

**Research Article**

# The Livelihood Vulnerability of Vannamei Shrimp Culture as the Impact of Climate Change in Banyuwangi Regency, East Java Province, Indonesia

Ervina Wahyu Setyaningrum\*, Mega Yuniartik, and Shinta Hiflina Yuniari

Fisheries Science Program, Faculty of Agriculture and Fisheries, Universitas 17 Agustus 1945, Banyuwangi, 68416. Indonesia



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\*) Corresponding author:  
E-mail: [ervinawahyu@untag-banyuwangi.ac.id](mailto:ervinawahyu@untag-banyuwangi.ac.id)

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## Abstract

During Covid-19 outbreak, the production of the Vannamei Shrimp (*Litopenaeus vannamei*) actually increased and even increased the value of Indonesia's exports. The existence of shrimp culture is closely related to the nature of the surrounding environment, especially climate change. Climate change has a potential impact on aquaculture production, which affects livelihoods that depend on aquaculture. This study aims to analyze the development of sea surface temperature (SST) and high tides over the last 10 years and to analyze the vulnerability of the vannamei shrimp culture to climate change. This research uses a descriptive method. Data were collected through direct interviews with respondents, while the model was a structured interview. Secondary data were obtained from satellite imagery through geographic information systems, and from literature. Data analysis used spatial analysis with Geographic Information Systems (GIS), and vulnerability analysis was carried out to build the Livelihood Vulnerability Index matrix. The results show that climate change affects the development of sea surface temperature (SST) and high tides on the coast of Banyuwangi Regency, East Java Province, Indonesia. It is proven that during the last 10 years SST and high tide data shows that it fluctuates every year, SST between 27.75-29.6°C, the high tide between 1.47-1.57 m. Changes in SST affects high tide, and both become variability that affects vannamei shrimp culture. The results of the vulnerability analysis show that vannamei shrimp culture livelihoods in Banyuwangi Regency are categorized as vulnerable to climate change, with a value of 3.30 (3.34 vulnerability threshold).

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## 1. Introduction

Climate change in Indonesia means the impact on shrimp culture can occur directly or indirectly, which cannot be attributed to just one factor. For example, an increase in temperature will affect the rate of evaporation of water in the aquaculture pond, increasing the intensity and frequency of disease outbreaks. Then a change in the amount of rainfall will have an impact on a decrease in salinity, a decrease in the oxygen content of the sea, and the growth of moss, especially in the summer months (Puspa et al., 2018). One of the provinces in Indonesia that has a fairly high coastal potential is East Java where one of the regencies that has the longest coast is Banyuwangi, with a coastal length of about 175.8 Km. The coastal administration of Banyuwangi is divided into nine sub-districts where one coastal sub-district faces the Indian Ocean, seven other coastal sub-districts face the Bali Strait, and the remaining one faces the Java Sea. Coastal potentials include vannamei shrimp (pond) culture that stretches along the coast (Setyaningrum et al., 2019). The direct impacts of climate change on aquaculture include changes in temperature, availability of fresh water, changes in sea level and an increase in extreme events such as floods and storm surges while the indirect impact has the potential on aquaculture production and livelihoods dependent on aquaculture (Salman, 2021).

The impact of climate change has increased in the last few decades, increasing pressure on ecosystems, especially coastal ecosystems. The relationship between a community and an ecosystem becomes vulnerable when one part of the system is threatened or its ability to respond to change is reduced. Natural and man-made adaptations to the impacts of climate change can be assessed by measuring their vulnerability. For coastal ecosystems, the assessment includes threats to rising sea surface temperatures, changes in storm frequency and intensity, and sea level rise, as well as the ability of ecosystems and human communities to respond to these threats (Cinco-Castro and Herrera-Silveira, 2020).

Vannamei shrimp (*Litopenaus vannamei*) is known as a fast-growing shrimp that can be cultured in high stocking density (Arsad et al., 2017). In aquaculture systems, physical and chemical parameters have a significant impact on organic and inorganic nutrients (Adam et al., 2022). The rise of sea levels, high temperatures, unpredictable weather, and too much rain has the greatest impact on shrimp production, with a loss of 10-30% or even 100% of shrimp income (Quach et al., 2017). The impact of climate change on shrimp culture causes different climate variables. The impact

of climate variables on shrimp culture also affects the socio-economic conditions of farmers' households because their livelihoods and income depend on shrimp production. Ecologically, climate change is currently having an adverse impact on shrimp culture because shrimp are very sensitive to ecological conditions and ecosystem changes so it can have a severe impact on shrimp growth and production (Ahmed and Diana, 2015). The development of sustainable aquaculture in the future in providing fish supplies is very important. Not only for human nutrition, but also for creating jobs, and meeting the food security of a rapidly growing human population. However, climate variability and change are the main challenges for aquaculture because it is highly dependent on the availability and quality of natural resources, especially water. So that the vulnerability of cultivation varies from one region to another, due to different climates (Islam et al., 2019).

The main element of climate change that has the potential to affect aquaculture is production, this affects livelihoods that depend on aquaculture. The direct impacts of climate change on aquaculture include changes in temperature, availability of fresh water, changes in sea level, and an increase in the frequency of extreme events such as floods or storms. Meanwhile, indirect impacts include: 1) Economic impacts, such as cost and availability of feed; 2) Stress due to increased temperature and oxygen demand; 3) Uncertain fresh water supply; 4) Increased disease frequency (Salman, 2021). The process of adaptation of species to climate change is different, depending on the extent of the sensitivity of farmers/fishers and the ability of the area to deal with climate change. In this case, climate change can cause serious economic impacts, so increasing adaptive capacity is very important (Kim et al., 2019).

Regarding livelihood vulnerability, people who work in shrimp culture usually have higher assets and even higher adaptive capacity than other types of livelihoods in coastal areas. Their income is very dependent on one commodity; the livelihoods in shrimp culture are very vulnerable to the nature of the shrimp culture's harvest. Livelihood vulnerability is dynamic, variable, and influenced by various environmental processes (Blythe et al., 2015). The Livelihood Vulnerability Index (LVI) provides household-level data to inform strategic community-level planning. In developing countries, the ability of the LVI to describe fairly subtle but critical differences in certain vulnerabilities (e.g., related to water, food, etc.) is critical in adapting policies that meet the needs of people in dependence on resources (Hahn et al., 2009).

Studies of climate change vulnerability mapping mostly rely on secondary data from various sources to determine the size of the indicator. In general, data quality tends to be difficult in the latter approach (Preston *et al.*, 2011). The vulnerability itself can be characterized as a function of three components, namely: adaptive capacity, sensitivity, and exposure. Adaptive capacity describes the ability of a system to adapt to actual or expected climatic stresses in order to cope with their consequences. Sensitivity refers to the extent to which a system will respond to positive or negative climate change. Exposure is related to the level of climate stress, this is represented as long-term changes in climate or changes in climate variability, including the magnitude of the frequency of extreme events. Accordingly, the vulnerability of livelihoods to climate change can be well understood as a result of biophysical and social factors (Shah *et al.*, 2013).

