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Geographical variations of woodfuel supply and trade within 30 km of two forest protected areas in northeastern Bangladesh: The question of sustainability

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Abstract

We studied woodfuel vendors in 112 markets within 30 km from the borders of Khadimnagar National Park (KNP subregion) and Lawachara National Park (LNP subregion), evaluating how two subregions differ in relation to market attribute (degree of urbanisation), environmental attributes (tree coverage and seasonality), vendor characteristics, and woodfuel sources utilised. A total of 206 vendors were interviewed, including wholesalers, mixed wholesalers, and sawmill operators. Survey results revealed that vendors in rural areas sold greater quantities of woodfuel within KNP subregion, and semi-urban vendors sold higher quantities within LNP subregion. A total of 126 sawmills in two subregions sold greater amounts of woodfuel than the 58 wholesale woodfuel vendors and 22 mixed wholesale vendors, with significant differences. In terms of seasonal variations in woodfuel sales, significantly lower amounts of woodfuel sold in monsoon months and higher amounts in winter months. Non-forest sources including homestead forests, roadside social forestry plantations, tea estates, and via sawmills supplied 72% of the total woodfuel sale. The study suggests that roadside social forestry plantations and homestead forestry are key for sustainable supply of woodfuel for meeting sustainable development goals in forest and energy sectors of Bangladesh.

Keywords: woodfuel vendors; woodfuel sources; non-forest sources; forest protected area; Bangladesh

Introduction, scope and main objectives

Households in developing countries rely heavily on woodfuel (fuel originating from tree stems and branches) for cooking, heating, and other uses for centuries (Behera et al. 2015), supplying the 6~7% of global primary energy source for the 2.4 billion people (FAO 2018). Many small and medium enterprises such as brick manufacturing, restaurants, food manufacturing, and coffee, tea and tobacco industries use woodfuel as the main energy source for purposes (FAO 2017).

Woodfuel in South and Southeast Asia, Sub-Saharan Africa and Latin America harvested from both forest and non-forest sources (Baker et al. 2014; Specht et al. 2015; Sola et al. 2017); traded informally or formally in the marketplace by commercial traders (hereafter “woodfuel vendors”) (Ullah and Masakazu 2017). Woodfuel trade in these countries create employment and income opportunities to millions of people (Miteva et al. 2017).

Previous studies found that, woodfuel production and supply patterns are affected by topographical conditions or elevation of the locality, degrees of urbanisation (e.g., rural and urban settings), road networks, and tree production systems that supply wood (Jama et al. 2008; Ndayambaje and Mohren 2011; Puri et al. 2017; Guild and Shackleton 2018).

Bangladesh is a South Asian country, currently consumed 15 to 18 million t/yr of woodfuel mainly for residential and commercial cooking and for brick burning purposes (BFD 2016; UNdata 2020). Illegal extraction of wood from natural forests is the major source of woodfuel supply in Bangladesh, leading to degradation of remaining forests and the homestead forests (Khan 2016). Moreover, non-forest sources such as homestead forests, social forestry plantations, and tea estates supply considerable amount of woodfuel in Bangladesh (Rahman et al. 2021).

Here, this study explores the spatial patterns of woodfuel supply and trade within 30 km from the borders of two forest protected areas namely Khadimnagar National Park (KNP) and Lawachara National Park (LNP) in northeastern Bangladesh (hereafter 'KNP subregion' and 'LNP subregion'). In the current study, we examine factors that affect woodfuel sale at markets and vendors levels, and also examine the supply sources of woodfuel for trade at markets in both subregions.

Methodology/approach

1-Selection of study sites

KNP established in 2006 (24°56'-24°58' N and 91°55'-91°59'E) (Fig. 1), with an area of 678.8 ha in Sylhet Sadar Upazila (sub-district) of the Sylhet District in northeastern Bangladesh. LNP (24°30'-24°32' N and 91°37'-91°47' E) was established in 1996. LNP has an area of 1,250 ha within the 2,740 ha of West Bhanugach Reserve Forest in Kamalganj Upazila of Moulvibazar District in northeastern Bangladesh (Fig. 1). KNP and LNP are around 100 km apart and situated in contrasting environmental settings.

