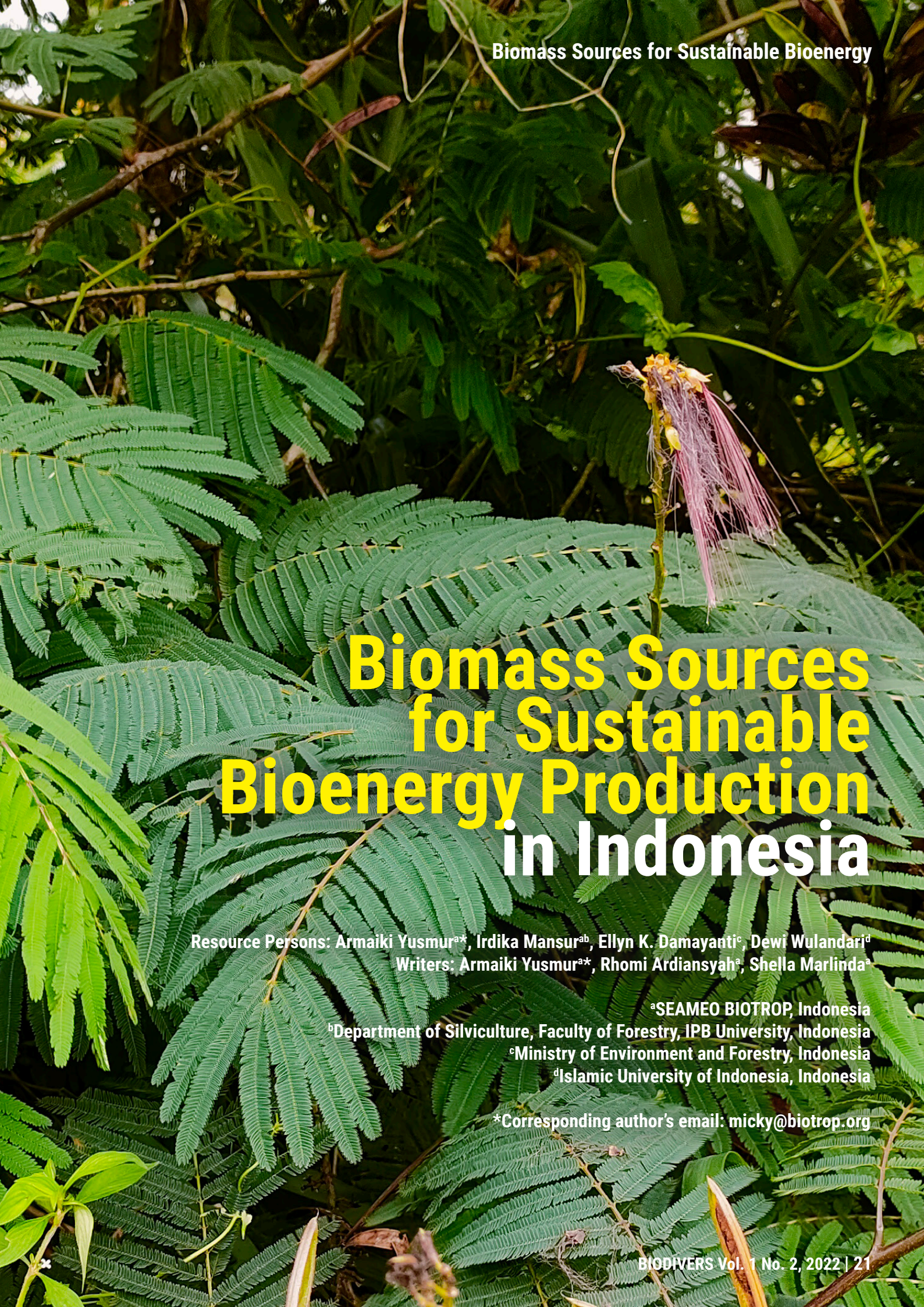

Biomass Sources for Sustainable Bioenergy Production in Indonesia

Resource Persons: Armaiki Yusmur[a]*, Irdika Mansur[ab], Ellyn K. Damayanti[c], Dewi Wulandari[d]
Writers: Armaiki Yusmur[a]*, Rhomi Ardiansyah[a], Shella Marlinda[a]