The Covid-19 outbreak began in 2019 which has affected the world economy, including Indonesia. Almost all sectors are affected, but vannamei shrimp production has increased and even increased the value of exports. Data obtained from the Ministry of Maritime Affairs and Fisheries, shrimp export performance in 2020 showed a significant growth reaching USD 1.86 billion. This figure is greater than the national shrimp exports throughout 2019 which amounted to USD 1.7 billion. In this regard, the most considerable contribution of vannamei shrimp production in Indonesia comes from East Java Province with Banyuwangi Regency the largest supplier. On the other hand, the existence of shrimp culture cannot be separated from the relationship with nature or the surrounding environment, especially to climate change. Meanwhile, until now there are still few studies that measure the vulnerability of aquaculture at the district level. Therefore, this study aims to analyze the development of SST and high tides over the last 10 years and analyze the vulnerability of vannamei shrimp culture to climate change.

## 2. Materials and Methods

### 2.1 Materials

This research objects are all shrimp farms in Banyuwangi Regency. The Survey used questionnaires with the parameters are SST (sea surface temperature), highest tide, and livelihood vulnerability.

### 2.2 Methods

This research was conducted on the coast (covering eight coastal sub-districts) of Banyuwangi

Regency, East Java Province, Indonesia (Figure 1). The types of data collected are primary data and secondary data. Primary data were obtained from direct interviews in the field with respondents, while the interview model used was structured interviews with reference to a list of questions that had been compiled and considered to be following the research theme. Secondary data were obtained from satellite imagery through geographic information systems, but also obtained from literature. The population in this study was shrimp farmers, both extensive and intensive ponds on the coast of Banyuwangi Regency. While the respondents who were targeted were obtained through the Slovin (1960) formula for determining the sample so from a population of 3615, a sample of 360 respondents was obtained.

This study uses a descriptive method, namely research that describes the conditions or phenomena being studied. In this case using a quantitative approach, which is defined as a research method based on the philosophy of positivism, namely analyzing data by describing the data that have been collected.

### 2.3 Data Analysis

Spatial analysis uses Geographic Information System (GIS), as an information system to enter, store, process, analyze and generate geospatial referenced data. In this case, the analysis will be used to map the potential for vannamei shrimp aquaculture, map water quality, and analyze trends in sea surface temperature for the last 10 years. The second analysis is vulnerability analysis of vannamei shrimp culture livelihoods, developed using the Livelihood Vulnerability Index matrix adapted from Wongbusarakum and Loper (2011), Can *et al.* (2013), FAO (2013), and Keshavarz *et al.* (2017). Vulnerability analysis was conducted to build the Livelihood Vulnerability Index matrix. This is discussed descriptively by looking at: a) Exposure, where the shrimp culture community system is affected by the changes that occur; b) Sensitivity, the extent to which the shrimp culture community system is affected by changes; c) Adaptive capacity, the ability of the community to accept change and anticipate by preparing adaptation and/or mitigation strategies. Each indicator will be assessed using a questionnaire guide and will be arranged in a matrix and tabulated based on the answers of each respondent. The value of each indicator will be given a score of 0-5, where 0 is the worst and 5 is the best. The final value of vulnerability will be categorized into three categories, namely: 1) 0-1.66 (very vulnerable); 2). 1.67-3.33 (vulnerable); and 3) >3.34 (not vulnerable/invulnerable).

