Dynamic analysis of policy impact of the warehouse receipt system on seaweed supply chain in Takalar Regency, South Sulawesi, Indonesia

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Abstract. Seaweed is one of the leading export commodities in South Sulawesi, Indonesia. It not only provides high economic returns but also offers significant ecological benefits, particularly in carbon sequestration. One of the main challenges in the development of seaweed commodities is the price volatility, which is highly dependent on market conditions. During harvest periods, prices tend to decrease, resulting in reduced profits for farmers. The aim of this research is to analyze the dynamic impact of the warehouse receipt system (WRS) policy on the seaweed trading systems in Takalar Regency, South Sulawesi. The research method employed is a quantitative approach using dynamic systems analysis. The study is conducted in Takalar Regency, which is one of the centers for seaweed cultivation in South Sulawesi. The findings indicate that the supply chain system, or trading system (sales), of seaweed in Takalar Regency generally consists of two components, namely: 1) direct sales of seaweed to collectors/wholesalers, and 2) sales of seaweed to cooperatives (Kospermindo) using the warehouse receipt system. The results of the dynamic systems analysis indicate that the average seaweed farmers can achieve a profit of approximately IDR 15.83 billion, which is around 246.39% higher compared to the direct sales system to traders, which yields a profit of only IDR 4.57 billion. There are several challenges in the development of the warehouse receipt system for seaweed, namely: 1) limited access to information about the warehouse receipt system, 2) insufficient socialization/education/extensive outreach and guidance, 3) the community's lack of interest in the warehouse receipt system due to an immediate need for cash, 4) farmers' mindset that perceives the warehouse receipt system as "digging a hole to cover a hole" approach, 5) difficulty for farmers in meeting the quality standards required for the commodities, and 6) limited availability of quality testing institutions at the warehouse locations.
Key Words: cooperative, fisherman, income, optimalization.

Introduction. Seaweed, as one of the important marine resources, not only provides economic benefits but also contributes to environmental well-being. According to a report from the Food and Agriculture Organization (FAO 2022), global seaweed production reached over 30 million tons, with Southeast Asia, particularly Indonesia, being one of the major contributors (Adiguna et al 2022). South Sulawesi is the largest contributor to seaweed production, accounting for 32.57% of Indonesia's total seaweed production (Adhawati et al 2024). Indonesia plays a significant role in the global seaweed market. According to data from the International Trade Center (2023), Indonesia ranks first in the world for seaweed exports in raw form, reaching 205.76 thousand tons. Seaweed production in Indonesia is spread across 23 provinces, with the national total seaweed production in 2020 amounting to 5.01 million tons (wet), comprising 4.66 million tons (wet) from the sea and 351 thousand tons (wet) from ponds (Basyuni et al 2024). South Sulawesi ranks first among the provinces producing seaweed in Indonesia, surpassing East Nusa Tenggara and other provinces (van der Heijden et al 2022).

The potential of seaweed production in South Sulawesi reaches 1.63 million tons (wet), derived from marine cultivation of 1.4 million tons and from pond cultivation of 222,601 tons (wet). South Sulawesi Province has a relatively vast aquatic area with good water quality and is one of the regions with high potential for blue economy (Yusuf et al 2024). Several types of seaweed can thrive in the waters of South Sulawesi, including: *Gelidium* spp., *Eucheuma spinosum*, *Eucheuma cottonii*, *Caulerpa* spp., and *Gracilaria* spp. (Perryman et al 2017). The species of seaweed that grow in the sea include: *Gelidium* spp., *Eucheuma spinosum*, *Eucheuma cottonii*, *Caulerpa* spp. (van der Heijden et al 2022). Meanwhile, a type of seaweed that grows in ponds is *Gracilaria* spp. The seaweed species *Eucheuma cottonii* is the most widely cultivated in the marine waters of South Sulawesi, accounting for 71.51% (Yusuf et al 2024).

The significant potential of seaweed in South Sulawesi not only provides substantial business opportunities and jobs creation but also serves an ecological function as a carbon sink or a natural marine ecosystem that can absorb carbon in response to the increasing concentration of CO_2 in the atmosphere. The carbon sequestration by photoautotrophic algae has the potential to reduce CO_2 emissions into the atmosphere and can help mitigate the tendency towards global warming (Bhuyan et al 2021). Seaweed or macroalgae is one of the coastal vegetation types that serves as an excellent carbon sink compared to terrestrial plants. According to Krause-Jensen and Duarte (2016), seaweed can store or absorb approximately 175 million tons of carbon each year, either by burying it in coastal sediments or by exporting it to the deep sea. Furthermore, the Energy Futures Initiative (2019) published a report finding that ocean-based carbon dioxide removal can absorb CO_2 on a scale of one billion tons, thanks to the abundant space available in the ocean and the absence of land-use complications. In addition, data from carbon absorption measurements in the waters show that there is a carbon absorption rate of 2.7 tons of carbon for every 3.5 tons of algae produced, which amounts to approximately 77.14% (Vergunst et al 2023). Furthermore, research by the Ministry of the Environment of Japan reported that waters in Japan containing seaweed (*Sargassum* spp., *Ecklonia* spp., seagrass, *Laminaria* spp.) can absorb up to 2.7 million tons of CO_2 per year, including contributions from cultivation activities (Muraoka 2004). The total seaweed production in Japan is 650,000 tons (wet) per year, with 530,000 tons (wet) coming from cultivation, which results in the absorption of 32,000 tons of carbon (Muraoka 2004).

Large-scale aquaculture activities, particularly for economically important seaweed species, can globally reduce atmospheric CO_2 concentrations while also producing biomass for the phycocolloid industry derived from seaweed (Kaladharan et al 2009). Therefore, seaweed cultivation is highly beneficial for production purposes and as a carbon sequestration agent. Consequently, the marine and fisheries sectors can also contribute positively to climate change mitigation efforts through culture-based activities. However, there are still various obstacles and challenges in the development of seaweed cultivation in South Sulawesi specifically and Indonesia in general, particularly concerning post-harvest handling, such as drying time. According to Ali and Ahmed (2018), the drying duration of seaweed can affect the carrageenan content. However, the ideal drying time will depend on several factors, including environmental conditions, the type of seaweed, and the drying methods used. According to Shimamune et al (1995), seaweed drying is generally performed using natural methods or with drying machines. When using natural methods (sun drying), the drying time required will be longer compared to using a drying machine. Sun drying takes about 2-3 days, depending on weather conditions and air temperature. According to Fleurence (1999), excessively long drying times can damage carrageenan content. Given that seaweed is an important export commodity, optimal drying and post-drying handling are necessary to maintain the quality of carrageenan content and ensure the price of the seaweed remains stable. Therefore, an appropriate storage or warehousing system is required.

