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Factors influencing use of fuelwood and its environmental impacts in Tapanuli Utara regency, North Sumatra

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Abstract. Deforestation and forest degradation, after burning of fossil fuels, is considered as the second leading cause of anthropogenic greenhouse emissions (accounting for over 17% of global carbon dioxide emissions) and has become an important issue concerning climate change mitigation. The provision of wood energy is generally thought to be a major contributor to forest loss. In Indonesia, more than half of the rainforest there, the third-largest swath in the world, has been felled in just a few years. Furthermore, permission has been granted to convert the majority of what remains into palm or acacia plantations. The logging and burning of forests to clear land for cultivation has made Indonesia one of the largest emitters of greenhouse gases. Therefore, the objective of this study was to assess the current level and influencing factors of the use of fuelwood among the rural population as well as the consequent environmental impacts in the target area in North Sumatra. The questionnaire survey using randomly selected households (n = 196) was administered in Tapanuli Utara regency from July to August 2014; followed by several field visits from August to September 2016. Obtained data were analysed with descriptive statistics and cross tabulation. The results indicate that fuelwood is a significant source of energy in the target area. For 31% of respondents it is the major energy source and for 64% it is a supplementary source. The high rate of use of wood as fuel corresponds to the poor financial situation of respondents and the easy accessibility of wood, but only from the surrounding area (own garden or adjacent land). Wood resources are often very distant (on average over 1,000 metres) as a consequence of high deforestation. This study reveals that there is a non-sustainable trend of forest conversion resulting in high land degradation in Tapanuli Utara regency.

Key words: rural household; energy sources; Indonesia; Developing countries.

INTRODUCTION

In the developing world, biofuel is widely applied for energy production (Barnes et al., 2005; Demirbas, 2009) and has the potential to secure the planet's future energy needs (Demirbas, 2009). The increase in population and income levels combined with increased per capita energy consumption requires energy production to keep pace with economic growth (Reddy, 2016).

Indonesia itself houses the most extensive rainforest cover in all of Asia; however its future is unsecure, as there is rapid transformation of these lands in order to accommodate increasing population and growing economy. Ensuring sufficient energy resources is a future issue that requires the attention of all the world's countries, because the well-being of humans in modern times is closely linked to the quantity, availability and quality of energy used (Hasan et al., 2012; Kimaro & Lulandala, 2013). In the case of Indonesia, the largest economy in Southeast Asia (Gunningham, 2013), sufficient energy supply is a very important factor in promoting further development (Hasan et al., 2012). The strong economic and population growth of the country and the development of the industrial sector are causing an ever-increasing demand for energy. From 1980 to 2010, total energy production rose 2.8 times, while consumption rose almost fivefold (Mujiyanto & Tiess, 2013). In 2010, approximately 96% of Indonesia's total energy consumption was covered by non-renewable energy sources – fossil fuels. Renewable resources, in particular geothermal and hydroelectric power, constituted about four percent; a very small proportion compared to other countries (Hasan et al., 2012). Given the fact that Indonesia is still energy dependent on the use of fossil fuels, with current oil and gas supplies estimated at 23 years and 52 years (MEMR, 2010), it is in the national interest to diversify the share of energy towards new and renewable sources which ensure energy self-sufficiency and autonomy (Ibrahim et al., 2010). It must be highlighted that the use of traditional biomass energy sources, which are used extensively in Indonesia, has many negative effects (Gurung & Oh, 2013), both social and environmental (Kimaro & Lulandala, 2013; Gunningham, 2013). Because the collection of fuelwood is time and labour intensive, and is mostly carried out by women (Grassi et al., 2015), it is also associated with gender equity issues (Gurung & Oh, 2013). Such consequences of women´s time allocation due to the fuelwood collection have already been discussed in the work of Kumar and Hotchkiss (1988).