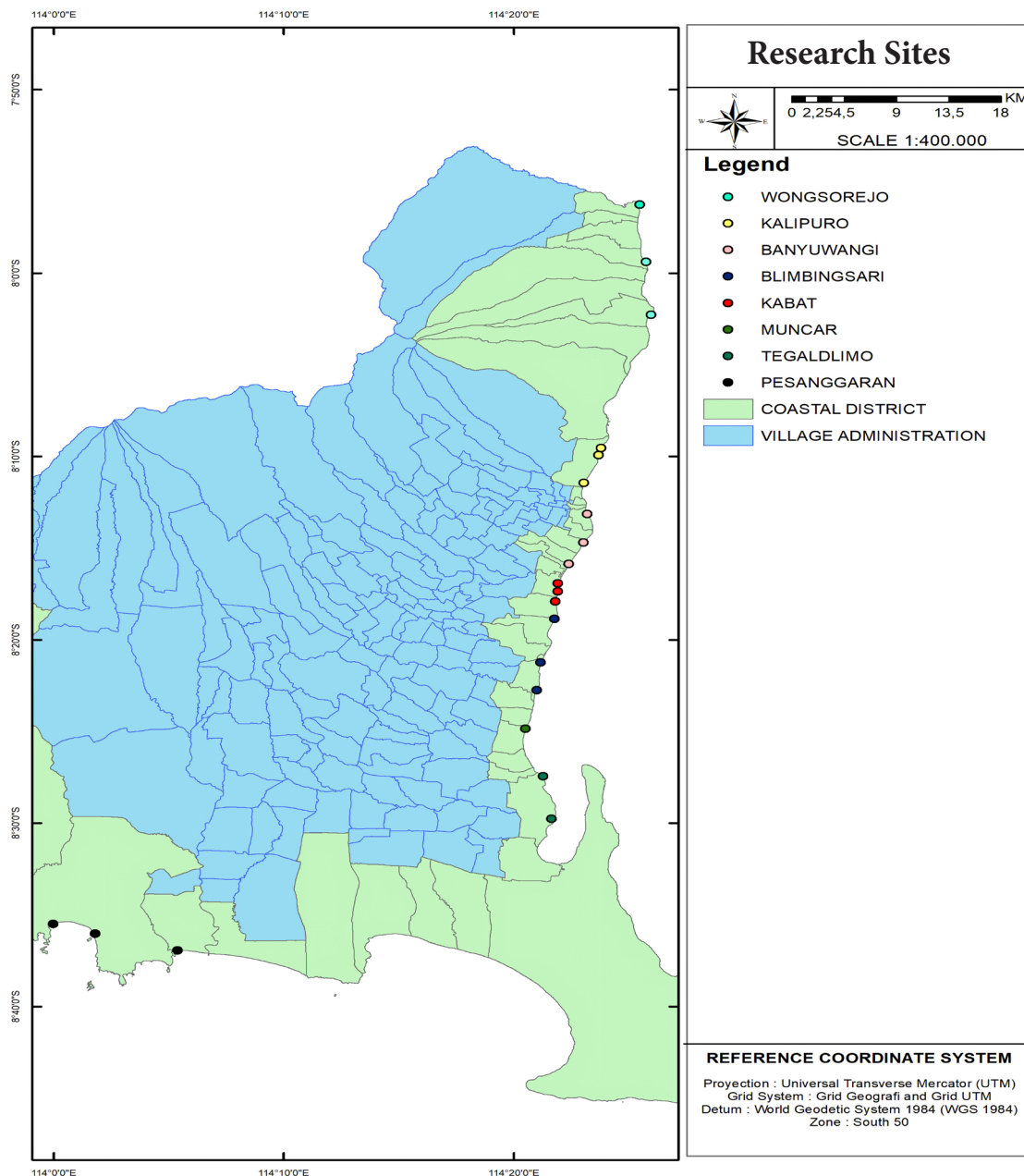


Figure 1. Research sites

### 3. Results and Discussion

#### 3.1 *Vannamei Shrimp Culture in Banyuwangi District*

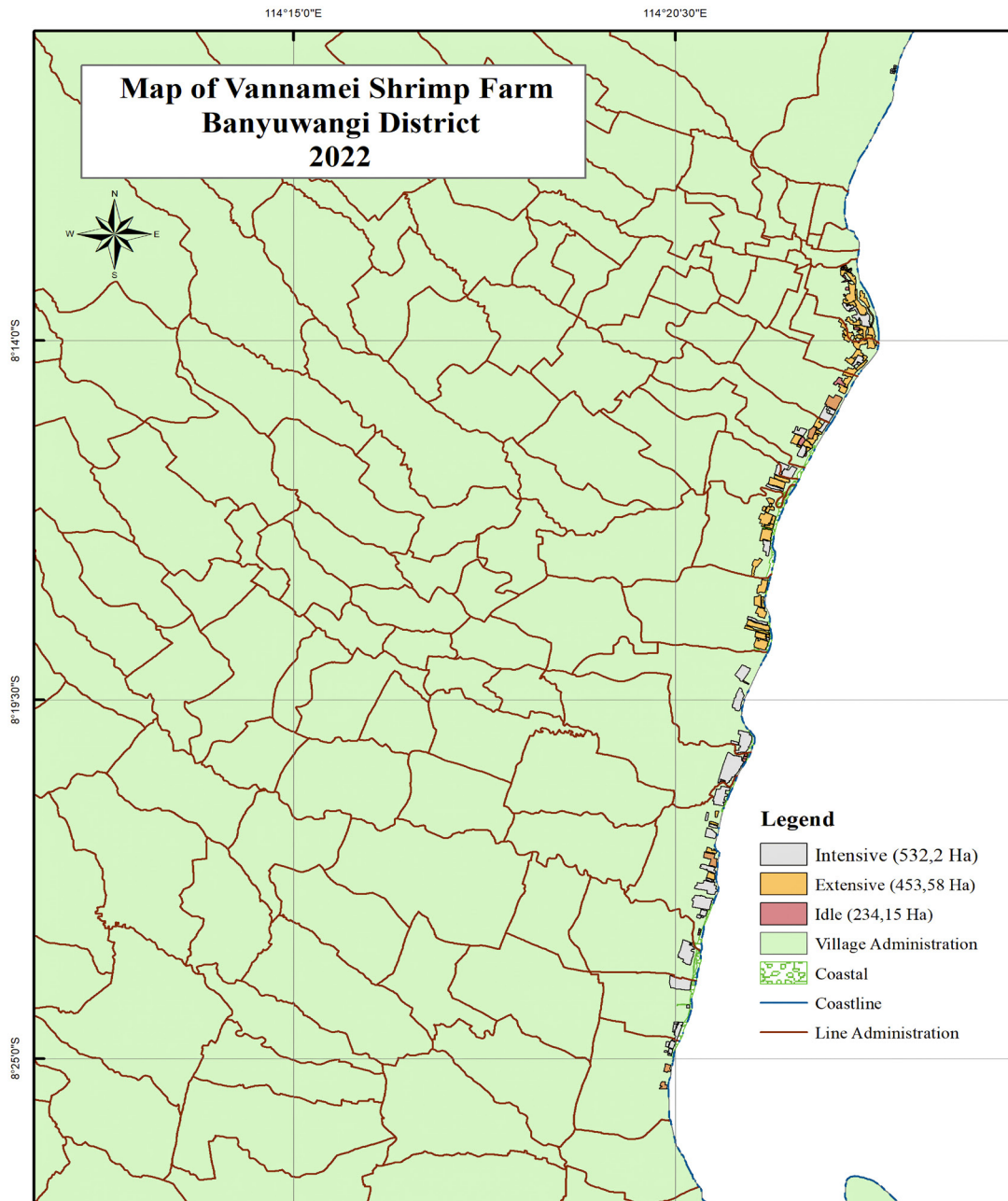
Vannamei shrimp culture in Banyuwangi Regency is spread over eight sub-districts with different areas. The total area of the vannamei shrimp culture is 1,219.93 Ha. The area is divided into intensive, extensive, or traditional culture, and non-functioning, where intensive culture has the largest area.

Based on the distribution map of vannamei shrimp culture (Figure 2), each sub-district has a

different area of shrimp culture, considering that each sub-district has different topography and water characteristics.

Related to production, vannamei shrimp production in Banyuwangi Regency is quite large (Figure 3). From 2017 to 2021, the production trend of vannamei shrimp in this district has always increased production, including when the global economy experienced an economic shock due to the Covid-19 pandemic, the shrimp culture sector experienced an increase. Vannamei shrimp farmers in Banyuwangi Regency have different business capacities and





**Figure 2.** Distribution map of vannamei shrimp culture in Banyuwangi Regency

aquaculture conditions. This depends on the area of land owned, the amount of land, maintenance time, the number of cycles per year, and the number of fries used in each stocking cycle.

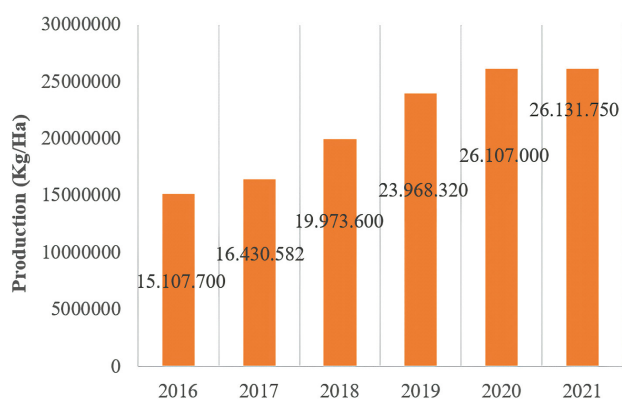
Aquaculture has experienced a rapid boom in much of Southeast Asia, driven through home and export markets, fast technological alternatives, and countrywide policies (Akber *et al.*, 2020). The quickest growing coastal cultivation sub sectors are shrimp, full-grown chiefly in coastal saltwater ponds, for export (particularly in Thailand, Vietnam, Indonesia, and