2-Sampling strategy

For the present study, two maps were prepared with ArcGIS for the area within 30 km from the borders of KNP and LNP for field survey. District and sub-district boundary and road networks are indicated in two maps. The Indian portion within boundary was not included in the field survey. We used 24 sub-district maps (16 sub-districts in KNP subregion and 8 sub-districts in LNP subregion) available from the Local Government Engineering Department (LGED) of Bangladesh for locating the markets to be included in the survey. Multiple vendors who procured, collected and sold woodfuel, including sawmill operators and wholesale vendors, were surveyed in each of the 112 markets (74 markets out of 324 in the KNP subregion and 38 markets out of 211 in the LNP subregion) out of a total of 535 markets within the study area.

3-Data collection from woodfuel vendors

We included three types of vendors in the study such as 'wholesale woodfuel vendor (WWV)' specialised in woodfuel trade only, 'mixed wholesale vendor (MWV)' who trade woodfuel and other fuels, and sawmill operators. This resulted in a total of 206 vendors, consisting of 125 from KNP subregion and 81 from LNP subregion. We conducted face-to-face interviews with the owner and/or the manager of each vendor to collect data using a semi-structure questionnaire. Global Positioning System (GPS) location of each vendor was recorded for mapping the spatial distribution of the vendors. The primary data on the quantity of woodfuel sales and the income from woodfuel sale per day were converted to annual total woodfuel sale and price value, respectively.

4-Data analysis

For the classification of land use types of KNP and LNP subregions, two GIS maps were prepared. Normalized difference vegetation index (NDVI), which is widely used for mapping vegetation and forest cover monitoring, was prepared from the cloud free Sentinel-2 imagery with 10 m × 10 m resolution. Based on the NDVI values, the study area was classified into four land use types. Furthermore, one-way and two-way ANOVA and box-and-whisker plots were performed with R (version 3.6.1).

