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Dynamic Modelling Analysis on The Effectiveness of Coastal Land Resources for Aquaculture Activities Utilization

Benny Diah Madusari[a], Heri Ariadi[a], Dewi Mardhiyana[b]

[a] Department of Aquaculture, Faculty of Fisheries, Pekalongan University, Pekalongan, 51111, Indonesia
[b] Department of Mathematics Education, Faculty of Teacher Training and Education, Pekalongan University, Pekalongan, 51111, Indonesia

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ABSTRACT

Coastal areas are considered biodiversity zones. This study aimed to analyze the effectiveness of land use on aquaculture productivity rate in coastal areas using a dynamic modeling analysis system. This study was conducted in the Pekalongan Province. Water quality parameters and qualitative research data were obtained from an in-depth survey. Furthermore, the data were analyzed using dynamic modeling analysis. The results of this study indicate that the level of coastal land use has a variable relationship with the productivity rate of aquaculture. Based on the causal loop model, it could be analyzed that the social, environmental conditions in coastal areas were described as continuing to experience quantification of population increase and environmental utilization rates. Overall, the productivity level of aquaculture cultivation in coastal areas tended to decrease along with the increasing value of productive land use accompanied by increased inputs and the number of human resource populations in coastal areas. The optimal inclusion of this study was that the optimal land use level would impact the productivity management level of aquaculture cultivation in coastal areas. Based on the results of this study, it can be concluded that the optimal utilization of coastal land greatly impacted the management of the productivity level of aquaculture cultivation, which was carried out in an integrated manner. Furthermore, the analysis of the dynamic modeling system also illustrated the increasing social-environmental conditions in coastal land utilization.

Introduction

Coastal areas are natural ecosystems with extraordinary biodiversity [1]. Biodiversity in coastal areas provides extraordinary resource utilization opportunities for development in the future [2]. The interaction between geophysical and geological elements has an impact on the anthropogenic characteristics of dynamic coastal areas [3]. The impact of dynamic changes in coastal areas has changed various ecological, social, and economic factors in coastal zones [4]. The current utilization of coastal areas refers to various substances such as land, water, or certain territorial zones. The wetland fisheries sector has been widely used as a model for managing the coastal areas in Indonesia [5]. Several activities in the fisheries sector that have been applied in coastal areas include the cultivation of shrimp, fish, seaweed, and shellfish, which can be carried out periodically [6]. Opportunities for the use of diverse coastal areas have provided opportunities for creating an integrated form of business activity [4].

In recent years, coastal land management has experienced a decrease in productivity due to various factors. The main factors that increased the level of land productivity in coastal areas were the impact of climate change and increasing population waste disposal [7]. Critical coastal areas also indirectly had an impact on all activities and efforts to utilize the resources that were there. The concept of managing coastal areas provided challenges that were vital enough to be solved to have an overall impact on the surrounding environment [8]. Several aspects that are directly affected by changes in natural habitats in coastal areas

Corresponding Author: Heri Ariadi ariadi_heri@yahoo.com Department of Aquaculture, Faculty of Fisheries, Pekalongan University, Pekalongan, Indonesia.

include aquaculture activities, such as shrimp, fish, seaweed, and shellfish cultivation [9]. The purpose of this study is to analyze the effectiveness of land use on the productivity level of aquaculture cultivation in coastal areas using a dynamic modeling analysis system. From the results of this dynamic modelling analysis, it is expected that there will be a forecasting concept for coastal area management that is integrated and takes place inclusively.

Material and Methods

Study Area

This research was conducted from August to September 2022. This research was conducted in the area of intensive fish farming activities in the coastal areas of Jeruksari and Degayu Village, Pekalongan City. The selection of research locations was based on the location which is the basis for aquaculture activities in Pekalongan City. Apart from that, the research location is also easy to reach based on the availability of available transportation facilities.