Philippines; Hall, 2004). Aquaculture plays a key role in increasing food production for human consumption and food security (Ahmed *et al.*, 2019). The rapid development of aquaculture has been considered the blue revolution, which is an associated degree approach to increasing world fish production to contribute to human nutrition and food security. There’s blue growth potential for increasing food production through the enlargement of coastal and marine aquaculture, that is important for sustainable development of the blue economy (Ahmed and Thompson, 2019). Global shrimp culture production reached 4.58 MMT in 2014

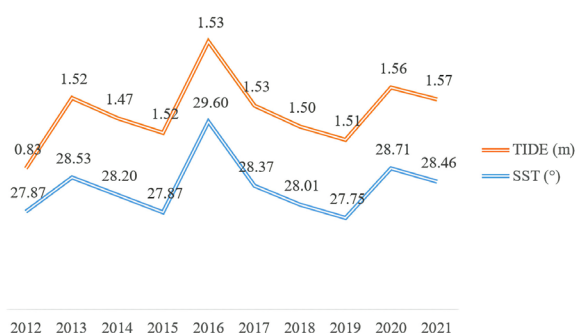
and should stay at an equivalent level in the near future. Shrimp culture makes important contributions to national and world economies, financial condition reduction and food security for the world's well-being and prosperity (Jayasinghe et al., 2019).

### 3.2 Sea Surface Temperature (SST) And Highest Tide

Concerning the impact of climate change on rising sea surface temperatures requires data for the last 10 years. Using GIS data obtained SST and the highest tide (Figure 4), where SST is at 27.75-29.60°C and high tide is at 1.47-1.57 m. Climate change is quite affecting climate variability such as SST which fluctuates every year. And the change in SST also affects high tides on the coast of Banyuwangi, where both things are quite variable which affects the existence of the vannamei shrimp culture.



**Figure 3.** Vannamei shrimp culture production in Banyuwangi Regency 2016 – 2021



**Figure 4.** Graph of SST fluctuating and high tides on the coast of Banyuwangi Regency in 2012 – 2021

The increase in sea level as indicated by high tides every year also increases every year. If this situation

continues, it is not impossible that the coastal area of Banyuwangi will continue to be degraded. This also happens to tidal conditions which show a relationship to the value of sea surface temperature (SST). Figure 4 shows that the SST variable affects changes in high tide, it is proven that the two graphs form the same direction every year. SST goes up, the tide goes up, SST goes down, and the high tide goes down too.

SST on the coast of Banyuwangi is getting lower to the north, in contrast to SST in the direction of southern Banyuwangi which is increasing (Figure 5). This is because the southern coast of Banyuwangi is directly adjacent to the Indian Ocean. Likewise, the tides (Figure 6) in the southern Banyuwangi coastal area produce higher tides along the Banyuwangi coast.

Fish survival, growth and production in aquaculture are highly vulnerable to environmental problems and climate change. Aquaculture production is often threatened by a combination of climate variables such as cyclones, droughts, floods, global warming, ocean acidification, rainfall variability, salinity, and sea level rise (Ahmed and Diana, 2015). Coasts are experiencing the adverse effects of climate related hazards related to nursing water levels (very high confidence). Coasts are extremely vulnerable to extreme events such as storms, which impose high costs on coastal communities. Expected climate-related changes include: the accelerated sea-level rise of up to 0.6 m or more by 2100; an additional increase in sea surface temperature of up to 3°C; an intensification of tropical and extratropical cyclones; larger extreme waves and storm surges; changed precipitation/run-off; and the natural process of the ocean (Nicholls et al., 2007).

Different climatical variables tend to cause coastal flooding, cyclone, lowland rise, salinity, drought, rainfall, sea surface temperature, and have had adverse effects on shrimp culture likewise as socioeconomic conditions of farming households. There's also overwhelming proof that changes in climatic variables have harmful effects on the system of shrimp culture, including severe effects on survival, growth, and production of shrimp. Considering extreme vulnerability to the results of global climate change on shrimp culture, community primarily based adaptation ways and integrated coastal zone management are required to counter the challenges (Ahmed and Diana, 2015). Although world water level rise isn't geographically equal because of its reference to regional ocean circulation processes, all coastal cultivation ecosystems are susceptible to sea level rise (Cochrane et al., 2009). Coastal cultivation is step-by-step in danger from water level rise thanks to inflated

exposure of coastal ecosystems to periodic event surges. Water level rise may have multiple impacts on biotic, ecological, and environs (mangroves, marshes, and

wetlands) changes, and thereby affecting aquaculture practices. Future sea level rise could have severe impacts on world fish production (De Silva et al., 2009).

