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Interactive Governance for Mangrove Social-Ecological System in Tangerang Regency: A DPSIR Approach

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***Abstract*—A conceptual model is needed to determine the interaction of ecological and social systems in the governance of a sustainable mangrove ecosystem. The SES approach can be used to analyze the management of mangrove ecosystem areas on the interaction or connectivity of functional system relationships. This research analyzes the social-ecological system (SES) model in managing mangrove ecosystem areas in Tangerang Regency. This research is a descriptive case study, where data collection is carried out through surveys, field observations, and literature studies. Analysis of SES problems with the DPSIR (Driving-force, Pressure, State, Impact, and Response) approach shows that the issues of governance of mangrove ecosystems in Tangerang Regency are driven by the mangrove ecosystem services themselves, population increase, space utilization, economic activities, and the welfare level and knowledge of sustainable ecosystem management. These driving factors cause pressure on the mangrove ecosystem due to the conversion of land functions and activities of ecosystem utilization, causing environmental degradation conditions and increasingly intensive use of mangrove ecosystems. These conditions cause impacts on the socio-ecological system, namely spatial use conflicts, deforestation, environmental pollution, the decline in ecosystem functions, abrasion and accretion, tidal flooding, and social conflicts. These impacts can be suppressed, mitigated, improved, and minimized through mangrove ecosystem governance policies, namely rehabilitation and restoration, ecotourism development, coastal border conservation, silvofishery ponds, coastal community development movement programs, increased public education, and cooperative management based.**

***Keywords*— Governance; mangrove ecosystem; social; ecology; system; Tangerang Regency; DPSIR approach.**

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I. INTRODUCTION

Integration of a coastal management-based ecosystem by considering the dynamics of the social system is known as the Social-Ecological System (SES) approach. SES is an interaction between ecological units and social systems that influence or are influenced by an interdependent relationship [1], [2]. Two systems interact dynamically and must be considered when managing coastal and marine areas. The socio-ecological system approach is based on the idea that people grow culturally and physically through a constant exchange of energy with their environment [3], [4].

SES is a systems approach that describes human systems proximity and interaction patterns with environmental ecosystems [5]. These two systems interact dynamically, which means that if one system changes, the other will also change. In the context of coastal management, the SES approach is critical and suitable to be used as a management approach considering the interrelated characteristics and dynamics between natural systems and human systems so that the two systems are the central systems that make up coastal areas [6].

The effectiveness of resource management is indicated in two ways, namely community welfare and ecosystem health, both of which will be influenced by ecological and social domains that influence each other [7]. In the part of social systems, it is known that several variables affect management effectiveness among knowledge systems, socio-cultural, livelihoods, and benefits of coastal resources. Meanwhile, the ecological domain includes the quality of the ecosystem, the landscape, the area's carrying capacity, and the running pattern of resource use. To ensure this effectiveness, we need an institutional system that binds and integrates social and ecological approaches to interact in a balanced way [8].

Connectivity of the socio-ecological system in the management of mangrove ecosystem resources is connected by a knowledge system that will be able to describe how the relationship between the community knowledge system, the ecology around its living space, and then tied into an effective

management institutional system based on ecological, economic and social integration which will carry out the effective management of mangrove ecosystem areas.

Utilization of the mangrove ecosystem in Tangerang Regency is a form of the social-ecological system, where a mangrove ecosystem is an ecological unit that acts as a service provider. At the same time, the community is a social unit that works as a user. In the context of SES, the effectiveness of mangrove ecosystem management is indicated in two ways: community welfare and ecosystem health. Both will be influenced by ecological and social domains that influence each other.

The SES approach can be used to analyze the management of mangrove ecosystem areas on the interaction or connectivity of functional system relationships. The community of Tangerang Regency takes advantage of the ecological services of the mangrove ecosystem so that in this connection, the community is an agent or actor who can have a relationship and interact reciprocally with these two systems. Various human activities can lead to the degradation of mangrove ecosystems, including clearing mangrove forests for shrimp ponds, using wood as building materials, excessive exploitation of mangrove ecosystem resources, and disposal of agricultural and household waste.