Data Collection

The data observed were water quality parameters and qualitative research data, which were obtained by distributing survey forms. The observed water quality parameters were pH, salinity, dissolved oxygen, and water temperature. Furthermore, data were collected according to research needs, which were then analyzed with a dynamic modeling system using Stella ver 9.0.2 software. Based on the causal model, the next analysis was used to qualitatively describe the graphical model.

Data Analysis

Water quality parameters were observed periodically during fish farming cycle in Degayu. Water quality parameters such as pH, salinity, dissolved oxygen and water temperature were observed in the morning and evening. To obtain qualitative data, interviews were conducted by distributing questionnaire surveys to obtain corroborating information about fish farming activities in Degayu. Data research is collected based on the variables and types of data needed before dynamic modeling system analysis is carried out.

Results and Discussion

Causal Loop Model

The causal loop model was constructed based on mathematical analogies and related theoretical studies connected to form a unified model that could be used as an analytical tool. This causal loop model can be used as a predictive estimation tool related to the object being assessed in a case study. The causal loop also makes it very easy to carry out managerial or practical activities. Analytical models have been developed to make it easier for users to make predictions and estimates of the object being studied [10].

Several causal loop models can be developed in the fisheries, agriculture, forestry, and other sustainable resource management sectors [6]. In this study, a causal loop model was created based on the research objective, namely, to analyze land use and its relationship to the productivity level of aquaculture cultivation in coastal areas. The sub-objects in this model were created based on existing indicators such as human resources, natural resources, land area, and aquaculture cultivation productivity data, which were dynamically integrated with each other.

The formulation of a causal loop model is based on the elements needed to create a dynamic model system by connecting one parameter to another for certain reasons [11]. The arrangement of the system in the causal loop can be described through certain formulas or an analogy analysis. The different elements or parameters in the causal loop model system can be polarized and tested to determine the validity of the model [12]. The causal loop model used in this research analysis is shown in Figure 1. The causal loop model pattern shown in Figure 2, explained that the pattern of the relationship between the level of productivity of regional management comes from the factors of natural resources, human resources, and skills, which then affect the pattern of regional management and social status.

Figure 1. The causal loop model describes the coastal management dynamics.

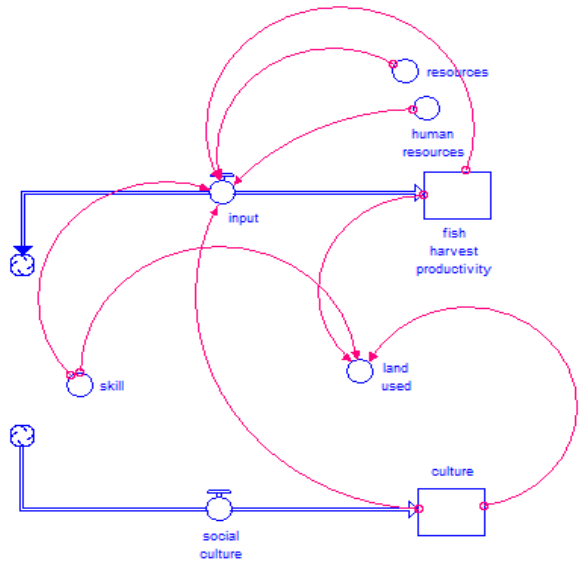
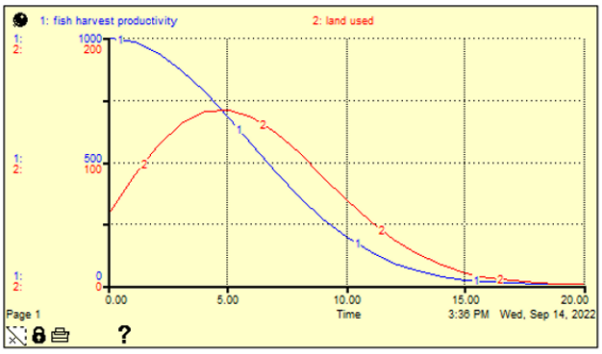


Figure 2. The causal loop model describes the coastal management dynamics.