To this end, the government of Indonesia has enacted Law Number 9 of 2011 (BPK 2011) concerning the warehouse receipt system (WRS) to facilitate agricultural production, including seaweed production, and to promote equitable welfare for the community through the warehouse receipt system as a financing mechanism. The warehouse receipt system provides farmers with the opportunity to sell their commodities at higher prices. When harvest time arrives and commodity prices are low, farmers can postpone sales and sell when prices rise by utilizing the warehouse receipt system (WRS). Theoretically, warehouse receipt financing allows farmers, traders, processors, and exporters in developing countries to use stored goods as collateral for loans while waiting to sell at higher prices in the future. Therefore, this warehouse receipt system helps prevent smallholder farmers from selling their surplus products during harvest when prices are typically at their lowest.

The SRG policy aims not only to enhance productivity and stabilize farmers' prices but also to ensure the sustainability of marine ecosystems. This is important considering that unsustainable cultivation practices can lead to environmental damage, such as declining water quality and loss of biodiversity. The global trend toward organic and sustainable products necessitates changes in the supply chain (Jihadi et al 2020), including for seaweed commodities. Data from the International Seaweed Association (2023) indicates that the demand for processed seaweed products, such as carrageenan, has increased sharply, creating new opportunities and challenges for producers (Liestyana et al 2024). The SRG policy also plays a role in addressing social issues arising from the seaweed industry, such as economic injustice and unequal market access, which align with the principles of blue economy that emphasize sustainability and inclusivity (Ya'la 2022). The development of the fisheries sector, including the cultivation of seaweed commodities, must be conducted optimally and sustainably, starting from upstream activities, such as sustainability and feasibility analysis of skipjack (*Katsuwonus pelamis*) (Hermawan et al 2021a), models of skipjack (*Katsuwonus pelamis*) production based on social and economic aspects (Hermawan et al 2021b), the economic potential of blood cockles (Yulinda et al 2020), and capture fishery management (El Fajri et al 2021), to downstream activities, including infrastructure improvements at fish landing place TPI Paotere (Danial et al 2020), designing management for sustainable shrimp cultivation (Eddiwan et al 2021), feasibility and strategies for developing agribusiness (Kasmi et al 2022), strengthening social frameworks (Hasbi et al 2022), and addressing mismanagement issues in sustaining capture fisheries (Purnomo et al 2024). Therefore, this research is important as part of the efforts to develop seaweed commodities in the blue economy sector of South Sulawesi through the optimization of the warehouse receipt system (WRS).

Material and Method. The research method used in this study is a quantitative research method with a dynamic systems analysis approach. The quantitative research method is deemed appropriate for addressing the research objective, namely the dynamic analysis of the impact of the warehouse receipt system (WRS) policy on the seaweed trading system in South Sulawesi, as conducted by Liu et al (2006) and Yusuf et al (2024). The research was conducted in Takalar Regency, South Sulawesi Province, Indonesia from August to December 2023. The location was chosen because Takalar Regency is one of the important regions for seaweed production in South Sulawesi. Below is a visual representation of the research location (Figure 1).

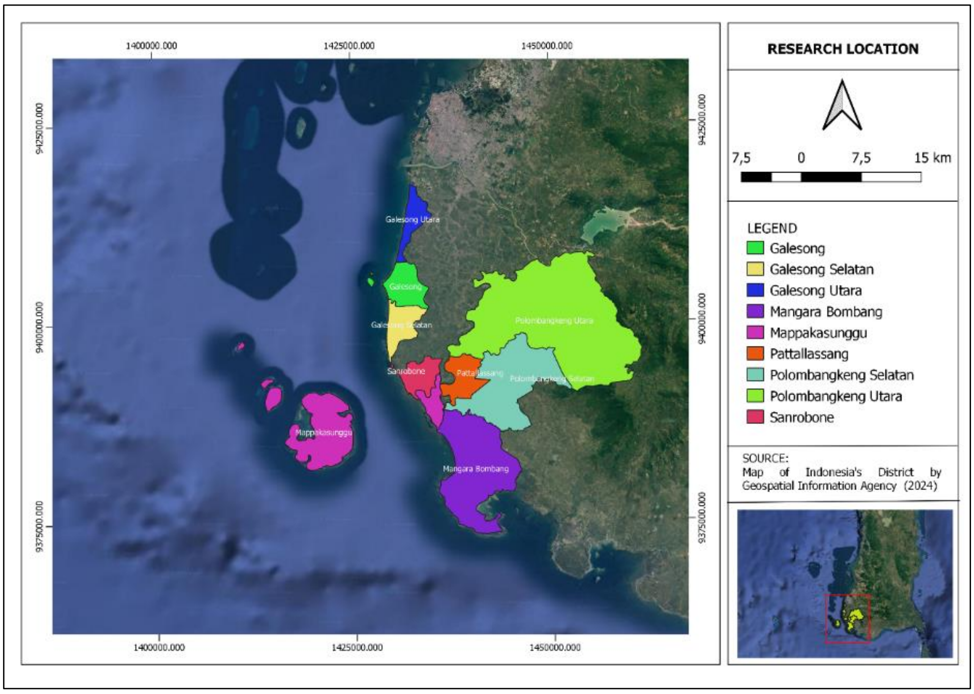

Figure 1. Map of research location (map generated using QGIS 3.14).

The types of data collected in the research are primary data and secondary data. Primary data includes data on the selling price of seaweed at the farmer and cooperative levels, grass production costs, maintenance period of seaweed cultivation, grass marketing (sales) methods, post-harvest seaweed handling, and WRS policies in purchasing seaweed at the farmer level. Secondary data includes: the number of seaweed cultivators, the number of seaweed production in the last 10 years, and government programs/policies related to seaweed cultivation and marketing in Takalar Regency. Primary data collection was carried out by interview methods with cultivators (30 persons), cooperative managers (Kospermindo) (8 persons), and local government institutions officials (2 persons) (Fisheries and Marine Service, and Trade and Industry Service). Meanwhile, secondary data was obtained through literature studies, which were obtained from the Fisheries and Marine Service/Office, as well as the Trade and Industry Office.