[a]SEAMEO BIOTROP, Indonesia
[b]Department of Silviculture, Faculty of Forestry, IPB University, Indonesia
[c]Ministry of Environment and Forestry, Indonesia
[d]Islamic University of Indonesia, Indonesia

*Corresponding author's email: micky@biotrop.org

Biomass Sources for Sustainable Bioenergy

Global Commitment to Energy Transition

The energy sector is currently dominated by fossil fuels that accounts for 73% of greenhouse gas emissions. A report prepared to support the High-Level Dialogue on Energy organized by the Secretary-General under the auspices of the United Nations General Assembly in September 2021 emphasized a need to accelerate the energy transition toward achieving SDG 7 (Affordable and Clean Energy) and Net Zero Emissions. Global CO2 emissions are targeted to be halved by 2030 to avoid an unprecedented increase in the frequency and severity of dangerous weather extremes, including devastating heat waves, floods, and droughts, risks to food and water security, population displacement, and loss of livelihoods.

The proposed recommendations include accelerated energy transition to reach 8,000 Gigawatt (GW) produced from renewable energy sources by 2030 considering the different contributions of every country. The utilization of renewable energy becomes an important de-carbonization option due to its abundance and cost-effective potential. For many countries, this is both a challenge and an opportunity to develop investment strategies, regulations, and socio-economic aspects. Over the next decade, every aspect of the national energy system will be affected by changes in climate and energy policies, financing, sustainable advanced technology, and shifts in energy supply and demand. The rapidly declining costs of renewable technologies are opening previously unimaginable opportunities around the world. The global commitment above could be a "market-driven" biomass based energy (bioenergy) for industries.

Wood pellet is one of the fastest-growing renewable bioenergy sources in the world. In 2019, around 38.9 million tons of pellets were produced globally[1]. Over the past 7 years, this source has reached an annual growth rate of 11.6% (Figure 1). Asia has the highest rate of 49% followed by Oceania at 30%. On the other hand, Europe dominated wood pellet production with a 55% share globally followed by America at 32% (Table 1).

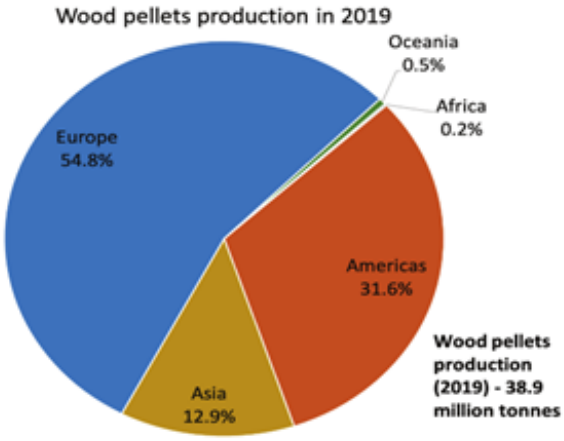

Figure 1. World wood pellet production in 2019 (%)

Table 1 Global Wood Pellet Production

Year	World	Africa	America	Asia	Europe	Oceania	EU-28
2012	18.1	0	5.1	0.3	12.5	0.03	11
2013	21.2	0	6.65	0.62	13.9	0.03	12.3
2014	25.1	0.04	7.96	1.72	15.2	0.14	13.3
2015	27.4	0.03	8.76	2.04	16.4	0.15	14.1
2016	29.3	0.04	9.49	2.59	17	0.16	14.3
2017	33.4	0.06	10.4	3.52	19.2	0.25	15.9
2018	36.6	0.07	11.2	5.01	20.1	0.21	16.9
2019	38.9	0.07	12.3	5.01	21.3	0.21	17.8
Growth	11.549413	-	13,401625	49.511219	7.91134	32.04692	7.117652

Source: Global Bioenergy Statistics, 2020

Opportunity and Challenge for Indonesia

The global market is widely opened for biomass, especially in the form of pellets. For Indonesia as a tropical country, where biomass can be produced throughout the year, the opportunity for producing bioenergy in the future is very prospective.

