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The Distribution, Habitat Characteristics, and Bioenergy Potential of *Sargassum* sp. in Indonesia

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ABSTRACT

Sargassum sp. is a brown macroalgae that has a habitat in tropical marine environments, including Indonesia. *Sargassum* sp. contains carbohydrate, alginate and bioactive compounds that have the potential to be used for bioenergy. The purpose of this study is to analyze water data to identify conditions suitable for the growth of *Sargassum* sp. and to pinpoint existing growth locations. The method of this activity is a descriptive method by reviewing articles and references related to the potential of *Sargassum* sp. and the location of growth points. The result of the study is the potential of *Sargassum* sp. found in Sumatera, in Lhok Bubon, Simeulue, and Tarahan. In Java, the habitat points of *Sargassum* sp. are in Karimunjawa, Rembang and Probolinggo. Madura has potential in Saronggi, Talango, Ponjuk, and Gili Genting. Kalimantan can also be found in Singkawang, Lemukutan and Bontang. Sulawesi has potential for *Sargassum* sp. in Bonerita, Takalar and Barrang Lompo. East Nusa Tenggara has potential in Katundu, Hansisi, Alor, and Netbaun. West Nusa Tenggara is located in Ekas, Gerupuk, Labuan Ijuk, Wane and Cempi. Bali has potential in Sanur, Sawangan, and Serangan. Maluku has potential in Weda, Hatumuri, and Tapi. Papua has potential in Raja Ampat and Manokwari. Environmental parameters that support the growth of *Sargassum* sp. include a bottom substrate of coral, temperatures ranging from 29.5℃ - 32.7℃, a salinity of 29-30 ppt, a pH 7.9-8.15, dissolved oxygen levels from 6.7 ppm - 8.5 ppm, and light intensity obtained ranged from 590×100 Lux to 772×100 Lux.

1. INTRODUCTION

Indonesia has tropical waters that have the potential for various types of macroalgae, including *Sargassum* sp., *Kappaphycus alvarezii*, *Gracillaria* sp., *Ulva* sp., *Padina*, *Caulerpa* sp. and *Tubinaria*. Macroalgae are utilised for food and non-food raw materials. Bin Stepanus and Kolibongso [1] explained that algae also contain lipid components that are useful as raw materials for biofuel production (biodiesel, biogas, and bioethanol). Lipids can be converted into biodiesel through esterification and transesterification reactions. Therefore, algae is an important source of biomass for the development of Renewable Energy in Indonesia. This is an alternative to overcome the threat of an energy crisis due to dependence on fossil fuels. Among the non-food macroalgae is *Sargassum* sp. *Sargassum* sp., which includes brown algae (Phaeophyceae), lives in tropical waters and typically attaches to aquatic substrates, especially corals. *Sargassum* sp. habitat is mostly on coral reefs. *S. aquifolium* easily spreads because it can float in the water column, carried by water currents [2]. *Sargassum* can be found in Indonesian waters including in the sea waters of Lombok Island, Sumbawa, Bali, Karimun Java, Madura, Ambon, Kalimantan, and Sulawesi. *Sargassum* sp. grows in tidal areas in almost all marine waters of Lombok Island and West Nusa Tenggara.

Sargassum sp. has morphological characteristics (a) cylindrical or flat talus; (b) lush branches resembling plants on land; (c) wide, oval, or sword-like leaf shape; (d) has an air bubble (bladder); (e) length can reach 7 meters; (f) talus color is generally brown. At each branching, there is a round air bubble (bladder) which is useful for floating to the surface of the water [2]. According to Cokrowati and Diniarti [3], *S. aquifolium* contains carbohydrates (59.51%), fat (8.41%), Ca (3.34%), Fe (0.12%), P (0.18%), Ca (3.34%), water (12.79%), ash (12.79%), and N (7.22%) [4]. *Sargassum* sp. has a polysaccharide content, namely cellulose 23.97-35.22%. *Sargassum* sp. has a ratio of C: N ratio of 20:1 to 30:1 which is included in the criteria for biogas raw materials.

The energy needs of the Indonesian people are increasing from year to year along with the increase in population. The Government of the Republic of Indonesia continues to strive to realize bioenergy to offset the availability of petroleum

energy. These efforts include realizing bioenergy made from *Sargassum* sp. The potential and habitat of *Sargassum* sp. in Indonesian waters are important to know to realize energy independence in the area around the habitat. A review of *Sargassum* sp. habitat in Indonesia is needed to determine its potential, so that it can be analysed whether the potential can be developed as a bioenergy material. *Sargassum* sp. can contribute to the development of bioenergy in Indonesia, its growth is found in most of the Indonesian waters. The potential of *Sargasum* sp. as a non-food seaweed that can be utilized as bioenergy without competing with the food supply chain. *Sargassum* sp. cultivation also needs to be started to maintain its availability and sustainability. Saldarriaga-Hernandez et al. [5] explained that Sargassum sp. biomass in the Mexican Caribbean grows rapidly at warmer temperatures. *Sargassum* sp. is notable for its rapid growth and accumulation in coastal areas. The potential can be used as bioenergy material because *Sargassum* sp. is a renewable, cheap, and naturally growing biological resource.

The purpose of this research is to compile data on the growth locations of *Sargassum* sp. in Indonesia using desktop research methods. The benefit of this research is to provide an overview of the presence of *Sargassum* sp. in Indonesia and an overview of the existing *Sargassum* sp. growth locations in Indonesia.

