Energy for Sustainable Development 19 (2014) 39–46

Contents lists available at ScienceDirect

Energy for Sustainable Development

Spatial and temporal projection of fuelwood and charcoal consumption in Mexico

Montserrat Serrano-Medrano [a,b,*], Teresita Arias-Chalico [c], Adrian Ghilardi [d], Omar Masera [b]

[a] Facultad de Ingeniería, Universidad Nacional Autónoma de México, D.F., México
[b] Centro de Investigaciones en Ecosistemas (CIECO), Universidad Nacional Autónoma de México, antigua carretera a Pátzcuaro 8701, Morelia, Michoacán 58190, México
[c] Naturaleza y Desarrollo A.C., Querétaro, México
[d] Centro de Investigaciones en Geografía Ambiental (CIGA), Universidad Nacional Autónoma de México, antigua carretera a Pátzcuaro 8701, Morelia, Michoacán 58190, Mexico

ARTICLE INFO

Article history:
Received 6 February 2013
Revised 10 October 2013
Accepted 25 November 2013
Available online 11 January 2014

Keywords:
Fuelwood
Charcoal
Spatiotemporal projections
Fuel stacking
Mexico

ABSTRACT

Fuelwood and charcoal are fundamental fuel sources for the residential sector in Mexico. A Business-As-Usual (BAU) projection by means of a spatially-explicit approach was developed to assess national fuelwood and charcoal consumption for the period 2010 to 2030. The model was calibrated for 1990–2000 and 2010 projections were validated against official census data for the same year. For 2010, we estimated that fuelwood and charcoal accounted for 48% of total residential energy demand. The projection of fuelwood consumption declined slightly from 19.4 Mt (dry matter) or 310 PJ in 2010 to 18.4 Mt or 294 PJ by 2030. An important future growth of mixed fuelwood–LPG users is expected pointing out that fuel stacking rather than fuel switching out of fuelwood would prevail. Charcoal consumption increased from 3.8 Mt (dried wood equivalent) or 61 PJ to 4.7 Mt or 75 PJ during the same period. A relevant outcome of the spatial assessment was the uncovering of large variations in fuelwood and charcoal use trends among spatial units (municipalities), hidden by the national aggregated trends. This opens up the opportunity to analyze regional variability to identify priority areas regarding fuelwood and charcoal use.
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Introduction

Biomass energy provided about 10.2% (50.3 EJ) of the world total primary energy supply in 2008 (Chum et al., 2011). Of these 50.3 EJ, traditional use of fuelwood along with other biomass residues mainly for cooking and heating in the poorer developing countries, contributed 30.7 EJ (Chum et al., 2011). If the informal economy sectors are included, solids biofuels, particularly fuelwood and charcoal, may contribute almost 14% of total primary energy supply globally and as much as one-third in developing countries (FAO, 2011). Furthermore, some 2.7 billion people – about 40% of the world's population – depend on biomass as their main source of energy supply. If current trends continue, the number of people relying on biomass to meet part of their energy needs, will reach 2.8 billion in 2030 (IEA, 2010). Socioeconomic scenarios indicate that reliance on fuelwood to meet energy needs is expected to continue for several decades (IEA, 2010).

Globally, there is a lack of detailed statistics on fuelwood and charcoal consumption, their spatial distribution and future projections. This is due to several factors such as the fact that a) a large proportion of fuelwood is harvested and used in rural areas without entering the formal markets and statistics, and, b) the commercial production of fuelwood and charcoal in many countries is done illegally, making the acquisition of reliable statics difficult (UNECE/FAO, 2012a). Some case studies have shown an underestimation of fuelwood consumption at national levels (Drigo, 2004, 2009; Drigo et al., 2007; Ghilardi et al., 2007). Detailed knowledge of fuelwood and charcoal use-patterns is challenging due to their dispersed nature (Arnold et al., 2003). Using aggregated data usually hides the inherent variability associated to fuelwood and charcoal spatial patterns (Arnold et al., 2003, 2006; Foley, 1987; Leach and Mearns, 1988; Lele, 1993; Mahapatra and Mitchell, 1999; Masera, 1994; RWEDP, 1997, 2000). A reliable, spatially explicit biomass fuels database is therefore a fundamental component for policy-making effectiveness (UNECE/FAO, 2012b; Ghilardi et al., 2009).