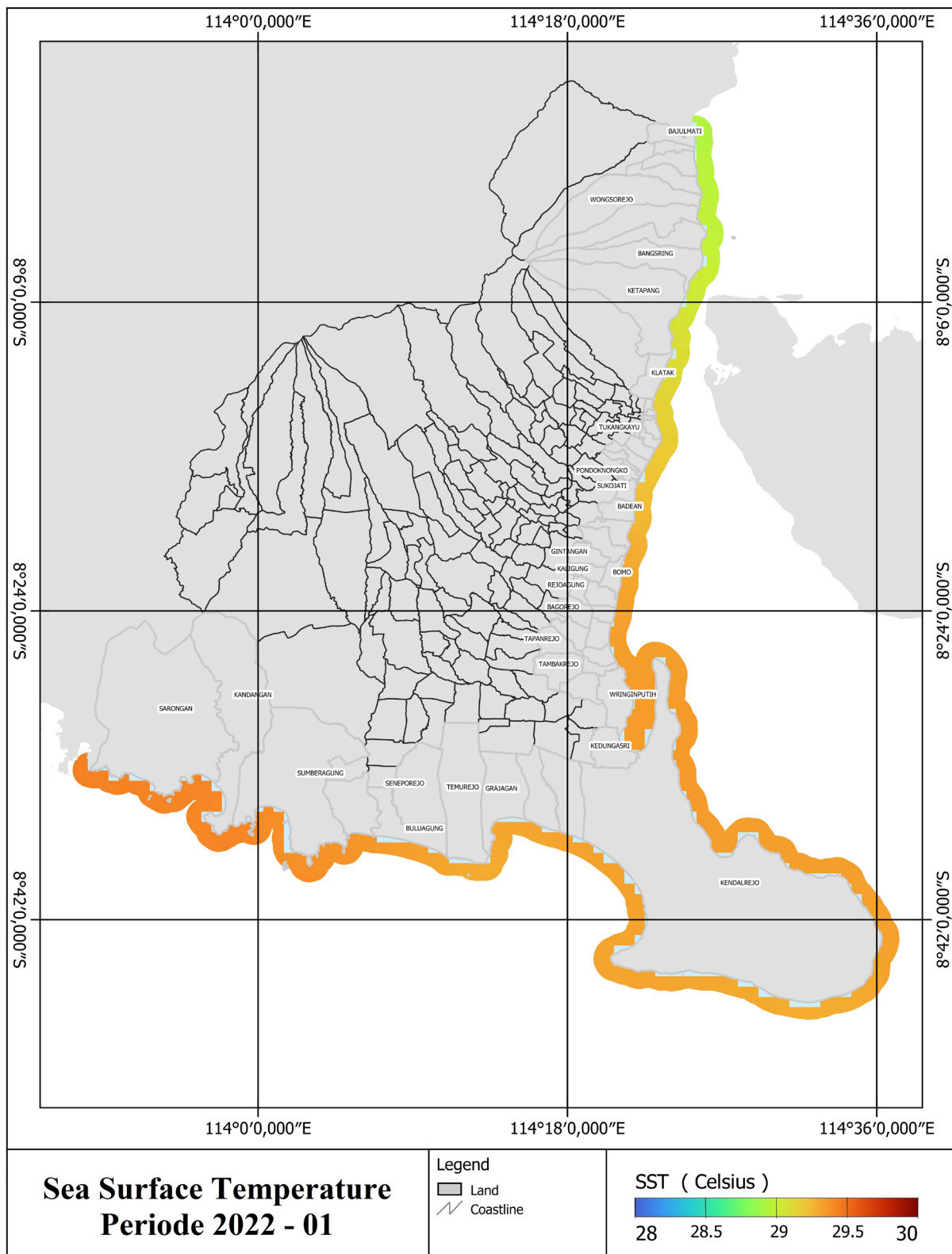


Figure 5. Map of Sea Surface Temperature (SST) on the coast of Banyuwangi Regency



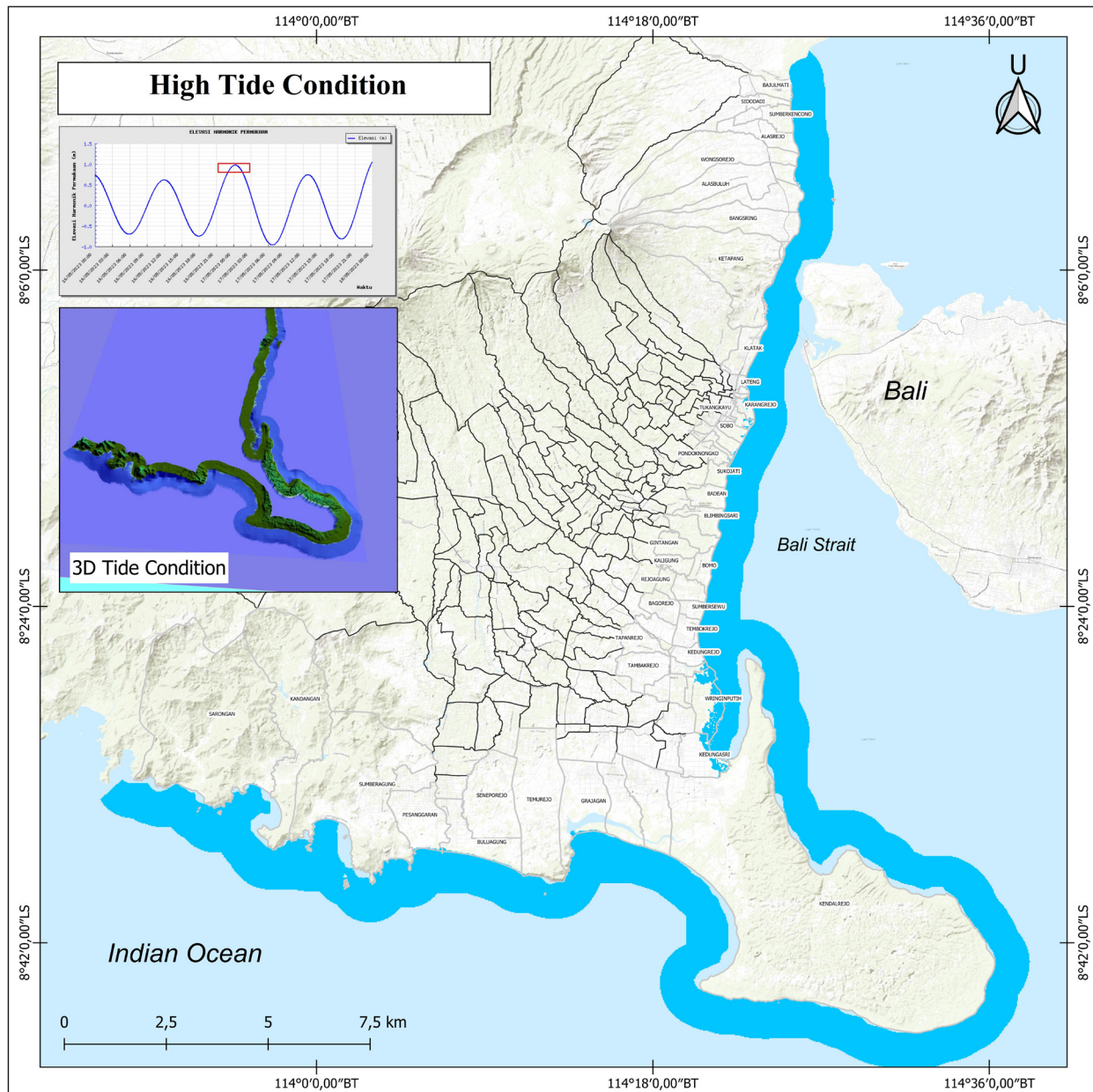


Figure 6. Map of high tide condition on the coast of Banyuwangi Regency

### 3.3 *Vannamei* Shrimp Culture Livelihood Vulnerability

The level of vulnerability of *vannamei* shrimp culture livelihoods to climate change is included in the vulnerable category, with a value of 3.30 ( $< 3.34$  as the lower threshold for non-vulnerable conditions) in Banyuwangi Regency (Table 1). The number 3.30 which includes the vulnerability rate, is a general description that if preventive action is not taken immediately, the livelihoods of *vannamei* shrimp culture in the following years will be very vulnerable due to the impact of climate change and, as a result, will greatly impact the lives of coastal communities in general, considering the multiplier effect of shrimp culture is quite high.

The results of research by Handisyde *et al.* (2017) showed that Indonesia is ranked fifth from the top 20 most vulnerable countries in relation to the freshwater and brackish environments, where vulnerability values are obtained via the combination of the sensitivity, exposure, and adaptive capacity. Work in shrimp culture is one of the livelihoods that are at risk of vulnerability, especially related to production-related risks (Blythe *et al.*, 2015). Climate change has a notable effect on shrimp farming activities. This can be seen from the high percentage of production failures during the rainy season. Fluctuations in water quality also often occur in shrimp ponds. In addition, the incidence of disease sporadically appears in some ponds (Yuniartik *et al.*, 2022). Vulnerability to excessive climate occasions and



slow weather adjustments and the potential of families and groups to be resilient to such situations have turn

out to be a main subject within the current improvement discourse (Kais and Islam, 2018).