2. MATERIAL AND METHOD

This article uses a literature study method from scientific articles, books, conference papers, and other sources. Literature study is the process of searching, collecting, and analyzing various sources of information relevant to a particular topic [6, 7]. The literature study is to understand and explore pre-existing knowledge regarding the presence of *Sargassum* sp. in Indonesian sea waters and its water characteristics. The material used in this review is articles, books, and proceedings. The selected article criteria were articles published in reputable journals on the topic of the potential of *Sargassum* sp. in the Indonesian region. The search terms used were *Sargassum* sp., Indonesia and Bioenergy. The literature was then categorised into four aspects: potential, cultivation, ecology, and bioenergy, all related to *Sargassum* sp. Literature in the 'potential' category discusses the presence of *Sargassum* sp. in the waters surrounding all Indonesian islands. The 'cultivation' category comprises articles that explore the cultivation techniques and practices of *Sargassum* sp. in Indonesia. The 'ecology' category includes articles that describe the environmental parameters of *Sargassum* sp. habitats. The 'bioenergy' category encompasses research articles on the utilization of *Sargassum* sp. as a source of bioenergy. Data were synthesized by analyzing the presence and potential of *Sargassum* sp. and its species across various regions of Indonesia. The ecological data synthesized for the habitats of *Sargassum* sp. included water substrate, temperature, pH, salinity, dissolved oxygen, and climate.

3. RESULT AND DISCUSSION

Sargassum sp. has a habitat in tidal areas of tropical marine waters. Sargassum species that are easily found in Indonesian waters include *Sargassum crasifolium*, *S. aquifolium*, *S. polycystum*, *S. binderi,* and *S. cristaefolium*. These species can be found in Indonesian waters. These species have different morphological forms, namely the shape of the talus that resembles a leaf. *S. crasifolium*, *S. aquifolium*, *S. cristaefolium* have a wider talus shape and are shaped like a widened leaf. *S. binderi* has a smaller talus shape and resembles a tapered leaf.

Cokrowati and Diniarti [3] explained that in general *Sargassum* contains carbohydrates (59.51%), fat (8.41%), Ca (3.34%), Fe (0.12%), P (0.18%), water (12.79%), ash (12.79%), and N (7.22%). These components are owned by almost all types of *Sargassum* sp. Carbohydrate is the largest component of *Sargassum* sp. [8]. According to study [9], *Sargassum* sp. also has potential as a source of immunostimulants in increasing the resistance of aquatic organisms to disease. *Sargassum* sp. extract has been shown to improve the immune system, growth, and survival of aquatic organisms and fight disease.

Sargassum sp. habitats are sheltered waters, waters that have large water movements, tidal areas, and subtidal areas [10]. *Sargassum* sp. is attached to coral substrates and rocks at the bottom of the water. *Sargassum* sp. grows throughout the season and its reproduction can produce offspring in large numbers. So *Sargassum* sp. can easily be found. Currently, *Sargassum* sp. has not been cultivated, its utilization comes from nature. *Sargassum* sp. which grows in waters naturally, has an ecological function as an oxygen producer, fish food, and fish eggs, where fish reproduce and where fingerlings take refuge. *Sargassum* sp. easily grows in its habitat, so it is often referred to as a weed for seaweed farmers. The presence of *Sargassum* sp. does not disturb the waters or the activities of fishermen, in fact, with the presence of *Sargassum* sp. the waters become more productive. *Sargassum* sp. can produce oxygen in the waters and can be used by another aquatic biota. *Sargassum* sp. like other macro algae has an important ecological role in marine water. Cotas et al. [11] explained that the role of seaweed ecology is as an oxygen producer, spawning ground for marine biota, and also serves as food for herbivores. It is also a habitat and shelter for gastropods and vertebrates. gastropods, vertebrates, and herbivorous fish. In the food chain, *Sargassum* sp. is at the first trophic level [12]. The presence of *Sargassum* sp. in the water can help in carbon sequestration. Many factors influence the value of stored carbon stored in *Sargassum* sp. such as the amount of biomass, environmental conditions, and physico-chemical parameters.

3.1 Sumatera

The potential of *Sargassum* sp. in the waters of Sumatra Island is found in several waters is shown in Table 1 [13-36].

According to study [15], the west coast of Aceh is dominated by brown seaweed as many as 17 species. Genus *Sargassum* as many as 10 species namely *Sargassum binderi, S. crassifolium, S. duplicatum, S. fluitan, S. granuliferum, S. ilicifolium, S. lineariforium, S. muticum, S. Polycystum* and *S. vulgare.* The biochemical component of *Sargassum* sp. used as bioenergy material is carbohydrate. The species with the most potential at Sumatera as a bioenergy feedstock is *S. fluitans*. According to Amador-Castro et al. [37], *S. fluitans and S. natans* are rich in carbohydrates, reaching values up to 78% of dry weight.