The data analysis method used in the research is dynamic system analysis. The dynamic systems analysis approach is one of the analytical tools that can be used to model complex systems (Yusuf et al 2020), including in the research on the dynamic analysis of the impact of the WRS policy on the seaweed supply chain in South Sulawesi. Dynamic systems were first introduced by Jay W. Forrester in the 1950s in an essay titled "System Dynamics, System Thinking, and Soft Operational Research" (Forrester 1961). Initially, dynamic systems were used to solve problems in the industrial world. Dynamic systems are related to questions about the dynamics of complex systems, specifically the patterns of behavior generated by the system over time. The emphasis in using dynamic systems is on the behavior that emerges from the policy structure within the system itself. This definition is crucial for effective and efficient policy planning. Furthermore, Muhammadi et al (2001) state that formulation in dynamic systems represents a problem formulation that depicts feedback relationships or feedback systems, which are typically illustrated in causal loops or feedback loops. Feedback relationships are characterized by mathematical signs and directional arrows (links). The direction of the arrows indicates the variable effects, while the signs (+ and -) are used to show the influence on those outcome variables. Systems within positive feedback loops tend to be divergent. In this system, a continuous growth process can be observed, resulting in exponential growth patterns. Conversely, systems within negative feedback loops aim to achieve a goal or balance. Because feedback systems influence each other, the output will impact the input again if the goal has not yet been reached. This system is dynamic, as it changes over time and reaches stability once the goal is achieved. Dynamic systems analysis fundamentally employs cause-and-effect relationships (causality) to construct a model of a complex system, serving as the basis for recognizing and understanding the dynamic behavior of the system. In other words, the use of dynamic systems analysis emphasizes enhancing understanding of how system behaviors (patterns) arise from their structure. According to Sterman (1984), the main assumption in dynamic systems is that persistent or continuously occurring dynamic tendencies in a complex system stem from the causal structure that forms that system. Furthermore, it is stated that dynamic systems can represent complex and dynamic actual conditions in a simpler form and examine the behavior of the components within the system to approximate real conditions. Meanwhile, Muhammadi et al (2001) state that dynamic systems are a comprehensive, dynamic, and integrated system approach capable of simplifying complicated and complex problems without eliminating the essential elements of the objects of interest. According to Sterman (2002), there are two important aspects to consider in the development of dynamic system models: 1) the model must represent real-world conditions, and 2) the model must be specific to address particular problems. Additionally, there are two main characteristics of dynamic systems: 1) the presence of causal relationships among variables, and 2) the existence of feedback. Below is the causal loop diagram (CLD) of the dynamic model illustrating the impact of the WRS policy on the seaweed supply chain in South Sulawesi (Figure 2).

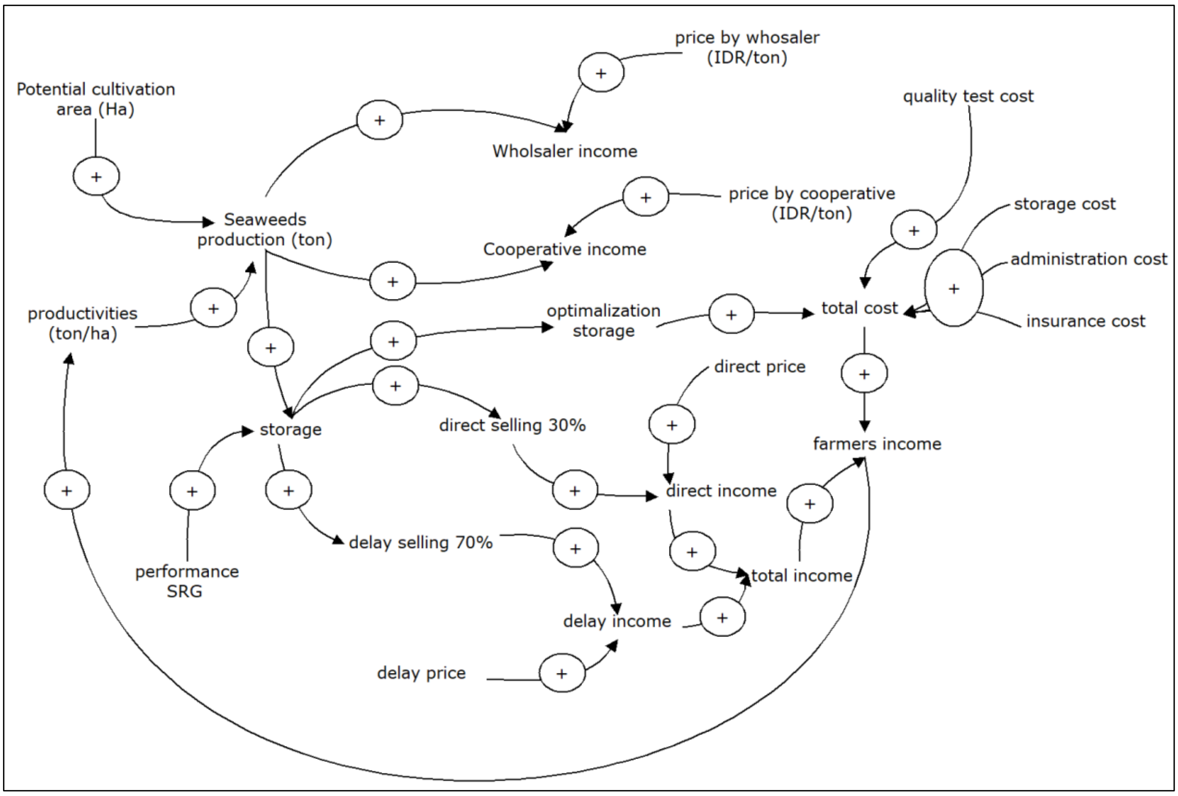

Figure 2. Causal loop diagram (CLD).

The CLD as shown in the figure above, shows the relationship between seaweed potential which is influenced by the area of cultivation and production level, having an impact on seaweed production which then affects the income level of farmers. Cultivators have the option to increase their income through the warehouse receipt system (WRS). Cultivators can sell their production to the cooperative (Kospermindo), where farmers can receive 30% of the initial seller's yield (direct income), and keep 70% (delayed income) which will be sold when the price of seaweed has increased. However, cultivators must also pay storage fees which consist of: warehouse fees, administrative fees and insurance costs.

The model developed illustrates the relationship between seaweed productivity, which is influenced by the area of cultivation and the level of productivity. Meanwhile, the optimization of the warehouse receipt system (WRS) serves as one of the options for farmers in selling their seaweed production, in addition to selling to cooperatives and wholesalers.

