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Research paper

Differences in consumption rates and patterns between firewood and charcoal: A case study in a rural area of Yedashe Township, Myanmar

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ABSTRACT

Firewood and charcoal are the main energy sources in developing countries, but much fewer quantitative data have been collected for charcoal consumption. This study compared firewood and charcoal consumption rates and patterns in a rural area of Yedashe Township, Myanmar. Household interviews were conducted for randomly selected households, resulting in 147 firewood users and 34 charcoal users. Forest inventory data was used to estimate forest area needed to meet woodfuel demand. Average per capita consumption rates were 780 and 280 kg year^{-1} for firewood and charcoal, respectively. Distinct differences were found in fuel sources and sizes; only 16% of firewood was collected from living trees in natural forests, of which 72% was from trees < 10 cm diameter, whereas 100% of the wood for charcoal was harvested from this source from 10 to 40 cm diameter. The per capita demand for forest-originated green-wood with ≥10 cm diameter was 1190 kg for charcoal, which is 33 times more than that for firewood. The forest area needed to meet the per capita demand for charcoal was 820 m^2, which is 23-fold larger than that for firewood. The estimated forest area to meet the current woodfuel demand from the rural population was 3430 ha year^{-1}, being 3.0% of the forest area within the distance < 5 km from the villages. This demand of forest area for woodfuel supply can be increased up to 15,440 ha (13%) along with increasing shares of charcoal users, resulting in a high risk of further forest degradation.

1. Introduction

Woodfuel is the oldest energy source. Over two billion people in developing countries are still dependent mainly on woodfuel for cooking and heating [1]. Firewood and charcoal are the main forms of woodfuel. In many developing countries, firewood users are dominant in rural areas while charcoal is commonly used in urban areas [2–5]. Along with the socioeconomic development and urbanization, the increase of charcoal production [6–8] and the energy transition from firewood to charcoal [2,9,10] are expected and so it is important to evaluate the environmental and socioeconomic impacts of changes in the energy sources [11–18].

Compared with firewood, charcoal is a relatively clean, convenient fuel [19]. However, it is perceived that charcoal is much more harmful than firewood, given that mostly dead wood or small branches are collected as firewood [20–22], while charcoal is produced from live trunks or limbs [23,24]. An almost total dependence on natural forests for charcoal production and perceived unsustainable harvesting are the primary reasons why many stakeholders are concerned about the environmental impact of charcoal production [25]. Studies showed that the impacts of charcoal production on forests largely depend on the degree of forest clearing, which varies considerably among counties and even sites within each country, and the spatial resolution of the analysis [25,26]. In most forests, the process of charcoal production can reduce standing woody biomass through selective harvesting of trees [4]. For example, Kiruki et al. [27] suggested that high charcoal making intensity has major effects on dry woodlands in Kenya and is leading to changes in species composition and diversity, whereas impacts of low to

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moderate rates of charcoal production are less pronounces. In contrast, clear-cutting for charcoal can occur, particularly on the 'frontier" of charcoal production around large cities [4]. Some studies simulated areas of deforestation under the assumption that clear-cutting was conducted for charcoal production [10,25,28].

Despite such increasing concerns and perceptions on impacts by charcoal production, there is a dearth of quantitative research on charcoal consumption and its determinants in developing countries, especially compared with the large body of literature on firewood production [19]. In addition, only limited studies directly compared consumption patterns between firewood and charcoal [29–32]. Therefore, it is not well understood how firewood and charcoal consumption differently affect forests and how the shift from firewood to charcoal impacts forests within the same region.

In Myanmar, almost 95% of the country's population depends on traditional solid fuels such as wood and rice husks for cooking and heating, and it was estimated that 70% of all primary energy consumption in 2009 came from woodfuel [5]. Firewood is the most common energy source for household use in rural areas, while charcoal use is dominant in urban areas [5]. Thus, like other developing countries, it can be assumed that charcoal users would be increased under urbanization and socioeconomic development in the future. Studies also indicated that firewood collection and/or charcoal production are one of the causes of deforestation in Myanmar [33–37]. However, none of these studies showed data of woodfuel consumption rates and patterns, and supply and demand potentials of woodfuel are still not clear in Myanmar.

In this study, we compared consumption rates and patterns between firewood users and charcoal users in a rural area of Myanmar. This study aimed to evaluate differences in consumption rates, factors affecting these rates, fuel sources, and preferred tree sizes and species between firewood and charcoal users. We also used forest inventory data to estimate potential supply of woodfuel and then to discuss how firewood and charcoal consumption have different impacts on natural forests.