Table 1. Location of potential *Sargassum* sp. in the waters of Sumatra Island

No.	Location	Species	References
1	Aceh South West	*Sargassum* sp.	[13, 14]
2	Aceh South West, Lhok Bubon, West Aceh	*Sargassum* sp.	[13, 14]
3	Aceh Besar: Layeun, Lamnga	*S. binderi*	[15]
4	Banda Aceh: Ulee Lheue	*S. cristaefolium*	[15]
5	Aceh Jaya Ketapang, Crak Mong, Ceunamprog.	*S. duplicatum*	[15]
6	Simeulue: Maudil	*S. fluitan*	[15]
7	Inor, Angkoe	*S.ilicifolium*	[15]
8	West Aceh: Lhok Bubon	*S. lineariforium*	[15]
9	South Aceh: Haloban	*S.muticum, S. polycystum, S.vulgare*	[15]
10	Aceh Jaya: Lhok Geulumpang	*S. polycystum*	[13, 14]
11	West Aceh	*S. ilicifolium*	[13, 14]
12	South Aceh	*Sargassum* sp.	[16]
13	Lam Lhom (Aceh Besar), Lange.	*S. polycystum*	[17]
14	Gunong Cut South Aceh	*Sargassum* sp., *S.polycystum*	[18]
15	Ujoeng Kareung, Aceh Besar	*S. polycystum, S.plagiophyllum*	[19]
16	Lhoknga, Aceh.	*Sargassum* sp.	[20]
17	North Sumatera	*S. plaagyophyllum*	[21]
18	Poncan Beach, Sibolga	*S. plagyophyllum*	[22]
19	Poncan Beach, Sibolga	*S. cinereum*	[23]
20	Poncan Beach, Sibolga	*Sargassum* sp.	[12]
21	Pane Island, Central Tapanuli	*Sargassum* sp.	[24]
22	Mursalah Island, Central Tapanuli	*S. cinereum*	[25]
23	Poncan Beach, Gadang Island	*Sargassum* sp.	[12]
24	West Sumatra, Padang Puruih.	*S. echinocarpum*	[26]
25	Teluk Bayur, Padang	*Sargassum* sp.	[27]
26	Nirvana Beach, Padang	*S. plagiophyllum*	[28]
27	Kasiak Gadang Island	*S. crassifolium, S. cristaefolium*	[29]
28	Coastal Beach, South Pesisir.	*Sargassum* sp.	[30]
29	Bungus Bay	*Sargassum* sp.	[27]
30	Riau, Riau Island	-	-
31	Bintan Island	*Sargassum* sp.	[31]
32	Malang Rapat, Bintan.	*Sargassum* sp.	[32]
33	Teluk Sasah	*Sargassum* sp.	[33]
34	Sebong Pereh	*Sargassum* sp.	[34]
35	Sebauk, Lampung	*Sargassum* sp.	[35]
36	Sebalang Beach, Katibung	*S.polycystum*	[36]

3.1.1 Characteristics of Sumatera Sea waters

Sumatra is classified as an A (very wet) climate type region whose peak rainy season falls between October and January, sometimes until February. Based on this climate, Sumatra has peat forests that are generally located in climate type A or B areas, namely on the east coast of Sumatra, tropical rainforests, and monsoon forests [38].

The water quality of marine waters around Sumatra Island can vary depending on location and environmental factors [15]. In general, marine waters around Sumatra can have good water quality, especially in areas that are more remote or far from human pollution sources. Substrate types and water movement in the coastal waters of Sumatra Island also vary depending on the region. According to Erniati et al. [15], the results of measurements of temperature parameters in coastal waters in Aceh Province ranged from 28.70-32.40℃ with an average value of 30.27℃. The temperature at the research site is still within the normal range that can be tolerated by seaweed. The study by Susanto et al. [39] demonstrated that surface water temperature is influenced by the intensity of solar radiation, air temperature, rainfall, evaporation, air humidity, and wind speed. According to Sulistiawati et al. [40], temperature plays a role in controlling enzymatic reactions in photosynthesis. High temperatures can increase the maximum rate of photosynthesis, while the indirect effect is a change in the hydrological structure of the water column which can affect the distribution of phytoplankton. Dissolved oxygen is an important parameter because oxygen is needed by seaweed for metabolic processes and respiration [41]. Dissolved oxygen is a limiting factor for all aquatic organisms. Dissolved oxygen is a basic requirement for the life of living things in the water [42]. Ramadhanty et al. [43] explained that the waters of the western Sumatra Sea have a surface salinity value (0 metres) ranging from 32-35.6 ppt. At a depth of 0-24 m, it has a salinity of 32.5- 33.62 ppt. This is suitable for macroalgae habitat.

3.2 Java

The waters surrounding Java Island are the Java Sea to the north, the Sunda Strait to the west, the Indian Ocean to the south, and the Bali and Madura Straits to the east. The following data on the distribution of *Sargassum* sp. on the island of Java can be seen in Table 2 [44-60]. *Sargassum* sp. in Java waters, has ecological functions as a producer of dissolved oxygen in the waters, as a habitat for juvenile fish and juvenile marine biota and food for herbivores.

3.2.1 Characteristics of Java Sea waters

The water temperature ranges from 26 to 30℃, with pH, current strength, and water depth in the waters of Untung Island Java, which ranges from 7-8 for pH, 14-25 cm/s for current strength, and 50-115 cm for water depth that can still be penetrated by light. Macroalgae growth can continue in the pH range of 7-8, the ideal current strength for macroalgae

growth is 20-40, and at a water depth of 30-90 cm macroalgae can still live, because sunlight can still penetrate to the bottom of the water so that macroalgae can carry out photosynthesis [61]. Based on study [38], Central Java has a tropical climate, with an average annual rainfall of 2,000 meters, and an average temperature of 21-32℃. East Java has a wet tropical climate. Compared to the western part of Java Island, East Java generally has less rainfall. Rainfall averages 1,900 mm per year, with a rainy season of 100 days. The average temperature ranges from 21 to 34℃.