The developed model is subsequently tested through model validation, which consists of structural validation and performance (output) validation. Structural validation is conducted by examining whether each established structure aligns with existing theories or counter-theories. For example, land cover changes will reduce water quality, or population growth will increase land conversion. Structurally, both concepts adhere to established theoretical principles. Therefore, it can be stated that the model is valid in terms of structure. This refers to Hartrisari (2007), who states that structural verification is carried out by examining the consistency of the model's structure with the descriptive knowledge of the systems involved in the modeling process. Meanwhile, output/performance validation involves testing the output/performance of the developed model to ascertain how closely the model's performance aligns with real-world performance, thereby meeting the criteria for a scientific model that adheres to factual accuracy. Various behavioral tests of the model can validate the developed model. Testing is conducted using statistical methods recommended by Tasrif (2005). Visual and statistical validation has also been utilized by Hartrisari (2007), where the developed model is tested using system dynamics. According to Sterman (2002), the robustness of a model requires several specific tests, which in turn will enhance users' confidence in the model's ability to represent the system it portrays. This confidence serves as the foundation for the model's validity. Once the validity of the model is established, subsequent simulations can be used to design effective policies. Various behavioral tests of the model can validate the developed model. Testing is conducted using statistical methods as recommended by Tasrif (2005). One commonly used method for measuring error is the mean absolute percent error (MAPE) or the absolute percentage error from the average (Sterman 2002). Furthermore, according to De Myttenaere et al (2016), MAPE is a relative accuracy measure used to determine the percentage deviation of forecasted results. The MAPE approach is useful when the size of the forecast variable is important in evaluating forecasting accuracy (Chai & Draxler 2014). Meanwhile, McKenzie and Tuck (2015) state that MAPE is intended to measure the accuracy of forecasting results by comparing the analytical output with the database (existing values). Below is the formula used to calculate the MAPE value:

$$\mathrm{MAPE} = \frac{1}{\mathrm{n}} \sum \frac{\mathrm{At} - \mathrm{St}}{\mathrm{At}} * 100$$

where: At = actual value (true value)
St = simulated model output (forecasting value)
n = amount of data that reflects a period (time)

Referring to the formulation (equation) above, if the actual value equals the forecast, then the MAPE is zero, which indicates high accuracy. In other words, the smaller the MAPE value, the better or more accurate the developed predictive model is, as the predictions approach actual conditions or real-world scenarios. The decision regarding the accuracy of the simulation/prediction model obtained is based on the criteria developed by Khair et al (2017) as depicted in Table 1:

Table 1

Prediction accuracy criteria based on MAPE values

MAPE value	*Criteria*
MAPE ≤ 10%	High Accuracy
10% < MAPE ≤ 20%	Good Accuracy
20% < MAPE ≤ 50%	Reasonable Accuracy
MAPE > 50%	Low Accuracy

Reference: Khair et al (2017).

Furthermore, once the model has been deemed valid for use as a predictor, scenario modeling (scenario simulation) is conducted. Scenario modeling is generally carried out with two models: 1) business as usual (BAU) simulation, which involves simulating the model without making any changes to the structure, data, or formulas used, but simply extending the simulation duration according to the model's needs; and 2) scenario simulation, which involves making changes to the model, including modifications to both the structure and the data and formulas developed, in order to obtain a better model.

Results

Supply chain/trading system of seaweeds. The research findings indicate that the seaweed trading system in Takalar Regency consists of two main components: 1) direct sales of seaweed to collectors/wholesalers, and 2) sales of seaweed to cooperatives (Kospermindo) using the warehouse receipt system (WRS). Both of these seaweed trading systems are well-known and practiced by seaweed farmers in Takalar Regency. Below is an illustration of the supply chain/trading system for seaweed sales in Takalar Regency (Figure 3).

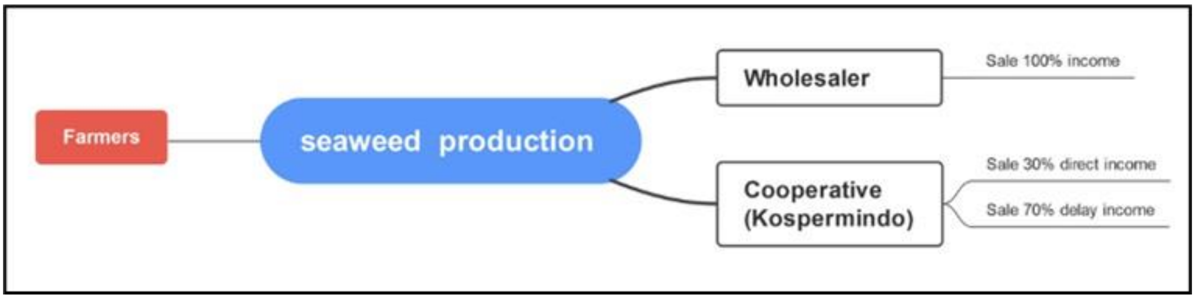

Figure 3. Seaweed trading system/supply chain in Takalar Regency.

The trading system of seaweed production indicates that there are two trading patterns employed by seaweed farming communities in Takalar Regency, both of which are options available for selling seaweed production. The most common type of seaweed produced by farmers in Takalar Regency is *Gracilaria* spp., commonly referred to as "sango-sango" (in the local language). Field observations indicate that seaweed cultivation is conducted using traditional methods, where one span of rope yields 5 kg of seaweed. Generally, each cultivator has 250-300 spans, with an average seaweed production of 1.0-1.5 tons (wet). The price of seaweed with a moisture content of 15% ranges from IDR 7,000 to 8,000 per kilogram. The selling price is approximately the same when seaweed is sold to cooperatives, priced at IDR 7,500 per kg with a moisture content of 15%. However, sales to cooperatives are conducted using the warehouse receipt system, where farmers must form groups to meet the minimum quota required by the system, which is 50-200 tons per receipt. This condition necessitates that cultivators join farmer groups in order to fulfill the required quota per receipt. This presents a challenge within the warehouse receipt system, although it offers greater profit potential, as the price difference can reach 50-100% of the actual selling price.