In Mexico, despite sustained government efforts to encourage the use of “modern” fuels in the residential sector, for example by subsidizing LPG, fuelwood still supplied 34% of the country's residential energy use in 2009 according to official statistics (SENER, 2009) and charcoal is still important as a complementary residential fuel. In Mexico, fuelwood is mostly used for cooking in traditional devices such as open fires and such use is concentrated in rural and semi-urban areas (Díaz, 2000). Fuel stacking is also very common (Masera et al., 2000). On the contrary, charcoal consumption is mostly located in urban localities. However, little is known about the country patterns of fuelwood and charcoal use and their future trends.

Deriving spatial estimates and future trends of fuelwood use is relevant given its social, economic and environmental impacts. For instance, indoor air pollution caused by the use of open fires in Mexican villages is several times higher than the level recommended by the World Health Organization and causes severe health problems,

* Corresponding author. Centro de Investigaciones en Ecosistemas (CIECO), Universidad Autonoma de Mexico, Antigua carretera a Patzcuaro 8701, Morelia, Michoacan 58190, Mexico.

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http://dx.doi.org/10.1016/j.esd.2013.11.007

Table 1
Fuelwood per capita consumption for exclusive users per macro-ecological region.

Ecological macro-region	Fuelwood consumption (tDM/cap/yr)
Tropical forest	0.73
Deciduous forest	0.91
Temperate	1.10
Semi-arid	0.55
Wetland	0.91
Others	0.55

Source: Adapted from Ghilardi et al. (2007).

particularly in women and children (Armendáriz et al., 2008; Romieu et al., 2009).

A first approach to explore the spatial patterns of fuelwood use, the Woodfuels Integrated Supply/Demand Overview Mapping (WISDOM) methodology was developed by Masera et al. (2003, 2006). WISDOM is defined as a "spatial-explicit method for highlighting and determining priority areas of intervention and supporting wood energy/bioenergy planning and policy formulation". WISDOM integrates available data on fuelwood and charcoal demand and supply into indicators that are used to identify priority areas in terms of fuelwood demand trends, and available resources. This method was conceived as a partnership between the Wood Energy program of the FAO products forest service (FOIP) and the Ecosystems Research Centre (CIECO) of the National University of Mexico (UNAM). Currently more than 23 case studies covering sub-national studies, countries and regions in Europe, Latin America, Asia and Africa have been conducted (Drigo, 2009).

The aim of this study is to assess fuelwood and charcoal consumption patterns in Mexico from 2010 to 2030 at the county (municipality) level in a BAU scenario and based on the WISDOM approach in order to: 1) obtain more realistic estimates of the current total use of fuelwood and charcoal in the country and project trends until 2030; and 2) examine regional differences, highlighting priority action areas regarding fuelwood and charcoal consumption.

Methods

Estimation of fuelwood consumption

Total fuelwood annual consumption (CT) was estimated as the product of per capita consumption (Cpc) and saturation (S) (percentage of users) times total population, considering two types of users: exclusive fuelwood users and mixed fuelwood–LPG users. The analysis was done at the county (municipality) level, with a total of approximately 2500 units of analysis. Mathematically total fuelwood consumption per county was calculated according to Eq. (1)

$$CT_k = \sum(C_{Ek} + C_{Mk}) \quad (1)$$

Where CT_k is total fuelwood consumption in tonnes of dry matter per year (tDM/year), C_{Ek} is fuelwood consumption per county attributable to exclusive users and C_{Mk} is the fuelwood consumption per county attributable to mixed fuel users.

