BIODIVERSITAS
Volume 23, Number 7, July 2022
Pages: 3507-3512

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230725

Tree species used for fuelwood by remote indigenous communities in West Papua, Indonesia: Implication of empowerment program

LASARUS INDOW[1], RUDI A. MATURBONGS[2,♥], SARASWATI PRABAWARDANI[3], HENDRI[2]

[1]Environmental Science of Graduate Program, Universitas Papua. Jl. Gunung Salju, Amban, Manokwari 98314, West Papua, Indonesia
[2]Faculty of Forestry and Graduate Program, Universitas Papua. Jl. Gunung Salju, Amban, Manokwari 98314, West Papua, Indonesia.
♥email: r.maturbongs@unipa.ac.id
[3]Faculty of Agriculture and Graduate Program, Universitas Papua. Jl. Gunung Salju, Amban, Manokwari 98314, West Papua, Indonesia

Manuscript received: 3 June 2022. Revision accepted: 22 June 2022.

Abstract. *Indow L, Maturbongs RA, Prabawardani S, Hendri. 2022. Tree species used for fuelwood by remote indigenous communities in West Papua, Indonesia: Implication of empowerment program. Biodiversitas 23: 3507-3512.* Fuelwood still contributes as an essential energy source for domestic uses especially in rural communities including in West Papua, Indonesia. While several development programs are implemented to enhance the life quality of rural indigenous communities, their implication for fuelwood use is not clear. This study aimed to identify fuelwood tree species used by communities in three villages in West Papua and to, assess its availability prior to the empowerment program and compare it to nowadays after the program based on the community's perspective. A descriptive method with qualitative and quantitative data components was used in this study. Data were collected at predetermined villages representing three ecological zones (i.e., Sakumi, Jamboi and Watitindau) using purposive sampling and semi-structured interviews with community representatives, tribal chiefs and leaders. The results showed that there were 5-7 plant species used as fuelwood, namely *Piper aduncum*, *Casuarina equisetifolia*, *Rhizophora* sp., *Gliricidia sepium*, *Intsia bijuga*, *Pometia pinnata*, *Dodonaea viscosa*, *Homalium foetidum*, *Syzygium* sp. and *Muntingia calabura*. These all-wood species have a good flame. Some high commercial tree species such as *I. bijuga*, *P. pinnata* and *H. foetidum* are only used in their branches and twigs for firewood. The local communities still use firewood despite the empowerment program since alternative fuel sources are not available or lacking, while the availability of firewood is plentiful. Nonetheless, in the long run, the continuous and extensive use of firewood will put pressure on the remaining trees and forest. Therefore, we recommend sustainably using firewood and replanting several species frequently used as firewood.

Keywords: Fuelwood, indigenous community, local trees, sustainability, West Papua

INTRODUCTION

Fuelwood has been an important source of domestic energy to fulfill household needs for cooking and heating, particularly in rural areas since prehistorical times (Bunafsha et al. 2014; Waris and Antahal 2014). About 2.5 to 3 billion people worldwide still depend on woody biomass as a source of fuel (UNEP 2019; Stoner et al. 2021; Scheid et al. 2019). According to Masera et al. (2015), about 40% of the global population depends on traditional bioenergy, accounting for 9% of global energy use and 55% of the global wood harvest. Waris and Antahal (2014) added that out of 2.7 billion people in developing countries who depend on wood for fuel, 82% live in rural areas. In Papua Indonesia, a total of 5,116 families still use fuelwood for household cooking activities. This number is the largest nationally in 2019 (Central Statistical Agency 2019), showing the high dependency of Papuan people on fuelwood.

Fuelwood has been used by rural communities in Papua for generations. Fuelwood is generally used for cooking in remote villages since fossil fuels, such as kerosene and LPG which are commonly used by the urban communities, are scarce or not available. Rural communities in Papua usually collect fuelwood from the nearby natural forests (primary and secondary forests) and also farmland. However, the extensive and continuous use of fuelwood causes pressure on the forest (Masera et al. 2015). This is further exacerbated by rapid population growth, resulting in an increase in fuelwood consumption (Amoah et al. 2015), causing a decline in forest tree species. If unresolved, this situation threatens tree biodiversity, adds pressure on forest sustainability and can drive environmental damage in the long run. For example, the forest in West Papua has depleted from 9.48 million in 2007 ha to 8.6 million ha in 2018 (Hendri et al. 2021). Although such loss is mostly caused by commercial logging, it is believed that fuelwood consumption has also contributed to deforestation and forest degradation.