Interview results with cultivators revealed that both trading systems (sales) for seaweed products are commonly used by the community and are highly dependent on market conditions at harvest time. When seaweed prices are favorable (high), farmers tend to sell directly to wholesalers or cooperatives. However, some cultivators who are already tied to cooperatives find it difficult to sell outside of the cooperative (Kospermindo). Kospermindo, as the warehouse manager for seaweed in South Sulawesi, provides facilities such as seeds and training for fishermen to produce seaweed. The wet seaweed is usually sold directly to traders or to cooperatives. This situation arises because cultivators in the field have not fully understood the warehouse receipt system, the advance selling system (ijon), and have a greater immediate need for cash for family expenses and upcoming harvests. Below is an illustration of the number of farmer groups selling their production to cooperatives using the warehouse receipt system (Table 2).

Table 2

Farmer groups using the warehouse receipt system (WRS)

Farmer group	*Seaweed production (tons)*	*Selling price (IDR)*	*Moisture content (%)*
Hati Mulia	45,05	7000-8000	15%
Bunga Laut	30,00	7000-8000	16%
Rezky Utama	40.05	7000-8000	15%
Pelita Abadi	23,25	7000-8000	15%
Mari Makmur	22,96	7000-8000	16%
Setia Maju	15,25	7000-8000	15%
Sumber Bahagia	26,25	7000-8000	15%
Paraikatte	40,75	7000-8000	15%

Source: 2024 data from Kospermindo cooperative.

Based on the obtained data, as shown in Table 2 above, there are 8 (eight) farmer groups that sell their seaweed harvest to the cooperative (Kospermindo) using the warehouse receipt system. The total production that has been registered is approximately 203.51 tons dry weight with a moisture content of 15-16%. The selling price of the seaweed ranges from IDR 7,000 to 8,000 per kilogram. Assuming the actual price is IDR 7,500 per kg, the initial revenue would be 1.09 billion IDR from 70% (142.46 tons) of the seaweed sold, while the remaining 30% (61.05 tons) of seaweed will be stored in the warehouse to await a relatively higher selling price, thereby yielding greater profits. This system provides specific advantages for farmers and warehouse managers. Additionally, farmers are attracted to the warehouse receipt system due to market clarity and funding assistance, ensuring that the system will be implemented without obstacles. Survey results indicate that approximately 70% of seaweed farmers in Takalar Regency have a good understanding of the WRS policy. However, only 40% of them have utilized this system to store their harvests. This indicates a gap between understanding and practice. Some farmers expressed their hesitation in using the WRS due to a lack of information regarding the procedures and long-term benefits. This data aligns with findings showing that farmers' knowledge of the WRS policy significantly influences their decisions regarding agricultural marketing. Below is an illustration of the development of the number of warehouse receipts and the volume of seaweed (tons) managed by the Kospermindo cooperative in Takalar Regency over the past five years (Table 3).

Table 3

List of warehouse receipts issued by Kospermindo cooperative

Year	*Number of receipts*	*Volume (tons)*	*Value of receipts (IDR)*
2019	17	520,95	3,281,985,000
2020	20	1.426,85	8,989,155,000
2021	7	519,45	3,234,035,000
2022	1	55,00	308,000,000
2023	4	137,50	770,000,000

Source: 2024 data from Kospermindo cooperative.

Based on the data presented in the table above, it is evident that the number of receipts issued has fluctuated from 17 receipts in 2019 to only 1 receipt in 2022, and just 4 receipts in 2023. This indicates instability in the implementation of the warehouse receipt system (WRS) for seaweed commodities in Takalar Regency. This situation may be influenced by external factors, such as the urgent needs of the community, leading them to prefer selling their seaweed harvest directly to traders rather than through the warehouse receipt system. Although the profits from the SRG can be substantial, there is a delay involved, as farmers must wait for some time until seaweed prices rise.

Another factor contributing to the fluctuation in the number of warehouse receipts issued is the suboptimal management of the warehouse receipt system. The WRS policy, which aims to help farmers secure stocks and gain access to financing, may not have been fully effective during this period. The low number of receipts in certain years and the unstable values could indicate a lack of adoption of the WRS by seaweed farmers or issues related to warehouse operations and market access. The limited volume of goods registered under the receipt system may also affect the smoothness of the seaweed supply chain in South Sulawesi, potentially impacting farmers' income and local economic resilience.

Optimization model of warehouse receipt system. The optimization model of the warehouse receipt system (WRS) is conducted by simulating the performance of the warehouse receipt system, comparing it with the actual model (Business as Usual). The BAU simulation model is a model that does not involve any changes to the structure, data, or formulas used; it merely extends the simulation time according to the model's needs. In contrast, the scenario simulation model involves not only extending the time but also implementing policy scenarios by intervening in a key variable to achieve the ideal conditions of the model, in this case, enhancing the performance of the warehouse receipt system to make it more optimal. Below are the results of the BAU simulation model and the scenario simulation model regarding the income levels of seaweed farmers in Takalar Regency (Figure 4).

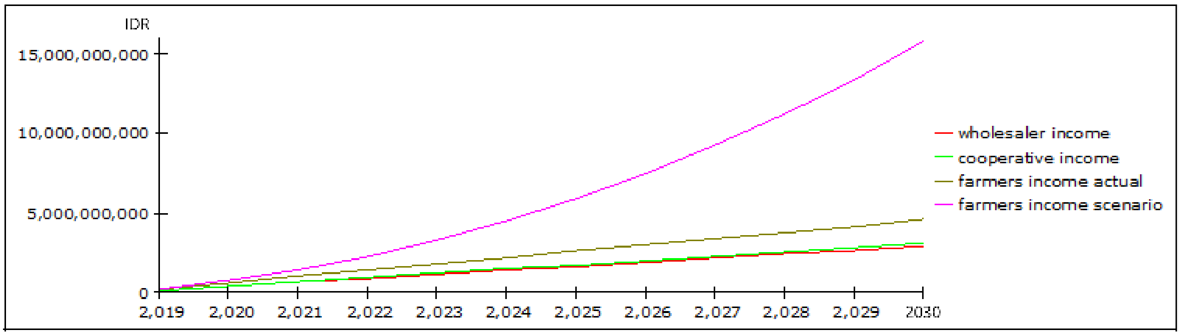

Figure 4. Scenario model.