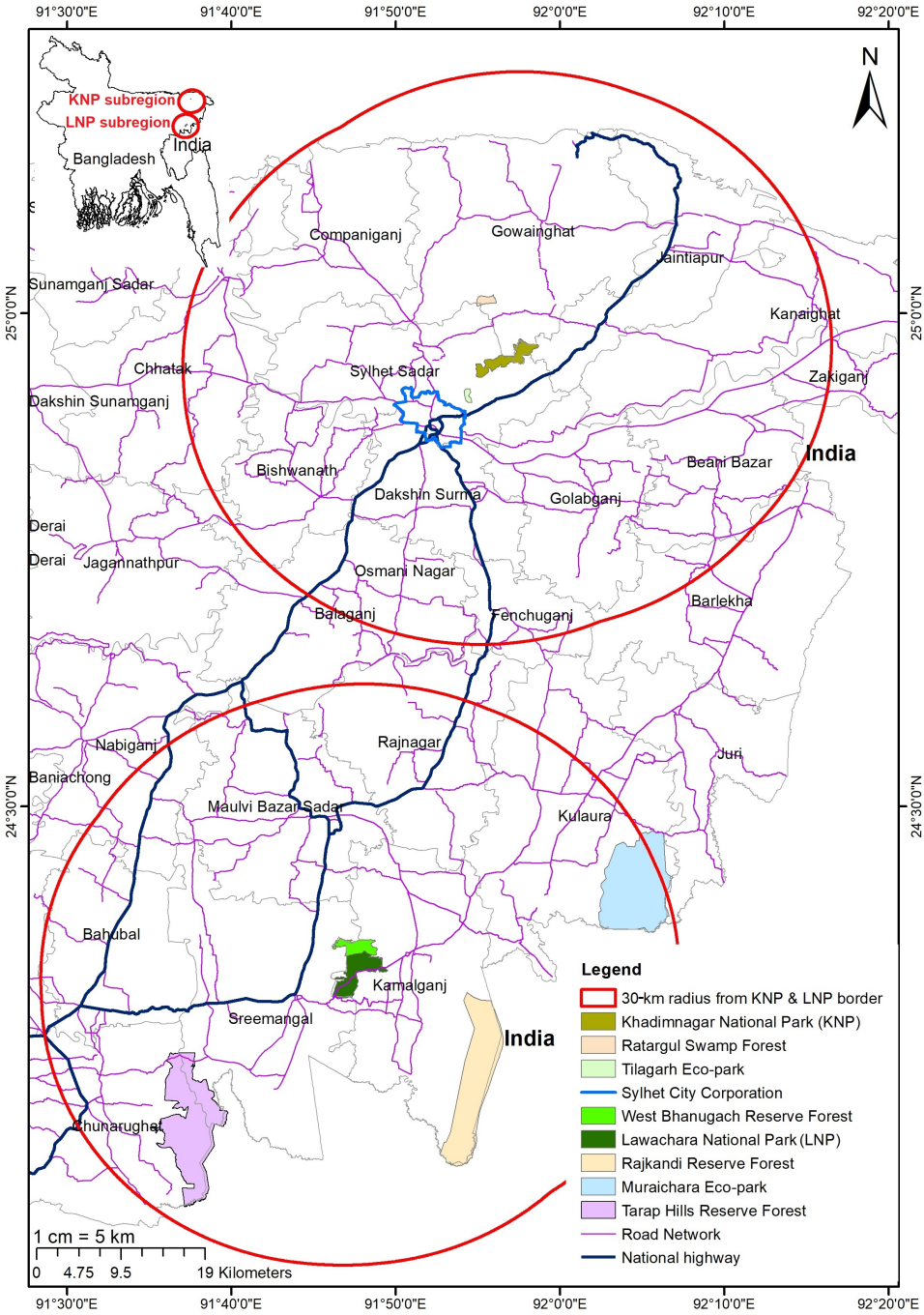

Fig. 1: Map of the study areas that include 30 km radius circles or subregions (red lines) from the border of Khadimnagar National Park (KNP) (olive green line) and Lawachara National Park (LNP) (dark green line) in northeastern Bangladesh, showing other forest protection sites inside the circles, names of the surveyed sub-districts, regional road networks (purple lines), national highways (blue lines), and borders between subdistricts and between Bangladesh and India (grey lines). Left top of the figure showing the location of the KNP subregion and the LNP subregion on the map of Bangladesh.

Results

1. Characteristics of the woodfuel vendors

The vendors in the KNP subregion were largely sawmills (51.2%) followed by WWVs (31.2%). Similarly, vendors in the LNP subregion consisted of sawmills (76.5%) and WWVs (23.5%) (Table 1). Less than half of the surveyed markets in KNP subregion and LNP subregion were located at rural areas (44.8% and 44.4%, respectively), whereas the majority of the markets and vendors in the LNP subregion occurred in rural areas (55.6%) (Table 1).

Table 1: Types of the 206 woodfuel vendors that operates at 112 markets surveyed within 30 km of KNP subregion and LNP subregion

Locality / Forest	Sawmill		Wholesale woodfuel vendor		Mixed wholesale vendor
	KNP subregion	LNP subregion	KNP subregion	LNP subregion	KNP subregion
Rural	31 (30.7)	36 (35.6)	19 (18.8)	9 (8.9)	6 (5.9)
Semi-urban	31 (30.7)	26 (25.7)	19 (18.8)	10 (9.9)	15 (14.9)
Urban	2 (50.0)	-	1 (25.0)	-	1 (25.0)
Total	64 (51.2)	62 (76.5)	39 (31.2)	19 (23.5)	22 (17.6)

Note: 125 vendors surveyed from KNP subregion and 81 vendors from LNP subregion; parentheses shows the percentage values; -, no data.

