classes; means of displacement by fuelwood gatherers; legal access to fuelwood sources areas; distance to selected fuelwood sources from settlements and roads; and local surveys concerning site specific parameters (e.g. willingness for gathering fuelwood or gender and age of fuelwood collectors) are things that need to be considered for conducting any accurate accessibility valuation. The information needed to conduct a thorough analysis include elevation maps; road and town maps; land use/land cover maps; ground measurements for travel velocities; maps of protected areas; cadastral data; or local surveys on fuelwood use.

In this section we conduct an accessibility analysis over the Purhepecha Region of the State of Michoacan, using a GIS platform. The example attempts to: 1) estimate the potential forest areas accessible to fuelwood users, and 2) categorize those accessible forest areas, according to the pressure exerted by local people's demand.

The "Purhepecha" Region

Situated within the state of Michoacan, the "Purhepecha" Region has an area of 653,547 ha from which 323,068 ha are forests. Vegetation in the area consists primarily of Pine-Oak forests, and dominant land uses are agriculture and permanent crops. By the year 2000, total population reached 732,480 inhabitants, distributed over 927 villages and 19 *municipios*. The number of exclusive fuelwood users is estimated in 236,510, more than 30% of the total population. "Purhepechas" are the dominant ethnic group in the region, accounting for 14.1 % of the total population. A comprehensive survey about the dynamics of forest resources has been conducted over this area by Masera *et al.* (1998). Although the study is oriented at local industries that use forest products, it highlights the importance of fuelwood for the whole region. Based on this survey and the WISDOM results (Figure 20), we decided to develop an accessibility model over this specific area.

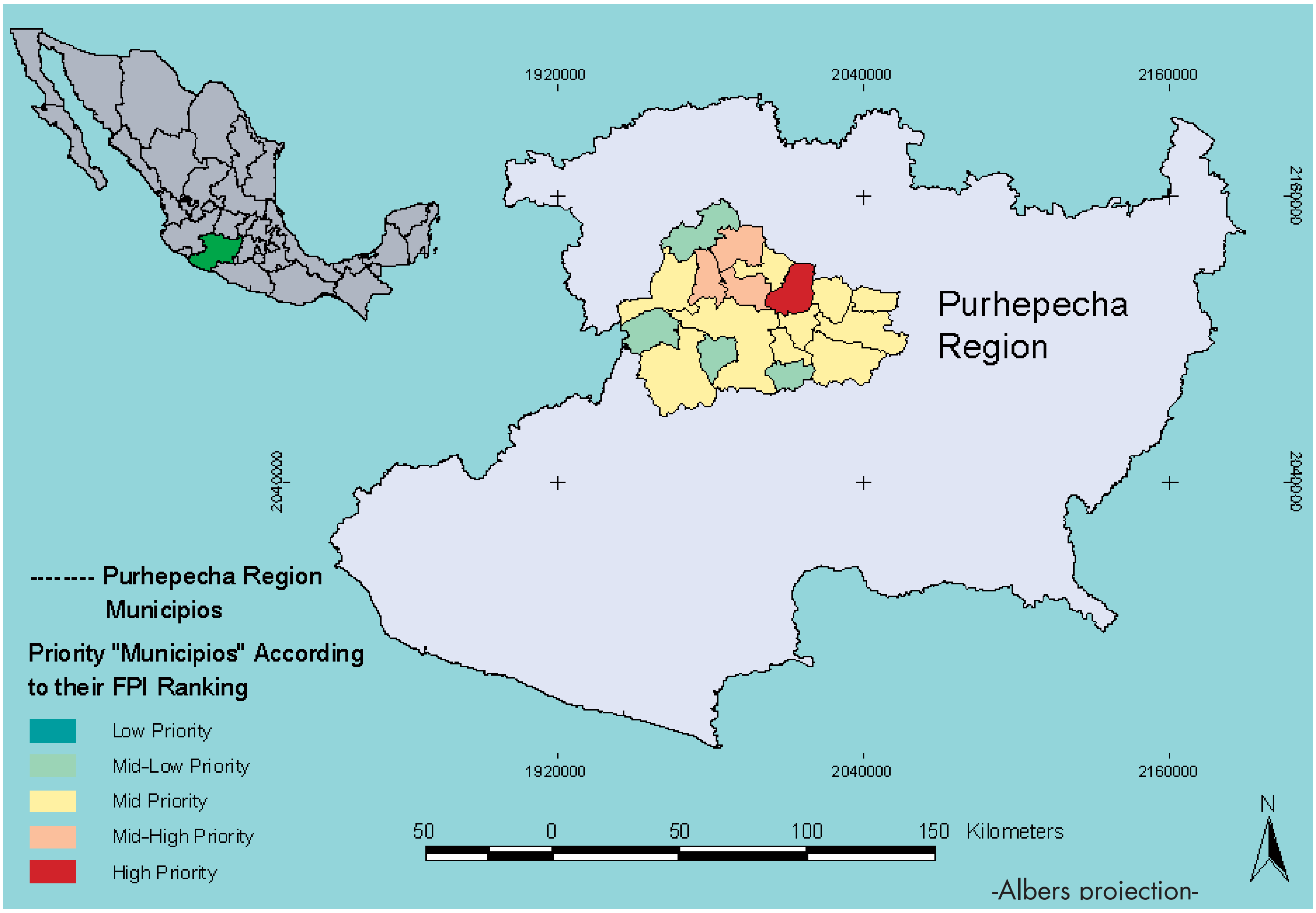


Figure 20. Priority *municipios* for the Purhepecha Region

Methods

The following assumptions were made to conduct the accessibility analysis:

- All human settlements censed by the National Census Bureau (INEGI) for the Purhepecha Region in the year 2000, in which at least one fuelwood user exist, were incorporated as starting points of fuelwood gatherers.
- Displacement velocities through the terrain are a function of the slope and the geographic barriers only.
- Only walking fuelwood gatherers, with or without draft animals, were considered.
- All fuelwood gatherers walk a maximum of 60 minutes, from their starting points and back. It should be noted that the actual gathering or cutting of fuelwood takes an extra time of one to three hours. Therefore, a round trip at a walking distance of 60 minutes actually means an overall trip of two to four hours for fuelwood collection. This is consistent with surveys conducted in the country (Masera, 1993; Del Amo, 2002). A second example of a two hour- walking round trip was also considered.
- The different forest land covers were unified as one target area.