Land Use and Aquaculture Productivity

The level of coastal land use and its relationship with existing aquaculture productivity are shown in Figure 3. The level of land use in coastal areas has a variable relationship with the productivity level of aquaculture cultivation in the region. Integrated coastal area management has a level of integrity relationship with the use of the surrounding environment [13]. Integrated coastal area management has an extraordinary impact on ecological and socioeconomic systems [14].



Time	Fish Harvest	Land Used
0	1.000.00	60.00
1	985.00	88.65
2	940.75	112.89
3	870.47	130.57
4	779.64	140.33
5	675.24	141.80
6	564.93	135.58
7	455.99	123.12
8	354.64	106.39
9	265.35	87.56
10	190.70	68.65
11	131.40	51.25
12	86.64	36.39

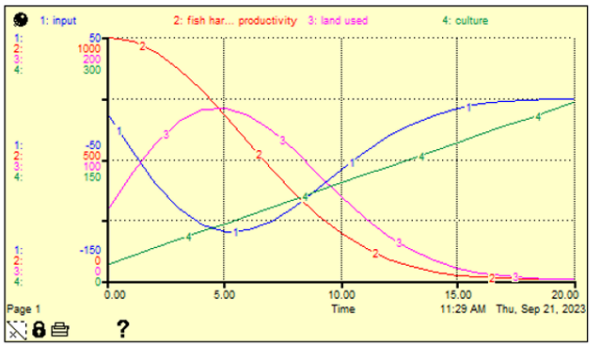
Figure 3. Relationship between aquaculture productivity rates and land use.

Figure 3 shows the relationship between aquaculture productivity and land use. It was interpreted that the level of productivity of aquaculture cultivation in coastal waters areas would increasingly decrease, while on the other hand, the level of productive land use in the area fluctuated. This means that fluctuations in productive land use were allegedly due to a decrease in the quality of land in coastal areas, resulting in a decrease in the productivity of aquaculture there. Carrying capacity will continue to decline as land use intensifies [15]. Weather fluctuations and changes in the biophysical structure of the environment are several factors that affect the decrease in land productivity in coastal areas [16]. The utilization of coastal ecosystems based on biodiversity management would improve the economy of the community [17].

More specifically, the biophysical conditions of the coastal environment in the Pekalongan region are dominated by lowlands with a sandy soil structure, which tends to cause abrasion and land contamination. Owing to this vulnerability, several environmental adaptation steps are necessary to ensure stable coastal area utilization activities [18]. Efforts to utilize integrated coastal areas have provided opportunities for the creation of various creative activities that can be developed in these water zones [19].

Coastal Zone Management

Coastal management areas are making an effort to improve environmental conditions in offshore areas in order to create a spatial utilization system [7]. Based on the causal loop model, the relationship between the parameters was analyzed to analyze coastal area management based on the case study data. The results of the modeling analysis are shown in Figure 4.



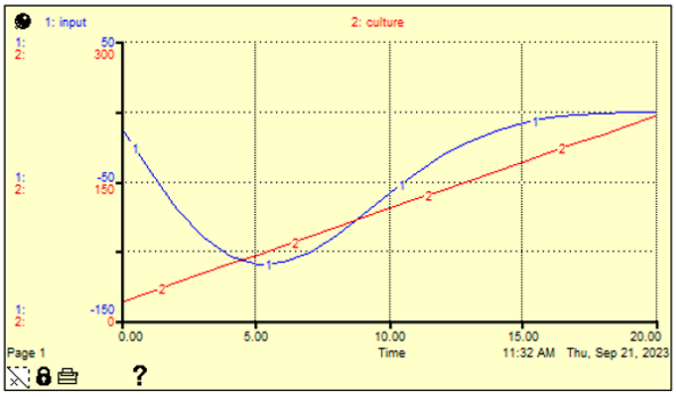
Time	Input	Fish Harvest	Land Used	Culture
0	-15.00	1.000.00	60.00	20.00
1	-44.25	985.00	88.65	30.00
2	-70.28	940.75	112.89	40.00
3	-90.84	870.47	130.57	50.00
4	-104.39	779.64	140.33	60.00
5	-110.32	675.24	141.80	70.00
6	-108.93	564.93	135.58	80.00
7	-101.36	455.99	123.12	90.00
8	-89.29	354.64	106.39	100.00
9	-74.65	265.35	87.56	110.00
10	-59.30	190.70	68.65	120.00
11	-44.76	131.40	51.25	130.00
12	-32.09	86.64	36.39	140.00

Figure 4. Analysis of the impact of coastal area management.