In the KNP subregion, only 37.6% of the vendors operating in their own shop, 60% in rented shops, and 2.4% were temporary shops. In the LNP subregion, 66.7% vendors owned their hops, while 24.7% operated their business in rented shops, and 8.6% were temporary vendors. About 71.2% of vendors in the KNP subregion and 77.8% in the LNP subregion ran their business as the primary occupation. The number of years in this business ranged from 0.2 to 40 years in the KNP subregion and 1 to 60 years in the LNP subregion. On average, a vendor employed 4 persons in both subregions (ranging from 1 to 13 and 1 to 16 in the KNP and LNP subregions, respectively).

2. Land use of the study area

Based on the range of NDVI values (-0.80 to + 0.84), the study area was classified into four land use types such as closed forests (which could be either natural forests or tea estates), agricultural land, homestead/settlements, water bodies and barren land. The highest NDVI value was +0.83 and +0.84 in the KNP and LNP subregions, respectively. Large areas of green vegetation (with NDVI values above 0.58) indicating forests, tea estates, and homestead forests occurred in both regions. Closed forests covered about 36% of the LNP subregion and only 18% of the KNP subregion (Table 2).

Table 2: Land use types in the KNP and LNP subregions on the basis of NDVI values

Land use type	NDVI value	KNP subregion (%)	LNP subregion (%)
Closed forest	0.58 - 0.84	18	36
Homestead	0.41 - 0.57	31	25
Agricultural land	0.21 - 0.40	37	31
Waterbody and barren land	-0.80 - 0.20	14	8

3. Annual woodfuel sold

The total woodfuel sold varied widely among markets and vendors levels, from 7.3 to 1675.7 t/yr (7.3 to 1,226.1 t/yr at the vendor level) in the KNP subregion, and from 72.6 to 1,407.7 t/yr (68.1 to 408.7 t/yr at the vendor level) in the LNP subregion. In the KNP subregion, the total annual woodfuel sold across 74 markets was 242.5 ± 282.8 t/yr (mean ± s.d), with the annual woodfuel sold per vendor was 143.6 ± 151.1 t/yr. In the LNP subregion, the total annual woodfuel sold across 38 markets was 333.2 ± 315.9 t/yr with annual woodfuel sold per vendor was 156.3 ± 63.9 t/yr.

4. Effects of degree of urbanisation and seasonality on woodfuel sale

Fig. 2a shows that, in both the KNP and LNP subregions, higher median of woodfuel were sold in the rural markets, 155.5 ± 122.3 and 160.7 ± 62.8 t/yr, respectively with no significant differences in one-way ANOVA. In terms of seasonal variations in woodfuel sales, significantly lower amounts of woodfuel were sold in monsoon months to summer and winter months in KNP subregion ($p<0.05$) and LNP subregion ($p<0.001$) (Fig. 2b). According to the two-way ANOVA, both seasonal variations in woodfuel sales ($p<0.001$) and subregions sales variations ($p<0.001$) had influence on annual woodfuel sold by individual vendors (Fig. 2b).

