The Seaweed Information System (SIRULA): A Preliminary Concept and Integrated Design

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Abstract. Seaweed is one of the fisheries commodities, which has been proven to improve the household income of coastal and small island communities in Indonesia for the last two decades. The global need for seaweed is rising, since it is used as a raw material for many industries, i.e.: food, pharmaceuticals, cosmetics, livestock feed, and fertilizers. These factors have encouraged the Government of Indonesia to increase the quantity and quality of seaweed commodities until it reaches a strategic position in the fisheries sector. One of the efforts in enhancing the data and information reliability, which will support all business actors from upstream to downstream; to accelerate the industrialization and production, resource sustainability, and improving the welfare of coastal and small island communities. This paper aims to provide an overview of the concept and design of seaweed information systems, based on the principles of traceability, sustainability, production process improvement, and system integration. It is expected that business actors, resources managers, and policymakers will take advantage of information system, where reliable data and information can be accessed easily in real-time.

1. Introduction
The world production of seaweed, has more than tripled, up from 10.6 million tons in 2000 to 32.4 million tons in 2018 [1]. Indonesia produces two-thirds of the global supply of Eucheumatoids consist of the three main cultivars seaweed i.e. 1) Eucheuma denticulatum (Spinsum of the trade); 2) Kappaphycus striatum (Sacol of the trade); 3) Kappaphycus alvarezzii (Cotonii of the trade) [2] and Agarophyte i.e. Gracilaria. These tropical red algae are tremendously important as raw material to the hydrocolloid industry for carrageenan and agar which is needed in domestic and international markets [3], [4]. The government of Indonesia through the programs of the Ministry of Marine Affairs and Fisheries (MMAF) makes seaweed as one of the leading fishery commodities to improve the economy, especially for coastal and small islands communities.

The rapid growth of seaweed production and market is the major driver to increase the economy and to improve the social welfare of coastal and small island communities through the principles of pro-poor, pro-job, and pro-growth. The seaweed farming activities are conducted as a family-owned business involving all family members, including their women role [5]. Seaweed cultivation is an attractive economic alternative to fishing because seaweed is relatively easy to cultivate, has low initial capital investment, short cultivation cycle (45 days) and provides a source of livelihood [6]. Therefore, seaweed farming areas in Indonesia are continue to increase and the potential area is grown across the archipelago in 23 provinces that span range of cultures and environments (Figure 1).
Based on the trade map processed by Director General of Marine and Fisheries Product Competitiveness Ministry of Marine Affairs and Fisheries [8], seaweed from Indonesian in 2019 (209.24 thousand tones) ranked first in global export volume. However, in terms of export value, Indonesia (USD 329.3 million) ranked third after China (USD 577.37 million) and South Korea (USD 420.07 million). There are still a lot of problems seaweed industries in Indonesia faced from upstream to downstream. According to Hikmayani et al. [9], Sumiono et al. [10] and Zamroni [11], there were several problems correlated to the lack of availability of information related to: 1) seed sources; 2) conditions and parameters of potential area (farming) and habitat (nature) adjusted for the season; 3) type and amount of seaweed and industrial-scale post-harvest processing based on SNI (Indonesian Standard National) and other certifications; 4) price list of dried seaweed and its derivative products; 5) types and methods of product marketing; 6) warehouse (receipt) system; 7) institutional; and 8) distribution and marketing network.

The lack of synergistic data and information on seaweed industry from upstream to downstream needs to be addressed with an information system. An integrated information system as an initial solution in documenting data and information needed by stakeholders and seaweed value-chain actors. Therefore, it is necessary to develop the concept and integrated design of seaweed information systems that consider traceability, food safety, accessibility and sustainability. This paper aims to provide an overview of the concept and design of information systems for seaweed commodities, based on the principles of traceability, sustainability, production process improvement, and system integration. This overview discusses 1) the information needs of the seaweed value chain system; 2) the concept of information system for seaweed value-chain; and 3) the content design of system information for seaweed value chain system.