Based on these assumptions, a method was developed, which is fully described on this section.

Estimation of the potential forest areas accessible to fuelwood users of the Purhepecha Region

Human settlements were incorporated into a Geographic Information System (GIS) of the Purhepecha Region, considering not only their cartographic position but also the number of fuelwood users by settlement. This information is used in the model as "starting points", from where fuelwood gatherers must begin their journey to the forest for gathering fuelwood.

As a parallel entry, a "time-distance" map was calculated based on a digital elevation map of the region. Access depends partly on the time needed to reach a certain point. Time is in turn a function not only of distance but of slope, particularly when considering walking people velocities. In this study we used the mean displacement velocities of walking fuelwood gatherers for different slopes to create a "time-distance" map (Table 14 and Figure 21).

Table 14. Mean displacement velocities of fuelwood gatherers according to slope angles

	Slope range				
	0° - 8.5°	8.5° - 16.7°	16.7° - 24.2°	24.2° - 35°	35° - 45°
Displacement velocity (seconds spent per meter walked)	0.8	1.2	2.1	4.5	9

Source: Adapted from a survey by Puentes (2002).

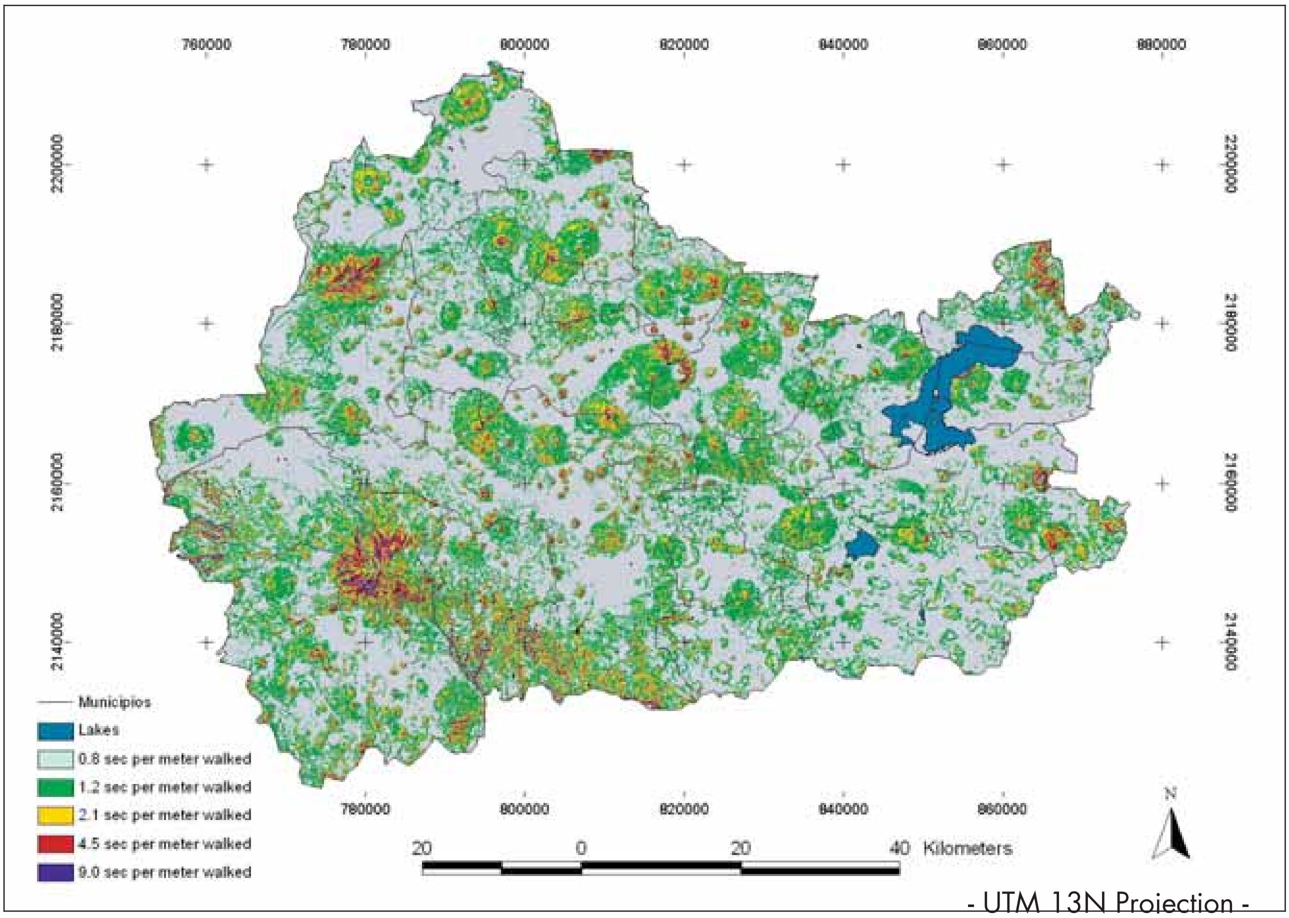


Figure 21. "Time distance" map

Buffers of 30 minutes radius (60 minutes round trip) and 60 minutes radius (120 minutes round trip) around each settlement were calculated by combining the human settlements map with the "time-distance" map. Notice that although buffers represent areas around settlements, the outer perimeters are defined by walking time limits (30 and 60 minutes radius) (Figure 22).