Table 2. Location of potential *Sargassum* sp. in the waters of Java Island

No.	Location	Species	References
A	Banten		
1	Sunda Strait: Merak Beach, Anyer, Cilurah, Sambolo, Cidatu, Banten.	*S. muticum* (Yendo) Fensholt	[44]
B	DKI Jakarta		
1	Untung Java Island, Kepulauan Seribu, DKI Jakarta Province	*S. binderi, S. asperifolium, S. ilicifolium, and S. polycystum*	[45]
2	Pramuka Island, Kepulauan Seribu, DKI Jakarta Province	*S. crassifolium*	[46]
C	West Java		
1	Sayangheula beach waters, Pamenungpeuk sub-district, Garut-West Java	*S. binderi, S. duplicatum, S. polycystum*	-
2	Karapyak Beach, West Java	*S. polycystum, S. crassifolium*	[47]
3	Rancabuaya Beach, Purbayani Village Garut District, West Java.	*S. polycystum*	[48]
4	Sindangkerta Beach, Cipatujah Subdistrict, Tasikmalaya Regency, West Java	*S. polycystum*	[49]
5	Permisan Beach Cilacap Regency Central Java	*S. binderi, S. duplicatum, S. polycytum*	[50]
D	DI Yogyakarta		
1	Krakal Beach Ngastirejo Village, Gunung Kidul District Yogyakarta	*S. duplicatum, S. echinocarpum S. binderi, S. cinereum*	[51]
E	Central Java		
1	Ranca Babakan Nusakambangan Beach Cilacap, Central Java	*S. duplicatum*	[52]
2	Awur Bay Jepara Regency Central Java	*S. binderi, S. crassifolium, S. echinocarpum, S. gracillimum, S. mollerii, S. polycystum, Sargassum* sp.	[53]
3	Karimunjawa islands, Menjangan Besar Island, Menyawakan Island, Central Java	*S. binderi, S. crassifolium, S. echinocarpum, S. polycystum*	[44]
4	Bandengan Beach Jepara, Central Java	*Sargassum* sp.	[54]
5	Barakuda Beach, Karimunjawa, Central Java	*Sargassum* sp.	[55]
6	Rembang Beach Waters, Central Java	*Sargassum* sp.	[56]
7	Waters of Tanjung Pudak Karimunjawa Island.	*S. duplicatum*	[57]
8	Permisan Beach, Cilacap Regency Central Java Menganti Beach, Jepara, Central	*S. binderi, S. duplicatum, S. polycytum*	[50, 58]
F	East Java		
1	Pidakan Beach, Pacitan Regency, East Java	*Sargassum* sp.	[59]
2	Srau Beach, Pacitan Regency, East Java	*Sargassum* sp.	[59]
3	Probolinggo coastal waters, East Java	*Sargassum* sp.	[60]

3.3 Madura

Madura Island is an island located in the northeast of Java. The island has four districts namely Bangkalan Regency, Sampang Regency, Pamekasan Regency, and Sumenep Regency. The mariculture commodity on Madura Island that is being developed is seaweed, which if managed and utilized properly, then this potential is not only a local asset but also a national one [62]. Madura island waters have the potential of *Sargassum* sp. as shown in Table 3 [63-83]. *Sargassum* sp. in Madura has not been utilised, people take it if there are buyers who order it only. Buyers come from Indonesia, usually for research purposes.

3.3.1 Characteristics of Madura sea waters

Madura island waters are divided into 2 areas, namely the northern area associated with the Java Sea and the southern area associated with the Madura Strait. The Java Sea is an ecological unit from the waters of the South China Sea, Kalimantan, and Makassar Bay, to the Flores Sea in the East. The oceanographic conditions of these waters are influenced by the movement of the Java Sea currents and changes in salinity due to the influence of river estuaries and the rainy season. Summer lasts for 6 months, from April to October, with an average daily high temperature above 29℃ [38]. The hottest month of the year in Madura is April, with an average low temperature of 21℃ and a high of 29℃. Winter lasts for 2.2 months, from June 20 to August 26, with average daily high temperatures below 28℃. The coldest month of the year in Madura is August, with an average low of 19℃ and a high of 28℃.