2. Materials and method
The mixed-method approach [11] was utilized to identify the information needs of the seaweed value chain, to describe the concept and to develop the design of the seaweed information system. The combination of external desk study, seaweed stakeholder interviews and field visit were conducted to collect and explore the information relevant to our research objectives. Desk research from 71 available literature selected i.e. scientific articles, program or annual reports, books, news and other web-items was undertaken to extract the information on seaweed value chain, theory and concept of information system development and management. Key institution and key person interviews were carried out to identify current seaweed value chain structure, governance, and information needs. Investigative field visits were conducted to observe seaweed production, post-harvest handling and processing. Field visits were carried out at two locations, i.e.: Panggang Island (-5.73833060 S, 106.58528434 E), Kepulauan
Seribu Regency-Jakarta and Tirtajaya, Karawang Regency (-6.00488240 S, 107.23380685 E), West Jawa during May 2021.

Based on a field observation in Kepulauan Seribu and Karawang Regency and interviews with key institutions and key persons about their data requirements in each business chain (Figure 2). By referring existing model, theory and regulation, the data requirements for seaweed cultivation business actors were designed in a seaweed information system.

![Figure 2. The methology flowchart.](image)

3. Result and Discussion

3.1 The Seaweed Value-chain: Indonesian Context

Literature study on seaweed farming has generated a basic understanding on the current status of seaweed production and trade. In Indonesia, there are two types of commercially distinct classes of seaweeds that consist of wild harvested seaweed e.g. Sargassum, Ulva and Gelidium and cultivated seaweed e.g. Eucheumatoids, Agarophyte and Caulerpa. However, Eucheumatoids are predominantly cultivated and exported unprocessed or low value-added dried seaweed as the major raw material sources of kappa- and iota-carrageenan. Both hydrocolloids possess rheological properties used for emulsifiers, binder, suspension or stabilization in a wide range of industrial purposes i.e. food, pharmaceuticals, cosmetics, livestock feed, and fertilizers [12], [13]. Unfortunately, Indonesia still plays a relatively minimal role in the processed hydrocolloid production and market [14]. Thus, despite being the top exporter, Indonesia loses out on earning from manufacturing value-added hydrocolloid and seaweeds derivate products.

Based on direct field observation and stakeholder interview at Seribu Islands and Karawang Regency, the needs of information in each level of seaweed value chain is identified (Figure 3). The keys information i.e. farming method, input material, seed stock, production, disease season, warehouse system, margin price, capital support and market networks were collected and categorized as a need to develop an information system. It would be developed based on production system management, market access service and financial inclusion [15]. Generally, there are 4 main actors in the seaweed value-chain: 1) Farmers; 2) Collectors; 3) Traders/Wholesalers; 4) Exporters and Processing industries.
In this study, farmers are actors in upstream level who plans seaweed and operate seaweed farm. Farmers take a part likewise in the drying process before the commodity is handed over to the collector. They were identified to have a high risk to suffer losses due to: 1) the unavailability of seed stock; 2) unpredictable weather and water condition; 3) the pyrite and diseases during farming; 4) the low capital investment; 5) the low-level knowledge about good seaweed farming practice, 6) potential seaweed area and post-harvest methods; 6) poor information of markets, prices and quality standards. Thus, seaweed farmers need the data and information to fulfil their needs such as seed stock [16], suitable location [17] and to mitigate the risk such as weather, climate and water condition [18].

Collectors are the first link in seaweed-based value chains [19]. It categorizes in this study as a middle-persons in village level or business level-1. Most collectors are also big farmers who produce and harvest seaweed the most. Other farmers sell their seaweed to the collectors. Moreover, farmers are usually depending on the collector to borrow money and input supplier i.e. rope, seed. The patron-client relationship between collectors and farmers within the seaweed farming scheme is often referred to as the middle-persons seaweed farmer system [20]. Further, level 2 is a buyer/trader/wholesaler in the district or regional area. They have a patron-client tie with seaweed farmers and collectors. Seaweed farmers are closely affiliated with a particular middle-persons. The middle-persons intends to obligate farmers to sell their yield to them. They need to promote their products to the buyer or industry; warehouse location and in/outflow information; profile farmers who affiliated; pricing service; virtual trading services; financial services; and other knowledge about seaweed farming.