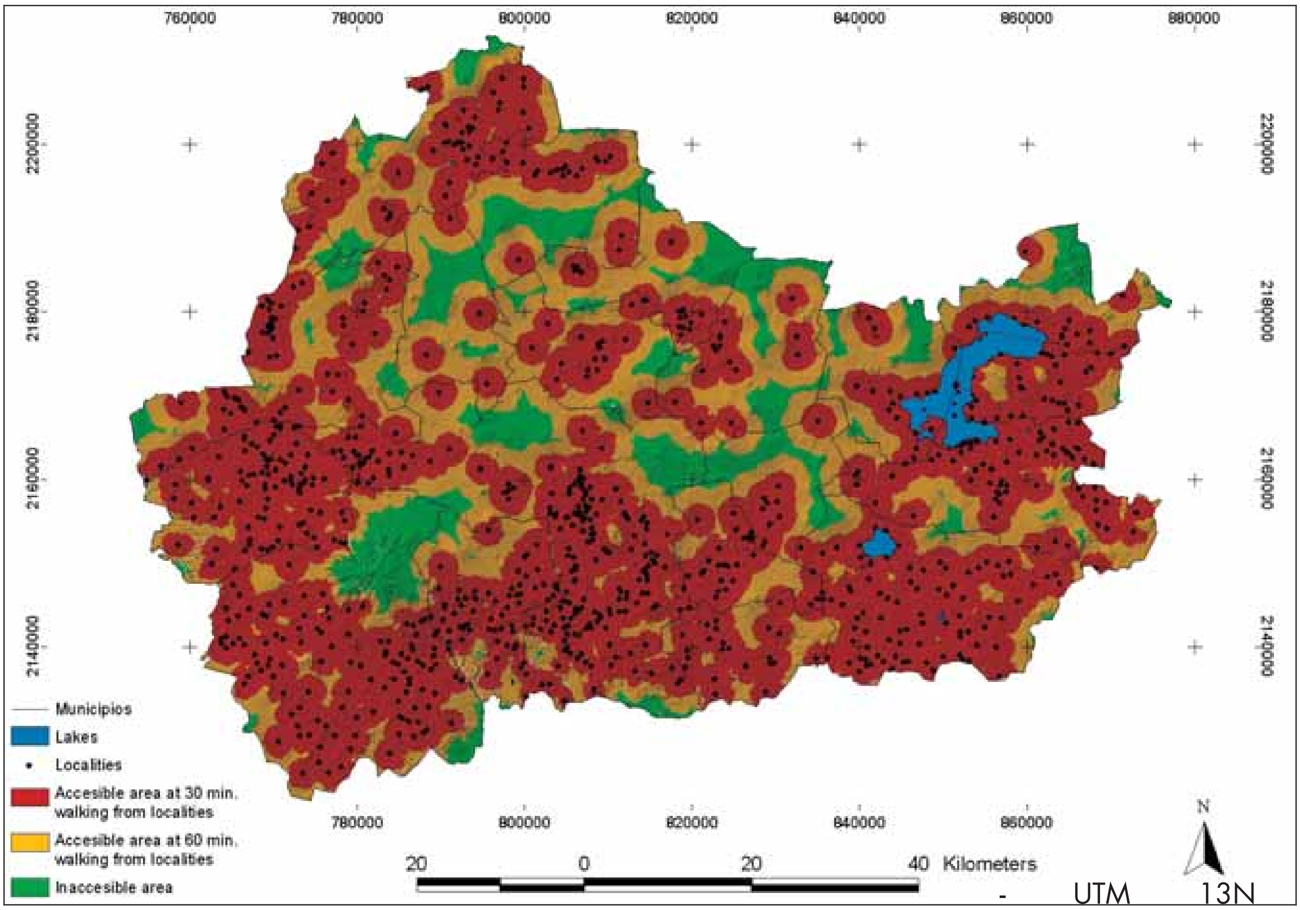


Figure 22. Buffers around settlements based on the "time-distance" map

The third parallel entry in the analysis was the forest map. As stated in the model assumptions, all forest classes were merged into one, so called the “target” area, or fuelwood supply area.

