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The Benefit of Decision Support System as Sustainable Environment Technology to Utilize Coastal Abundant Resources in Indonesia

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Abstract. Being the largest archipelagic state in the world (± 81 000 km of coastline), Indonesia has a great potential for developing the aquaculture industry. But, the accomplishment of sustainable practices and management systems are still in its infancy. Therefore, it is vital to improve aquaculture technology and develop management tools that address the need for an eco-friendly production process. In this manuscript, the Decision Support System software is applied for the management of sustainable floating net cage finfish cultures. This software integrates physical, chemical, biological properties and information on coastal uses to determine site selection, production carrying capacity, ecological carrying capacity and socio-economic assessment of 18 cases, focusing on the economic viability of Tiger grouper [*Epinephelus fuscoguttatus* (Forsskål, 1775)], Humpback grouper [*Cromoliptes altivelis* (Valenciennes, 1828)] and Leopard Coral grouper [*Plectropomeus leopardus* (Lacepède, 1802)] at three remote areas in Indonesia, including: Ekas Bay, Talise and Galang Island. The outcomes demonstrate that only Galang Island provides a suitable area of 12 940 ha with the estimated production carrying capacity of (0.5 to 366) t/annual per fish farm along with ecological carrying capacity are limited of (18 393 to 21 727) t/annual and economic evaluation highlighted that all cultures development are economically viable.

Key words: Decision Support System, Indonesia, sustainable.

1 Introduction

Indonesia is the largest aquaculture producer of marine finfish in Southeast Asia [1]. Being the largest archipelagic state in the world with about 81 000 km of coastline, corresponding to approximately 14 % of the world's coastlines, Indonesia has a great potential for developing the aquaculture industry [2]. The expansion of the aquaculture and fishery sector is expected to improve the country's welfare, especially for fishermen and fish farmers that are currently living under the poverty level. On other hand, the accomplishment of sustainable practices and management systems to preserve coastal environments is still in its infancy and more emphasis should be given to it. In particular, the degradation of coastal environments, overlapping and conflicting utilization of the coastal areas and enforcement of laws regarding the management of the marine and coastal environments are not being addressed properly. Therefore, it is essential to improve aquaculture technology and to expand management tools that address the need for an eco-friendly production [3].

During the development, the extensive measurements and monitoring programs along with system application have been successfully implemented to several coastal areas in Indonesia, including Pegametan Bay Bali, Seribu Islands in the Java Sea, Celukan Bawang in Bali and Saleh Bay in Lombok [4, 5]. In this manuscript, the application of the system for the management of sustainable floating net cage finfish cultures of the Decision Support System SYSMAR DSS

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software for the sustainable environmental and socio-economic management of floating net cage finfish culture is assessed.

Along with recent developments in SYSMAR DSS, we have turned our attention to the need for substantial and user-friendly software. The lack of measurement data in remote areas has been identified as a major problem for many years and is addressed in this study. This will be complemented with an evaluation of the economic viabilities. The outcomes achieved are going to support decision makers and the public with respect to the selection of best sites, assessment of the impacts and estimation of economic viabilities for the sites under investigation.

2 Material and methods

The investigations will be carried out at three priority sites in Indonesia namely: Talise Island located in the northern most tip of Sulawesi; Galang Island which is part of the Riau Archipelago located opposite of Singapore and Ekas Bay located south of the Lombok Island. The development focuses on the most common high-value finfish species nurtured in floating net cage (FNC) in Indonesia [6–9]. In this study Tiger grouper (*Epinephelus fuscoguttatus* (Forsskål, 1775)), Humpback grouper [*Cromoliptes altivelis* (Valenciennes, 1828)], and Leopard Coral grouper [*Plectropomeus leopardus* (Lacepède, 1802)] are considered.

This software is integrated into a graphical user interface (GUI), which has been constructed in Matrix Laboratory (MATLAB) by van der Wulp et al. [5]. These interfaces have several databases for quick access, and they are linked to a geographic information system (GIS) to process and visualize spatial information. In this paper, the MATLAB version 7.11.0.584 (R2010b), 32 bit (win32) was used.