The middle-persons is the central set of seaweed market systems that exchange between upstream i.e. input suppliers and farmers into the downstream side i.e. exporters, overseas buyers/traders and the processing industry. The middle-persons serve as a liaison function to meet the supply of seaweed on the downstream side as well as a marketing function on the upstream side. The middle-persons needs of data and information are real-time production data based on location, type of seaweed commodity, potential and suitable seaweed farming area, warehouse site, price and product catalog, knowledge on how to cultivate, harvest time, dry level required quality standards.

In the last level, there are national traders, exporters and the domestic processing industry. Exporters and national traders were found at the Kepulauan Seribu Regency value chain. Meanwhile, domestic...
seaweed manufacturing is the last level of value-chain at Karawang Regency. Recently, the pricing is depending on this level of actors. The price of dried seaweed can be determined based on dried seaweed quality. The length of market channels has also influenced the price formation of dried seaweed at the farm level [21]. The need of this level consists of: 1) real-time data products based on location or spatial data; 2) National standard quality 3) R&D and Innovation centre; 4) Export and industry permits, licences, certifications and tax regulation; 5) Promotion, distribution and market networks for overseas and domestic industries.

3.2 The Concept and Design of the seaweed farming information system (SIRULA)
The synergetic data from upstream to downstream play a crucial role in sustainable seaweed farming. Information services provide data that helping the stakeholders or business actor improve their productivity and yield, arise profitability, prevent losses and manage the risk. Therefore, the seaweed farming information system is one appropriate strategic approach to integrate the technology, ecology, sociology and economics to perform the integrated and sustainable seaweed business. Better seaweed farming practice and supply chain traceability generate the sustainability of the seaweed business. Market is increasingly interested to consider in food origins and overall sustainability i.e. sustainably-sourced, fair trade, and organic products. Indeed, reliable sources of seaweed that are farmed in environmentally better ways are not only beneficial to coastal communities and environments, but they also are interested in seaweed buyers and industry who are interested in securing stable and traceable sources of seaweed, in mitigating business reputational risks, and in seeking to obtain market advantage [21].

In this concept of seaweed farming information system, the bottom-up system was carried out for developing supply chain traceability and for providing the information from seaweed value-chain actors upstream to downstream and vice versa. The role of Information and Computer Technology (ICT) is needed because a large number of seaweed farmers are located in geographical island and remote areas and it is still a lack of standard quality control. To answer the needs of seaweed value-actors, the first seaweed value-chain information system was developed. It is likewise to face the recently challenges i.e. the expansion of the benefits of the internet for everything/Internet of Things (IoT), the development of artificial intelligence (AI), and the use of big data, which is followed by the development of various technologies and massive innovations. It is time for coastal and marine management including seaweed farming to take advantage of new technology 4.0 to ensure precision and efficiency. The development of new technologies such as robotics, AI, drones, satellites, big data, and IoT has become a necessity in line with the tendency of the industrial revolution 4.0 and especially the ICT’s needs during the Covid-19 pandemic.

Information about seaweed should be more easily accessible to the public through a system, namely the seaweed farming information system or literally Sistem Informasi RUmput LAut (abbreviated: SIRULA), either based on the website or mobile apps. The SIRULA website aims for the public to be able to get non-spatial and spatial information about seaweed online. The SIRULA concept encourages Indonesian one-data (satu data) and one-map (satu peta) policy for open, inclusive and accountable government to the public. Thus, seaweed value-chain actors, resources managers, and policymakers will take advantage of this improved information system, where reliable data and information can be accessed easily in real-time. For equitability, this information system would be managed by the central government.

The seaweed information system is a digital transformation that transforms analog data and information into digital. In the 4.0 revolution era, especially during a pandemic, most businesses and activities are conducted online. People are required to distance themselves from each other and outside limited activities, which forces them to do digital activities. Digitization keeps everyone productive and works faster and more efficiently. There is no denying that digital transformation is the solution to survive during the pandemic [23]. The information needs from upstream to downstream and vice versa in the value-chain are the issues in the seaweed industry. To answer this challenge, a system is built to fulfill the data and information requirements of each stakeholder, especially at the downstream to middle-persons level.

