VULNERABILITY ASSESSMENT OF AQUACULTURE USING GEOGRAPHIC INFORMATION SYSTEM (GIS) AND REMOTELY SENSED DATA

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ABSTRACT: The Philippines is one of the top countries in fish production using aquaculture. Through the use of remotely sensed data, such as LiDAR and satellite imagery, with the aid of geographic information system (GIS) software, several methodologies have been developed in order to map aquaculture areas. Vulnerability of features is assessed by incorporating the potential impacts, which is the combination of exposure and sensitivity, and the adaptive capacity. The exposure is the severity of the physical environment conditions that drive alterations in the state of bio-physical systems. The present characteristics which defines the current state of the resource from different properties that is from climate change is the sensitivity. Adaptive capacity is the ability of the system to cope up with the changes in the environment. In this study, a GIS-based methodology is implemented to assess the vulnerability of aquaculture due to climate change and anthropogenic activities. The potential impact is computed using the exposure data from a related study conducted in the country and the sensitivity layer outputs (proximity to urban areas, elevation, and type of structure) from different GIS tools. The adaptive capacity scores, which are mainly based on the adjacent habitats, are also assigned using the outputs of GIS tools and socio-economic factors. The combination of the potential impact and the adaptive capacity are used for the final computation of vulnerability scores. As a result of this study, a vulnerability assessment methodology is developed and used to create a vulnerability map of aquaculture.

1. INTRODUCTION

1.1 Aquaculture in the Philippines

In the Philippines, aquaculture or fish farming is one of the sources of the country's food security, livelihood, and foreign exchange earnings. Different species and farming practices are involved in the aquaculture industry of the country. The production in aquaculture areas are mostly from farming of different fishes like milkfish, carps, and tilapia. Shrimps, oysters, clams, and even seaweeds are also cultivated in aquaculture in some provinces in the country. According to the Philippine Fisheries Profile 2014 of the Bureau of Fisheries and Aquatic Resources, the Philippines ranked 11th among the top aquaculture production of fish, crustaceans, and mollusks.

The milkfish industry in the country is most common use of aquaculture in the Philippines. Fish ponds and pens are developed in the Laguna de Bay, which is the country's largest freshwater lake, and in the Lingayen Gulf area.

Figure 1. Fish Cages in Bolinao, Pangasinan

1.2 Mapping of Aquaculture in the Philippines

The agency in-charge of the aquaculture management in the country is the Bureau of Fisheries and Aquatic Resources (BFAR) which is under the Department of Agriculture (DA). A project by the Department of Science and Technology (DOST), with the Philippine Council for Industry, Energy, and Emerging Technology Research and Development (PCIEERD) as the monitoring agency, and the Training Center in Applied Geodesy and Photogrammetry (TCAGP) under the Department of Geodetic Engineering, University of the Philippines – Diliman is tasked to create an inventory maps of the coastal resources of the country including the aquaculture areas using the light detection and ranging (LiDAR) technology. This project is also with coordination with the state universities and colleges and other higher education institutes across the country.

With this project, some inventory maps for each municipalities with LiDAR data are available and being turned-over to the local government units which will help in the local management and planning.