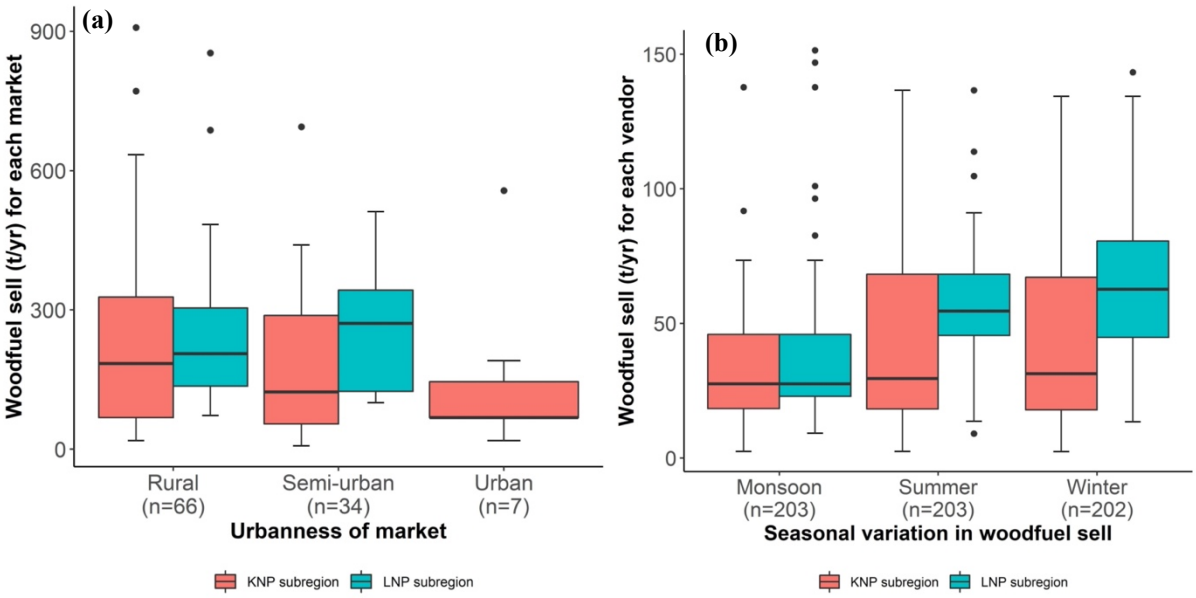

Fig. 2: Box-and-whisker plots of the effects of (a) urbanness (rural vs. semi-urban vs. urban) of 107 markets, and (b) seasonal variations in woodfuel sale by 203 commercial woodfuel vendors. The sample size of each category (number of markets and shops) is indicated by n, after removing 5 outliers from (a) and 3 outliers from (b) from the analysis. The box spans the middle 50% of the data. The lower and upper hinges (outer edges) of the box correspond to the 25th and 75th percentiles, and the solid line inside the box correspond to the 50th percentile is the median. Whiskers extending from the hinges show the ±1.5 × inter-quartile range. Data values beyond the extremes are considered outliers and are marked as individual points.

5. Sources of trees for producing woodfuel

For the study, we have grouped the woodfuel sources into three main types and their combinations, such as forests including those in the Indian hills, homestead forests, and others. These sources were also combined differently by sawmill operators, WWVs and MWVs (Table 3). Forests plus other sources were the major sources of woodfuel used by 40 vendors in the KNP subregion and 53 vendors in the LNP subregion. Homestead forests was one of the important sources of woodfuel for the two subregions as 50 vendors in the KNP subregion and 28 vendors in the LNP subregion obtained trees from homestead forests plus other sources. In overall, 93 vendors who sold woodfuel from forests in combination with other sources together

sold 14,854 t/yr (48.5%), and 78 vendors who sold woodfuel from homestead forests alone or in combination with other sources contributed 9,847.9 t/yr (32.2%) (Table 3).

More specifically, sawmill operators, which were 126 of the surveyed 206 vendors, sold 166.0 ± 102.3 t/yr (mean ± s.d) and 152.8 ± 60.8 t/yr woodfuel in the KNP and LNP subregions, respectively. A total of 58 WWVs sold 162.7 ± 222.7 and 167.8 ± 73.8 t/yr woodfuel in the KNP and LNP subregions, respectively. The 22 MWVs found only in the KNP subregion sold much lower amount of woodfuel (44.4 ± 32.0 t/yr) than sawmills and WWVs.