In order to improve the life quality of rural villagers, the Ministry of Social Affairs of the Republic of Indonesia supported by the Presidential Regulation of the Indonesian Republic on the regulation No. 39 of 2012 and No. 186 of 2014 introduced the Remote Indigenous Community (RIC) Empowerment Program (Indow et al. 2021). RIC is defined as a local community group that is left behind, has less access to social services, economic, and political aspects, has a high dependency on local natural resources, uses traditional ways and generates income from subsistence livelihood (Indow et al. 2021). RIC is characterized as

having a limited relationship with other communities, living below the poverty line, and living in less developed and lives traditionally (Hatu 2020). In regard to energy, RIC depends mostly on fuelwood for its energy supply.

The RIC empowerment program aims to improve education, accessibility, income, environment, living conditions, etc. An important aspect of the program that it is prepared in accordance and in response to the basic needs of the society, supporting the poor, women, illiterates and other neglected and undeveloped groups, built from local resources, sensitive to local cultural values, concern to environmental impacts, not creating dependence on various related parties and sustainable (Fanida and Fitrotun 2015). The implementation of the RIC empowerment program is supposed can help remote people in overcoming poverty, improve the quality and quantity of human resources, health, environment and socio-culture (Indow et al. 2021). The empowerment program is hoped to open up opportunities for the RIC to get access and may encourage technology transfer to the RIC.

Regarding household energy fulfillment, it is hoped that RIC empowerment program can change how the community in using energy sources from fuelwood to more modern technology. The rationale is that the presence of the RIC empowerment program may stimulate the traditional way of life into modernization, and as a consequence the use of local firewood can slowly decline with the introduction of other energy sources from outside. Therefore, this research aimed to investigate the impact of the RIC empowerment program on reducing the use of fuelwood in West Papua. In doing so, we identified the fuelwood tree species and their availability in the past (before the RIC empowerment program) and compared them to those presently in use (after the RIC empowerment program) based on the community's perspective. Another question in this study is whether with the presence of the RIC program, the community is still using the local fuelwood tree species. We expect the result of this study can inform the effectiveness of the RIC empowerment program in the context of forest and biodiversity conservation, especially fuelwood tree species.

MATERIALS AND METHODS

Study period and area

The study was carried out from February to June 2019 in three ecological zones of remote indigenous communities (RIC) villages in West Papua Province, Indonesia (Figure 1), namely: (i) Jamboi Village, Ransiki Sub-district, South Manokwari District representing lowland ecological zone; (ii) Sakumi Village, Anggi Gida Subdistrict, Arfak Mountains District representing highland ecological zone (foothill forest ecosystem, 400 m above sea level); (iii) Watitindau Village, Rumberpon Sub-district, Teluk Wondama District representing island ecological zone.

The research was done using a descriptive method with qualitative and quantitative approaches through surveys and field observations. Key informants were determined using purposive sampling based on the following criteria: (i) Involved in the local RIC empowerment program activities, and (ii) Deliver actual information. Informant representatives were local indigenous peoples, ethnic chiefs, qualified leaders, or figures in every three villages. Data collection was carried out by interviewing the selected respondents. The respondent selection was made by purposive sampling, with the number of respondents as much as 20% of the total number of households in these 3 villages.

The variables observed were species use value based on the species identification and the local village people's perspective on the abundance and sustainability of fuelwood plant species. Data were collected based on observation, interviews in a semi-structural method and document analysis.