Table 3. Location of potential *Sargassum* sp. in the waters of Madura Island

No.	Location	Species	References
1	Madura Strait, Bangkalan.	*Sargassum* sp.	[63]
2	Camplong Beach, Sampang.	*S. duplicatum*	[10]
3	Mandangin, Sampang	*Sargassum* sp.	[64]
4	Jumiang Beach, Pamekasan	*S. duplicatum, S. filipendula, S. plagyophyllum, S. polyceratium*	[10]
5	Kapong Beach, Pamekasan	*S. vulgare*	[65-67]
6	Saronggi Beach, Sumenep	*Sargassum* sp.	[60]
7	Sumenep waters, Sumenep	*S. dublicatum, S.crassifolium, S. binderi S. filipendula,Sargassum* sp.	[60]
8	Talango waters, Sumenep	*S. cristaefolium*	[68]
9	Padike village, Talango, Sumenep	*S. cinereum, S. echinocarpum, S.filipendula*	[69-71]
10	Talango beach, district Sumenep	*S. polycystum*	-
11	Poteran Island beach, Sumenep	*Sargassum* sp.	[72, 73]
12	Cabbiya village, Talangoh, Sumenep	*S. polycystum*	[74]
13	Talango Island waters, Sumenep	*S. aquifolium, S.filipendula, Sargassum* sp.	[75-78]
14	Pager Betoh village, Blutoh sub-district, Sumenep district	*Sargassum* sp.	[79]
15	Tanjung village, Saronggi sub-district Saronggi, Sumenep district	*Sargassum* sp.	[79]
16	Sumenep district	*Sargassum* sp.	[80]
17	Sumenep coastal waters, Sumenep district	*S. cristaefolium*	[81]
18	Ponjuk village, Talango island, Sumenep district	*S. duplicatum, S.polycystum, S. filipendula*	[82]
19	Padike Ponjuk village, Talango island Talango, Sumenep district	*S. cinereum, S.echnocarpum, S. filipendula*	[69]
20	Poteran Island, sub-district Talango, Sumenep district	*S. cristaefolium*	[73, 83]
21	Gili Genting Island, Sumenep district	*S. duplicatum*	-

3.4 Kalimantan

Waters in Kalimantan that have *Sargassum* sp. potential are shown in Table 4. According to study [84], *Sargassum* sp. was found dominantly on the island of Lemukutan Island, Sungai Raya Islands District, Bengkayang Regency, West Kalimantan with a density of 29.84 ind/m^2. According to Husni and Budhiyanti [85], the dominant *Sargassum* found in Singkawang is the type of *Sargassum policystum*. *Sargassum* sp. in the waters of Java, has an ecological function as a producer of dissolved oxygen in the waters, as a habitat for juvenile fish and juvenile marine biota, and as food for herbivorous animals.

Table 4. Location of *Sargassum* sp. potential in Kalimantan waters

No.	Location	Species	References
1	Kabung Island, South of Bengkayang, West Kalimantan.	*Sargassum* sp., *S. polycystum, S. binderi*	[86-88]
2	Singkawang, West Kalimantan	*S. polycystum*	[89]
3	Lemukutan, West Kalimantan	*S.polycystum*	[23]
4	Temajo Island, Mempawah, West Kalimantan	*Sargassum*	[90]
5	Tanjung Pura West Kalimantan	*Sargassum* spp.	[91]
6	Lemukulan Waters West Kalimantan	*S. polycystum* Agardh	[92]
7	Temajuk, Paloh, West Kalimantan	*Sargassum*, sp.	[93]
8	Lemukutan Waters West Kalimantan	*S. polycystum*	[94]
9	Tamiang, Kotabaru, South Kalimantan	*S.olygocistum*	[95]
10	Amal Village, East Tarakan, North Kalimantan	*Sargassum* sp.	[96]

3.4.1 Characteristics of Kalimantan Sea waters

Climatic conditions in Kalimantan is a tropical climate with a relatively constant temperature throughout the year, which is 25-35°C in the lowlands [38]. Every month the Borneo region gets a minimum rainfall of 60 mm. According to Salim et al. [97], Kalimantan waters have a maximum current speed of 0.604 m/s. Different conditions occur at low tide and towards low tide, the current speed is 0.128 m/s and 0.214 m/s. The temperature around the waters shows values ranging from 27°C-30°C with an average of 28°C. The turbidity parameter showed a range of 0.66-4.21 NTU with brightness ranging from 0.5 m to 2 m. The depth of water is the depth with an interval of 0-5 m. The composition of the beach substrate consists of sand and coral fractions and mollusk fragments. The dissolved oxygen ranged from 6.8 mg/l to 7.5 mg/l. Phosphate levels ranged from 0.10 to 0.12 mg/l. Nitrate levels ranged from 0.5 to -0.8 mg/l. Salinity is in the range of 28 -29 ppt and pH range 7.5-7.7.

Table 5. Location of *Sargassum* sp. potential in Sulawesi

No.	Location	Species	References
1	Bonerita Buton Strait Southeast Sulawesi.	*Sargassum*	[98]
2	East Tuntung, Mongondow, North Sulawesi.	*Sargassum*	[99]
3	Takalar, South Sulawesi	*Sargassum*	-
4	South Tabula, Boalemo district, Gorontalo.	*S. polycystum*	[99]
5	Barrang Lompo Island, South Sulawesi.	*Sargassum*	[100]

3.5 Sulawesi

Sargassum sp. potential in marine Sulawesi is shown in Table 5. Published habitats of *Sargassum* sp. in Sulawesi are not as numerous as in other waters in Indonesia.