Indonesia consists of numerous islands with some areas still under-developed. To meet the targeted electrification ratio in the frontier, the outermost, and the least developed areas, often referred to as 3T (*Terdepan, Terluar, Tertinggal*) areas, the State Electricity Company (PLN) proposes that 23% of the supply must originate from renewable energy sources (Electricity Supply Business Plan (RUPTL) 2019-2028). The Indonesia Power Enterprise, a subsidiary of PLN, strives to fulfill the target through the development of Hybrid Power Plants (PLTH) among Biomass Power Plants (PLTBm), Solar Power Plant (PLTS), and Battery Energy Storage Systems (BESS) with the Minigrid concept spreading over the 3T islands. By implementing this concept, energy in the 3T Islands could be more affordable, reliable, sustainable, and available for 24 hours. In addition, this concept could also be a

solution to implement de-dieselization, decarbonization, and digitization of power plants.

Some advantages of wood biomass as the energy source, compared to fossil energy sources, are the following; wood is numerically abundant, available throughout the year, emits lower carbon quantity, and environmentally friendly because CO_2 released during combustion/oxidation will be compensated by the photosynthesis process[2]. Thus, the bioenergy from biomass sources will contribute less carbon emissions to the atmosphere.

Biomass Plantation Species as an Alternative Sustainable Bioenergy in Indonesia

Indonesia has numerous potential sources as raw materials for bioenergy from biomass with a high productivity level. These are tropical tree species having a short-time production age or rotation. Those trees with faster growth rates, and having many branches tend to have higher energy contents (Cahyono et al)[3]. Considering growth characteristics, the trees producing biomass sources for bioenergy should have the following characteristics:

1. Fast growth with a dense branching.
2. Considerable weight.
3. Easy to grow in various conditions.
4. Quickly sprout after pruning.

While the tree species to be planted must have the following characteristics:

1. Adaptable to various soil and climatic conditions.
2. Grows fast (high increment) and can compete with reeds.
3. Fast-growing after pruning.
4. Wood has a high calorific value.
5. Possess other economic values.

There are 147 forest tree species are potential for bioenergy production[4]. Meanwhile, seven species are highly recommended by the Forestry Research and Development Agency (FORDA) of the Ministry of Forestry Republic of Indonesia for biomass plantations, i.e., *Acacia auriculiformis* (akasia kuning)[5], *Acacia mangium* (akasia) [6], *Albizia procera* (waru)[7], *Calliandra calothyrsus* (kaliandra)[8], *Gliricidia sepium* (Gamal)[9], *Leucaena leucocephala* (lamtorogung)[10] and *Sesbania grandiflora* (turi)[11,12].

Potential Species for Biomass Plantation

Among the species, *Gliricidia sepium* has the most potential, with the remaining 6 species as alternatives, for biomass plantation. Among the 6 species, two have been domesticated, namely, (*Calliandra calothyrsus* and *Leucaena leucocephala*) and the other 4 grow naturally

Figure 2. Gamal (*Gliricidia sepium*) (Source: Armaiki Yusmur, 2021)

(*Auliculiformis acacia, Acacia mangium, Albizia procera,* and *Sesbania grandiflora*). These species have been planted widely for commercial and industrial plantations or for commercial and traditional agroforestry farms/ plantations, and utilized for various purposes[13].

Among the fast-growing tree species, Gamal (Figure 2) and Kaliandra (Figure 3) meet closely the above criteria. These trees are not endemic but adaptable to various conditions. These trees do not tolerate soils with poor drainage and frequent flooding but grow well in acidic and infertile soils[14]. Gamal does not grow well under other plant canopies but Kaliandra can live under the shade with moderate to high-intensity sunlight. In the highlands, Kaliandra that originated from Central America, can grow well in an elevation of up to 1,400 m above sea level with high and low rainfall in a long dry season of up to 6 months[15]. On its native place in Mexico and Central America, Kaliandra grows at elevations up to 1860 m above sea level, especially on areas where the annual rainfall ranges from 1,000 to 4,000 mm with a dry season lasting 2-4 months. This species can also grow at a minimum temperature of 18–22° C. In contrast, Gamal requires warmer conditions for its growth around 25–30° C for its optimal growth. Therefore, Kaliandra is preferably planted on a higher land.