The social conditions of the community living around the mangrove area do not understand wisely the functions and benefits of mangroves in sustainable area management. This is one of the problems in maintaining the sustainability of the mangrove ecosystem. Based on these conditions, an SES model is needed in the direction of mangrove ecosystem areas to realize integrated and sustainable governance. In this effort, a mangrove governance model has required scientific support to map a complex system model. This system model must explain a management basis that can be seen through the interaction of community activities around the mangrove ecosystem (social) and environmental conditions (ecology). One approach that can assess these interactions is the DPSIR (Driving-forces, Pressure, State, Impact, and Response) approach.

DPSIR can study the interrelationships of factors causing stress on ecosystems and assess the intensity of human resource use [9]. The DPSIR approach can also find out the interrelationships of the factors causing pressure on the ecosystem so that it can be used to assess the intensity of human resource use and activities in coastal areas and the relationship between ecological and social systems [10]. The DPSIR method can be used as a more comprehensive framework for analyzing the causal relationship of various environmental problems. In this method, ecological issues are placed as variables to show cause and effect and their connection with human activities that cause pressure on the environment, changes in initial conditions, and environmental responses to these changes.

This study aims to determine a conceptual model of the mangrove ecosystem governance using the D-P-S-I-R approach using the case of the Tangerang Coastal Zone of West Java Province, Indonesia. Using this approach, we formulate a sustainable strategy for managing mangrove ecosystems in Tangerang Regency.

II. Materials and Method

A. Study Site

This study was conducted at Tangerang Regency, Banten Province, Indonesia, from December 2021 to February 2022. Geographically, Tangerang Regency is located at 6°00' – 6°20' South Latitude and between 106°20' – 106°43' East Longitude.

B. Procedures

Governance of mangrove ecosystem areas has a high complexity of problems both from the social and ecological systems. The socio-ecological system is a broad concept of humans in nature where human and ecological systems are seen as interrelated [1], as shown in Fig. 1.

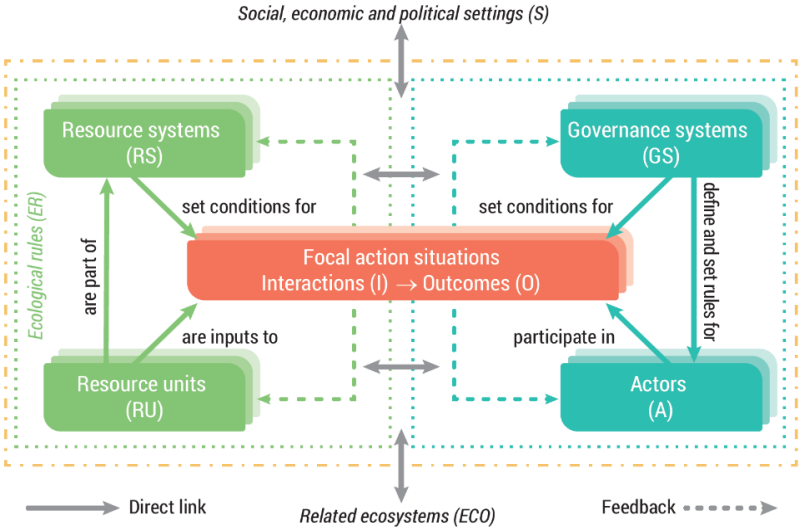

Fig. 1 SES framework [1]

DPSIR is an approach that looks at causal relationships among five categories: driving force, pressure, state, impact, and response [11]. An essential strength of the DPSIR framework is its ability to simplify causal effects on ecosystem services between factors in social and ecological systems [12]. The socio-ecological system's conceptual

model for managing mangrove ecosystems in the Tangerang Regency has used the DPSIR approach, as shown in Fig. 2.

The DPSIR scheme is an analysis of the environmental management process described as feedback to control a cycle consisting of five stages [13], [14], namely:

- Driving-forces (roots of the problem) are factors or pressure on the environment, such as human needs for agricultural land, energy, industry, transportation, housing, etc.
- Pressure is a human activity on the environment, for example, the exploitation of land, water, mineral, and other natural resources.
- The state is a condition of environmental status that changes due to pressure, for example, the quality of various environmental media such as water, soil, and air, as well as the consequences of the ecosystem's ability to meet the demands of human life.
- The Impact is a change in environmental conditions on human health, ecosystems, biodiversity, amenity value (comfort), financial value, and so on. It can also be expressed in the level of environmental damage.
- The response is an effort by stakeholders to solve problems on the impacts that have been evaluated, namely in the form of policy measures and planning actions.