Deforestation and forest degradation is considered as the second leading cause of anthropogenic greenhouse emissions after the burning of fossil fuels (van der Werf, 2009) (accounting for over 17% of global carbon dioxide emissions) and has become an important issue concerning climate change mitigation (Ter-Mikaelian et al., 2015). The provision of wood energy is generally thought to be a major contributor to forest loss (Ter-Mikaelian et al., 2015). In Indonesia, more than half of the rainforest there, the third-largest swath in the world, has been felled in a few years. Furthermore, permission has been granted to convert the majority of what remains into palm or acacia plantations (Vidal, 2013). The logging and burning of forests to clear land for cultivation has made Indonesia one of the largest emitters of greenhouse gases (Harrison et al., 2009). Therefore, the objective of this study is to assess the current level and influencing factors of fuelwood use among the rural population as well as the consequent environmental impacts in the target area in North Sumatra.

MATERIALS AND METHODS

Description of the study area

The survey was conducted in the province of North Sumatra, Tapanuli Utara regency (Fig. 1). The population of North Sumatra consists of over 13.9 million inhabitants, which constitutes around 5.4% of the population of Indonesia (currently 255,461,700 inhabitants; the prediction for 2035 is around 305,652,000 inhabitants [BPS, 2015]). North Sumatra is the fourth most populous province in the country. The population of Tapanuli Utara regency, according to the latest data from 2014, is over 290,000.

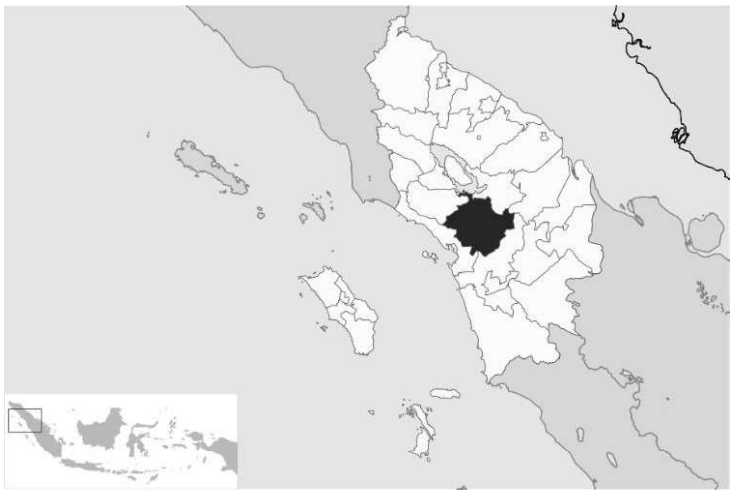

Figure 1. Target area (Tapanuli Utara regency) of North Sumatra (Adjusted from: Wikimedia Commons).

Data collection and analysis

The survey was conducted using randomly selected households (n = 196) (with a confidence level of 95% giving a margin of error of less than 7%) from July to August 2014 and followed by several field visits from August to September 2016. The methods of data collection consisted of one-hour questionnaire. The questionnaire included different types of questions such as open, closed, semi-open, evaluation and multiple-choice questions. The questionnaire was subject to pilot testing and was subsequently adjusted and translated into the Indonesia language before final distribution. Main categories of the questionnaire are given in Table 1. Data obtained in the survey were analysed with descriptive statistics and cross tabulation.

Table 1. Main categories of the questionnaire

Category	Type of questions
Socio-economic characteristics of respondents related par	District, village, sex, role in household, size of family, education, occupation, income, farm size, crops, equipment in household.
Usage of energy sources related part	Use of energy sources, main and additional cooking fuels, LPG consumption, availability of LPG, cooking time, fuelwood collection and related factors.