Figure 4 shows the comparison of the income of seaweed cultivators with 4 conditions, namely: 1) the income of the cultivators when sold directly in the market (red color line), 2) the income of the cultivators when sold to the cooperative (green color line), 3) the income of the cultivators when using the warehouse receipt system (WRS) without waiting for the price to rise (grey color line), and 4) the income of the cultivator when using the warehouse receipt system (WRS) by waiting for the price to rise (stored until the price of seaweed is high) (pink color line). As shown in the simulation results depicted in the graph above, the BAU model indicates a relatively low income level of IDR 4.57 billion per year compared to the income that seaweed farmers could achieve by optimizing the warehouse receipt system (WRS), which amounts to IDR 15.83 billion, an increase of 246.39%. This condition provides an optimal profit that can be realized by seaweed farmers in Takalar Regency. Based on interviews with seaweed farmers, it was found that farmers using the warehouse receipt system (WRS) experience an average income increase of 20% compared to those who do not use the system. This indicates that the SRG policy can provide significant economic benefits for seaweed farmers. However, challenges related to warehouse accessibility and storage costs also need to be addressed. Research by Pratama (2023) notes that high storage costs can reduce farmers' profits, highlighting the need for subsidies or support from the government to address this issue. Below is a comparison of the income levels of seaweed farmers based on the trading systems (sales) implemented (Table 4).

Table 4

Farmers' income based on the seaweed trading system (sales)

Years	*Wholesaler income (IDR)*	*Cooperative income (IDR)*	*Actual farmers income (IDR)*	*Farmers income scenario (IDR)*
2019	154,400,000.00	162,120,000.00	243,353,700.00	243,353,700.00
2020	406,540,892.50	426,867,937.13	641,102,012.00	769,518,116.51
2021	658,681,785.00	691,615,874.25	1,038,071,839.18	1,458,355,279.03
2022	910,822,677.50	956,363,811.38	1,434,263,181.26	2,314,758,970.27
2023	1,162,963,570.00	1,221,111,748.50	1,829,676,038.34	3,343,753,343.75
2024	1,415,104,462.50	1,485,859,685.63	2,224,310,410.41	4,550,496,181.14
2025	1,667,245,355.00	1,750,607,622.75	2,618,166,297.47	5,940,282,227.69
2026	1,919,386,247.50	2,015,355,559.88	3,011,243,699.53	7,518,546,607.71
2027	2,171,527,140.00	2,280,103,497.00	3,403,542,616.58	9,290,868,321.78
2028	2,423,668,032.50	2,544,851,434.13	3,795,063,048.63	11,262,973,827.77
2029	2,675,808,925.00	2,809,599,371.25	4,185,804,995.67	13,440,740,707.57
2030	2,927,949,817.50	3,074,347,308.38	4,575,768,457.71	15,830,201,421.40

Source: Results of dynamic systems analysis.

The process of issuing warehouse receipts for seaweed commodities in Takalar Regency begins with farmer groups bringing dry seaweed to the Makkio Dalle Cooperative. The seaweed is tested for quality and registered with Jasindo insurance to mitigate risks, with the costs of quality testing and insurance borne by the farmer groups through the BPSMB (Quality Testing and Certification Institute) of South Sulawesi. The quality certificate issued includes a number, date of issuance, owner's identity, testing method, and a description of the goods. If the requirements are met, the warehouse manager establishes a goods management agreement and then issues a warehouse receipt after receiving the registration code from the registration center. The warehouse receipt contains information about the owner, warehouse location, registration number, as well as a description and storage costs of the goods. The receipt can then be monetized through BJB Bank in Makassar, which provides initial financing of 70%, with the remaining 30% held as a reserve. Once the goods are sold, the business operators pay 70% to BJB Bank, while the remaining 30% is kept to anticipate risks or to wait for an increase in national commodity prices. According to Law Number 9 of 2011 (BPK 2011), ideally, 30% of this amount can be enjoyed by farmers or business operators when commodity prices rise.

Based on the results of observations, interviews, and analysis, it is found that the warehouse receipt system for seaweed commodities in Takalar Regency is still suboptimal due to several factors: 1) limited access to information about the warehouse receipt system for seaweed, financing constraints due to financial ties with middlemen, and the quality of seaweed not meeting the Indonesian National Standard Number 2690:2015 for dried seaweed (SNI 2015), 2) insufficient socialization/education/outreach and guidance regarding the benefits of the warehouse receipt system for farmers, in particular, 3) the community's lack of interest in the warehouse receipt system because they require immediate cash without being burdened by the numerous procedures imposed by the system, 4) the mindset of fishermen/farmers who believe that the warehouse receipt system is akin to "digging a hole to cover a hole," due to their ties with warehouse managers who provide facilities and infrastructure for them, 5) farmers' difficulties in meeting the quality standards required by the warehouse receipt system, and 6) the limited availability of quality testing institutions at the warehouse locations established by the government.

In addition, there are several challenges in the implementation of the warehouse receipt system for seaweed commodities in Takalar Regency, which are also supported by research related to similar constraints in other regencies in Indonesia that have adopted the warehouse receipt system. According to Edi et al (2019), the obstacles faced by farmers in the warehouse receipt system include: limited access to information regarding the warehouse receipt system, financing issues due to financial ties with middlemen, and the quality of seaweed not meeting the Indonesian National Standard Number 2690:2015 for dried seaweed (SNI 2015). Meanwhile, warehouse managers face challenges related to the time required for quality testing and the process of disbursing funds from financial institutions, both banks and non-banks. Furthermore, coordination and collaboration among stakeholders in the seaweed supply chain/trading system are still relatively weak. According to El Ouarrak et al (2024), a lack of communication and information among supply chain actors can lead to inefficiencies, affecting selling prices and farmers' profits. Therefore, efforts are needed to strengthen communication networks among actors in the supply chain.

Meanwhile, the integration of the warehouse receipt system with commodity auction markets, particularly for seaweed, can be implemented to accelerate market development. Initially, the warehouse receipt system was used as a tool to delay sales (delay market), but it can now be utilized by business operators to support export activities of commodities. Currently, seaweed commodity exports are still dominated by raw materials. Therefore, the implementation of the warehouse receipt system should not only occur upstream, particularly at the farmer level, but also downstream. Commodities stored in warehouses are now not only raw materials but have also been processed into by-products with market value, such as seaweed that is no longer stored in dry form but has been processed into a base material for gelatin production from seaweed (*Gracilaria* spp).