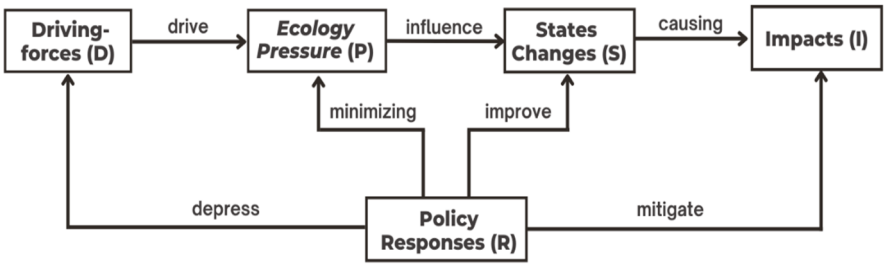

Fig. 2 DPSIR conceptual model schematic for the governance of mangrove ecosystem in Tangerang Regency

C. Data Collection and Analysis

This research is a descriptive case study. Descriptive analysis is carried out to describe in more detail a symptom or phenomenon whose final results can be in typologies or patterns regarding the phenomenon being discussed and the relationship between the components studied. Descriptive case studies aim to broadly describe a problem, symptom, fact, event, and reality broadly and deeply so that a new and profound understanding is obtained and a new agreement is obtained.

Data was collected to identify the categories of the driving force, pressure, state, impact, and response using surveys and field observations. Inventory and tabulation of secondary data were collected from the Regional Development Planning Agency, Fisheries Agency, Central Bureau of Statistics, Regional Finance and Accounting Management Agency, and other related institutions. Additional supporting data are literature reviews and previous research reports. Direct field observations on research objects are carried out to complement survey data, descriptions, and official publications and to match and see the current condition of the data or results. Descriptive qualitative data analysis was carried out from the effects of mapping the DPSIR model.

III. Results and Discussion

A. Identification Ecological Systems of Mangrove Ecosystem Governance in Tangerang Regency

Tangerang Regency is a lowland area with an area of 959.61 km^2 with an altitude of 0 – 85 meters above sea level. The northern part is a coastal area of ± 51.2 km directly adjacent to the Java Sea and Jakarta Bay. In general, the characteristics of the coast in Tangerang Regency are sandy and muddy beaches suitable for mangrove habitats. The average climatic conditions in Tangerang Regency are the maximum temperature of 32.3^{o}C; a minimum temperature of 24.8^{o}C; air humidity of 81.3%; sunlight of 49.4%; rainfall of 237.7 mm per month; the number of rainy days of 16 days per month; wind speed is 3 km per hour; the air pressure is 1,010.9 millibar, and the wind speed is 3.0 knots.

Tangerang Regency has 9 species of mangrove vegetation, namely *Avicennia marina*, *Avicennia officinalis*, *Bruguiera cylindrica*, *Sonneratia caseolaris*, *Sonneratia alba*, *Sonneratia ovata*, *Rhizophora mucronata*, *Rhizophora stylosa*, and *Excoecaria agallocha* spread over 8 coastal districts of Tangerang Regency, namely Kronjo, Mekar Baru, Mauk, Kemiri, Sukadiri, Pakuhaji, Teluknaga, and Kosambi. The central mangroves in Tangerang Regency are *Avicennia alba*, *Avicennia marina*, *Rhizophora mucronata*, and *Sonneratia caseolaris* and have an average density of 58 trees/100 m^2 with a potential of 4.8 m^3/ha/year [15]. The mangrove ecosystem in Tangerang Regency is dominated by pioneer mangrove species, namely *Avicennia sp* > 60%, *Rhizophora sp* > 25%, and *Sonneratia sp* > 5%, with a thickness of ± 20 meters along the coastal or estuary [16].