Table 3: Annual mean woodfuel sold by the 206 woodfuel vendors surveyed within 30 km of KNP and LNP subregions

Sources of woodfuel	KNP subregion		LNP subregion	
	Vendors	Woodfuel sold (t/yr) per vendor	Vendors	Woodfuel sold (t/yr) per vendor
Forest and non-forest sources				
Forests	4 (3.2)	13.7	-	-
Forests + Homestead forests	17 (13.6)	197.7	6 (7.4)	143.8
Forests + Tea estates	2 (1.6)	40.9	8 (9.9)	188.5
Forests + Homestead forests + Tea estates	17 (13.6)	152.8	22 (27.2)	169.5
Forests + Mixed sources	-	-	17 (21.0)	156.5
Non-forest sources				
Homestead forests	47 (37.6)	119.0	10 (12.3)	128.5
Homestead forests + Mixed sources	3 (2.4)	118.1	18 (22.2)	145.3
Indian hills	5 (4.0)	91.6	-	-
Indian hills + Homestead forests	13 (10.4)	182.7	-	-
Indian hills + Tea estates	3 (2.4)	28.0	-	-
Indian hills + Homestead forests + Tea estates	14 (11.2)	213.5	-	-

Note: 125 vendors in the KNP subregion and 81 vendors in the LNP subregion; mixed sources included tea estates, sawmills and roadside plantations; parentheses shows the percentage of the vendors; -, no data.

Discussion

A key finding of our study was that in areas with high NDVI values, woodfuel was available not only from natural forests but also from available non-forest sources. This study found that seasonality has a significant impact on woodfuel supply and trend, highest sold in the winter season and lowest in the monsoon season. Fardusi et al. (2011) reported that KNP-dependent people collected less amount of woodfuel in the months of wet monsoon season. In Nepal, Webb and Dhakal (2011) reported the similar trend that woodfuel collection effort was highest before the onset of the monsoon season, and was the lowest during the monsoon season. In the the Sariska Tiger Reserve of India, forest-dependent people collected highest amount of woodfuel in the months of winter season (Heltberg et al. 2000).

In the current study, we found that vendors in semi-urban markets constitute 49% of the total vendors in the study. Similarly, other studies like Foley (1985) in some developing countries, Campbell et al. (2003) in Zimbabwe, Farsi et al. (2007) in India, Gebreegziabher et al. (2012) in Ethiopia, and Zhang and Hassen (2017) in China reported that major woodfuel markets occurred in the urban areas. In these countries people purchase woodfuel from urban woodfuel vendors. But, in Sub-Saharan Africa, the woodfuel demand for trade is higher in rural markets whereas higher charcoal demand in rural markets (Zulu and Richardson 2013; Atyi et al. 2016).

Present study assessed that non-forest sources supplied 72.7% of the total amount of woodfuel for trade in study subregions. Smeets and Faaij (2006) reported that globally about 30% of woodfuel are obtained from non-forest sources or trees outside forests, while it is up to 50% in Asia (FAO 2008). Arnold et al. (2006) and Bensel (2008) also pointed that most of woodfuel demands in developing countries met by homestead forests and woodlot plantations.

Muhammed et al. (2011) argued that rural people in Bangladesh are interested in planting exotic fast-growing trees, native fruit-bearing trees, as well as fuelwood species in their homestead forests to meet their daily demand of timber, fruits and fuel. Roadside strip plantations in Bangladesh managed under a participatory social forestry scheme produced 0.38 million t woodfuel between 1999-2000 to 2013-14 with involving 109,000 participants (Hossain 2016). Furthermore, a significant amount of woodfuel is supplied from shade trees in nearby tea estates in two study subregions. Rahman et al. (2021) found that tea estates in the northeastern Bangladesh supplied woodfuel to households and commercial sectors. Furthermore, sawmill residues are widely used by commercial users, but occasionally used by residential users in Bangladesh (Hassan et al. 2013). Sawmill operators in two subregions procured most of their trees from homestead forests and social forestry plantations through private and government auctions. They also purchased trees those were illegally harvested from forests and tea estates, act as catalysts of illegal logging in Bangladesh (UN-REDD 2017).