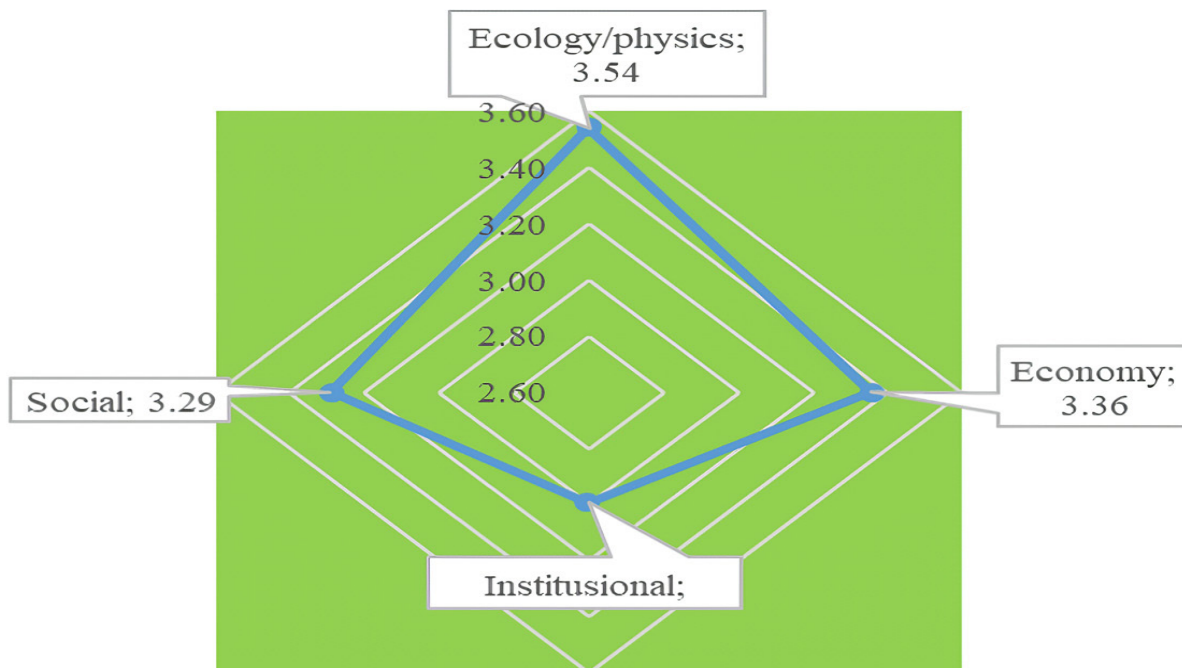


Figure 7. Radar graph of livelihood vulnerability index of vannamei shrimp culture in Banyuwangi Regency

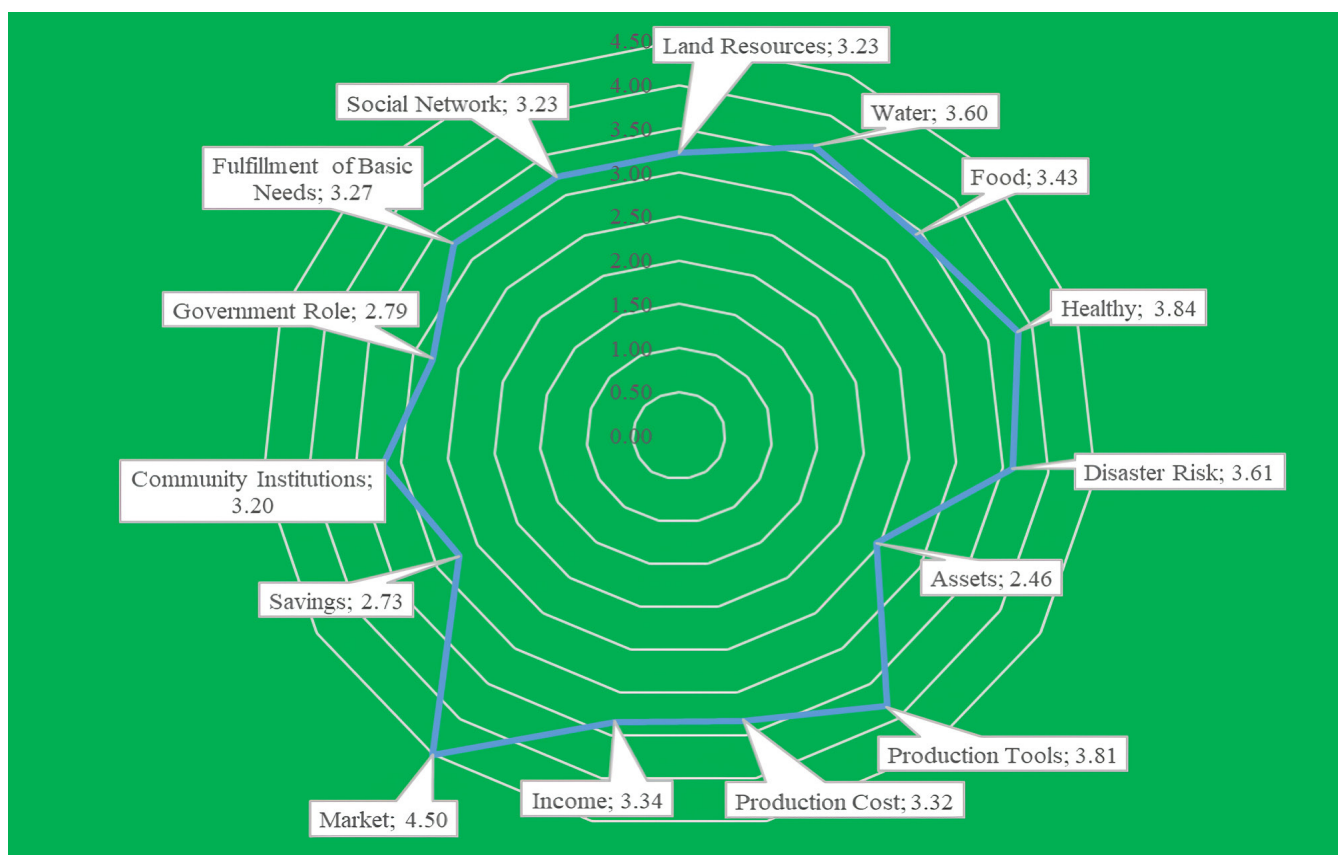


Figure 8. Radar graph of vulnerability index of each livelihood variable

Table 1. Shrimp culture livelihood index in Banyuwangi Regency.