Avicennia marina is a species of mangrove in Tangerang Regency that has the highest relative density compared to other types of mangroves, which is 66.01% for the tree category, then 79.62% for the sapling category, and 67.24% for the seedling category, while the lowest value is in the sapling category trees, namely the *Excoecaria agallocha* species at 0.36%, the tiller category *Rhizophora mucronata* at 1.42% and the seedling category *Rhizophora stylosa* at 32.76% [17]. This research shows that the *Avicennia marina* has a large adjustment pattern compared to other types of mangroves in the Tangerang Regency. The density value of a mangrove species offers the abundance of species in a community, meaning that the higher the relative density, the more mangrove species. The existence of *Avicennia marina* species is determined by environmental conditions that can allow mangroves to grow optimally.

The highest essential value index for mangrove species in Tangerang Regency is *Avicennia marina*, which is 187.24 individuals/m^2 for the tree category, then 155.94 individuals per m^2 for the seedling category, and 124.38 individuals per m^2 for the seedling category. In comparison, *Excoecaria agallocha* had the smallest most important value index in the tree category (1.44 individuals per m^2), *Rhizophora mucronata* in the tiller category (4.05 individuals per m^2), and *Rhizophora stylosa* in the seedling category (75.61 individuals per m^2) [17]. The type of mangrove with the critical value index means it has a minor influence on the community. In contrast, the highest significant value index significantly affects the mangrove community in Tangerang Regency. The higher the critical value index, the more the species will be able to adapt to the environment well and compete with other species, so it is more likely to grow dominantly over other mangrove species.

Mangrove ecosystems are natural resources with many functions and services directly and indirectly for the community. The ability of nature to provide goods and services is known as ecosystem services. Assessment of the condition of mangrove ecosystems is essential for conservation planning, management research, and economic evaluation [18]. Ecosystem services are contributions the environment makes to support, maintain and benefit human life [19]. Ecosystem services consist of 4 categories: provisioning, regulatory, cultural, and support services [20], [21]. Table 1 shows the economic value of mangrove ecosystems in Tangerang Regency based on the types of ecosystem services.

TABLE I
THE ECONOMIC VALUE OF MANGROVE ECOSYSTEMS IN TANGERANG REGENCY

Category Ecosystem Services	Economic Value (IDR/hectare/year)	Reference
Provisioning services		
Capture fisheries	357,183,461.00	[17]
	458,979,715.00	[16]
Aquaculture	11,160,766.00	[17]
	29,621,646.58	[16]
Mangrove fisheries	196,311,374,912.53	[22]
Mangrove seed suppliers	494,693,729.00	[22]
Regulating services		
Abrasion resistant	37,727,268,200.00	[17]
Breakwater	207,500,000.00	[22]
Carbon storage	5,107,280,468.00	[17]
Supporting services		
Biodiversity	1,706,513,238.98	[22]
Spawning area	72,276,967,837.50	[22]
Cultural services		
Education	71,352,978.78	[22]
Recreation	2,299,963,754.49	[22]

The average capture fisheries production in Tangerang Regency in 2019 – 2020 was 20,702.41 tons with a production value of IDR. 688,805,471.50, while aquaculture production, including ponds, floating nets, and marine aquaculture, amounted to 20,500.45 tons with a production value of IDR. 171,602,843.00 (Fisheries Agency of Tangerang Regency 2022). The value of provisioning services can be felt in actual and direct benefits (tangible) because they are relatively wasteful [23]. The food potential of the mangrove ecosystem in Tangerang Regency has high productivity from the presence of fisheries resources such as fish, crustaceans, mollusks, and another marine biota. The existence of mangroves is strongly correlated with the reality of fisheries production because mangroves provide a habitat for fisheries resources [24]. The loss of mangrove ecosystems will directly impact ecosystem services for human life [25].