2.1 Data

When using this system, data input or analysis types are selected by the user through the interface that controls the type of analysis to be made of the model components of the DSS. The compulsory data for the purpose of the DSS is gained from several sources. The hydrodynamic and wave models require bathymetric data along near shore areas in Indonesia which is usually obtained from nautical charts issued by the *Badan Koordinasi Survey dan Pemetaan Nasional* (National Coordinating Agency for Survey and Mapping). General Bathymetric Chart of the Oceans (GEBCO) data is issued by the British Oceanographic Data Centre, U.K. It is usually adopted to provide information in deeper areas. For tidal variations and wind characteristics for diving, the numerical models are extracted from *Total Modal Driver*. The wind data is obtained from the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP/NCAR) reanalysis database. Water quality information is usually obtained from agencies and measurements taken in the vicinity of the selected areas. In many cases, it is supported by analysis of satellite data. Problems resulting from conflicts of integrated coastal zone management or coastal uses and adverse natural environmental conditions are also accounted for in the selection of suitable sites, and for this purpose geographic data of National Development Planning are collected to identify the most relevant problems in the coastal zone.

2.2 Opening screen

Practical information through the SYSMAR DSS is accessible by choosing buttons from the opening screen of the interface, as shown Figure 1. Under the database menu, new database entries can be added, modified or removed. The following windows are shown to illustrate the presentation of SYSMAR DSS. The next selection window is displayed for preparing a DSS input (See Figure 1).

2.3 Farm properties

Figure 2 shows how the window interface of farm properties allows the user to select the FNC grouper culture farm type for decision purposes. The tab allows a specification of farm type, dimensions, investment description, maintenance cost and staff along with wages of a representative FNC grouper culture unit. It contains farm size; estimated investment cost, maintenance cost, as well as staff and technician wages and anticipated farm lifespan. Prices given are valid for the local market.

2.4 Stock properties

In this study, SYSMAR DSS allowed the selection of a combination of one out of three types of grouper species with three feed types. For example, tiger grouper can be selected for species and then combined with feeding by trash fish, pellet, as well as a mix of 30 % pellet and 70 % trash fish. The selected combination of fish species and feed types allows the DSS to establish the production characteristics per ton of production. Site selection criteria are defined in the table shown in Figure 3.

2.5 Site selection criteria interface

Table 1 presents the windows of site selection criteria, which allow the user to input data based on 32 parameters (e.g. physical, chemical and Integrated Coastal Zone Management (ICZM)) related to suitability and sustainability analysis. In this module, the user can define allowable ranges or optimal ranges with respect to the information data.

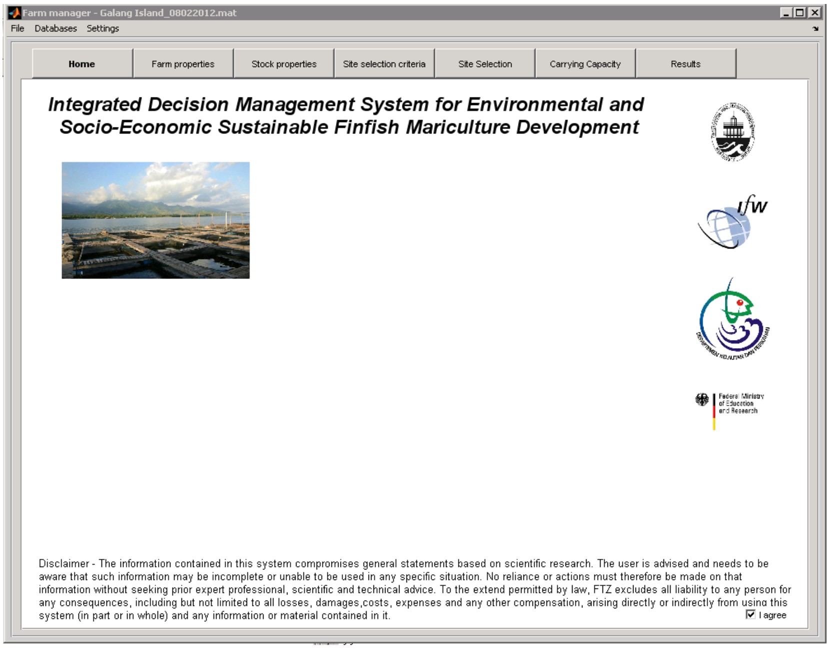

Fig. 1. The opening screen of the SYSMARDSS interface [9].