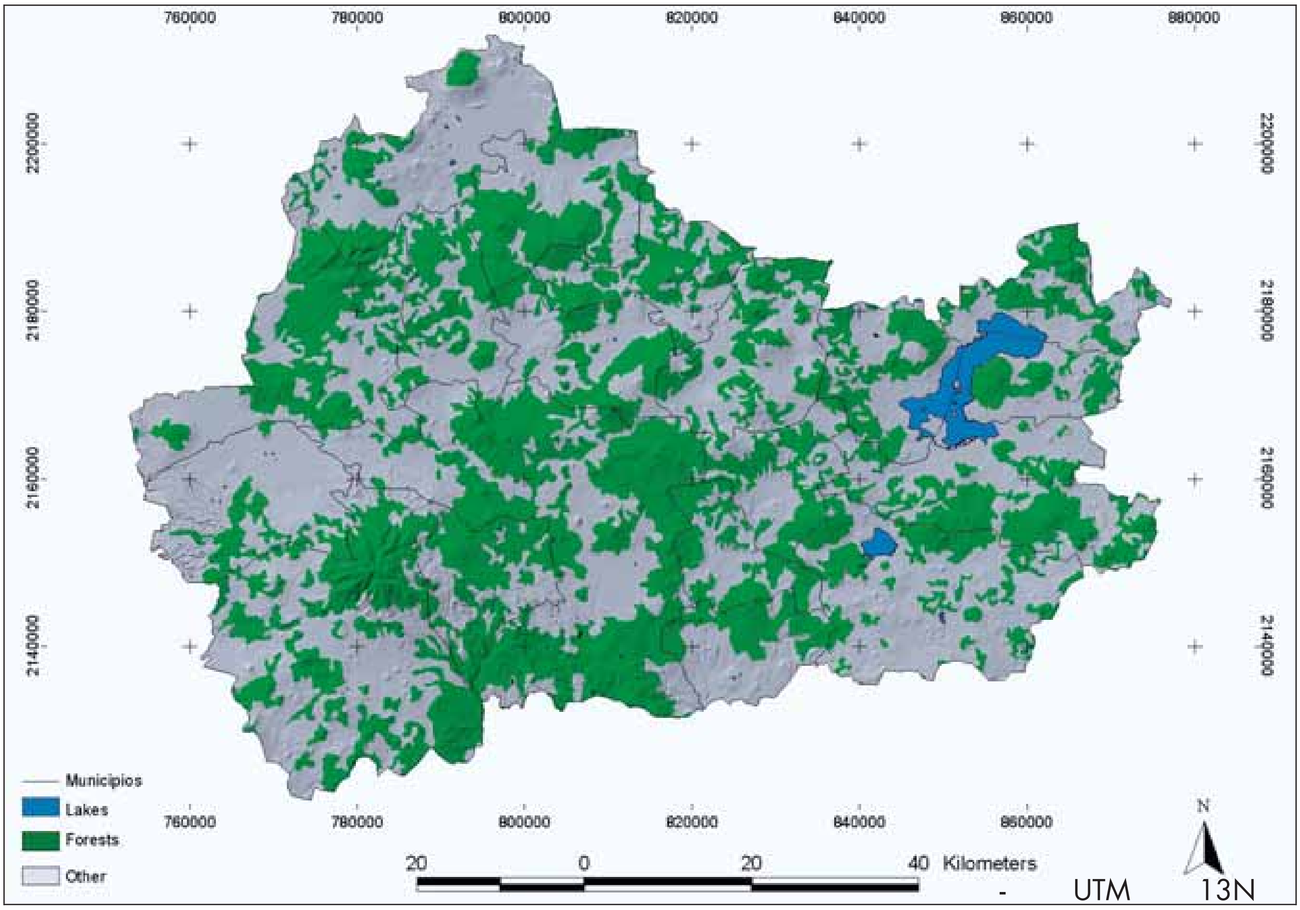


Figure 23. Forests cover of the Purhepecha Region, 2000

Finally, buffers were overlapped to this forest cover map of the Purhepecha Region. The resulting intersections were considered as those areas potentially accessible from settlements by walking fuelwood gatherers (Figure 25, Table 16)

Categorization of accessible forest areas according to the pressure exerted by local people's demand

As seen in Figure 22, accessible areas at a one-hour walking round trip from settlements, prior to the overlapping to the forest map, cover a major part of the entire Region. However, the population distribution through these localities is highly heterogeneous. As fuelwood demand is concentrated over more populous settlements and their closest forest areas, a new categorization of the already accessible forests, based on population density ranges, was made.

Circle areas of 3 Km radius around each settlement were selected. These areas were then divided by the number of fuelwood users in each corresponding locality so as to calculate their densities. All density circles where then overlapped with each other and the resulting intersections where considered as new density areas. A reclassification into four groups was then made considering this last map (Figure 24). Finally, the density range map was overlapped to the accessible forest area (Figure 25) for the identification of priority areas (Figures 26 and 27, Table 16).

It is important to remark that this type of analysis is aimed at classifying the accessible forests according to the estimated pressure from villages with different number of fuelwood users. Local surveys should be conducted in order to validate the areas at risk from fuelwood shortages identified with the proposed method.