Fish catches in Tangerang Regency include *peperek* (*Eubleekeria sp*), *manyung* (*Arius sp*), *biji nangka* (*Upeneus sp*), *bambangan* (*Lutjanus sp*), grouper (*Epinephelus sp*), snapper (*Lates sp*), *kurisi* (*Nemipterus sp*), *ekor kuning* (*Caesio sp*), *tigawaja* (*Johnius sp*), *cucut* (*Rhizoprionodon sp*), stingray (*Potamotrygon sp*), *selar* (*Selaroides sp*), *kuwe* (*Caranx sp*), *tetengkek* (*Megalaspis sp*), *belanak* (*Mugil sp*), teri (*Engraulis sp*), *japuh* (*Dussumieria sp*), *trembling* (*Sardinella sp*), *kembung* (*Rastrelliger sp*), *tenggiri* (*Scomberomorus sp*), *layur* (*Trichiurus sp*), crab (*Portunus sp*), white shrimp (*Penaeus merguiensis*), *bulu* clams (*Anadara antiquata*), blood clams (*Anadara granosa*), squid (*Loligo sp*) and other fish.

While the types of aquaculture are milkfish (*Chanos sp*), *belanak* (*Mugil sp*), tiger shrimp (*Penaeus monodon*), white shrimp (*Penaeus indicus*), *api-api* shrimp (*Metapenaeus monoceros*), *mujair* (*Oreochromis mossambicus*), goldfish (*Cyprinus sp*), tilapia (*Oreochromis niloticus*), catfish (*Pangasius sp* and *Clarias sp*), carp (*Osphronemus sp*), grouper (*Epinephelus sp*), vaname shrimp (*Litopenaeus vannamei*), seaweed (*Eucheuma sp* and *Gracilaria sp*) and snapper (*Lates sp*).

The regulating service of the mangrove ecosystem in the Tangerang Regency includes carbon storage and coastal protection from oceanographic influences such as waves and currents. The presence of mangrove can anticipate disasters in coastal areas stands to protect the coast from storm attacks [26]. Mangroves can also inhibit the rate of coastal abrasion [27]. Mangroves will function optimally in their role as wave barriers when they are over three years old because they have formed a strong foundation. Carbon storage by mangroves is carried out by utilizing carbon dioxide (CO_2) for photosynthesis and storing it in biomass and sediment [28]. The storage of CO_2 emissions by mangrove forests is more effective than in rainforests or peatlands [29].

The value of supporting services from the most important mangrove ecosystem is the provision of nutrient sources through litter production for the productivity of coastal waters in Tangerang Regency. Mangrove litter is a major component of primary productivity because it is an important carbon source in decomposition [30]. Mangrove litter in the form of leaves, twigs, and other parts will fall and decompose so that it enters the energy system that produces fishery potential. The economic value of the mangrove ecosystem of Tangerang Regency is based on the fisheries potential of mangrove litter with an average selling price of IDR. 35,000.00 is IDR. 7,229,200,349.00 per hectare per year [17].

Total production of mangrove litter on the coast of Tangerang Regency reached 3.47 $mg.m^{-2}$ per day or 12,492 $kg.ha^{-1}$ per year, with the main component being >80% leaves, then the rest were twigs and other mangrove organs [16]. Based on these calculations, the potential for coastal fisheries that the mangrove ecosystem can support is 1,134.01 $kg.ha^{-1}$

per year with a value of IDR. 27,016,978.57 per hectare per year, where this value will continue to increase if it is balanced with mangrove rehabilitation efforts. The high ecological function of mangroves to support coastal fisheries can be seen from the high number of fish species found in this ecosystem.

The cultural services of the mangrove ecosystem are one of them, namely the provision for marine tourism activities. Currently, mangrove forest ecotourism in Muara Village has the potential to be managed and developed. This ecotourism activity can also be a vehicle for learning about the mangrove ecosystem for visitors who come. Mangrove ecotourism in Tangerang Regency can be created through activities such as boating, enjoying the natural beauty, and planting mangroves [31].

B. Identification of Social Systems of Mangrove Ecosystem Governance in Tangerang Regency

Tangerang Regency consists of 29 sub-districts (8 coastal districts and 21 non-coastal sub-districts) with 274 villages. Mapping of social systems in the governance of mangrove ecosystems in Tangerang Regency is carried out by setting key statistics from several indicators, namely population, population growth rate, population density, life expectancy, literacy rate aged 15 years and over, labor force participation rate, level of open unemployment, number of poor people, percentage of poor people, human development index, regional original income, gross regional domestic product at current prices, and the rate of economic growth (Table 2).