Besides being fast growing, these species also have high calories and productivity. The productivity of Kaliandra is between 30-54 tons/ha/year with an average calorific value of 4,423 kcal/kg while Gamal trees produce 40-50 tons/ha/year with an average calory value of 4,529 kcal/kg. Considering the physical conditions in Indonesia and the characteristics of wood as a raw material for energy, Gamal wood is more suitable for production because of its high calorific value., low ash content (0.74%), and high melting point (1,400oC). Gamal plants have considerable ability to survive in areas with long dry periods. Nursery management of Gamal plants is relatively easy compared to Kaliandra. Quality analysis of the chips and wood pellets from Gamal trees are also very promising (Table 2).

Table 2. Gamal wood pellet and chips quality analysis result

Parameters	Chips Gamal Wood	Pellet Gamal Wood Without Adhesive	Molasses Adhesive Gamal Wood Pellet	SNI 8951-2020		
				Premium	Standard	Utilities
Density (g/cm^3)	0.69	0.86	1.00	0.5	0.5	0.5
Moisture content (%)	1.94	1.19	1.07	9.5	10	12
Flaying matters (%)	78.44	76.97	76.16	72	71	70
Ash content (%)	2.19	1.44	1.48	1.5	3	4
Fixed Carbon (%)	19.37	21.59	22.36	17	16	14
Ash (%, adb)	0.94	1.08	1.81	1.5	3	4
Gross Calorific Value (Cal/g, adb)	4,242	4,500	4,526	4,300	4,300	4,040
Total Sulfur (%, adb)	0.087	0.022	0.078	0.05	0.05	0.1
Carbon (%, adb)	46.74	48.77	48.78	17	16	14
Hydrogen (%, adb)	6.57	6.42	6.32			
Nitrogen (%, adb)	0.47	0.42	0.42			
Oxygen (%, adb)	45.19	43.29	42.59			
Chlorine (%, adb)	0.020	0.017	0.11			
HGI	19	25	33	32	32	32

Source: Prima Kelola IPB, 2021

Figure 3 Kaliandra (*Calliandra callothyrsus*)
(Source: Armaiki Yusmur, 2021)

SEAMEO BIOTROP assessment on the suitability and adaptability of Gamal in Indonesia show that this species can grow well in Java and Kalimantan Islands[16]. An ecological feasibility study has been conducted using literature and spatial data to support the recommendation on suitable areas for Gamal plantation in Indonesia. The study concluded that about 7.716,65 km^2 are suitable and expandable for Gamal plantation on Java Island (Figure 4), while 4.064,59 km^2 are on Kalimantan Island (Figure 5).