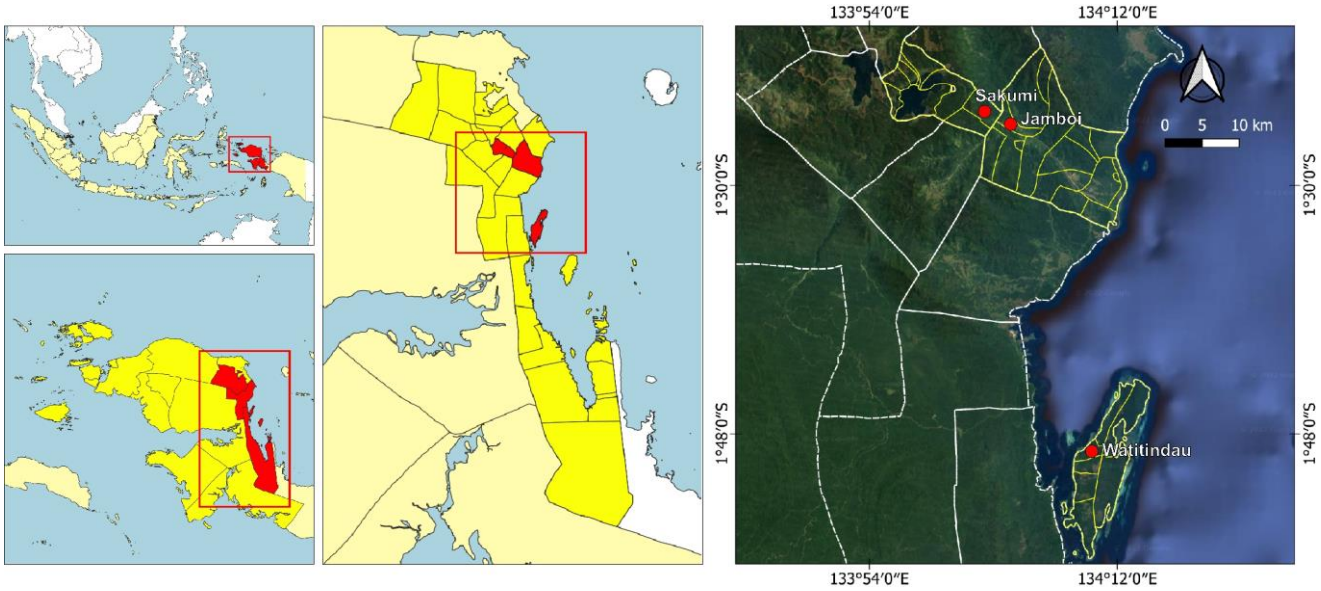

Figure 1. Map of the study area in Sakumi, Jamboi, and Watitindau villages of West Papua Province, Indonesia (Source: Indow, 2021)

Sp*ecies identification*

Identification was carried out for species mentioned by the respondents during the interview. In the field, documentation was carried out for the type of plants that are commonly used for fuel by village people of Sakumi, Jamboi and Watitindau.

Sp*ecies use value*

The formula of species use value (UV) is as follows:

$$UV = \sum U/n$$

Where: UV = Use Value of a Plant Species, U = Number of Informants Who Know/Use Per Species n = Total Number of Respondents

Respondent perspective on species abundance: 1 = Abundant (fuelwood collected in the settlement areas, farmland, river bank, coastal edge, forest edge, dense or deeper forest. 2 = Moderate (fuelwood collected in riverbank, forest edge, dense or deeper edge). 3 = Rare (fuelwood collected in a dense or deeper forest)

Data were analyzed using the tabulation method and presented in figures and tables.

RESULTS AND DISCUSSION

The indigenous community in the village of Sakumi, Jamboi and Watitindau collect fuelwoods from the surrounding home garden, farmland, river banks and forests. They generally collect fuelwood twice a week for daily use with each wood collection lasting for 2-3 days. Both women and men are responsible for finding, gathering, and carrying fuelwood. The collected fuelwood is for self-consumption. Based on the identification in the field, there are 5 to 7 species used as fuelwood with some of the fuelwood used by people of Sakumi, Jamboi and Watitindau villages being the same species (Table 1).

Fuelwoods in the villages are not usually marketed. Every household has its own responsibility to look for fuelwood. The distance to collect fuelwood from the settlement to the farmland and forest varies between 1-7 km. The villagers search for several trees in the areas where timber harvesting is traditionally permitted. The types of trees used for firewood consist of the remnants of big and tall trees which usually have commercial values and small-sized trees or shrubs. While the local villagers use trees with big diameters for building, furniture materials and other uses, the leftover branches are used for household fuelwood. For shrubs, all plant parts are taken for fuelwood and other needs. A single harvest activity requires about 2 to 3 hours of collection. Fuelwood is mostly used for cooking; however, it is also used for heating in Sakumi village. All of the fuelwood species (Table 1) have a good flame or good burning efficiency and heat retention qualities, are durable and are easy to ignite.