Woodfuel shortage in Bangladesh is increasing steadily, and traditional use of woodfuel is often not sustainable under growing population. Moreover, existing energy policies in Bangladesh so far have neglected the role of woodfuel for cooking and burning purposes. Yet, woodfuel production and trade in Bangladesh are not organised, and without a legal framework, no revenues are generated to support the Forest Department's effort to promote sustainable use and management of forest resources.

Conclusions/ wider implications of findings

Present study addressed a knowledge gap about the scale, spatial distribution, and sales patterns of woodfuel by the vendors within 30 km of two forest protected areas in northeastern Bangladesh. We found that woodfuel supply and sales patterns could be largely explained by environmental and market attributes that were associated with each other. Study results suggest that sustainable management of homestead forests will be key to reduce forest dependency for woodfuel. However, further research needs to be carried out to understand the patterns of supply-demand relationships and for the development of market structure for sustainable woodfuel trade. The study findings are informative to Forest Department for efforts to design effective forest management plans and policies towards reducing deforestation and forest degradation in the natural forests including forest protected areas.

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References

Arnold M, Kohlin G, Persson R. 2006. Woodfuels, livelihoods and policy interventions: Changing perspectives. World Development, 34: 596-611.

Atyi RE, Poufoun JN, Awono J-PM, Manjeli AN, Kankeu RS. 2016. Economic and social importance of fuelwood in Cameroon. International Forestry Review, 18(s1): 52-65.

Baker K, Bull GQ, LeMay VM. 2014. The use of fuelwood market segmentation and product differentiation to assess opportunities and value: a Nicaraguan case study. Energy for Sustainable Development, 18: 58-66.

Behera B, Rahut DB, Jeetendra A, Ali A. 2015. Household collection and use of biomass energy sources in South Asia. Energy, 85: 468-480.

Bensel T. 2008. Fuel wood, deforestation and land degradation, 10 years of evidence from Cebu Province, the Philippines. Land Degradation and Development, 19: 587-605.

BFD, 2016. Bangladesh Forestry Master Plan 2017-2036. Available at: https://pubdocs.worldbank.org/en/848671521827530395/FMP-Full-report-final.pdf [accessed 09.06.21].

Campbell BM, Vermuelen J, Mangono J, Mabugu R. 2003. The energy transition in action: Urban domestic fuel choices in Zimbabwe. Energy Policy, 31: 553-562.

FAO, 2008. Forests and energy: Key issues, FAO Forestry Paper 154. Available at: https://www.fao.org/3/i0139e/i0139e00.htm [accessed 16.07.21].

FAO, 2017. Sustainable woodfuel for food security. A smart choice: Green, renewable and affordable. Available at: https://www.fao.org/3/i7917en/I7917EN.pdf [accessed 16.07.21].

FAO, 2018. The State of The World's Forests 2018 - Forest pathways to sustainable development. Available at: https://www.fao.org/documents/card/en/c/I9535EN/ [accessed 16.07.21].

Fardusi MJ, Rahman MH, Roy B. 2011. Improving livelihood status through collection and management of forest resources: an experience from Sylhet Forest Division, Bangladesh. International Journal of forest Usufructs Management, 12(2): 59-76.

Farsi M, Filippini M, Pachauri S (2007). Fuel choices in urban Indian households. Environment and Development Economics, 12:757-774.

Foley G. 1985. Wood fuel and conventional fuel demands in the developing world. Ambio, 14(4/5): 253-258.

Gebreegziabher Z, Mekonnen A, Kassie M, Kohlin G. 2012. Urban energy transition and technology adoption: The case of Tigray, northern Ethiopia. Energy Economics, 34(2): 410-418.

Guild J, Shackleton CM. 2018. Informal urban fuelwood markets in South Africa in the context of socioeconomic change. Energy Policy, 117: 136-141.

Hassan MK, Halder P, Pelkonen P, Pappinen A. 2013. Rural households' preferences and attitudes towards biomass fuels - Results from a comprehensive field survey in Bangladesh. Energy, Sustainability and Society, 3: 24; https://doi.org/10.1186/2192-0567-3-24.