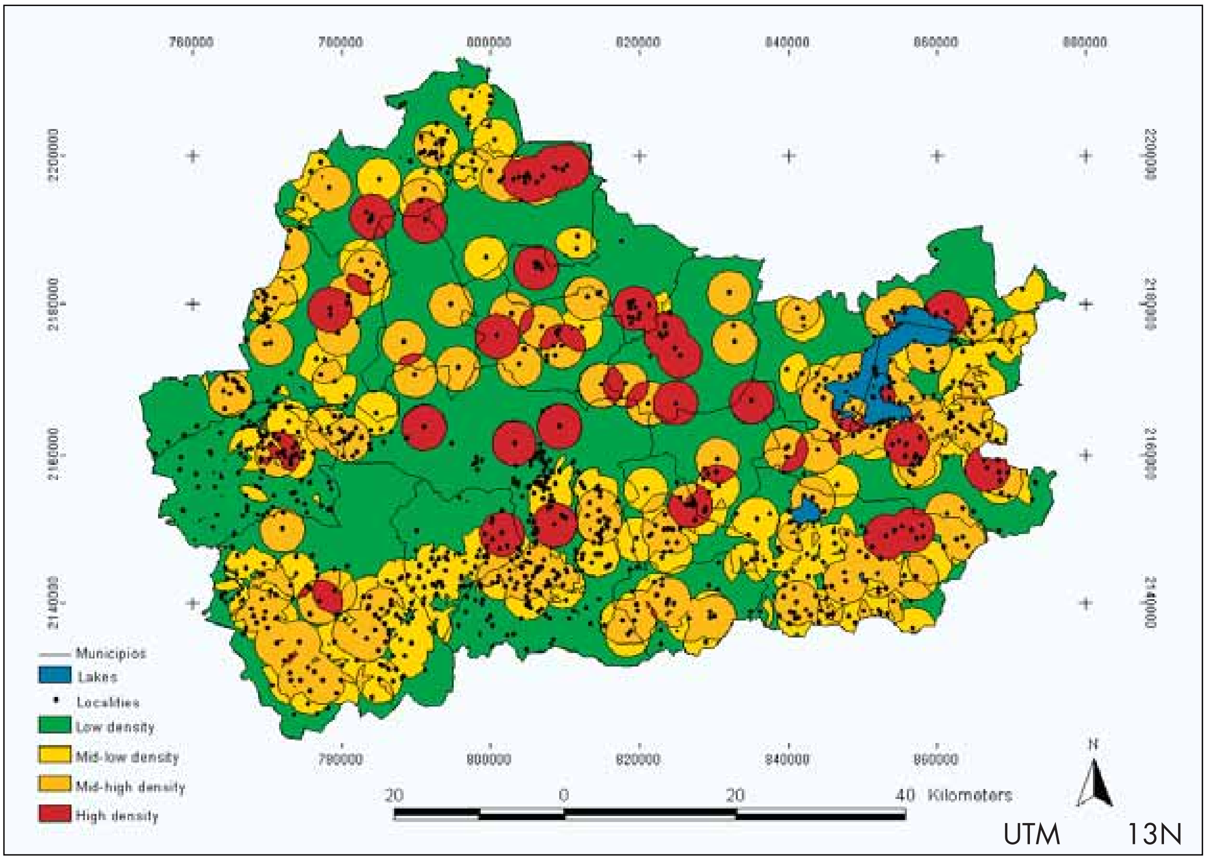
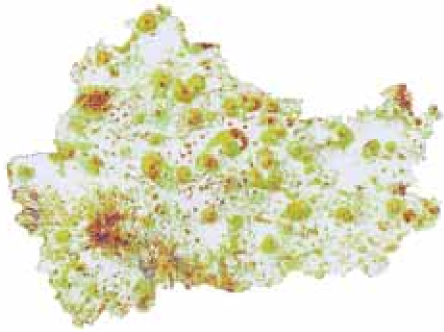
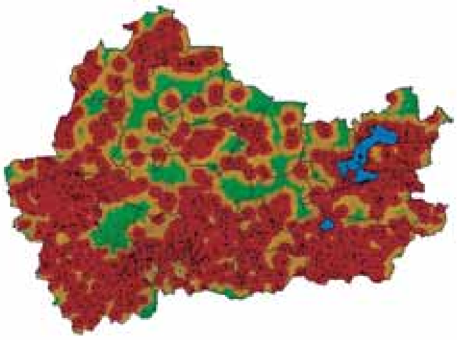
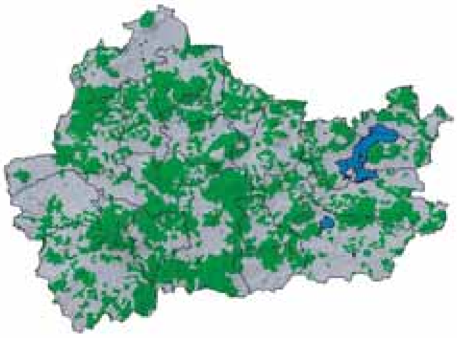
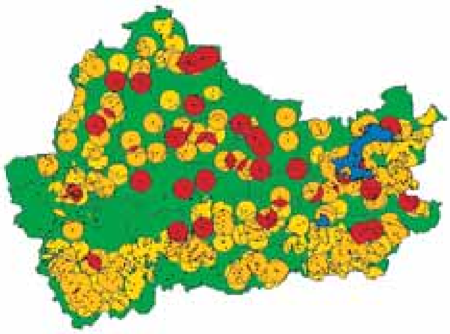


Figure 24. Density population map of the Purhepecha Region considering 3 Km radius circles around settlements

Table 15 gives a summary of the maps and general data needed to conduct the accessibility analysis presented in this report.

Table 15. Information used for conducting the accessibility analysis

Map	Description	Example
Starting points map	Corresponds to the starting points of fuelwood gatherers (e.g, isolated country households, small towns, and villages from the Purhepecha Region).	
Digital elevation model	A digital elevation model needs to be reclassified into those slope ranges that match with the displacement velocities classification. In our case, the elevation map was reclassified into five slope ranges: 0°-8.5°; 8.5°-16.7°; 16.7°-24.2°; 24.2°-35°; 35°-45°. See Table 14.	
Reclassified slope map or "time distance map"	A simple reclassification transforms the slope range map into a map resembling the five velocity displacement ranges. See Table 14.	
Buffers map	The outer perimeters of buffers were set as 30 minutes and 60 minutes walking following the displacement velocities shown on Table 14 and the reclassified time distance map shown on Figure 22. Note that a 30 minute radius buffer corresponds to a 60 minute round trip, without considering neither the time spent in the gathering of fuelwood itself.	

Map	Description	Example
Forest map	Forest cover classes were unified into one forest category namely “target” area or fuelwood supply area. See Figure 23.	
Fuelwood users density map	A density map using 3 km radius circles around each starting point. Further reclassification into few desired groups, considering the resulting intersection of densities is needed. See Figure 24.	

Data	Description
Displacement velocities	Displacement velocities of walking fuelwood gatherers according to few ranges of slope angles. We based our data on a field survey by Puentes (2002).
Fuelwood users density	Number of fuelwood users per locality shown over the starting points map. This information is used to calculate the fuelwood density map. See Figure 24.