Aspects	Variable	Indicator	Indicator Value (1-5)	Variable Value	Aspect Value
Ecology/Physics	Land Resources	The area of potential resources used	2,76	3,23	3,54
		Area of land that can produce all the time (seasonal)	3,1		
		Land productivity per land area	3,46		
		Changes in land use for conservation or special economic zones	3,59		
	Water	Farmers use sea water for their pond needs	3,81	3,60	
		Have clean water available	3,26		
		Ease of getting clean water	3,74		
	Food	Availability of food around the clock	5	3,43	
		Foodstuffs from own production	2		
		Consumption of family food "4 sehat 5 sempurna"	3,3		
	Health	Availability of health care facilities and distance to home	4,24	3,84	
		Family life expectancy	3,4		
		Permanent house with good sanitation and there are MCK (bath, wash, toilet)	3,88		
	Disaster Risk	Floods in the last 2 years	4,574	3,61	
		The pond has IPAL	3		
		Experience of disease occurred during floods	4,38		
		Occurrence of disease in the dry season	3,75		
The occurrence of disease in the rainy season		2,63			
Impact of climate change flood disaster		3,327			
Economy	Assets	Land status (common property land)	2,5	2,46	3,36
		Have certification	1,87		
		There is a sharing of production tools	3		
	Production tools	Completeness of vannamei shrimp production equipment	3,65	3,81	
		Amount of production obtained	3,96		
	Production Cost	Source of capital/production costs independently or depending on others	2,89	3,32	
		The existence of sources of production financing from other parties	3,75		
	Income	The priority of shrimp culture livelihoods	3,57	3,34	
		There are alternative livelihoods	2,88		
		Income per capita in the family $\geq$ MSE	3,56		
	Market	There is a certain production market	5	4,50	
		Product Price	4		
Savings	There are savings that can be made every production period	2,45	2,73		
	If there is an emergency there is an alternative to getting funds	3			
Institutional	Community Institutions	There is a group together with the same profession	3,8	3,20	3,00
		There is a financial institution (bank or non-bank)	3		
		There are accompanying institutions from the government or non-government	3		
		There are counseling and coaching institutions	3		
		A structured marketing agency to sell community products	3,2		
	Government Role	Government policy in disaster control related to green belt	2,978	2,79	
		Government policies in disaster control related to spatial planning	2,252		
		Government policies in disaster control related to water quality management	2,997		
		Government policies in disaster control related to flood management	2,949		
Social	Fulfillment of Basic Needs	Residential Conditions	3,53	3,27	3,29
		Level of education	3,09		
		The acquired capacity building program	3,14		
		There is a land use/production conflict	3,3		
	Social Network	There are savings and loans between farmers	3,4	3,32	
		Solidarity/cooperation to work together to solve problems	3,23		
<b>Average Vulnerability Rating</b>					3,30

The main areas of documented climate change impacts relate to extreme events and the general impacts of climate change on the aquaculture sector (Galappaththi *et al.*, 2020). Shrimp culture in Banyuwangi Regency, which is included in the vulnerable criteria, can be linearized with the carrying capacity of the pond, in that the ponds in Banyuwangi Regency have exceeded the carrying capacity of the environment. Setyaningrum *et al.* (2019) explained that the carrying capacity of land for the improvement of aquaculture in Banyuwangi Regency is 73.57% of the land place proper for pond improvement. From a proper pond place (1,221,535 Ha) which may be advanced primarily based totally at the carrying capacity in Banyuwangi Regency is 898,71 Ha. Of the many coastal sub-districts which have ability for ponds, nearly all have passed the carrying capacity in order that the usage of ponds has to be decreased in every of those locations. Thus, from the place of ponds proper for pond usage of 1,221,535 Ha, approximately 26.43% or 322,827 Ha of pond land needs to feature as a buffer for the pond environment. The buffer place is suggested as an inexperienced place, which is a mangrove vegetation.

The aspect with the lowest score is the institutional aspect with a value of 3.00 and social aspect 3.29, while the ecological/physical aspect is the highest (strong) with a value of 3.54 with the Livelihood Vulnerability Index radar graph (Figure 7). The picture shows that the social and institutional aspects in the vannamei shrimp culture community are less sustainable, which shows that social conditions are not good, and the social network system is still low. Government regulations are still low to protect the sustainability of vannamei shrimp culture in Banyuwangi, including the level of education of the community who do not all have the ability to carry out aquaculture based on standards.

There is a significant influence of social networks to vulnerability mitigation (Zhao, 2013). The low influence of local government on decision-making and a lack of membership in community-based organizations result in high livelihood vulnerability (Sujakhu *et al.*, 2018). Participating in social organizations for improving adaptive capacity is important (Alam *et al.*, 2016). So far there is no debate regarding increasing production of vannamei shrimp culture in several countries, but problems still arise, especially regarding the socioeconomic impact. Some argue that fish farming (all types of fish resources) has been responsible for the marginalization of coastal communities and increased unemployment. However, different views from shrimp industry players and stakeholders and other supportive politicians view that shrimp culture or industry provides

great opportunities for livelihoods and economic growth in remote areas of the country (Macusi *et al.*, 2022a).

It is crucial to enhance the social capital to effectively deal with climate-related livelihood vulnerabilities. Furthermore, a partnership between government agencies and the community could lead to new perspectives on climate risk mitigation measures, innovative adaptation solutions, and empowerment in terms of livelihood opportunities through the integration of climate-related hazards into participatory resource management and income generation. In this case, the coastal community should be given opportunities for alternate livelihoods as part of a plan to reduce vulnerability (Shaw *et al.*, 2013). This collaboration will also be effective for monitoring the actions that will be implemented for the improvement of adaptive capacity of the households and minimizing shrimp culture livelihood vulnerability in the coastal area of Banyuwangi Regency.

The low score of vulnerability may well be thanks to a scarcity of support from government or non-government organizations in battling the impacts of temperature change. Several of the shrimp farmers weren't aware of what climate change is and its variabilities (Macusi *et al.*, 2020). Integrated aquaculture may be a kind of property intensification for manufacturing a lot of food from a similar space of land and water with no or fewer environmental impacts (Godfray *et al.*, 2010). Sustainable intensification is significant for adapting to temperature change as each are closely interlinked ideas (Campbell *et al.*, 2014).

Based on 15 vulnerability variables, only three are below number 3, namely Assets, Savings, and the Role of the Government, while the value of other variables is at number 3 (Figure 8). Therefore, the variables that are still vulnerable to livelihood vulnerability in the Regency Banyuwangi need to be strengthened as a priority in development and management program interventions. The variables with a high enough value so that they are categorized as not vulnerable are water, food, health, disaster risk, production tools, income, and market. Where Banyuwangi is a district that not only has a long coast, but also has wide mountains so that the level of the Banyuwangi land slope is quite high, this reduces the risk of flooding in coastal areas. Likewise, the supply of water is easy to obtain, both fresh water and sea water, where all vannamei shrimp culture in Banyuwangi uses both.