RESULTS AND DISCUSSION

Energy sources used for cooking and their relationship to household incomes

The target area is relatively well electrified, as one of the main electrification networks of Sumatra (GENI, 2014) passes through this area. However, as in many areas of Indonesia, several-hour electricity breakdowns still occur almost every day. Among the respondents, 88% had access to the electricity network and 19% of the farms (farm buildings). Therefore, the most widespread source of energy for daily usage in the area is electricity, followed by LPG and fuelwood, which is mainly due to low incomes and the relatively easy availability of fuel. Kerosene was not included in the research because the target region was converted during 2010–2011 (World Bank, 2013) as part of the national kerosene replacement programme for LPG. The main and secondary sources of energy used for cooking were identified in the research, and their distribution is shown in Fig. 2. The respondents were given three fuel type options to be determined as the main (only one option possible) and the secondary fuel (max. two options possible). In many cases, however, respondents had a problem with determining the main fuel, especially those who used LPG and electricity in a balanced ratio. From Fig. 2, we can see the percentage of secondary fuels (n = 135), expressed as a percentage of 150%, which was due to the fact that 45 respondents out of 90 chose two fuels as secondary. The remaining 45 respondents (50%) used only one major fuel and the other as a supplementary fuel.

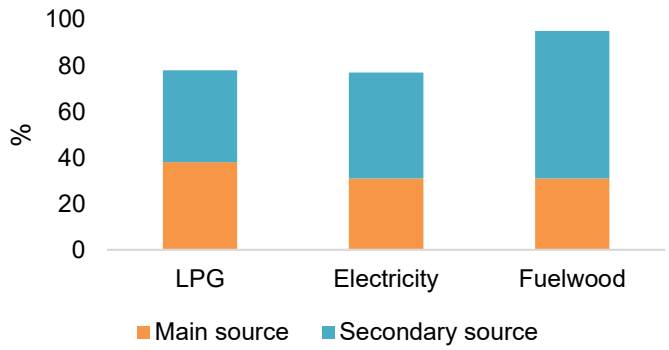

Figure 2. Used energy sources for cooking in the target area.

Respondents did not only use the three main fuels under investigation for cooking for their own use, but also for preparing feed for livestock (39%) and coffee roasting (8%).

According to Fig. 2, there is a balanced share between LPG users and electricity. Both of these sources provide high quality energy and, above all, suitable user conditions in terms of air cleanliness and kitchen accessories, and efficiency and time savings. Due to frequent power outages, LPG is a suitable source of energy, which may be one of the main reasons for the balanced combination of use of these two energy sources in the target area. Therefore, biogas from a biogas plant has the potential to be an appropriate energy source. According to the research developed for Hivos (a Dutch organization for development), which assessed the impact of the national IDBP (Indonesia Domestic

Biogas Programme) programme among new users of biogas plants, LPG consumption decreased from 76% to 27% (JRI Research, 2011). This result confirms the assumption that biogas is a suitable substitute for LPG. The same study also demonstrates that LPG is a suitable complementary fuel when a biogas plants user owns only one biogas burner that does not cover their daily needs and/or there is reduced or insufficient biogas production in the biogas plant.

Other research indicates that the choice of the selected energy source is evaluated on the basis of the functional relationship between household incomes and relative prices of available fuels or energy sources (Barnes et al., 2005) resulting in the so called 'energy ladder model', which is given in three phases. The first phase is the absolute dependence on traditional biomass sources. In the second phase, the transition to kerosene, coal and charcoal is linked to higher income, deforestation and urbanization. The third phase is the transition to LPG, natural gas, electricity, biogas and other renewable energy sources. It is only a simplified model; in practice, there is usually no complete transition to a new energy source, but a partial substitution (Andadari et al., 2014). A similar trend was also observed during our research. Even households from higher income groups use fuelwood as fuel as well as electricity and LPG as a supportive energy source.

LPG consumption, availability and costs

According to the study by Budya & Arofat (2011) – which presents the results of a survey of a private research organization in collaboration with Frontier which evaluated the satisfaction of LPG users who received the LPG Initiative Package under the Indonesian National Program – the following data was found: on average, respondents used 3 kg of LPG bottles for 10.58 days and 1.92 hours of cooking each day. This means that the average monthly consumption was approximately three bottles of LPG, 9 kg. The price for filling 3 kg of LPG bottle was 13,800 IDR (1.38 USD). Hence, the respondents spent on average 41,400 IDR (4.14 USD) monthly.