2. Materials and methods

2.1. Study area

Our surveys were conducted in 16 villages of Yedashe Township, Bago region, Myanmar (Fig. 1). Yedashe Township has an area of 2618.7 km^2, approximately 76.6% of which is covered with forests, based on the internal report in 2014 from the Forest Department of Myanmar. The majority of the forests occur in the western part of the township, and there is a small forested area in the eastern part. The climate is a tropical monsoon climate, and the average annual rainfall and temperature are approximately 2000 mm and 32 °C, respectively.

According to 2014 National Census results, the population and number of households in the township are 213,593 and 50,527, respectively, and 88.6% of the people live in rural areas. The average household size is 4.09, which did not differ significantly between urban and rural areas. The average population density is 81.5/km^2. Most of the forests in this area are state-owned, while private forest plantations account for a small portion of the forests. Generally, most of the villages are located near and along transport routes, and they are more densely distributed in the eastern part of the township, which is located primarily on a plain. For the people living in rural areas, forests are the main resources of energy because most of the villages are unable to access electricity. Traditionally, people collect firewood from state-owned forests.

2.2. Household survey

We selected 16 villages along the roads for the household survey to cover villages with different levels of accessibility to the forest, as shown in Fig. 1. For each village, households were selected randomly, resulting in a total of 181 households comprising 147 firewood users and 34 charcoal users. The surveys were conducted twice; the first in February 2014 for 40 firewood users and the second in December 2014 for the other users. These households used only either firewood or charcoal. This sampling intensity covered approximately 10% of the total number of households in the 16 surveyed villages. The interviews were based on semi-structured questionnaires focusing on household sector energy uses only. The questionnaires were linked to a family member, income, woodfuel consumption, stove types, and cooking frequency, which can influence the amount of woodfuel consumption. Additional variables, such as the species and sizes of trees used for firewood, whether dead or green wood was collected for firewood, and the sources of firewood, were included in the questionnaires. Among the 147 firewood users, the 40 users during the first survey were not interviewed for income, species and sizes, because the first survey was conducted just under the narrower scope. The 2 users among the rest 107 users had no idea about the sizes. The firewood sources were classified into four categories (natural forest, private plantation, agricultural farm and buying) and the respondents (n = 107) answered the fraction of each of the four categories they sourced from. For each source except for buying, the fraction of dead or green wood was also asked. These respondents also listed species that they used for firewood. The firewood sizes were classified into four classes (≤5.0 cm, 5.1–10.0 cm, 10.1–20.0 cm, 20.1–30.0 cm and 30.1–35.0 cm) and the respondents (n = 105) answered the fraction of consumption among the size classes. It was difficult for the respondents to answer a specific range of size, and so we showed actual wood samples with different size classes to them during the interviews.

Five additional respondents who produce charcoal for income were interviewed in December 2014. Emphasis was given to the sizes and species of trees used in charcoal production, the sources of wood, and the method of charcoal production. A group discussion was also conducted in December 2015 to classify species into four grades in terms of charcoal production: grade 1 is the best quality species for charcoal, followed by grades 2 and 3, while grade 4 comprises species that are not used for charcoal production.

To estimate the amount of woodfuel consumption, two different measurements were used: measuring the user-stated amount and the actual amount for daily consumption. To measure the user-stated amount, the main cooks were requested to show how much woodfuel they thought would be consumed daily, and then the interviewer weighed and recorded the woodfuel used for all 181 households. Measurements of actual consumption for one day were conducted using a weight survey method [38,39] in 100 households that were selected from the 147 firewood users and 34 charcoal users. During the course of the interviews, the interviewer weighed some woodfuel, which was the amount more than the main cook's answer about their daily consumption, and requested the cook to use the woodfuel for one day's cooking. The following day, the interviewer visited those households again, measured the remaining woodfuel, and calculated the actual daily consumption. Then, the daily consumption was converted into annual consumption. Woodfuel weights (in kg) were recorded under air-dried conditions when the available firewood in the household was ready for use.

Additionally, to determine the solid wood volume of the consumed woodfuel, we measured the stacked volume and weight of firewood in 43 randomly selected households. Then, we converted the stacked volume into the solid volume (m^3) using a conversion factor applied by the Forest Department of Myanmar (1.0 m^3 stacked volume = 0.66 solid m^3). These measurements and the conversion factor resulted in 710 ± 34 kg (mean ± standard error) of air-dried firewood per 1.0 m^3 of solid wood. This value is very close to the 700–720 kg/m^3 of solid volume that was estimated by the United Nations Food and Agriculture Organization (FAO) [40] as average values for tropical species. The FAO [41] reported that the conversion factor for charcoal weight and