Results

Approximately 40% of total forest area (120,867 ha) is accessible at a time-distance of 30 minutes. This value rises to 80% when considering 60 minutes buffers (241,757 ha) Table 16. Figure 25 shows the potential forest areas accessible to fuelwood extraction within the Purhepecha Region considering a 30 minute radius buffer around each settlement (red areas). Out of this range, under the model assumptions, the forest remains inaccessible for walking fuelwood gatherers (green areas).

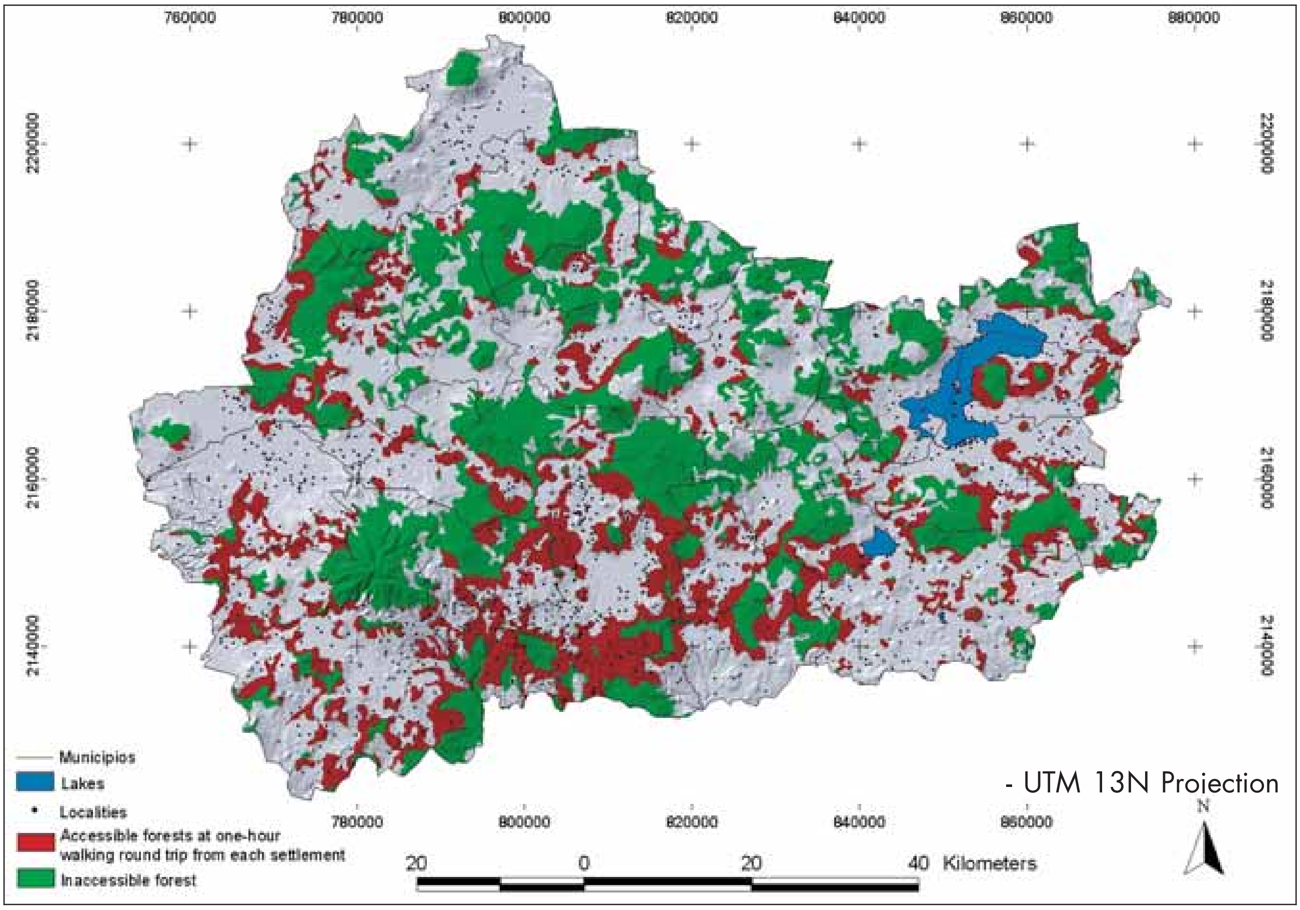


Figure 25. Accessible forest areas of the Purhepecha Region at one-hour walking round trip from each settlement

Table 16. Accessible forest areas of the Purhepecha Region by walking fuelwood gatherers, and further priorization according to four fuelwood users densities

	Area (ha)	Percentage
Total Forest Area of the Purhepecha Region	301,397 ha	100 %
Accessible forest areas at one hour walking round trip from each settlement.	120,867ha	40 %
Low density	38,490 ha	**31.9 %** of 40%
Mid-Low density	34,984 ha	**28.9 %** of 40%
Mid-High density	30,710 ha	25.4 % of 40%
High density	15,984 ha	**13.2 %** of 40%
Accessible forest areas at two hours walking round trip from each settlement.	241,757 ha	80 %

Figures 26 and 27 show the accessible forest areas for each density group. Red areas represent the highest priority sites, considered by the model as prone to degradation because of the pressure exerted by local fuelwood users. Priority sites sum almost 16,000 ha, corresponding to 13% of the region total accessible forest when considering buffers of one-hour. This percentage is reduced to 11% of the accessible forests when considering buffers of two hours. In these sites, specific actions such as forest restoration or multipurpose plantations may be relevant (Table 16).