Watitindau Village

People of Watitindau village live on a small island where mangroves grow along the coastline. Mangrove wood is the most preferred fuelwood used by all households in Watitindau village. Table 1 and Figure 1 shows that 100% Watitindau people use mangrove for their domestic fuel energy with species index value (UV) = 1. Mangrove fuelwoods are easier to collect as most people live along the coast. According to the local people, wood from mangroves can produce a large fire and does not produce a lot of smoke. Their statement is in line with Numbere (2018) which also revealed that mangrove wood retains heat for a long period. Mangrove wood is quite strong, and the fuelwood is taken from the old mangrove trees. Before this fuelwood is used for cooking, it must be dried first. This is because mangroves usually have a fairly high-water content, considering the habitat of this tree in the intertidal area. The good flame of mangrove wood is caused by its fairly high wood density. According to the local community mangrove species with high wood density is heavier, harder and have long durability, making it has high temperature and long flame period. Mangrove population has been declining in Watitindau, but restoration effort has been carried out to ensure resource sustainability and to secure it for future generations.

Following mangrove, about 81% of the respondents use *Homalium foetidum* as fuelwood with the species UV of 0.81, followed by *Pometia pinnata* with UV of 0.54, while *Casuarina* sp., *Piper aduncum*, and *Gliricidia sepium* have the same UV (0.36). *Homalium foetidum* has a hard trunk with a redwood color. Besides it is used as fuelwood, *H. foetidum* can be used for building, bridge materials and other purposes. However, most people in this village prefer this species for fuelwood as it produces good flame quality. This tree species can grow into big size in forest and farmland. The population of *P. pinnata* has been declining as this species is widely used for building materials, especially after the RIC program entered this village. One of the RIC programs is to build decent houses and proper bridges using high quality wood materials. There are about 60 new houses built through RIC program for the local people using high quality wood trees including *Instia bijuga* and *P. pinnata*.

Table 1. Fuelwood species used in Watitindau, Jamboi and Sakumi villages in West Papua, Indonesia

Common name/ Scientific name	Village		
	Watitindau (n= 22)	Jamboi (n=12)	Sakumi (n=19)
	UV	UV	UV
Cassowary (*Casuarina equisetifolia*)	0.36	1	0.74
Gia *(Homalium foetidum)*	0.81	0.17	0
Gliricidia (*Gliricidia sepium*)	0.36	1	0.47
Iron wood (*Intsia bijuga*)	0	0.17	0.16
Matoa wood (*Pometia pinnata*)	0.54	0.33	0
Spiked pepper (*Piper aduncum*)	0.36	0	0.95
Mangrove (*Rhizophora* sp.*)*	1	0	0
Hopbush (*Dodonaea viscosa*)	0	0	0.53
Singapore Cherry (*Muntingia calabura*)	0	0	0.05
Roseapple (*Syzygium* sp.)	0	0	0.16
Species number	6	5	7

According to the local people, the flame quality of *P. pinnata* is lower than mangrove, *Casuarina* sp. and *H. foetidum*. *Casuarina* sp. mostly grows in the forest but few occur in the coastal areas. Some people in Watitindau village use *Casuarina* sp, *P. aduncum*, and *G. sepium* for fuelwood. Although several fuelwood species are present, mangroves are dominantly used as fuelwood by Watitindau village people, because this wood is easier to access from the settlements and provides good combustion qualities. Moreover, the population of *Casuarina* sp. is also declining because people intensively use this species for many purposes besides for fuel sources, such as traditional house materials, fences, traditional bridges and other purposes. *Casuarina* sp. is a pioneer tree and invasively can grow well. Similarly, *P. aduncum* and *G. sepium* are also easy to grow, but they are less used by Watitindau people.

Jamboi Village

All households in Jamboi village predominantly use *Casuarina* sp. and *G. sepium* as fuelwood. Both species produce a Use Value (UV) of 1, followed by *P. pinnata* with a UV of 0.33. On the other hand, *Instia bijuga* and *P. aduncum* produce the lowest UV of 0.17 (Tabel 1 and Figure 2). *Casuarina* sp. and *G. sepium* are used by most people due to their availability, function and good flame. According to Marques (2020), a good quality fuelwood species has characteristics of high wood density, low ash content and high heating value. *Casuarina* sp. and *G. sepium* are also used in this village for several other purposes besides fuelwood, such as fencing. These fuelwoods have a good flame quality according to all respondents.