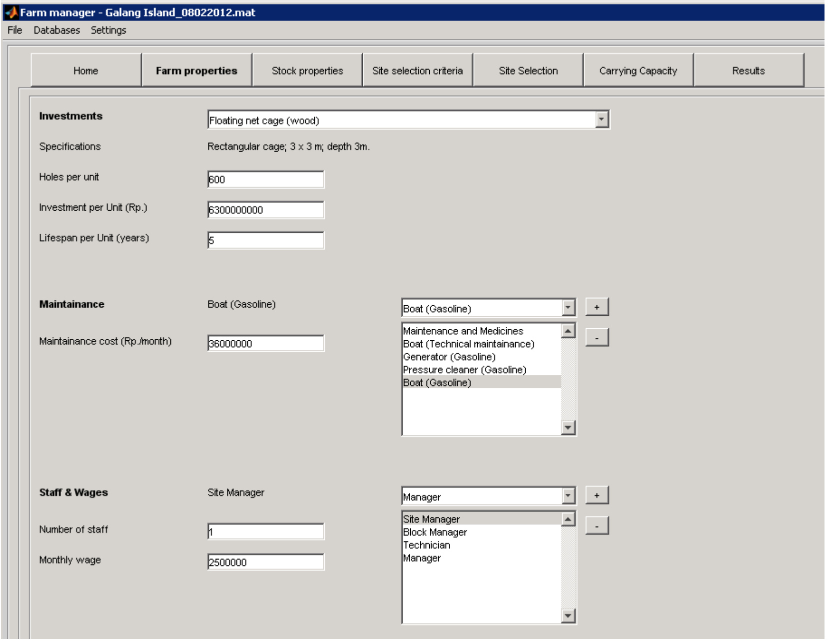

Fig. 2. Farm properties interface.