The role of ICT’s agriculture strategy guide from FAO-ITU [22] could be referred to as a basis of value chain of this seaweed farming information system (SIRULA). From all the data and information needed of each stakeholder in the seaweed value chain, the MMAF through the Marine Research Centre
creates an initial design of the information system. It was designed into four content menus on the website which consists of: 1) visualization of weather and climate prediction; 2) warehouse apps; 3) map of potential/suitable area; 4) repository and thematic search engine (Figure 4). The basic data for each content menu will be collaborated and coordinated with the relevant agencies/institutions. The downstream to upstream actors who engage in the seaweed value chain are effectively provide and access information in this platform/website.

In the climate and weather menu, the users will be provided with data and information about temperature, sea surface temperature (SST), waves, wind direction and solar radiation. This information helps in the management of seaweed growing season and post-harvest drying treatment. Besides, these menus play a vital role to promote environmentally sustainable farming practice and disaster risk management and early warning system. Temperature, no rain days, humidity, rainfall intensity, velocity and direction of wind, sea surface temperature (SST) are used by the majority of farmers to determine the planting season and the conventional drying process. This drying was varied and depend on weather conditions. It is done 2-3 days in good weather and dried until 7 days in rainy days [24]. This menu is applicable for determining the quality of dried seaweed products. Information on climate weather in collaboration with the Marine Research Center and the Applied Climate Service Center of Meteorological, Climatological and Geophysical Agency (Badan Meteorologi, Klimatologi dan Geofisika, BMKG). From the weather information menu, stakeholders get information about temperature, temperature, waves, wind direction and solar radiation. This information helps manage the seaweed growing season and drying after harvest.

Suitable and potential seaweed farming area menu is visually showed a thematic map which compiles, collects, synchronizes and integrates the basic map with the site of land suitability, production, warehouse, manufacturing, seed stock. The essential role of potential and area mapping promotes the environmentally sustainable farming practice, enhanced market access, financial inclusion, insurance and risk management. The data evaluation and analysis of water quality based on model and field observation, physical and chemical parameters were compiled on suitability matrix design to generate the potential and suitable area for seaweed farming in each season [25]. The area of seaweed farming was correlated to the market access and seed stock area. The potential area contains spatial information about potential seaweed cultivation locations. This information is useful in determining the location of seaweed cultivation by taking into account various environmental requirements. Based on land potential and production data in each region, in the future as a basis for estimating seaweed production in the region [26]. The data of potential land information is obtained from the modelling results of the Institute for Marine Research and Observation (BROL=Balai Riset Observasi Laut), based in Bali and existing data for seaweed farming from the Directorate General of Aquaculture, MMAF.

The third menu, the warehouse system is an application for the middle-person (Figure 4). The remote condition of seaweed farming areas in coastal and Small Island stimulate to find the facility and the accessibility for the seaweed supply chain. In some conditions, the middle-persons have to ensure the quantity targets and quality standard demand. There are significant challenges for collectors and traders for re-drying, co-mingling, and re-packing of products to keep the good quality during the post-harvest process. Some conflicts occur among/between the value-chain actors due to distrust, dissatisfaction and inconvenience. In this design system, farmers and middle person may propose to establish the community enterprises to own and manage the good seaweed farming, the process systems that produce high-quality seaweed biomass and also the creation and innovation of value-added products from the biomass. The community enterprises (Figure 3) could be actualized through cooperative unit, village owned enterprise, called badan usaha milik desa (BUMDES), or seaweeds farmers groups.

The warehouse application would be vital to the traceability system of seaweed products from downstream to upstream. The seaweed information system will be a production, traceability and sustainability-based system. This system should be quite simple, effective and easy to use by every stakeholder. Although it requires a smartphone or computer to access it, the limitations of the use of these two devices, especially for farmers, can be assisted by filed extensions (called penyuluh lapangan) and capacity building training.