TABLE II
KEY STATISTICS FOR IDENTIFICATION OF SOCIAL SYSTEMS IN TANGERANG REGENCY

Indicator	Unit	Year 2017	2018	2019	2020	2021
Social						
Population	people	3.584.770	3.692.693	3.800.790	3.908.880	3.293.533
Population growth rate	%	3,08	3,01	2,93	1,26	1,97
Population density	/km^2	3.736	3.848	3.961	3.382	3.432
Life expectancy	year	69,47	69,61	69,79	69,89	69,93
Literacy rate age 15+	%	95,5	95,7	95,7	97,62	97,84
Labor force participation rate	%	63,79	63,49	66,96	65,43	63,94
Unemployment rate open	%	10,57	9,70	8,91	13,06	9,06
Poor population	people	191.620	190.050	193.970	242.020	272.350
Percentage of Poor Population	%	5,39	5,18	5,14	6,23	7,12
Human development index	-	70,97	71,59	71,93	71,92	72,29
Economics						
Regional original income	billion rupiah	279.105,87	287.256,85	281.293,31	246.536,47	286.992,87
Gross regional domestic product	billion rupiah	118.994,08	129.825,98	140.089,29	136.005,32	145.210,12
Economic growth rate	%	5,82	5,80	5,56	-3,75	4,65

Source: Central Bureau Statistics of Tangerang Regency

The average population of Tangerang Regency in the 2017 – 2021 period is 3,656,133 people, with a population density of 3,672 people per km^2, where the average population growth rate is 2.3% per year. The population is one of the Tangerang Regency's economic development resources. Population productivity of good quality can improve a region's economy to produce more output. Population growth causes increasing human pressure on natural resources and the environment, including the mangrove ecosystem.

Life expectancy in Banten Province in 2021 is 70.02 years. Tangerang Regency has a slightly lower life expectancy than Banten Province, which is 69.93 years (Banten Province in Figures 2022). Life expectancy is one of the indicators used to see the level of public health in an area where this value is obtained from the estimated average number of years a person can live during his life. The human population in a room with a better level of health has a longer average life so that, economically, they can generate higher incomes. The average literacy rate for those above 15 years in Tangerang Regency in the 2017–2021 period is 96.47%, which means that the population of that age can already read and write. The literacy rate indicates the existence of an effective primary education system and literacy program that enables a large proportion of the population to acquire the ability to use the written word in daily life and continue learning.

The labor force participation rate in the 2017 – 2021 period in Tangerang Regency is 64.72%, where this indicator is the percentage of the workforce to the number of residents aged fifteen years and over and describes the level of labor absorption. Meanwhile, the average open unemployment rate in the same period in Tangerang Regency was 10.26%. This indicator measures the workforce not absorbed by the labor market and illustrates the lack of utilization of the labor supply. Open unemployment consists of residents who do not have a job and are looking for work, those who do not because they feel it is impossible to get a job, and those who already have work but have not started working.

The unemployment rate positively and significantly affects poverty in Tangerang Regency, where the average number of poor people for 2017 – 2021 is 218,002 people, with a percentage of 5.81%. This is due to the loss of job opportunities, resulting in a reduced income that the community will use to meet their daily needs. Accessing education, health, clean water, and decent housing services is not easy. This condition worsens if unemployment occurs in low-income groups, especially for groups of people against poverty, then the unemployment problem will be able to shift their position into the poor group quickly.

The average human development index (HDI) for the 2017 – 2021 period in Tangerang Regency is 71.74; this indicator is used to measure success in efforts to build the quality of human life. HDI can also determine a region's ranking or level of development and the general allocation fund. This indicator is formed by three fundamental dimensions: healthy living, knowledge, and a decent standard of living. The healthy life dimension uses life expectancy at birth. In contrast, the

knowledge dimension combines the expected schooling and the average length of education.

The original regional income of Tangerang Regency in the period 2017 – 2020 is IDR. 2.76 trillion, while the gross regional domestic income (GRDP) is IDR. 1.45 trillion. Regional original income is earned by regions based on provincial regulations and statutory regulations to meet regional needs in financing their activities.