The result showed that institutional aspect had the lowest value in supporting the sustainability of vannamei shrimp culture in Banyuwangi (Figure 8),



then in this case we also have to look at other aspects such as the economic aspect. Considering that these economic and institutional aspects are related to humans, be it the farming community itself, communities around aquaculture, coastal communities in general and stakeholders (government, private sector, academics, NGOs). Because to consolidate many thoughts into one vision is quite difficult, it takes time, a patient process and continuity. The economic aspect and the institutional aspect must be improved, in this case the government's concern. The variable of government role is vulnerable in supporting vannamei shrimp cultivation against climate change impact (Figure 8). How important is the government to position shrimp culture as a livelihood in coastal areas, especially in improving other areas in general? If shrimp culture becomes an important factor, then the logical consequence will be that various legal/regulatory products that regulate the wheels of the economy or the sustainability of shrimp culture from upstream to downstream, as well as legal umbrellas can protect shrimp culture not only from the economic side, but also to the environment threat of climate change.

For shrimp culture, the environment is a major factor in the success and sustainability of the business. Although the ecological/physical variables are not vulnerable, several environmental improvement steps are needed to increase the vulnerability of vannamei shrimp culture to climate change. These include increasing the presence of wastewater treatment, where currently only around 49.85% of vannamei shrimp culture in Banyuwangi has implemented wastewater treatment, as well as improving the coastal environment in terms of disaster mitigation, such as increasing the green belt program, namely planting suitable plants in coastal areas (mangroves, cypresses, etc.). In addition, there is a need for technological or financial support that can help farmers in managing water quality in ponds. This assistance is expected to encourage farmers to prioritize environmental aspects in aquaculture.

The indicator interventions to improve the vulnerability of vannamei shrimp culture livelihoods are: 1) Production Equipment, namely complementing the production equipment in the aquaculture household, fulfilling the ownership of production equipment and increasing business productivity through increasing technology and capacity of business actors; 2) Production costs, through the provision of business financing schemes with easy access to capital schemes, and encouraging the establishment of productive financing institutions; 3) Fulfillment of basic needs, through a program for structuring healthy and livable settlements, increasing access to public education to at least high school with

scholarship and subsidy schemes, capacity building and management programs, mentoring, technical counseling and management of vannamei shrimp culture; 4) Social networks, by promoting social security networks based on local wisdom such as savings and loans between communities; 5) Reduction of disaster risk, including anticipation of harvest failures by using anticipation/prediction technology, understanding the introduction of disaster risk through disaster mitigation counseling, formation of working groups for Disaster Preparedness (educated and skilled), counseling on anticipation of disaster response and mapping of disaster-prone areas.

The sustainability of the sector depends on its willingness to adapt to climate change. Incorporating climate change impacts and adaptation into fisheries management documents is essential to ensure that appropriate short- and long-term climate change adaptation measures are implemented. In fact, the impacts of climate change and adaptation are rarely included in key fisheries management documents (Ortega et al., 2021). Three classes of adaptation to climate change are identified: indigenous scale upstream mechanisms (e.g., water quality management techniques), adapted construction methods (e.g., ever-changing cultural practices), and management (adaptation planning, community-based adaptation) (Galappaththi et al., 2020).

Adaptation techniques in managing the influences of climate change on shrimp culture should be evolved to attain a green and strong economy. Regarding weather alternate, that is a venture for the sustainability of coastal aquaculture. Considering excessive vulnerability to the consequences of weather alternate, community-based techniques should be delivered to address the challenges (Macusi et al., 2022b). As the aquaculture industry survives with the impact of climate change, encounters heavy rains, weather anomalies, extreme weather that impacts the growth, survival of culture species, and reduces their productivity with a higher probability of disease transmission due to decreased water quality, it all comes at a cost. In this regard, the government should adopt adaptation measures in preventing disasters from climate change and variability in the aquaculture sector (Macusi et al., 2021). Such actions include monitoring climate after harvest, increasing the number of aquaculture hatcheries to avoid supply shortages, enforcing regulations on cultivation, regulating stocking density and proper land use planning, adherence to cultivation practices, and good coordination between local governments and other government agencies related to cultivation to licensing (Macusi et al., 2022b). Aquaculture manufacturing has

to grow sustainably, while its environmental effects have to lessen considerably. A conceptual framework has been evolved for growing aquaculture manufacturing, decreasing environmental degradation, and weather extreme edition. Proposed edition techniques to weather extrude appears to growth aquaculture manufacturing with environmental sustainability (Ahmed *et al.*, 2019).

While the hyperlinks to greater market-orientated livelihoods turning stronger are effective, the nature of those hyperlinks is changing. Coastal communities now have an increasing number need of stable livelihoods in the physical contexts of distinctly evolved landscapes, in which a fee is realized via the manufacturing of secondary commodities made in factories, the improvement of artificial environments to offer possibilities for brand spanking new monetary growth, or via the modification of natural landscapes for tourism (Fabinyi *et al.*, 2022). Those hooked into fisheries and aquaculture for his or her livelihoods should navigate the increasing disaster risks due to climate change and human-induced hazards (Liu *et al.*, 2021). The adaptative methods taken by the shrimp farmers to mitigate the impacts of temperature change were largely derived from their own experiences and not from the experts. Adaptation for the impacts of climate change will be achieved through higher management practices in site selection, pond construction and preparation, selection of post-larvae for stocking, pond management, bottom sediment management, ans unwellness management, besides reducing non climate stressors, pollution, conservation of sensitive ecosystems and therefore the adoption of dynamic management policies (Macusi *et al.*, 2022a).

#### 4. Conclusion

Climate change affects the development of sea surface temperature (SST) and high tides on the coast of Banyuwangi Regency, East Java Province, Indonesia. It is proven that during the last 10 years SST and high tide data shows that it fluctuates every year, SST between 27.75-29.60°C, the high tide between 1.47-1.57 m. Changes in SST affects high tide, and both become variability that affects vannamei shrimp culture. The results of the vulnerability analysis show that vannamei shrimp culture livelihoods in Banyuwangi Regency are categorized as vulnerable to climate change, with a value of 3.30 (3.34 vulnerability threshold).

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#### Authors' Contributions

The entire writing team contributed to the writing of this article is as follows, Ervina; compiled conceptual ideas, compiled manuscripts, and revised articles. Mega and Shinta; collected data and designed tables and figures. All authors discuss the final manuscript for the revision of the article.

#### Conflict of Interest

The writing team stated that there was no conflict of interest in the preparation of this article, and all teams agreed to publish the journal.

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