The use of the warehouse receipt system (WRS) allows farmers to sell their harvests at more favorable times, thereby reducing the pressure to sell at low prices post-harvest. The WRS policy also focuses on the development of infrastructure that supports the supply chain, such as ports and processing facilities. This is important considering that the seaweed supply chain is often hindered by a lack of accessibility to markets. Research by Musdalifah et al (2022) indicates that with the improvement of infrastructure, product distribution time can be reduced by up to 30%, which in turn enhances the competitiveness of Indonesian seaweed products in the international market. In line with this, Fauzi (2023) states that a good storage system can increase farmers' bargaining power in the market. Therefore, the WRS policy not only serves as collateral for credit but also as a tool to enhance farmers' bargaining positions. The warehouse receipt system (SRG) is expected to be an optimal storage system, allowing farmer groups to store their production when market prices are unfavorable and sell it when product prices are higher. The volatility of prices can be mitigated by storing products in warehouses. In the scenario of the WRS policy, farmers have the option to store their products until prices improve, which can increase their income. Moisture content is an important factor in the quality of seaweed, which also affects the selling price. The WRS policy can assist in setting quality standards by ensuring that products stored in warehouses have stable moisture content, which is crucial for marketability. In the context of dynamic analysis, changes in market prices and warehouse availability can influence farmers' decisions about when and how to sell or store their seaweed harvests.

Conclusions. The research findings indicate that the seaweed supply chain or trading system in Takalar Regency consists of two main components: 1) direct sales of seaweed to collectors/wholesalers, and 2) sales of seaweed to cooperatives (Kospermindo) using the warehouse receipt system. The dynamic systems analysis shows that the average seaweed farmers can achieve a profit of IDR 15.83 billion, which is approximately 246.39% higher compared to the direct sales system to traders, which yields only IDR 4.57 billion in profit. However, there are still several challenges in the development of the warehouse receipt system, namely: 1) limited access to information about the warehouse receipt system for seaweed, 2) insufficient socialization/education/outreach and guidance regarding the benefits of the warehouse receipt system for farmers, 3) the community's lack of interest in the warehouse receipt system because they require immediate cash without being burdened by the numerous procedures imposed by the system, 4) the mindset of farmers who believe that the warehouse receipt system is akin to "digging a hole to cover a hole", due to their ties with warehouse managers who provide production facilities and infrastructure, 5) farmers' difficulties in meeting the quality standards required by the warehouse receipt system, and 6) the limited availability of quality testing institutions at the warehouse locations established by the government.

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References

Adhawati S. S., Nurdin N., Azis H. Y., Akbar M., Aris A., 2024 Status of seaweed (*Kappaphycus alvarezii*) farming land ownership and business productivity in Sulawesi Island: quantitative study. Fisheries and Aquatic Sciences 27(1):35–47.

Adiguna A. D., Krisnamurthi B., Erwidodo E., 2022 [Analysis of competitiveness of processed seaweed exports in Indonesia]. Journal of Indonesian Agribusiness 10(1):31–39. [In Indonesian].

Ali A., Ahmed S., 2018 Carrageenans: structure, properties and applications. In book: Marine Polysaccharides. 24 pp.

Basyuni M., Puspita M., Rahmania R., Albasri H., Pratama I., Purbani D., Aznawi A. A., Mubaraq A., Al Mustaniroh S. S., Menne F., Rahmila Y. I., Salmo III S. G., Susilowati A., Larekeng S. H., Ardli E., Kajita T., 2024 Current biodiversity status, distribution, and prospects of seaweed in Indonesia: a systematic review. Heliyon 10(10):e31073. doi: 10.1016/j.heliyon.2024.e31073.

Bhuyan M. S., Islam M. N., Sharif A. S. M., Islam M. M., Islam M. S., Hoq M. E., 2021 Seaweed: a powerful tool for climate change mitigation that provides various ecological services. In: Bangladesh II: Climate Change Impacts, Mitigation and Adaptation in Developing Countries. Springer Climate. Springer, Cham. 159-192 pp.

Chai T., Draxler R. R., 2014 Root mean square error (RMSE) or mean absolute error (MAE)? Arguments against avoiding RMSE in the literature. Geoscientific Model Development 7(3):1247-1250.

Danial, Syahrul, Hamsiah, Ernaningsih, Yusuf M., 2020 Evaluation and development strategy of PPI Beba (Fish Landing Port) in Takalar District, Indonesia. AACL Bioflux 13(5):3037-3045.

De Myttenaere D. A., Golden B., Grand B. L., Rossi F., 2016 Mean absolute percentage error for regression models. Neurocomputing, Elsevier, 23rd European Symposium on Artificial Neural Networks 192(2):38-48.

Eddiwan, Sukendi, Siregar Y. I., Saam Z., Yusuf M., Sabiq M., 2021 Designing management of sustainable shrimp cultivation area in East Lingga, Lingga District. AACL Bioflux 14(3):1317-1325.

Edi S., Siregar H., Baga L. M., Suroso A. I., 2019 [Stakeholder analysis of Indonesian seaweed supply chain based on warehouse receipt system]. Buletin Ilmiah Litbang Perdagangan 13(2):281–308. [In Indonesian].

El Fajri N., Prianto E., Adriman, Sibagariang R. D., Batubara U. M., Yusuf M., Riana A. D., 2021 Capture fishery management status through the ecosystem approach on fish resources domain in Sungai Apit sub-district, Siak district. AACL Bioflux 14(3):1308-1316.

El Ouarrak Y., Hmioui A., 2024 Communication between supply chain actors: a risk reduction factor in supply chains. Proceedings of Eighth International Congress on Information and Communication Technology. ICICT 2023. 695–703 pp.

Fauzi A., 2023 Improving farmers' participation in the warehouse receipt system. CIPS Policy Brief no. 17. 12 pp.

Fleurence J., 1999 Seaweed proteins: biochemical, nutritional aspects and potential uses. Trends in Food Science & Technology 10(1):25-28.

Forrester J. W., 1961 Industrial dynamics. MIT Press, Cambridge, Mass. 464 pp.

Hasbi, Armin, Sakaria, Sabiq M., Murni A., Yusuf M., Malik, 2022 Determinants of 'punggawa-sawi' power relations and capital on the socio-economic household of the fishing community in Paotere Port of Makassar City. AACL Bioflux 15(1):164-173.