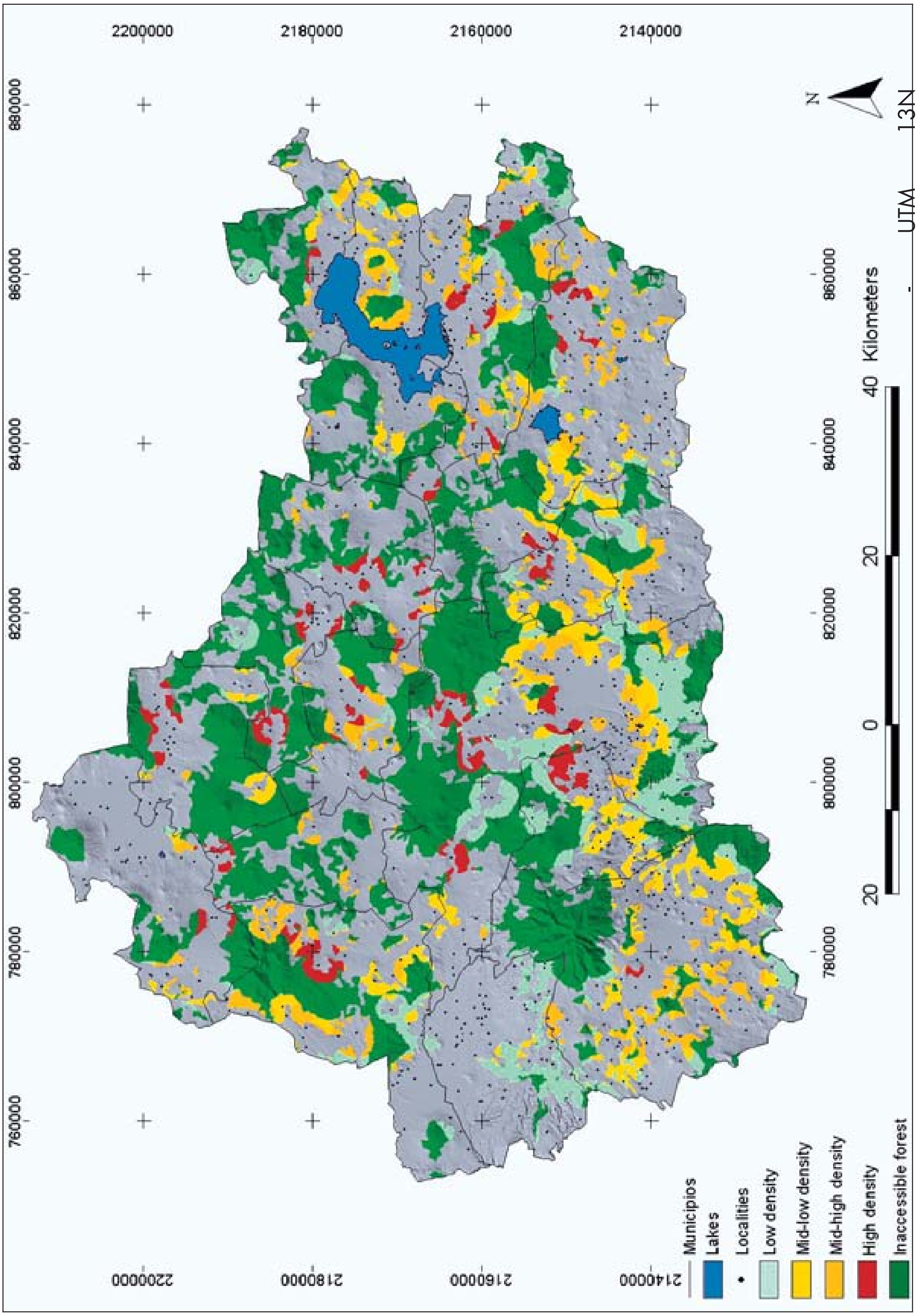


Figure 26. Accessible forest areas of the Purhepecha Region at one-hour walking round trip from each settlement, according to four fuelwood users densities