Based on the results of our study, the average cooking time was 1.84 hours (on average two to three meals a day). The monthly average household consumption was 9.48 kg of LPG, which also corresponds to the consumption of approximately three 3 kg LPG bottles per month. The LPG price was significantly higher in the target area of research. The price of a 3 kg LPG bottle (subsidized by state subsidies) was around 19,000 IDR (1.84 USD). The higher price was probably due to the relative remoteness from the nearest cities Siborongborong and Tarutung, where the price was about 4,000 IDR lower. The LPG bottles were delivered to the stores in the target area by intermediaries or imported by sellers themselves, which was probably the reason for the higher prices. In the target area, 12 kg of LPG bottles that were not subsidized by the state were also used, and the price was around 90,000 IDR (8.74 USD). However, most respondents reported the use of 3 kg LPG bottles, as they are subsidized (World Bank, 2013). In addition, there are 6 kg and 50 kg LPG bottles available in Indonesia that are not subsidized.

To determine the availability of LPG, a scale rating ranging from 1 (easy accessibility) to 5 (difficult accessibility) was used. The response rates for each grade are as follows: 1 (3%), 2 (38%), 3 (34%), 4 (13%), 5 (12%). This question was addressed to all respondents, not only to LPG users, so it is possible to assume that grades four and five were mainly chosen by non-LPG users. Based on observations from the target area, it was not physical LPG availability that was the issue but rather financial, in particular

due to the relatively high value of LPG from local dealers and low household incomes. The key figure is the LPG cost as a percentage share of total household income. The average revenue in the target area amounted to 132.38 USD and the average percentage share of LPG expenditure of total revenue was 6.78%, i.e. 8.97 USD. Research results from Andadari et al. (2014), which examined similar parameters in the Central Java region in two rural areas (Semarang Regency), two suburban and one urban area (the city of Salatiga), indicate the following results. The average household income was 134.43 USD and LPG cost as a percentage of total household income was 2.91%, or 3.91 USD. Given the similarity between the average household income and the fact that 91.1% of respondents used LPG, we can assume that the lower percentage of LPG expenditure in the comparative research was due to lower LPG use compared to the target area of our research as well as lower LPG consumption per household. In a comparative study, the average number of household members was 3.42 compared to 6 members in our target area, which is significant if we assume a direct ratio between the growing number of household members and the increasing consumption of LPG. The lower LPG price in the comparative research could be due to a more developed LPG distribution network and also the shorter distance from Saltiga to the rural areas: 7 and 9 km, compared to the distance from the target research area (Pagar Batu) to Siboronborong – 14.2 km – and Tarutung – 13.3 km. The reason for this was also the better accessibility of rural areas in Java compared to other areas of Indonesia, as is also reported by Andadari et al. (2014). According to the authors, the target area of the research is quite remote from the surrounding cities, mainly due to the undeveloped road infrastructure. The area is situated on the Sipoholon plateau where it is not possible to transit larger trucks and the overall transport of the area is not very optimized, which increases the price of imported goods.

Factors influencing the use of wood as a fuel and its environmental impacts

Fuelwood is a significant source of energy in the target area. According to Fig. 2, wood was the main source of energy used by 31% of respondents and 64% of respondents as supplementary fuel. The main reason for the high rate of use of wood as fuel is mainly its easy physical and financial availability in rural areas (World Bank, 2013; Andadari et al., 2014). Based on observations and interviews in the target area, wood was freely available from surrounding forests or own gardens or adjacent plots, i.e. completely free of charge. However, a high level of deforestation was seen on the landscape profile, which is one of the main warning signals in the area that needs to be addressed. Unexpected knowledge was the presence of frequent and extensive forest fires. After interviewing the employees of the agricultural training centre Agroihutan, it was apparent there was not a well-founded reason for these fires, but according to their claims, they were intentionally started to entertain a certain group of locals. Such practices are not, to the best of our knowledge, cited in any scientific sources. In addition to these fires, the burning of already leached forests or shrubs was recorded for the purpose of setting up new agricultural parcels (see Fig. 3, a and b).