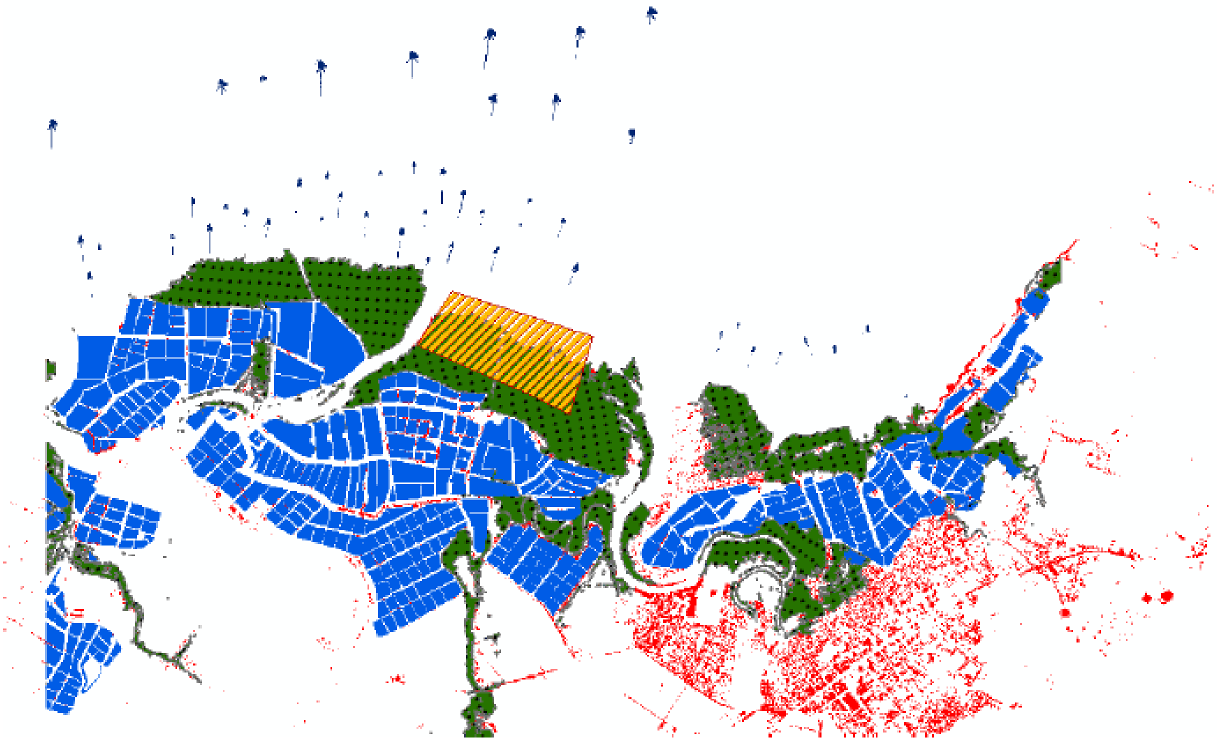

Figure 2. Sample output of the Phil LiDAR 2 CoastMap

1.3 Vulnerability Assessment

According to the third IPCC Assessment Report on 2001, the vulnerability is the degree or measurement in which a system is prone to the effects of climate change. It is based on the exposure, sensitivity and adaptive capacity of the system to the different rates of climate variations. The exposure is the extent a resource is subject to the climate change stressors. The sensitivity is the extent a resource responds to the different stressors, directly or indirectly. Combining the exposure and sensitivity is the potential impact of climate change and other factors to the resource. The adaptive capacity is the ability of the resource and the community efforts that help these resources to minimize its response to climate change.

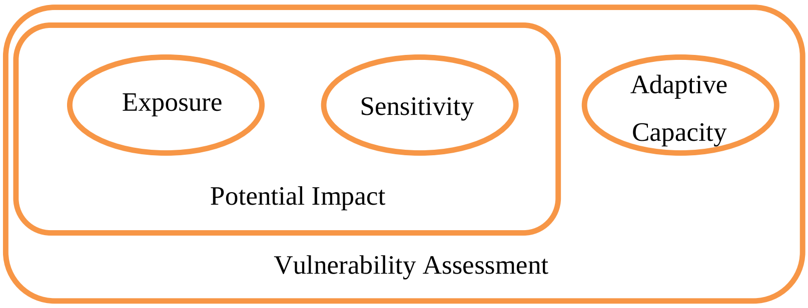

Figure 3. General framework of the vulnerability assessment

The vulnerability of resources also considers the anthropogenic effects, which are the response of the system with the human and other activities, to determine the response of the resources with the climate change.

1.4 Purpose of this Study

This study aims to develop a geographic information system (GIS)-based framework for the vulnerability assessment of aquaculture areas. Different layers in GIS are generated based from remotely sensed data and other secondary data such as studies from the coastal resource management office of the municipalities and conducting a focus group discussion with the local fishermen.

2. DEVELOPMENT OF THE VULNERABILITY ASSESSMENT FRAMEWORK

2.1 Exposure

The exposure indicates how the resource is subject to climate change and other stressors. In a study by Dr. Laura David of the University of the Philippines Marine Science Institute (UP MSI), a shapefile for the country is generated in which exposure clusters with different ratings that correspond to the different type of hazard such as sea-level rise, waves and storm surge, sea-surface temperature, and rainfall.