3.5.1 Characteristics of Sulawesi sea waters

Sulawesi island is included in a tropical climate which

consists of two seasons, dry season and rainy season [38]. The months with the highest rainfall are February, and June with 270 mm of rainfall. The highest rainfall occurs in February with an average rainfall of 90 mm. The annual amount of rainfall in Sulawesi is 880 mm. The average annual temperature is 32℃ in Sulawesi. The hottest month of the year is January, with an average temperature of 32℃. According to study [101], the characteristic current speed ranges between 1.6 and 82.5 cm/s. According to study [102], a good current speed for seaweed cultivation is 20-40 cm/s. Water brightness in Talengen Bay is 1.5-13.5 m or 18-100%, in Manalu Bay waters 0.7-4.5 m or 7-100%, and Dagho Bay waters 1.0-16.0 m or 8-100%. The water brightness of locations suitable for seaweed cultivation is more than 2m. Water temperature ranges from 27.0-30.8℃. The appropriate temperature for seaweed growth is best for seaweed growth is 25-31℃. Salinity waters Sangihe islands Regency 32.95-35.13 ppt, seaweed cultivation required a salinity range of 31-35 ppt [101]. Dissolved oxygen concentration to support seaweed cultivation is 3-8 mg/L. Seaweed requires a pH of 7.0-9.0 with a very suitable range of 7.5-8.5 [103]. This shows that the pH of the waters of the Sangihe Islands Regency can support the growth of seaweed. The pH of the waters in the Sangihe Islands Regency is at the pH of seawater in general. Previously, study [104] found the pH of the water in Talengen and Manalu Bay to be 7.8-8.0 and 7.7-7.9 respectively.

3.6 Bali, West Nusa Tenggara and East Nusa Tenggara

East Nusa Tenggara is a body of water in Eastern Indonesia that has potential waters for the development of seaweed cultivation and has the potential for seaweed that grows wild in its waters including *Sargassum* sp. Bali, West Nusa Tenggara, and East Nusa Tenggara have *Sargassum* sp. potential as shown in Table 6 [105-117].

Sargassum sp. is abundant in the waters of Sanur Beach in Bali Province. *Sargassum* sp. is popular as a traditional food among locals and is offered in traditional markets [118]. *Sargassum* sp. has prospects as an alginate producer but this seaweed has not been cultivated [8]. Alginate can be used as medicine capsule wrapping material, food additive, and cosmetic material [119, 120]. According to study [113], *Sargassum aquifolium* is found in Ekas Bay, East Lombok, and West Nusa Tenggara and is abundant and untapped. *Sargassum aquifolium* contains carbohydrates (59.51%), fat (8.41%), Ca (3.34%), Fe (0.12%), P (0.18%) Fe (0.12%), water (12.79%), ash (12.79%), N (7.22%). *Sargassum* sp. in these waters is untapped, but has ecological functions for the waters and their biota.

3.6.1 Characteristics of Bali, West Nusa Tenggara, and East Nusa Tenggara Sea waters

According to study [38], rainfall in the West Nusa Tenggara region is generally in the medium (51-150 mm/das) to high (> 300 mm/das) category. West Nusa Tenggara waters consist of the waters of Lombok Island and Sumbawa Island. The substrate of West Nusa Tenggara waters where *Sargassum* sp. grows is in the form of crusted sand substrate. Ismunarti and Rochaddi [121] explained that the current pattern in the waters of West Nusa Tenggara with an average current speed ranging from 0.053 -0.223 m/sec with a direction to the southwest. According to study [122], *Sargassum* sp. growth is influenced by aquatic environmental factors, including water quality. The temperature of Lombok Sea waters ranged from 29.5℃ - 32.7℃, the range is the optimal range for the growth of *Sargassum* sp. Extreme temperature changes can cause death in seaweed, disrupt reproduction, and inhibit growth. pH waters on the island ranged from 7.9-8.15, quite optimal for seaweed growth. Dissolved oxygen in Ekas waters obtained values suitable for seaweed growth ranging from 6.7 ppm - 8.5 ppm. Light intensity obtained ranged from 590×100 Lux - to 772×100 Lux. The value of light intensity is influenced by the depth of the water, the higher the depth of the water the lower the light intensity. Seaweeds need sunlight to perform photosynthesis, the main process for growth and energy production.

Table 6. Location of *Sargassum* sp. in Bali, West Nusa Tenggara and East Nusa Tenggara

No.	Location	Species	References
1.	Katundu, East Sumba, NTT	*Sargassum* sp.	[105]
2.	Hansisi, Semau, Kupang. NTT	*Sargassum* sp.	[106]
3.	Alor, NTT	*S. muticum* (Yendo) Fensholt.	[107]
4.	Netbaun, Semau, Kupang, NTT	*Sargassum* sp.	[108]
5.	Sanur, Bali	*S. binderi, S. crassifolium*	[109]
6.	Sawangan, Bali.	*S. binderi*	[109]
7.	Serangan, Bali.	*S. fluitans,*	[110]
8.	Ekas Bay, East Lombok, NTB	*S. aquifolium*	[111]
9.	Gerupuk, Central Lombok, NTB	*Sargassum* sp.	[112]
10.	Labuan Ijuk, Moyo Hilir, Sumbawa,NTB.	*Sargassum* sp.	[113]
4.	Labuan Bua, Sumbawa, NTB.	*Sargassum* sp.	[114]
5.	Luk Beach, Sumbawa, NTB	*S. crassifolium*	[115]
6.	Rontu, Bima, NTB	*Sargassum* sp. *S.histryx, S. cymosum C., S. oligocystum*	[116]
7.	Wane, Bima Regency, NTB	*Sargassum* sp.	[117]
8.	Cempi, Hu'u, Dompu, NTB	*Sargassum* sp.	[3]

The climatic conditions of East Nusa Tenggara include dry tropics with a fairly long dry season, which is about 8 months per year with uneven distribution of rainfall. The air temperature varies between 21.2℃-33.4℃ [38]. The East Nusa Tenggara waters have substrates of muddy coral, sandy coral, sand, and sandy mud.