Whistler and Elevitch (2006) stated that *Casuarina* sp. produces fine quality fuelwood and it is one of the best firewood in the world. They also reported that *Casuarina* sp. burns with little smoke and produces little ash. *Casuarina* sp. has a very hard, heavy, dark red-brown wood which is used for part of the housing material and various other tools and artifacts in the past. However, due to its extreme hardness it was replaced by other more favorable woods (Whistler and Elevitch 2006). Jamboi villagers also use *Gliricidia* sp. because the wood quality is good for cooking as it burns slowly and emits a small amount of smoke. Atapattu et al. (2017) also reported that *Gliricidia* sp. shows good fuelwood characteristics. Oladipo et al. (2013) reported on the analysis of calorific energy content and economic value of *Gliricidia* sp. as fuelwood based on the energy content. *Gliricidia* sp. is suitable for fuelwood and economically viable, and this can substitute coal which has low heat value and contain high sulfur and water. *Gliricidia* sp. can be propagated quickly using seed and stem cutting (Nyoka et al. 2015), and this causes the abundance of plants to be quite high (Figure 2). Meanwhile *Instia bijuga* and *Pometia pinata* have good quality and have an economic value for household income. However, the population *Instia bijuga* and *P. pinata* is declining due to exploitation.

Sakumi Village

Sakumi village is located at 400 m above sea level, making the temperature in this area quite cool at night, therefore fuelwood is not only used for cooking but also for heating. Based on the identification, there are 7 fuelwood tree species used by local people in this village namely *Casuarina equisetifolia*, *P. aduncum*, *G. sepium*, *Instia bijuga*, *Dodonaea viscosa*, *Muntingia calabura* and *Syzygium* sp. (Table 1 and Figure 2). The highest proportion (95%) of Sakumi villagers use *P. aduncum*, while 74 % use *C. equisetifolia*, 53% use *D. viscosa*, 47% use *G. sepium*, 16% use *Instia bijuga*, and 5% use *M. calabura*, with the species Use Value of 0.95, 0.74, 0.53, 0.47, 0.16, 0.16 and 0.05, respectively. Table 1 and Figure 2 show *P. aduncum* and *C. equisetifolia* are widely used by Sakumi village people for fuelwood.

Piper aduncum, which is categorized as shrubby tree species, is widely grown in Sakumi village and well adapted to various growing conditions. It grows well in the home garden, farmland, forest edge and dense forest. *Casuarina equisetifolia* mostly grows in farmland as well as in forests, but a decade ago before the RIC program was implemented it was also found around the settlement area. People of Sakumi use *C. equisetifolia* for other purposes such as traditional house poles, fences, bridge piers, pig sty and traditional medicine. In many areas of India this species is also used as fuelwood (Ezhumalai and Kumar 2018).

Among the listed tree species in Table 1 and Figure 2, *Instia bijuga* is categorized as commercial tree with high economic value. The demand for *Instia bijuga* is high since it has very good quality building and furniture materials. Currently, the price of *Instia bijuga* wood increases remarkably compared to a decade ago as this tree species has become rare on farmland and forest edge. As a consequence, people just collect the leftover branches of this tree for the fuel source. According to the respondents, population of this tree species is declining, and to find this species at this day, people must go deeper into the dense forest. Other tree species such as *Casuarina* sp. also is declining but mostly due to habitat destruction, road infrastructure, etc. On the other hand, the population of *Dodonaea* sp. and *Muntingia* sp are still abundant (Table 2). The village people do not restore or replant these species after the trees are cut down as they believe that the seeds of these trees will grow naturally, however not all types of trees have the ability to grow fast. Among the fuelwood species used by Sakumi villagers, the population of *Piper* sp. and *Gliricida* sp. are still high (Table 2) despite the threats caused by habitat destruction. This is because these plant species grow easily, fast and are well adapted to any environment. These species also grow in the surrounding farmland areas, making it is easier to collect these plant species as they grow closer to the settlement. Besides being consumed for their fruits, *Muntingia* sp. and *Syzygium* sp. are used for fuelwood. According to the local people, the abundance of these species is still high. At this time, not many people use these species for fuelwood despite its potential as an energy source.