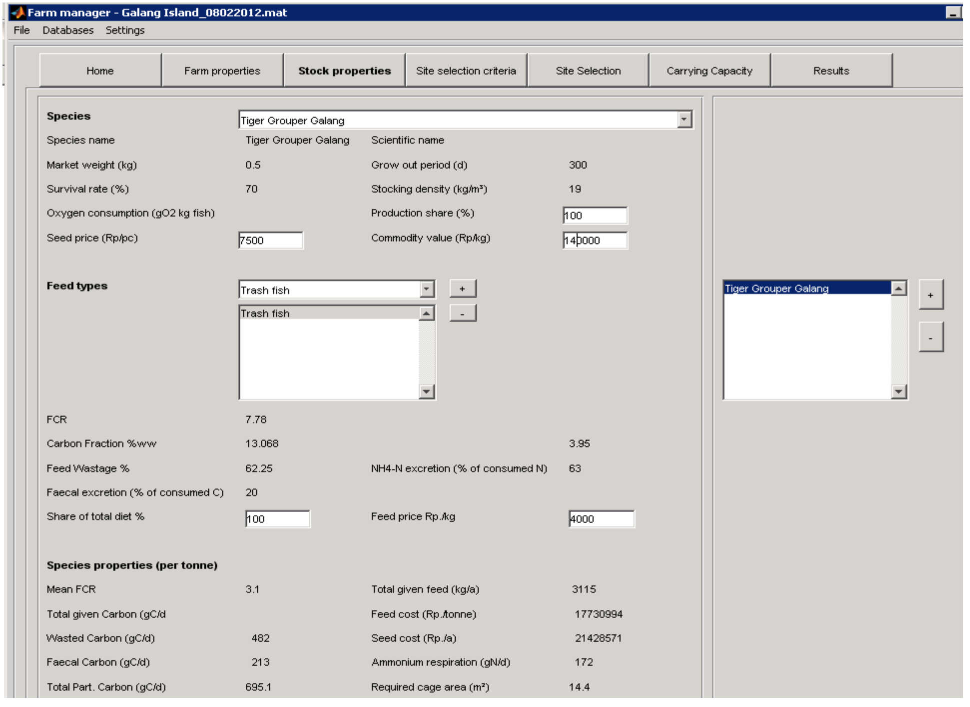

Fig. 3. Stock properties interface

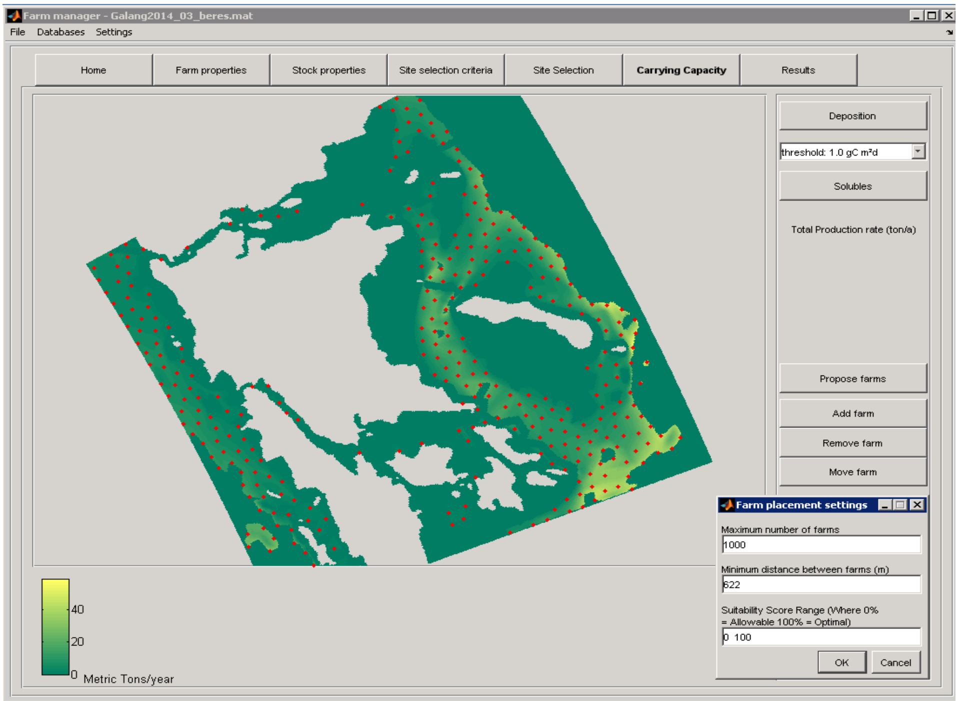

Fig. 4. GIS for carrying capacity.

Table 1. Site selection interface [4, 5, 10–12].

Description	Parameters	Indicators	Units	Unsuitable	Allowable	Optimal
Physical Process	Min. water depth	water depth	m	< 6	> 6	> 8
	Max. mooring	water depth	m	> 25	< 25	< 20
	Flushing	mean current	m s^{-1}	< 0.01	> 0.01	0.2 to 0.5
	Currents	mean current	m s^{-1}	> 1	< 1	0.2 to 0.5
	Exposure to waves	significant wave	m	> 1	< 1	< 0.6
	Exposure to wind	max wind speed	m s^{-1}	> 15	< 15	< 10
Water Quality	Water temperature	water temperature	°C	< 20 or > 35	20 to 35	27 to 31
	Salinity	salinity	nL L^{-1}	< 15 or > 35	15 to 35	26 to 1
	Dissolved oxygen	dissolved oxygen	mgO_2 L^{-1}	< 4	> 4	> 5
	Acid-base balance	pH	-log H^+	< 6 or > 8.5	6 to 7.8	7.8 to 8.5
	Water transparency	Secchi depth	m	< 2	> 2	> 4
	Turbidity	suspended matter	mg L^{-1}	> 10	< 10	< 5
	Ammonium	ammonium	mg NH_4-N L^{-1}	> 1	< 1	< 0.5
	Nitrate	nitrate	mg NO_3-N L^{-1}	> 200	< 200	< 200
	Nitrite	nitrite	mg NO_2-N L^{-1}	> 4	< 4	< 4
	Phosphate	total phosphate	mg P L^{-1}	> 70	< 70	< 70
ICZM						
	Villages	thematic map	m	< 200	> 200	> 500
	Towns	thematic map	m	< 200	> 200	> 500
	Cities	thematic map	m	< 200	> 200	> 500
	Harbours	thematic map	m	< 200	> 200	> 500
	Industry	thematic map	m	< 200	> 200	> 500
	Tourism	thematic map	m	< 200	> 200	> 500
	Streams	thematic map	m	< 200	> 200	> 500
	Rivers	thematic map	m	< 200	> 200	> 500
	Erosive shoreline	thematic map	m	< 200	> 200	> 500
	Semi intensive hatcheries	thematic map	m	< 200	> 200	> 500
	Intensive hatcheries	thematic map	m	< 200	> 200	> 500
	Ponds	thematic map	m	< 200	> 200	> 500
	Sewage discharges	thematic map	m	< 200	> 200	> 500

	Traffic lanes	thematic map	m	< 200	> 200	> 500
	Coastal usage	thematic map	m	< 200	> 200	> 500
	Environmentally protected area	thematic map	m	< 200	> 200	> 500

2.6 GIS for processing and spatial planning data for carrying capacity

Figure 5 shows how the carrying capacity tabs are used to determine carrying capacities with respect to particulate carbon. Locations can be selected by adding farms (manual or auto). For each farm, the suitability analysis and carrying capacity are summarized including needed farm area and economic analysis. This figure has been generated with a particulate carbon deposition threshold of (1 to 2) g cm^{-2} d^{-1}, as well as the settings of the tab for farm placement with the maximum number of farms being adjusted for farms located at a minimum of farm distances of 500 m.