The Warehouse menu will be useful for knowing the amount of real-time seaweed production in each region. Warehouse data information will be obtained from storage warehouse operators who record
the amount of dried seaweed harvested by farmers. Access to warehouse information requires cooperation with the local government which has authority over seaweed business in its territory. Information and production data from the warehouse will be helpful for middle person to fulfill the seaweed supply both for export and domestic processing industries.

Repository data menu contains all scientific and updates information relevant to seaweed. The scientific article, farming methods from planting, harvesting, drying to packing according to Indonesian National Standards (SNI) and update news and bulletin are provided by the search engine system. It is a formed-like thematic library for the reader who interests in the seaweed theme. The seaweed stakeholders can gain important information about all matters of seaweed production, quality, industry and regulation as well. The knowledge menu is a search engine that is used are social and dynamic network analysis and text mining. The task of researchers within the Marine Research Centre is to update every information into the knowledge menu.

Figure 4. Content design of seaweed farming information system based on needs of business actors and their information role.

3.3 Implementing concept and integrated design of SIRULA

An information system has a function to make business processes more effective and efficient. Through the system, it can improve performance and competitiveness, and make each party make the right decisions easier. Development of information systems to improve the performance of each process to be faster and more accurate. The goals of the development of the seaweed information system are (1) improving performance; (2) improving the quality of data and information, both speed and accuracy; (3) improving the service functions to stakeholders as end-users.

The process of development of the system will be through the cycle of his own life and every process must be enhanced to meet the goals and objectives. In the development system, 6 stages must be passed (Figure 5) to improve the processes of the organization: planning stages, systems analysis, design, implementation and use. Each stage can be further subdivided into more detailed stages so that its implementation can be more systematic and planned.
Figure 5. Cycle stages of seaweed farming information system conceptual framework that consists of: 1) Planning; 2) Analysis of design content; 3) Design System; 4) Implementation, 5) Evaluation; and 6) Maintenance for next work (Scheme modified from Achimugu et al. [27] and McLeod in Haluan et al. [28].

Based on Figure 5, information system development is part of post-implementation. This development is based on the evaluation of implementation success and feedback from end-users. In principle, the development of seaweed information systems in the future is by adding information to fulfill the stakeholder needs (Table 1). Besides adding the information, the improvement of the performance of the system is the important thing to make the functionality of the service to the end-user better. The way to improve the system is by updating both the database and algorithm to obtain data and more accurate information through this system. The development of information systems continues to be carried out to improve the service to the end-user while supporting the downstream of the national seaweed industry. The purpose of this development is to fulfill the requirement for data and information to increase the productivity of every stakeholder in the seaweed supply chain.
Table 1. The development of information system based on the required information

| Required Information                              | Farmers | Collators | Buyers | Exporters / Processing Industries |
|---------------------------------------------------|---------|-----------|--------|----------------------------------|
| Seed Source                                       | ✓       |           |        |                                  |
| Weather and climate when planting and drying. Environmental suitability parameters | ✓       |           |        |                                  |
| Potential area / Land suitability                 | ✓       | ✓         |        |                                  |
| Dried seaweed price list                          | ✓       | ✓         |        | ✓                                |
| Real time data production                         |         | ✓         | ✓      |                                  |
| Product knowledge                                 | ✓       | ✓         |        |                                  |
| Warehouse location and commodity                  |         |           | ✓      |                                  |
| Consistency regarding seaweed standard quality    |         |           | ✓      |                                  |
| Distribution and marketing network                |         |           | ✓      |                                  |

The development concept of Seaweed Information System

4. Conclusion
Seaweed information system (SIRULA) may fulfill the lack of synergistic data and information on seaweed industry from upstream to downstream. This integrated information system is the initial solution in documenting data and information needed by main actors in the seaweed value-chain i.e. farmers, middle persons (collectors and traders/wholesalers), exporters and processing industries. Traceability, sustainability and productivity are tagged as the concept of SIRULA. Based on stakeholder requirements, the integrated design of seaweed information systems present the visualization of weather and climate prediction; warehouse apps; map of potential/suitable area and repository and thematic search engine in the websites.

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