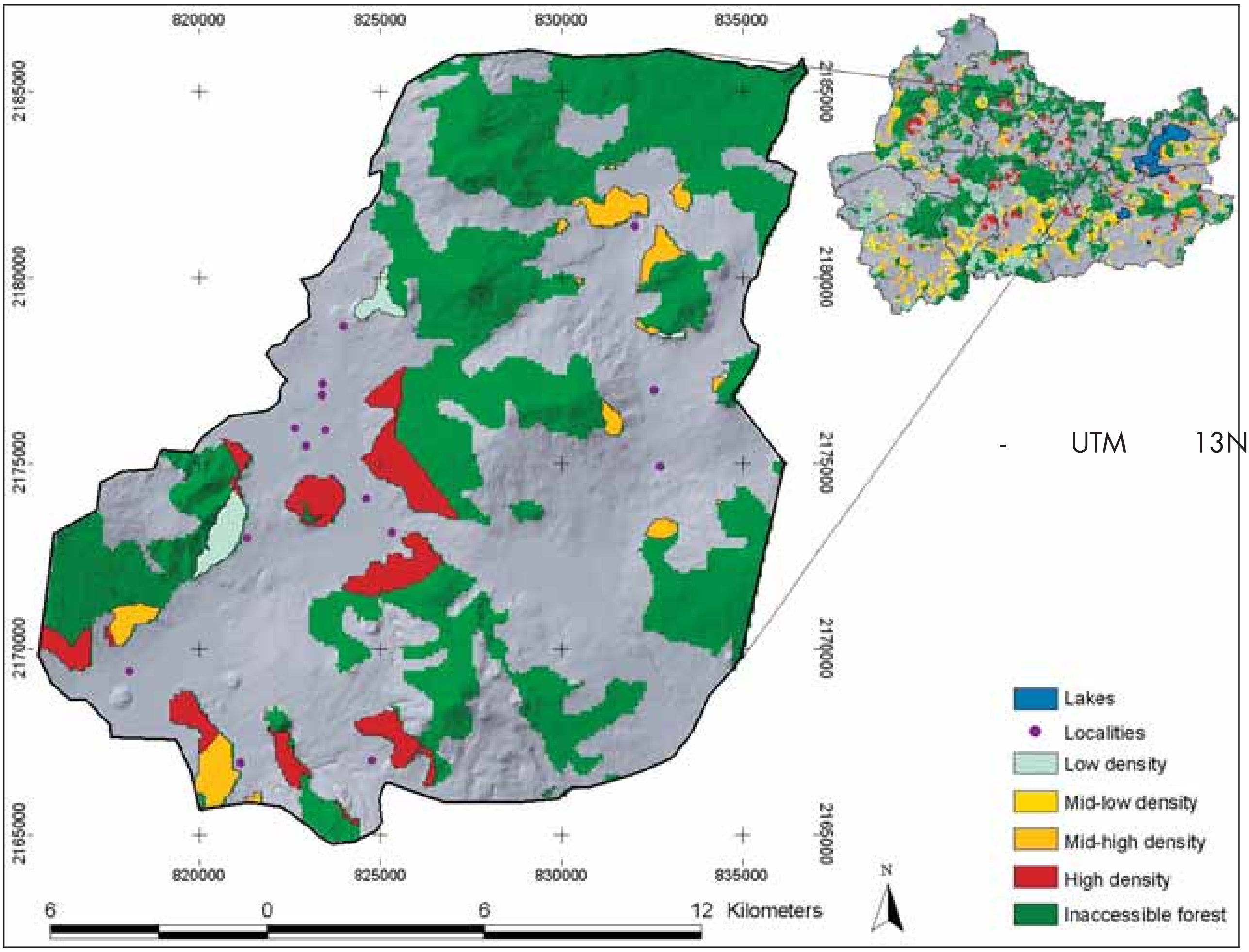


Figure 27. Accessible forest areas of “Nahuatzen”, a *municipio* in the Purhepecha Region, at one-hour walking round trip from each settlement, according to four fuelwood users densities

The accessibility analysis presented here is a good first step to further guide strategic planning into actual implementation. It helped to preliminary identifying concrete -spatial-explicit- areas where forest management or restoration activities directed to fuelwood production may be undertaken. Subsequent work is needed with local people in order to validate the analysis and also to select the concrete forest management options suitable to the specific conditions of each village.

Analytically, more sophisticated analyses of accessible forests may include the use of friction functions of velocity displacement according to land cover classes; fuelwood gatherers using motorized vehicles; data from land property and rights; fuelwood market dynamics; competition from small industrial woodfuel demand; and assigning woody biomass productivities by forest type.

5. Conclusions

Most developing countries have scarce financial and human resources for the design and implementation of appropriate policies and measures to promote a sustainable use of woodfuels. As shown by the Mexican example presented in this report, multi-scale assessments of woodfuel priority areas are an attractive option to focus government resources to critical areas -or fuelwood "hot spots"- where action is more needed. Within priority areas, multi-scale assessments further help to preliminary identify in a spatial-explicit fashion, those forest areas under greatest pressure from fuelwood harvesting.

The analysis conducted in Mexico confirmed that the fuelwood situation is very heterogeneous within the country; therefore broad generalizations about the impacts of fuelwood use are wrong. Much more effective policies and more efficient use of resources can be assured by focussing actions to priority areas. In the Mexican example, the analysis using WISDOM allowed the identification of 262 *municipios* out of a total of 2,401, leading to a reduction of target areas of almost 90%.

Following the multi-scale hierarchical framework, an accessibility analysis was conducted over the Purhepecha Region (a region composing a cluster of priority municipios) to further define and spatially explicitly identify areas under pressure from fuelwood harvesting. In the case analyzed, 40% of the forest area is physically accessible for fuelwood gatherers at one-hour walking round trip (equivalent to an overall fuelwood collection trip of two to four hours), and 13% of it is estimated to have the highest pressure from fuelwood gatherers.

Operatively, we established a comprehensive and flexible GIS platform that permits a readily spatial representation of *municipios*, according to a set of predefined criteria concerning environmental, social or economic issues. In addition to identify priority areas, the GIS platform can be used for a variety of applications: for example, to develop future scenarios of the fuelwood situation in the country, to help identify population at risk from indoor air pollution by fuelwood burning within households, or to establish target areas for forest management of restoration efforts oriented to fuelwood production. In our case, we used the WISDOM database to preliminary estimate the CO_2 emissions coming from the non-sustainable use of fuelwood in Mexico. The analysis showed emissions in the order of 1.9 to 3.8 million ton of CO_2 per year when considering total and accessible forests, respectively. This range is lower than previous estimates conducted using more aggregated information.

The following actions are needed to improve the present analysis:

- To validate the results of "priority municipios" and forest areas under fuelwood pressure on the field.
- To expand the demand module in order to include: non exclusive fuelwood users (i.e. households that simultaneously use fuelwood and LPG); other uses of woodfuels (such as the demand for small industries), and demand from timber.
- To expand the supply module, with more detailed estimates of forest biomass productivity according to forest classes, forest status (degraded or not) and geographical location within the country
- To conduct a more detailed accessibility analysis including other physical, and very particularly legal and social constrains.