Hermawan D., Andriawan S., Yusuf M., Riana A. D., Masriah A., Suryahman A., Sabiq M., 2021a Sustainability and feasibility analysis of the skipjack (*Katsuwonus pelamis*) fishery in Buhung Pitoe Island, Indonesia. AACL Bioflux 14(3):1513-1523.
Hermawan D., Andriawan S., Yusuf M., Riana A. D., Alpiani, Sabiq M., 2021b Model of skipjack (*Katsuwonus pelamis*) production based on social and economic aspects in the Buhung Pitue Island, Indonesia. AACL Bioflux 14(4):2436-2446.
Jihadi M., Usman I., Asrini, Musnaini, Lutfi, Indrawijaya S., Dahmiri, 2020 The effect of supply chain dynamism and supply chain disruption orientation on supply chain resilience in indonesian manufacturing industry. International Journal of Supply Chain Management 9(4):1244–1251.
Kaladharan P., Veena S., Vivekanandan E., 2009 Carbon sequestration by a few marine algae: observation and projection. Journal Marine Biology Ass. India 51(1):107–110.
Kasmi M., Sulkifli, Yusuf M., Sutinah M., Riana A. D., Ramis I., 2022 Feasibility and strategy of developing the agribusiness of marine ornamental fish for export. Poeciliid Research 12(1):1-11.
Khair U., Fahmi H., Sarudin A. H., Rahim R., 2017 Forecasting error calculation with mean absolute deviation and mean absolute percentage error. Journal of Physics Conference Series 930: 012002. doi: 10.1088/1742-6596/930/1/012002.
Krause-Jensen D., Duarte C., 2016 Substantial role of macroalgae in marine carbon sequestration. Nature Geoscience 9:737–742.
Liestyana Y., Wahyuningsih T., Natasha A., Utami Y., Oetomo H., Tugiyo T., 2024 The analysis of dynamic supply chain capability and operational performance of food and beverage MSMEs in Sleman, Indonesia. International Journal of Business Ecosystem & Strategy (2687-2293) 6(2):13–24.
Liu Z., Li Y., Chen Y., 2006 Dynamic performance analysis in supply chain. 2006 6th World Congress on Intelligent Control and Automation 2:6822–6825.
McKenzie M., Tuck E., 2015 Place in research: theory, methodology, and methods. Routledge, New York. 216 pp.
Muhammadi E., Aminullah E., Soesilo B., 2001 [Dynamic system analysis of environmental, social, economic, management]. UMJ Press, Jakarta. 403 pp. [In Indonesian].
Muraoka D., 2004 Seaweed resources as a source of carbon fixation (Special Issue: Aquaculture and Stock Enhancement of Algae and Filter Feeders) (Capter 2. Aquaculture as a nutrient recycling technology). Bull. Fish. Res. Agen. Supplement 1:59-63.
Musdalifah M., Natsir M., Syafiuddin S., 2022 [Determinants of seaweed commodity exports in Southeast Sulawesi Province]. Mimbar Agribisnis: Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis 8(2):778–784. [In Indonesian].
Perryman S. E., Lapong I., Mustafa A., Sabang R., Rimmer M. A., 2017 Potential of metal contamination to affect the food safety of seaweed (*Caulerpa* spp.) cultured in coastal ponds in Sulawesi, Indonesia. Aquaculture Reports 5:27-33.
Pratama A., 2023 Warehouse receipt as credit guarantee to welfare farmers based on Pancasila Justice at Bandar Lampung. Pancasila and Law Review 4(1):29-38.
Purnomo A. H., Aidi M. N., Wahyono A., Soeprobowati T. R., Hartati S. T., Tirtadanu, Chodrijah U., Prasetyo S., Prihatiningsih, Jumari, Yusuf M., 2024 Mismanagement issues in sustaining capture fisheries in Lake Batur. International Journal of Design & Nature and Ecodynamics 19(4):1129-1138.
Shimamune T., Wada K., Kanaoka M., Hamano M., 1995 A study of the drying method of *Porphyra yezoensis*. Nippon Suisan Gakkaishi 61(4):495-499.
Sterman J. D., 2002 Business dynamics: system thinking and modeling for a complex world. Irwin McGraw-Hill, Boston. 32 pp.
Sterman J. D., 1984 Apropriate summary statistics for evaluating the historical fit of system dynamics models. Dynamica 10(2):51-56.
Tasrif M., 2005 [Policy analysis using the system dynamics model]. Lecture/Course Modules. Program Magister Studi Pembangunan-SAPPK ITB, Bandung. 56 pp. [In Indonesian].
van der Heijden P. G. M., Lansbergen R., Axmann H., Soethoudt H., Tacken G., van den Puttelaar J., Rukminasari N., 2022 Seaweed in Indonesia: farming, utilization and

research. Wageningen Centre for Development Innovation, Wageningen University & Research. Report WCDI-22-220. Wageningen. doi: 10.18174/578007.
Vergunst F., Berry H. L., Minor K., Chadi N., 2023 Climate change and substance-use behaviors: a risk-pathways framework. Perspectives on Psychological Science 18(4):936-954.
Ya'la Z. R., 2022 Economic feasibility analysis, value added and marketing of semi refined carrageenan (SRC) seaweed processing industry. Jurnal Sosial Teknologi 2(6):534–543.
Yulinda E., Saad M., Yusuf M., 2020 A study on the economic potential of blood cockles (*Anadara granosa*) in Rokan Hilir, Riau Province, Indonesia. AACL Bioflux 13(3):1504-1510.
Yusuf M., Nurhamli, Yunianto S., Supeni E. A., 2020 [Decision support system in the 4.0 era: theory & application of analysis tools]. Penerbit IPB Press, Bogor. 260 pp. [In Indonesian].
Yusuf M., Samsir A., Tiro S., Ilyas M., Riana A. D., Saru A., Ahmad M., Pratama D. C., 2024 Blue economy policy model for encouraging regional growth in South Sulawesi. AACL Bioflux 17(1):272-283.
*** Audit Board of The Republic Of Indonesia (BPK), 2011 Law Number 9 of 2011 concerning amendment of warehouse receipt system. https://peraturan.bpk.go.id. [Last accessed on 19 September 2024].
*** Energy Futures Initiative, 2019 Clearing the air: a federal RD&D initiative and management plan for carbon dioxide removal technologies. www.efifoundation.org. [Last accessed on 19 September 2024].
*** Food and Agriculture Organization (FAO), 2022 The state of world fisheries and aquaculture 2022. Towards Blue Transformation. Rome, FAO. 266 pp.
*** Indonesian National Standards (SNI), 2015 [Indonesian National Standard number 2690:2015, dried seaweed]. [In Indonesian]. www.bsn.go.id. [Last accessed on 19 September 2024].
*** International Seaweed Association, 2023 The 24th International Seaweed Symposium, that was held in Hobart, Tasmania and Online from the 19 – 24 February 2023. www.iss2023.net. [Last accessed on 19 September 2024].
*** International Trade Center, 2023 LDC Trade Report 2023: Improving food security. www.intracen.org. [Last accessed on 27 September 2024].

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