Figure 3. Burning of forests to clear land for cultivation.

Important information is provided in Table 2, which lists the main factors and data on the collection of wood in the target area. The data in the table shows that wood resources are often very distant, which is one of the impacts of high deforestation; on the other hand, the low value of distance demonstrates the easy availability of wood fuel from their own garden or adjacent land.

Table 2. Fuelwood collection factors in the target area

	N	Average	St.Dev.	Min	Max
Age of fuelwood pickers (men)	60	34.1	11.8	18	67
Age of fuelwood pickers (women)	32	35.9	11.5	19	64
Age of fuelwood pickers (children)	33	12.6	2.8	5	17
Distance to the source of fuelwood (metres)	86	1,013.8	-	10	5,000
Length of the path to the source of fuelwood (minutes)	86	46.1	-	1	180
Time of fuelwood collection (hours/week)	86	4.8	-	1	36
Frequency of fuelwood collection (times/week)	76	2.1	1.2	1	7

It is clear from the results of our research that the persistently high rate of use of wood as fuel is due in particular to the poor financial situation of respondents and the easy accessibility of wood from the surrounding area. The results of Andadari et al. (2014), who assessed the effects of the kerosene replacement programme for LPG, demonstrate that in the surveyed rural areas covered by research there was only a slight decrease in the consumption of wood as fuel from 50.3% to 49.7% for those who had the main wood source. The results of the study (World Bank, 2013) show that even a LPG-subsidized state is financially inaccessible to many households. The same source states that 40% of LPG comes from imports, which, as a result of price increases on the international market, may lead to the inability to maintain the same subsidy rate. Such a situation would lead to an increase in LPG sale prices, which would likely lead to an even higher rate of use of wood and biomass. In the future, therefore, this trend can be anticipated in rural areas especially, where the consequences may include increased deforestation, soil degradation and increased greenhouse gas emissions and, above all, air pollution – not only outdoors but especially in the home, leading to increased health problems and reduced life expectancy and comfort. One of the appropriate solutions may

be the adoption of effective biomass stoves, the extension of which belongs to one of the three main national initiatives for 'access to clean cooking'. These stoves greatly increase the efficiency of combustion and reduce the amount of air pollution. Another solution is the installation of a biogas plant, which significantly reduces the negative aspects of the use of wood as a fuel and increases comfort. Research findings from southern Sri Lanka showed an 86% decrease in fuel consumption after biogas plant implementation (de Alwis, 2002); therefore, this could be a very suitable option for the target area (Roubík et al., 2016; Ginting 2017).

Other benefits included, for example, more time for gainful activities, rest and social participation, more time for children, better study conditions, and a reduced risk of eye inflammation and respiratory diseases (JRI Research, 2011). With sufficient production, biogas surpluses could be used to light gas lamps or generate electricity after installing additional accessories.

CONCLUSIONS

Currently, the majority of respondents use 3 kg LPG bottles, as they are subsidized, but once the subsidies stop some rural households are likely to face difficulties to ensure their energy consumption by LPG of higher price. Furthermore, the results demonstrate that fuelwood is a significant source of energy in the target area. For 31% of respondents it is the major energy source and for 64% of respondents it is a supplementary source. The high rate of the use of wood as fuel corresponds to the poor financial situation of respondents and the easy accessibility of wood, but only from the surrounding area (own garden or adjacent land). Wood resources are often very distant (on average over 1,000 metres) as a consequence of high deforestation. Our study reveals that there is a non-sustainable trend of forest conversion, resulting in high land degradation in Tapanuli Utara regency.

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