As stated, C_E and C_M are calculated as follows:

$$C_{E_k} = Cpc_{E_k} \times S_{E_k} \times P_k \quad (2)$$

and

$$C_{M_k} = Cpc_{M_k} \times S_{M_k} \times P_k \quad (3)$$

where Cpc_{Ek} and Cpc_{Mk} are fuelwood annual consumption per capita for exclusive and mixed use per county "k" respectively; S_{Ek} and S_{Mk} are fuelwood saturation for exclusive and mixed use per county respectively and P_k is total population per county.

Estimation of fuelwood use saturation

Fuelwood saturation for exclusive users was defined as the rate between dwellings using fuelwood to cook over total dwellings per county and it was obtained based on the National Bureau of Statistics (INEGI) county census data. Data regarding population; average inhabitants per dwelling; and dwellings using one of the following fuels for cooking: fuelwood, LPG, charcoal, electricity or oil for the years 1990 and 2000 were used to obtain number of exclusive fuelwood users. Since Díaz (2000) found that between 90 and 100% of fuelwood residential use in México is for cooking, it is assumed that dwellings using fuelwood for cooking is a good estimation of families using this fuel as a residential fuel.

Fuelwood saturation for mixed users (i.e. users of both fuelwood and LPG) was estimated as a function of fuelwood saturation for exclusive users per county. Based on case studies, Ghilardi et al. (2007) estimated that mixed fuel users accounted on average for 25% of exclusive users. Hence, we assumed that in addition to exclusive users, 25% of households in the county are mixed users. For counties where fuelwood saturation for exclusive users was above or equal 75%, fuelwood saturation for mixed users was estimated subtracting exclusive fuelwood users to the total number of users in the county. For counties where fuelwood saturation of exclusive users was less than 75%, fuelwood saturation for mixed users represented an additional 25%.

Saturation for exclusive users is calculated as follows,

$$S_{E_k} = \frac{U_{E_k}}{D_k} \quad (4)$$

where S_{Ek} is the saturation of exclusive users per county, U_{Ek} is the number of exclusive fuelwood users, and D_k is the total population in the county.

Estimation of fuelwood consumption per capita

Per capita fuelwood consumption, defined as the tonnes of dry matter (tDM) of fuelwood consumed per capita per year, was obtained for different regions by means of an exhaustive literature review for Mexico (Díaz, 2000; Masera et al., 1997; Puentes, 2002; Sánchez Gonzales, 1993; Tovar, 2004). Following the approach outlined by Ghilardi et al. (2007) average per capita consumption values for exclusive fuelwood users were obtained for each of the 5 main ecological areas in Mexico (Table 1) and then adjusted by minimum annual average temperatures with values ranging between 1 (for mild cold regions) and 1.7 (for cold regions).

To estimate per capita fuelwood consumption for exclusive users per county per year a weighted average value according to the proportion of each main ecological area within each county was used. Hence, per capita fuelwood consumption for exclusive users was estimated according to Eq. (5).

$$Cpc_{E_k} = \left(\sum_{i=1}^{5} Cpv_i \times A_i \times F_T\right)_k \quad (5)$$

where Cpc_{Ek} is the weighted annual per capita consumption for exclusive users per county, Cpv_i is the annual per capita consumption per main ecological region i per county k, A_i is the proportion of the main ecological area i in a county k, and F_T is the adjustment factor per minimum temperature per county k.

Table 2
Evolution of fuelwood users and consumption 2010–2030.

Year	Exclusive users	Mixed users	Total users	Exclusive use	Mixed use	Total use
	(Million users)			(MtDM/year)		
2010	16.8	5.7	22.5	16.6	2.8	19.4
2020	16.0	6.3	22.3	15.8	3.1	18.9
2030	15.3	6.7	21.9	15.1	3.3	18.4

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