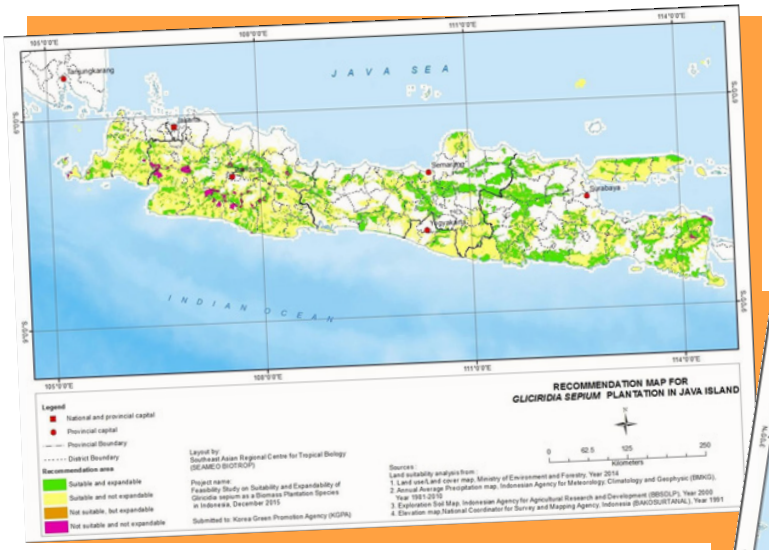

Figure 4. Suitable and expandable areas for Gamal plantation in Java Island

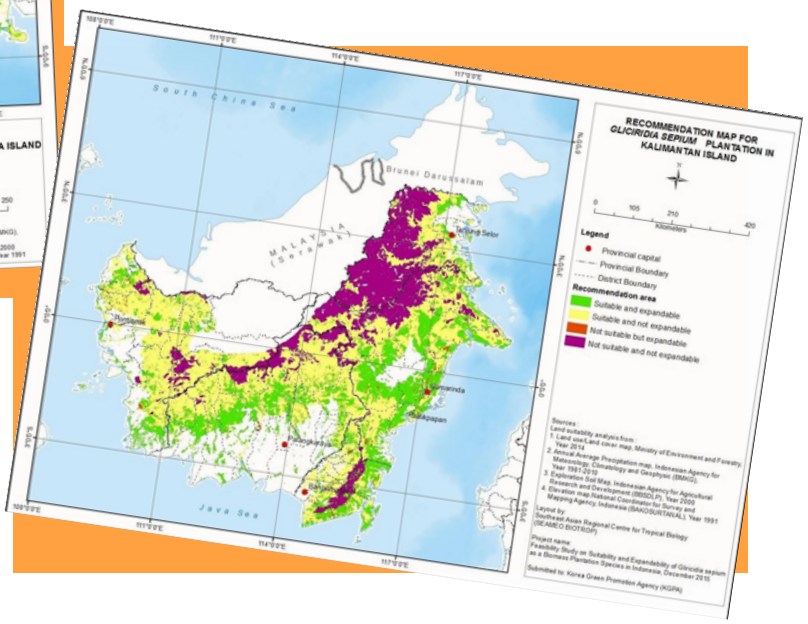

Figure 5. Suitable and expandable areas for Gamal plantation in Kalimantan Island.

Indonesian Action Plan for Bioenergy Policy on Climate Change Mitigation

The government, as a policy maker, tries to encourage the increase in the use of New and Renewable Energy (NRE). This National Energy Policy targets the NRE mix of 23% in 2025 based on PP Number 79 of 2014. On the other hand, PT PLN in the 7th Business Plan for Power Supply (RUPTL) in 2021-2030 estimates the need for electricity to reach 55,000 MW, where the average increase in electricity demand per year is 5,500 MW. Meanwhile, the Ministry of Energy and Mineral Resources also projects the next five-year EBT plant development plan for the construction of Geothermal PLT worth USD 17.45 billion, Water or Microhydro PLT worth USD 14.58 billion, PLT Solar and PLT Bayu worth USD 1.69 billion, PLT Waste is worth USD 1.6 billion, PLT Bioenergy is worth USD 1.37 billion and PLT Hybird is worth USD 0.26 billion. Based on these conditions, the development of energy plant biomass as a raw material supply for PLTU co-firing is a huge opportunity, especially for energy biomass that has been converted into the form of chips, sawdust and wood pellets.

With the high demand for biomass energy, it is necessary to identify potential areas for garden development and industrial support. In addition to utilizing non-forestry areas with agroforestry and monoculture schemes, industry can also open energy plant plantations through forestry multi-enterprise schemes utilizing forest areas. This policy is regulated in the Regulation of the Minister of Environment and Forestry No. 3 of 2021 Regarding Business Activity Standards in the Implementation of Risk-Based Business Permits in the Environment and Forestry Sector and the Regulation of the Minister of Environment and Forestry No. 8 of 2021 Regarding Forest Management and the Preparation of Forest Management Plans, and Utilization of Protected Forests and Production Forests.

Currently, the industry of wood energy, especially wood pellets, is still relatively small in Indonesia. Some wood energy producers who have produced in Indonesia are generally export-oriented (to South Korea and Japan), and only a small part is sold in the domestic market. This happens because the price of wood pellets in the international market is much higher than in the local market. By setting a maximum tariff of 85% of the price of coal, it is expected that the domestic production of wood

pellets will be encouraging enough for the industry to be able to supply domestic needs. By creating investment in the green industry and green energy, it is hoped that the development of biomass potential in Indonesia can contribute to the movement of reducing emissions and the impact of climate change.

The main challenge for most of these industries is how to replace the current use of fossil fuels with renewable energy sources, both in the production process and in the supply of energy. Available technology options include:

a. Electricity generation from cleaner and renewable energy sources.
b. Renewable energy sources from the heat of the sun, geothermal, or sustainable biomass.
c. Production of hydrogen, ammonia, and other synthetic fuels from renewable energy (green hydrogen).
d. Reduction of carbon dioxide emission, through biomass production and carbon capture with Storage/ Utilization.

References

[1] Global Bioenergy Statistical, 2020.