2.7 Economic analysis

It can be seen in Figure 6 below how an overview of the economic flow of development for a FNC tiger grouper culture fed with the pellet is executed under the SYSMAR DSS interface. The capital cost of 600 cages for a 5 yr project is shown by the annual depreciation cost. The variable cost including maintenance, seed and feed are also presented. As can be seen from this figure, the wage costs are defined by one manager, one site manager, two block managers as well as 25 technicians.

The manuscript presents and applies economic models which have been developed as an amendment using SYSMAR DSS in conjunction with a Microsoft Excel spreadsheet program with respect to the cost-benefit analysis technique. All biological data, production cost, and profit are obtained from personal communication and literature data from the development of FNC cultures in Indonesia. Data were obtained from many institutions, including Coral Reef Information And Training Centers (CRITC) COREMAP-LIPI [13] and Indonesian Bank, about progressive tax for domestic agency Indonesian [14]. This method has not been comprehensively reviewed and discussed in previous research with the application of DSS.

Table 2. Economic analysis interface of the SYSMAR DSS.

A	Depreciation		Euro/Year
	Floating net cage (wood) (600 holes,m 16200 m^2)		100 800
B	Variable cost		
	Maintenance	Freshwater	5 760
		Boat (Gasoline)	5 280
		Boat (Technical Maintenance)	2 880
		Generator (Gasoline)	3 840
		Maintenance and Medicines	14 400
	Seed		
		Tiger Grouper (438 000 pcs)	262 800
	Feed		
		Pellet (520 t)	541 158
			836 118
c	Wages		
		Site Manager	2 400
		Manager	4 800
		Technician	33 648
		Block Manager	3 840
D	Revenue		
		Tiger Grouper (197.1 t)	2 207 520
		Total Revenue	2 207 520
		Profit (D-(A+B+C)	1 225 914

3 Results

The performance of this system will be presented through the use of a geographic information system (GIS) as a spatial planning tool. Applying site selection of the SYSMAR DSS shows that Galang Island provides a bright potential for FNC finfish culture development which is indicated by a suitable area of about 12 940 ha (see Figure 5). The results of hydrodynamic and wave numerical models show that Ekas Bay and Talise Island are not suited for FNC finfish culture projects.

Regarding production carrying capacities, the marine environment in the vicinity of Galang Island obviously has a large potential for the development of FNC grouper culture. The findings of this study indicate that the estimation of maximum and minimum production carrying capacity of all potential farms with distances of at least 500 m between farm sites are in the range of (51 to 366) t per farm and (0.5 to 2) t per farm, respectively and estimated production regarding ecological carrying capacity could produce in the range of (18 393 to 21 727) t/yr per community area, respectively (see Figure 5).

The results from the present study have provided vital information on about 18 cases regarding the economic viability of tiger, humpback and leopard coral groupers FNC farming utilizing various feed types and production scales. Every prototype farm consists of 600 cages and 10 cages, respectively in Galang Island with a standard cage size of (3 × 3 × 3) m for width, length, and depth. Different types of feed are also considered, such as trash fish, pellet, as well as mixing 70 % trash fish and 30 % pellet. The study shows that FNC finfish culture developments are economically viable as a whole, because after a 5 yr projection period, positive cumulative cash flow and net present value (NPV), internal rate of return (IRR) at rates above the bank rates, and a payback period (PP) far below the 5 yr projected lifetime of the project are evident.

4 Conclusion

In aquaculture management, the attention to DSS to utilize coastal resources abundant is relatively new along with the development of such a technology will play an increasingly important role in analyzing and planning potential aquaculture site selection, production, environmental impacts and sustainability. SYSMAR DSS intends to help decision makers in Indonesia to collect useful information from a variety of information systems (GIS, remote sensing, online data, etc) for future of sustainable aquaculture development. A possible explanation for some of our results may be the lack of adequate raw data. These results, therefore, need to be interpreted with caution. However, with model simulations, caution must be applied, as the findings might be utilized to identify tasks and make decisions. It is also a priority to develop a management system to ensure that the environmental impact from Indonesian mariculture does not exceed acceptable levels. These results advertise a strategy for the incorporation of aquaculture within the broader ecosystem in a way that supports sustainable development, equity, and the resilience of interlinked social and ecological systems.

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