Bali has a tropical climate and warm and humid weather. Throughout the year Bali has only two seasons, namely the rainy and dry seasons. Throughout the year, temperatures usually vary from 14℃ to 27℃ and rarely below 12℃ or above 29℃ [38]. Bali's waters are one of the habitats of seaweed with a surface temperature range from 25℃ to 31℃, with an average current speed of 2.5 m/s through the northern tidal current and 3 m/s through the Bali Island tidal current has a temperature range of 29-30℃, salinity of 29-30 ppt, pH 7-9, and dissolved oxygen content of 3-7 mg/L [123, 124].

3.7 Maluku

The type of seaweed that has development potential in the Maluku region is *Sargassum* sp. as presented in Table 7. According to study [125], the frequency of *Sargassum* presence on the coast of Ambon Island is quite high. The high frequency of presence is influenced by its adaptability to the substrate of reef flats, sandstone, and coral fragments mixed with sand.

Table 7. Location of *Sargassum* sp. potential in Maluku

No.	Location	Species	References
1	Weda Bay, North Maluku	*Sargassum* sp.	[126]
2	Hutumuri, Ambon	*S. crassifolium, S.vulgare, S. cinereum*	[127]
3	Tial, Ambon	*Sargassum duplicatum.*	[128]
4	Liang, Ambon	*Sargassum polycyctum*	[128]
5	Tapi, Tawiri and Allang, Ambon	*Sargassum* sp.	[125]

3.7.1 Characteristics of Moluccas Sea waters

Maluku is declared as a humid tropics climate region. The temperature varies from 23℃ to 31℃ and rarely below 22℃ or above 32℃ [38]. Lokollo and Hukubun [128] explained that Liang Village Beach as a whole has a variety of substrates of rocky bottom, rocky sand, and sand mixed with dead coral breaks. Ode and Wasahua [127] explained that the substrate that dominates the waters of Hutumuri beach is a rocky substrate, and sand mixed with dead coral fractures.

3.8 Papua

Sargassum sp. potential in Papua is found in the Raja Ampat Islands of West Papua. The Raja Ampat Islands, which span an area of 4,600,000 ha, are located on the island of Papua and to the east of Halmahera Island. Potential location of *Sargassum* in Papua are mentioned in Table 8. *Sargassum* found in Raja Ampat Islands precisely at the location of West Wagio Island and Salawati Island are; *S. paniculatum*, *S. grevillei*, *S. polycystum, S. cristaefolium*. According to study [129], there is little information on the economic value and bioactive compounds of algae. Bin Stepanus and Kolibongso [1] explained that brown macroalgae which is often found on the coast of Manokwari is *Sargassum binderi.* The results of the analysis explained that *S. binderi* from these waters has a lipid component of 46.56% and has the potential to be used as a bioenergy material as well.

Table 8. Potential locations of *Sargassum* sp. in Papua

No.	Location	Species	References
1	Raja Ampat, West Wagio Island and Salawati Island	*S. paniculatum, S.grevillei, S. polycystum, S. cristaefolium*	[130]
2	Papua	*Turbinaria*	[131]
3	Manokwari, West Papua	*Sargassum* sp.	[132]
4	Jayapura	*Sargasum* sp., *Sargassum binderi*	[61]

3.8.1 Characteristics of Papua Sea Waters

Papua has rainfall variations between 45-255 mm/yr with an average number of rainy days varying between 148-175 rainy days/yr. The average temperature is 29℃-31.8℃. Average air humidity varies between 79%-81% [61]. Environmental parameters in Yakoba coastal waters are suitable for macroalgae growth. Dissolved oxygen ranges from 5-14 mg/L are the optimum oxygen for macroalgae growth while the temperature ranges from 29-32℃. pH ranges from 7-8 and salinity ranges from 34-37 ppt, these values are optimum for macroalgae growth. The characteristics or types of substrates in Jayapura waters are sandy coral, sandy loam, and coral substrates. The following is the value of water quality parameters in Papua waters.