[2] Amirta R, Anwar T, Sudarajat, Yuliansyah, Suwinarti W. 2018. Trial production of fuel pellet from Acacia mangium bark waste biomass. *IOP Conf. Ser.: Earth Environ. Sci. 144(1)*, Article 012040. doi: 10.1088/1755-1315/144/1/012040

[3] Cahyono TD, Coto Z, Febrianto F. (2008). Analisis nilai kalor dan kelayakan ekonomis kayu sebagai bahan bakar substitusi batu bara di pabrik semen. *Forum Pascasarjana 31(2)*: 105-116.

[4] Hartono, BT. 2015. National energy related policy. Presentation for International Symposium on Wood Biomass in Indonesia "Current Status and Perspectives of Wood Biomass Business". Semarang, Indonesia, October 28, 2015.

[5] Hendrati, RL, Nurrohmah, SH, Susilawati, S. and Budi, S. 2014. Budidaya Acacia auriculiformis untuk Kayu Energi. Badan Penelitian dan Pengembangan Kehutanan, Balai Besar Penelitian Bioteknologi dan Pemuliaan Tanaman Hutan dan Direktorat Jenderal Bina Usaha Kehutanan. IPB Press. Jakarta, Indonesia.

[6] Jøker, D. 2000. Acacia mangium Willd. Seed Leaflet No. 3. Danida Forest Seed Centre. Humlebaek, Denmark. 2p.

[7] Van Valkenburg, JLCH. 1997. Albizia procera (Roxb.) Benth. In Faridah Hanum, and van der Maesen, LJG. Plant Resources of South-East Asia No. 11: Auxiliary plants. PROSEA (Plant Resources of Southeast Asia) Foundation. Bogor, Indonesia. Retrieved from http://www.proseanet.org on 7 December 2015.

[8] Hendrawan, I, Fanindi A. and Semali, A.2005. Karakteristik dan Pemanfaatan Kaliandra (Calliandra calothyrsus). Lokakarya Nasional Tanaman Pakan Ternak. Pusat Penelitian dan Pengembangan Peternakan, Kementerian Pertanian. Bogor, Indonesia. p.141-148.

[9] Simons, AJ. and Steward JL. 1994. Gliricidia sepium – a multipurpose forage tree legume. Retrieved from http:// www.fao.org/ag/agp/agpc/doc/publicat/ guttshel/x5556e07.htm on October 29, 2015.

[10] Jones, RJ, Brewbaker, JL. and Sorensson, CT. 1992. Leucaena leucocephala (Lamk) de Wit. In Mannetje, L't and Jones, RM. Plant Resources of Southeast Asia No. 4: Forages. PROSEA (Plant Resources of Southeast Asia) Foundation. Bogor, Indonesia. Retrieved from http://www.proseanet.org on 2 November 2015.

[11] Ahmad NR. 2013. Bioenergy industry based on forest biomass. Presentation for Panel Discussion Forum of Biomass Inductry in Indonesia. Embassy of South Korea and Ministry of Forestry Republic of Indonesia, on Septemer 5, 2013 at Grand Melia Hotel, Jakarta Indonesia.

[12] Heering, JH. and Gutteridge, RC. 1992. Sesbania grandiflora (L.) Poiret. In Mannetje, L't and Jones, RM. Plant Resources of South East Asia No. 4: Forages. PROSEA (Plant Resources of Southeast Asia) Foundation. Bogor, Indonesia. Retrieved from http://www.proseanet.org on 7 December 2015.

[13] Wawo, AH, Utami, NW. and Syarif, F. 2013. Konservasi Tumbuhan Bernilai Ekonomi Tinggi Melalui Pengembangan Model Agroforestri. Prosiding Seminar Nasional Agroforestri. p.104.

[14] Simons, AJ. and Steward JL. 1994. Gliricidia sepium – a multipurpose forage tree legume. Retrieved from http:// www.fao.org/ag/agp/agpc/doc/publicat/ guttshel/x5556e07.htm on October 29, 2015

[15] Jøker, D. 2003. Calliandra calothyrsus Meissner. Seed Leaflet No. 76. Danida Forest Seed Centre. Humlebaek, Denmark. 2p.

[16] Ellyn KD, Dewi W, Armaiki Y. 2015. Feasibility Study on Suitability and Expandability of Gliricidia sepium as a Biomass Plantation Species in Indonesia. Research Report, SEAMEO BIOTROP - Korea Green Promotion Agency (KGPA) Collaboration.