Heltberg R, Arndt TC, Sekhar NU. 2000. Fuelwood consumption and forest degradation: A household model for domestic energy substitution in rural India. Land Economics, 76(2): 213-232.

Hossain MK. 2016. Plantation forestry: paradigm to meet the demand of the forestry resources in Bangladesh. In: T.K. Nath and P. O'Reily (eds), Monoculture farming- global practices, ecological impact and benefits/drawbacks. New York: Nova publishers, pp. 57-74.

Jama BA, Mutegi JK, Njui AN. 2008. Potential of improved fallows to increase household and regional fuelwood supply: Evidence from western Kenya. Agroforestry Systems, 73(2): 155-166.

Khan NA. 2016. Public policy and governance in Bangladesh: Forty years of experience. New York, NY: Routledge, 270 pp.

Miteva DA, Kramer RA, Brown ZS, Smith MD. 2017. Spatial patterns of market participation and resource extraction: Fuelwood collection in northern Uganda. American Journal of Agricultural Economics, 99(4): 1008-1026.

Muhammed N, Masum MFH, Hossain MM, Chakma S, Oesten G, von Detten R. 2011. Floral composition and biodiversity conservation in homestead forests in Mymensingh, Bangladesh. International Journal of Biodiversity Science, Ecosystem Services & Management, 7(4): 247-257.

Ndayambaje JD, Mohren GMJ. 2011. Fuelwood demand and supply in Rwanda and the role of agroforestry. Agroforestry Systems, 83: 303-320.

Puri L, Nuberg I, Ostendorf B. 2017. The adequacy of community forest operational plans for estimating fuelwood supply and consumption in Nepal. Australian Forestry, 80(5): 317-327.

Rahman MH. Kitajima K, Rahman MF. 2021. Spatial patterns of woodfuel consumption by commercial cooking sectors within 30 km of Lawachara National Park in northeastern Bangladesh. Energy for Sustainable Development, 61: 118-128.

Smeets E, Faaij A. 2006. Bioenergy potentials from forestry in 2050: An assessment of the drivers that determine the potentials. Climatic Change, 81(3-4): 353-390.

Sola P, Cerutti PO, Zhou W, Gautier D, Iiyama M, Schure J, Chenevoy A, Yila J, Dufe V, Nasi R, Petrokofsky G, Shepherd G. 2017. The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: A systematic map. Environmental Evidence, 6: 4; https://doi.org/10.1186/s13750-017-0082-2.

Specht MJ, Pinto SRRP, Albuquerque UP, Tabarelli M, Melo FPL. 2015. Burning biodiversity: Fuelwood harvesting causes forest degradation in human-dominated tropical landscapes. Global Ecology and Conservation, 3: 200-209.

Ullah SMA, Masakazu T. 2017. Fuelwood consumption and its impact on forests in the Teknaf Peninsula on the southern coast of Bangladesh. American Journal of Environmental Sciences, 13(3): 225-232.

UN-REDD. 2017. Drivers of deforestation and forest degradation in Bangladesh: Final report. Available at: http://www.bforest.gov.bd/site/page/5d40ef21-5f56-4933-af1d-5972252852f2/- [accessed 02.06.21].

UNdata. 2020. Fuelwood Statistics: United Nations Statistics Division. Available at: http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AFW [accessed 07.06.21].

Webb L, Dhakal A. 2011. Patterns and drivers of fuelwood collection and tree planting in a Middle Hill watershed of Nepal. Biomass and Bioenergy, 35: 121-132.

Zhang X-B, Hassen S. 2017. Household fuel choice in urban China: evidence from panel data. Environment and Development Economics, 22(4): 392-413.

Zulu LC, Richardson RD. 2013. Charcoal, livelihoods, and poverty reduction: Evidence from Sub-Saharan Africa. Energy for Sustainable Development, 17(2): 127-137.