Table 2. The perspective of local people on the population of fuelwood species before and after the RIC empowerment program

Fuelwood species	Watitindau Village (n= 22)		Jamboi Village (n=12)		Sakumi Village (n=19)	
	Before	**After**	**Before**	**After**	**Before**	**After**
Cassowary (*Casuarina equisetifolia*)	Abundant	Moderate	Abundant	Abundant	Abundant	Moderate
Gia *(Homalium foetidum)*	Abundant	Moderate	Abundant	Moderate	-	-
Gliricidia (*Gliricidia sepium*)	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Iron wood (*Intsia bijuga*)	-	-	Abundant	Rare	Abundant	Rare
Matoa wood (*Pometia pinnata*)	Abundant	Moderate	Abundant	Moderate	-	-
Spiked pepper (*Piper aduncum*)	Abundant	Abundant	-		Abundant	Abundant
Mangrove (*Rhizophora* sp.*)*	Abundant	Moderate	-	-	-	-
Hopbush (*Dodonaea viscosa*)	-	-	-	-	Abundant	Abundant
Singapore Cherry (*Muntingia calabura*)	-	-	-	-	Abundant	Abundant
Roseapple (*Syzygium* sp.)	-	-	-	-	Abundant	Moderate

Note : * RIC Development Program

Figure 2. Some tree species used for household fuelwood in Sakumi, Jamboi and Watitindau villages: (A) *Homalium foetidum*, (B) *Casuarina equisetifolia*, (C) *Piper aduncum*, (D) *Pometia pinnata*, (F) *Instia bijuga*, (H) *Rhizophora* sp.

The dependency of people on fuelwood in all three villages is not declining although the RIC empowerment program is present in these villages. Fuelwood has still been widely used by local people. This is likely because other energy sources, such as kerosene and LPG which are commonly used in urban areas, are not still available. Despite the presence of the RIC empowerment program, the reasons why people still use firewood because of financial limitations, and their reluctance to change their traditional habits as firewood is still plentiful in these villages. Sulaiman and Abdul-Rahim (2020) and Kamwilu et al. (2021) stated that most rural people use fuelwood to date due to its availability, cultural preferences, economic factors, unavailability of other energy sources and poverty.

The use of these tree species as fuelwood continues to increase if alternative fuels are not made available and

affordable. The use of wood as fuel does not necessarily cause the decline or extinction of firewood species, because the population decline of tree species used as firewood is primarily due to other factors. The village communities only use the remaining logs of selected species used for building materials and some shrub tree species that are easy to regrow naturally. However, without any reforestation efforts, it may cause pressure on the firewood trees in the future. This is in accordance with Khaing (2017) who stated that fuelwood consumption by a local household might not be the main cause of deforestation, unless fuelwood is collected in densely populated areas. Banerjee (2020) added that the effective management and conservation strategy should be driven to comprehend the way of harvesting wood resources from the forests. According to Kaburi and Medley (2022) the sustainability of wood resources is an important consideration in both conservation and development, so it needs to be echoed because of the potential conflict between communities using firewood and local authorities. Sustainable strategies should be developed to meet energy needs, and we recommend to carry out replanting fuelwood trees to maintain their sustainability in the long term.

ACKNOWLEDGEMENTS

We thank Domberai traditional territory communities, particularly the local indigenous peoples, tribal chiefs, traditional figures, and leaders in Sakumi, Watitindau, and Jamboi villages for the kind support during the interview. The authors also thank the field team of this research for supporting the data collection.

REFERENCES

Amoah M, Marfo O, Ohene M. 2015. Fuelwood consumption pattern, availability and coping strategies adopted to mitigate fuelwood scarcity: a case of rural households in Ghana. For Trees Livelihoods 24 (3): 202-218. DOI: 10.1080/14728028.2015.1052854.

Atapattu AAAJ, Pushpakumara DKNG, Rupasinghe WMD, Senarathne SHS, Raveendra SAST. 2017. Potential of *Gliricidia sepium* as a fuelwood species for sustainable energy generation in Sri Lanka. Agric Res J 54 (1): 34-39. DOI: 10.5958/2395-146X.2017.00006.0.

Banerjee P. 2020. Conservation of forest based on a fuelwood substitute as well as considering the cultural and spiritual values: an optimal fuelwood harvest model. DOI: 10.21203/rs.3.rs-93345/v1+.

Bunafsha M, Hable R, Fezakov M, Samimi C, Abdulnazarov A, Koellner T. 2014. Factors influencing households' firewood consumption in the Western Pamirs, Tajikistan. Mount Res Dev 34 (2): 147-156. DOI: 10.1659/MRD-JOURNAL-D-13-00113.1.

Central Statistical Agency. 2019. Statistik Indonesia 2019. https://www.bps.go.id/publication/2019 [Indonesian]

Ezhumalai R, Kumar R. 2018. Study the gasification performance of *Casuarina equisetifolia* wood. Indian Forester [S.l.]: 540-544. DOI: 10.36808/if/2018/v144i6/90663.