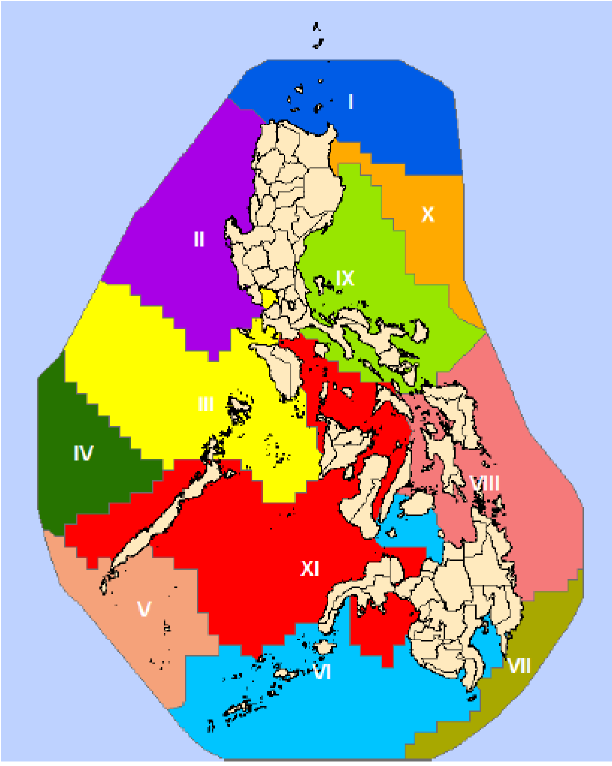

Figure 4. Shapefile of the exposure layer derived by Dr. Laura David

2.2 Sensitivity Layer

The sensitivity is the measurement on how the resource is responding with the climate change and other stressors. For this study, the criteria shown in the table below are the layers generated and used for the computation of sensitivity score of the aquaculture.

Table 1. Sensitivity Criteria used in this framework and their description

SENSITIVITY CRITERIA		DESCRIPTION	TYPE OF AQUACULTURE
GIS-DERIVED CRITERIA	**Proximity to Coastal Development**	Coastal Development is a possible source of pollution and other disturbances, thus increasing the resource's sensitivity to climate change.	Mari culture
	Depth	Depth is also considered as a criteria because this may correlate with the temperature changes and other threats such as sedimentation and anthropogenic disturbances.	Mari culture
WATER QUALITY	**Murky/ silty water**	Water turbidity is an important indicator of water quality. It suggests high sedimentation rates as well as high nutrient content which can lead to hypoxic/ anoxic environment.	Mari culture
	Solid waste accumulation and management	Solid waste from human activities are harmful to coastal resources. Presence of effective solid waste management can decrease sensitivity to climate change impacts.	Mari culture
ANTHROPOGENIC DISTURBANCES	**Stacking Density**	The stacking density is considered since over-stacking is more sensitive due to the high density of fishes in a structure.	Mari culture, fish pond
	Species Cultured	Some species of fish are also more sensitive with the climate change. The time also for the fishes for it to be harvested is also a factor for the sensitivity.	Mari culture, fish pond
	Structure Type	The type of the structure, whether it is a fish pond, fish cage, or fish corral, is also considered in this study. It is known that non-fixed structures are more sensitive to climate change.	Mari culture, fish pond

2.3 Potential Impact

The combination of scores for the exposure and sensitivity layers correspond to the potential impact of the aquaculture. The grading for the combination of the two layers is shown below.

Table 2. Potential Impact scoring table

		Sensitivity				
		Very Low	Low	Moderate	High	Very High
Exposure	Very Low	Very Low	Low	Low	Moderate	Moderate
	Low	Low	Low	Moderate	Moderate	High
	Moderate	Low	Moderate	Moderate	High	High
	High	Moderate	Moderate	High	High	Very High
	Very High	Moderate	High	High	Very High	Very High

2.4 Adaptive Capacity

The adaptive capacity is the measurement of the resource on how it can adapt with the climate change and other stressors. This may be because of the other habitat available in the area or any human management. The criteria considered for the adaptive capacity is shown below.

Table 3. Criteria for adaptive capacity

ADAPTIVE CAPACITY CRITERIA		DESCRIPTION	COASTAL RESOURCE
GOVERNANCE AND HABITAT	**Local Ordinances**	Local ordinances to protect and conserve coastal resources and strict implementation of such increases the adaptive potential of coastal resources.	Mari culture, fish ponds
	Community Support and Local Knowledge	Community support and awareness that these ordinances exist and how they respond to it is important to the success of any management and conservation effort.	Mari culture, fish ponds
ADJACENT HABITAT	**Mangrove cover along coast**	Since mangroves are considered as barriers against waves, it can be included in the adaptive capacity of fish pond areas.	Fish ponds

2.5 Vulnerability Assessment

For the final computation of vulnerability assessment of the resource, the table shown below is used as a guide in combining the adaptive capacity and the potential impact.

Table 4. Scoring for the final vulnerability assessment

		ADAPTIVE CAPACITY				
		Very High	High	Moderate	Low	Very Low
SENSITIVITY	Very Low	Very Low	Low	Low	Moderate	Moderate
	Low	Low	Low	Moderate	Moderate	High
	Moderate	Low	Moderate	Moderate	High	High
	High	Moderate	Moderate	High	High	Very High
	Very High	Moderate	High	High	Very High	Very High

3. CONCLUSION

In this study, it is shown that the geographic information system is an effective tool in conducting a vulnerability assessment for aquaculture areas. With the aid or remotely sensed data and other secondary data, the vulnerability of aquaculture to climate change and other anthropogenic effects. This study can be a baseline for future vulnerability studies for aquaculture areas. Other criteria can be also considered based on its availability as long as it can be represented spatially.

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