Based on the results of the data analysis and interpretation shown in Figure 4, it is illustrated that the higher the resource input given to the coastal environment, the lower the level of land use and productivity of aquaculture farming there, or there will be a gradual decrease in carrying capacity. This means that the higher the intensity of land management, the lower the productivity of the land [20]. Managing land that is not well planned would greatly impact the level of productivity of the land [21]. The number of human and natural resource inputs provided to coastal areas fluctuated owing to dynamic management systems (Figure 4). Integrated management of coastal areas must be achieved by understanding the characteristics of the ecosystems [22]. Several applications of coastal area management based on ecosystem management have been developed as anticipatory measures against the phenomenon of climate change. Climate change has a significant impact on coastal and fisheries resource management activities [23].

Social Environment Conditions

The social conditions of the coastal environment were described using a dynamic modeling system, as shown in Figure 5. The social environmental conditions in coastal areas were described as continuing to experience an increase in quantification, meaning that the number of populations and the use of the environment in coastal areas increased daily. The coastal zone is an area that is very at risk of urban population problems owing to the high increase in the per capita population there [24]. One effort was to create productive activity options that could be applied directly by the community [25].



Time	Input	Culture
9	-74.65	110.00
10	-59.30	120.00
11	-40.76	130.00
12	-32.09	140.00
13	-21.83	150.00
14	-14.07	160.00
15	-8.58	170.00
16	-4.93	180.00
17	-2.67	190.00
18	-1.35	200.00
19	-0.64	210.00
Final		220.00

Figure 5. Relationship between social impacts and activity inputs in coastal areas.

Fluctuations in resource inputs in coastal areas can also be caused by various resource conditions. Changes in natural resources will greatly affect a region [14]. The preparation of a coastal area management system that focuses on the regional framework has a significant impact on the development of coastal areas [26]. The biophysical characteristics, along with the cultural richness that existed in coastal areas when combined, could provide examples of harmonious regional management implementation. Coastal areas provide promising opportunities for optimizing management in all fields [27].

Based on the results of dynamic modeling analysis, it could be explained that the productivity level of aquaculture cultivation in coastal areas tended to decrease along with the increasing number of productive land uses accompanied by increased inputs and human resource populations in coastal areas. This means that to obtain an optimal level of cultivation productivity in coastal areas, there had to be a balanced management system. Coastal areas have very high resource potential, but poor spatial management conflicts make this management suboptimal [28].

The increase in human population on the coast has made the concept of managing coastal areas very dynamic. The rapid development of humans has made the use of space even more difficult [29]. The difficulty of using regional space has implications for decreasing the productivity of several activities in the coastal zone [26]. Therefore, it is better to create several concepts regarding environmental management standards in coastal areas that have a legal patent basis. The existence of a strong legal umbrella would protect the existence of existing resources in coastal areas as well as the management model [30].

Conclusions

Based on the results of this study, it can be concluded that the optimal utilization of coastal land greatly impacted the management of the productivity level of aquaculture cultivation, which was carried out in an integrated manner. Furthermore, the results of the analysis of the dynamic modeling system also illustrated that increasingly intense social environmental conditions in utilizing coastal land areas and increasing waste input loads would affect the decrease in aquaculture productivity. This means that there needs to be real collaboration between the coastal community and aquaculture activities, so that there is no impact of environmental pollution due to aquaculture waste and a decrease in fish harvest productivity.

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