Fanida EH, Fitrotun N. 2015. Sustainable practice of revolving fund program: An effort to empower small and medium enterprises (SMEs) in Indonesia. Special Issue on Social Entrepreneurship. JGD 11: 67-81.

Hatu RA. 2020. The remote indigenous community empowerment based on local wisdom (Case study Limbula, Wanggarasi, Pohuwato, Gorontalo, Indonesia). J Seybold Rep 15 (9): 1432-1444.

Hendri, Karuniasa M, Prabawardani S, Syamsudin K, Pradafitri WS. 2021. Scenario for West Papua contribution for NDC from forestry sector. IOP Conf Ser: Earth Environ Sci 716: 012017. DOI: 10.1088/1755-1315/716/1/012017.

Indow L, Maturbongs RA, Saraswati Prabawardani, Hendri. 2021. Implementation of the remote indigenous community empowerment program on the sustainability of the local food crops in West Papua, Indonesia. Biodiversitas 22 (12): 5247-5254. DOI: 10.13057/biodiv/d221202.

Kaburi SM, Medley KE. 2022. Community perspectives on fuelwood resources in East Africa; Enrichment and extraction along the eastern slopes of Mount Kenya. Mt Res Dev 3 1 (4): 315-324. DOI: 10.1659/MRD-JOURNAL-D-10-00121.1.

Kamwilu E, Duguma LA, Orero L. 2021. The potentials and challenges of achieving sustainability through charcoal producer associations in Kenya: A missed opportunity? Sustainability 13: 2288. DOI: 10.3390/su13042288.

Khaing T. 2017. An Econometric Analysis of the Causes of Deforestation of Southeast Asian Countries. [Thesis]. KDI School of Public Policy and Management. https://archives.kdischool.ac.kr/handle/11125/32146.

Marques RD, Cunha TQG, Chagas MP, Venturoli F, Belini GB, Yamaji FM, Sette Junior CR. 2020. Wood quality of five species of the Cerrado for energy purposes. Scientia Forestalis 48 (125): e3225. DOI: 10.18671/scifor.v48n125.11.

Masera OR, Bailis R, Drigo R, Ghilardi A, Ruiz-Mercado I. 2015. Environmental burden of traditional bioenergy use. Ann Rev Environ Resour 40 (1): 121-150. DOI: 10.1146/annurev-environ-102014-021318.

Numbere AO. 2018. Mangrove species distribution and composition, adaptive strategies and ecosystem services in the Niger River Delta, Nigeria. In: Sharma S (eds). Mangrove Ecosystem Ecology and Function. IntechOpen, London. DOI: 10.5772/intechopen.79028.

Nyoka BI, Sileshi GW, Silim SN. 2015. Flower and pod abortion and its implication to seed production in *Gliricidia sepium* (Jacq.) Walp. Intl J Agrofor Silviculture 2 (6): 144-148.

Oladipo IO, Olawale UD, Ayodele AE. 2013. Energy economic value and climate change adaptation potentials of *Gliricidia sepium*. Universal J Environ Res Technol 3: 441-446.

Scheid A, Hafner JM, Hoffmann H, Kächele H, Uckert G, Sieber S, Rybak C. 2019. Adapting to fuelwood scarcity: The farmers' perspective. Front Sustain Food Syst 3 (28): 1-13. DOI: 10.3389/fsufs.2019.00028.

Stoner O, Lewis J, Martínez IL et al. 2021. Household cooking fuel estimates at global and country level for 1990 to 2030. Nat Commun 12: 5793. DOI: 10.1038/s41467-021-26036-x.

Sulaiman C, Abdul-Rahim A. 2020. The impact of wood fuel energy on economic growth in sub-Saharan Africa: dynamic macro-panel approach. Sustainability 12: 3280. DOI: 10.3390/su12083280.

UNEP. 2019. Review of woodfuel biomass production and utilization in Africa: A desk study" United Nations Environment Programme.

Waris VS, Antahal PC. 2014. Fuelwood scarcity, poverty and women: Some perspectives. IOSR J Hum Soc Sci (IOSR-JHSS) 19 (8): 21-23. DOI: 10.9790/0837-19822133.

Whistler AW, Elevitch CR. 2006. *Casurina equisetifola* (beach she-oak) *C. cunninghamiana* (river she-oak). Species Profiles for Pacific Island Agroforestry 2 (I).