3.9 Map of *Sargassum* sp. distribution in Indonesia

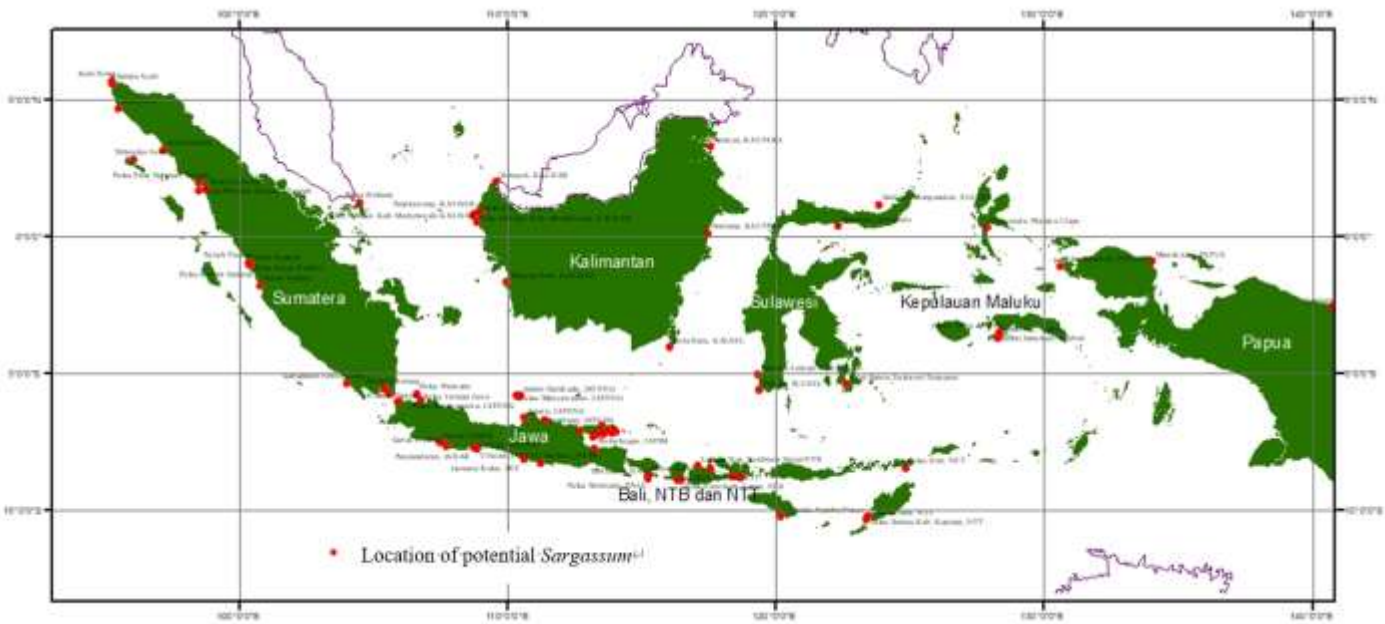

Figure 1. Distribution point of *Sargassum* sp. in Indonesia

Based on the discussion of the distribution of *Sargassum* sp. on each island, the distribution location points can be depicted in Figure 1. According to study [133], *Sargassum* sp. can grow in various water conditions, including in various types of small islands because of its resistance to extreme conditions through the talus part which is shaped like a root with a function to strongly attach to the substrate. According to study [134], the types of bottom substrates used by seaweeds as habitat are hard and soft substrates. Hard substrates are dead coral, and rocks, as the preferred habitat for *Sargassum* sp., *Turbinaria*, and *Eucheuma*. Soft substrates include mud, sand, or a mixture of sand and mud. Soft substrates are suitable for populations of *Gracillaria, Caulerpa, Halimeda,* and *Hypnea.*

Sulistiyani et al. [135] explained that seaweed is a marine biota that has an important role in primary productivity, ecology, and economy. Brown algae genus *Sargassum* sp., can be found in coastal waters, Indonesia. *Sargassum* sp. grows at the bottom of ocean waters, beaches with coral reef bottoms, and tidal areas in tropical and subtropic oceans. *Sargassum* sp. lives attached with its root-like talus to rocks or other hard substrates. According to Puspita et al. [136], *Sargassum* sp. biomass reaches its peak in May and June during the dry season. Substrate nutrients, quantity, quality of light, pH, salinity, temperature, and hydrodynamics are important factors that affect the growth of *Sargassum* sp.

Sargassum sp. is spread across all major islands in Indonesia. The most distribution points can be found in the waters of Java and West Nusa Tenggara. There is no data on the production and abundance of *Sargassum* sp. in these two regions. Based on direct observation in the West Nusa Tenggara region, it can be said that the abundance of *Sargassum* sp. is quite a lot in each habitat in the waters of Lombok and Sumbawa. West Nusa Tenggara waters have good and productive water quality, so *Sargassum* sp. can grow well. Based on the location of the potential distribution of *Sargassum* sp. The type of *Sargassum* sp. that is commonly found in West Nusa Tenggara waters is *Sargassum aquifolium*. It can be used as a reference for its development as a raw material for biofuel and bioenergy. So that each region can realize the provision of bioenergy independently and not depend on petroleum energy.

4. CONCLUSIONS

Sargassum sp. is currently located in all major islands in Indonesia, namely Sumatra, Java, Kalimantan, Sulawesi, Bali, West Nusa Tenggara, East Nusa Tenggara, Maluku, and Papua. *Sargassum* sp. habitat in these waters with tropical climate characteristics, sandy coral substrate, temperature 28℃-32℃, pH 7-8, salinity 25-34 ppt, Nitrate 0.09-0.1 mg/l, Phosphate 0.03-0.06 mg/l, current speed 14-25 cm/sec, brightness 1-5 m, and dissolved oxygen 4-5 mg/l.

The potential location recommendation for *Sargassum* sp. development in West Nusa Tenggara waters, based on the potential of *Sargassum* sp. that grows naturally. The potential of *Sargasum* sp. as a non-food seaweed that can be utilized as bioenergy without competing with the food supply chain. West Nusa Tenggara waters have characteristics of coral reef bottom substrates with a range of water quality values suitable for *Sargassum* sp. habitat. *Sargassum* sp. and non-food macro algae species are easily found in West Nusa Tenggara waters because the waters still have good water quality in terms of water quality, physical and biological waters. The use of *Sargassum* sp. as a bioenergy feedstock is an effort to reduce Indonesia's dependence on fossil fuels.

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