C. Socio-Ecological System (SES) Model with DPSIR Approach in Governance Mangrove Ecosystem in Tangerang Regency

DPSIR factor in the conceptual model of mangrove ecosystem governance in Tangerang Regency is identified from the mapping of ecological systems and social systems that have been carried out. These results obtained six driving-force factors, two pressure factors, two state factors, seven impact factors, and seven response factors (Fig. 3). The elements in the socio-ecological system form causal effects in governance mangrove ecosystem areas in the Tangerang Regency.

Mangrove ecosystems are natural resources in the tropics with multiple benefits or services from ecological, social, and economic aspects. The triggering or driving factors in the problems of the socio-ecological system in the governance of the mangrove ecosystem in Tangerang Regency are the services of the mangrove ecosystem itself, the increase in population, the level of welfare has not been evenly distributed, the existence of economic activity, the pattern of space utilization and public knowledge regarding the management of the mangrove ecosystem area sustainable.

The increase in population in Tangerang Regency forces the use of mangrove ecosystem areas in the level of exploitation, leading to commercial industries without paying attention to the environmental carrying capacity of the ecosystem. The rapidly increasing population will have implications for high pressure on space utilization, often accompanied by a decrease in the quality and quantity of mangrove ecosystem areas [12], [32]. The relatively fast growth of the Tangerang Regency has also made the region undergo rapid physical, social, and economic changes. This is followed by the addition of space requirements and new activities to support the lives of the residents. The increasing need for housing and all life support activities causes the process of compaction of settlements and additional space carried out on open land to other potential areas.

Tangerang Regency is strategically positioned because it is the gateway for Jakarta Province and serves as a buffer zone within the Jabodetabek (Jakarta, Bogor, Depok, Tangerang, and Bekasi) development area. The accessibility of the Tangerang Regency has a significant effect on the city's development as a settlement, industry, and trade, which has an impact on the transformation of the physical environment of the land, including mangrove land, on the quality of society and ecology. Limited land in Jakarta Province for industrial and residential activities resulted in activities shifting to buffer areas, including Tangerang Regency. If it is not balanced with the addition of green open space, utilization of space can cause a decrease in environmental quality.

The mangrove ecosystem area in Tangerang Regency in 1996 was 487.5 hectares by clearing land for aquaculture and the construction of housing complexes [33]. The propagation of mangroves in the Tangerang Regency in the form of changes in the area's status for the private sector, which is carried out on
a large scale, causes pressure on the ecosystem itself. In addition, the increasing need for housing affects the expanding demand for land, which is also increasing. Land that is relatively fixed with unlimited needs and markets results in land conversion.

The increase in land conversion in the mangrove ecosystem area in Tangerang Regency is influenced by population growth, economic growth, and government intervention through the regional spatial plan. Changes in land-use patterns are dynamic following population development and regional development patterns. Land conversion occurs because the community's needs are increasing every year, the demands of life to obtain better conditions, and the level of human egoism toward the ecosystem [34].

The community uses the mangrove ecosystem in Tangerang Regency to fulfill daily needs. The direct economic benefits of mangrove ecosystems felt by the people of Tangerang Regency include mangrove wood having high calories so that it can be used as firewood or charcoal and building materials; then mangrove bark is a source of tannins, glue, and dyes, then the leaves can be used as food ingredients. Moreover, medicines and is a fishing ground for various economically essential commodities. Direct ecosystem benefits are benefits that can be directly used and whose value can be quantified to meet human needs [35]. An essential function of the mangrove ecosystem is the socio-economic benefits for the surrounding community, namely as a source of livelihood and the production of by-products [36].

Community Knowledge in Tangerang Regency regarding sustainable mangrove ecosystem management is still minimal, so its use often exceeds the environment's carrying capacity of the environment which causes the rate of ecosystem damage to increase. Activities that often cause damage to the mangrove ecosystem are due to the role of humans due to exploitation with a slashing system without paying attention to the sustainability and survival of the biota in them [37].

The pressure factor in ecosystem utilization in Tangerang Regency causes impacts on social and ecological systems, namely a decrease in ecosystem function, mangrove deforestation, abrasion and accretion, environmental pollution, tidal flooding, spatial use conflicts, and social conflicts. Land conversion and more intensive use activities have led to a decline in the function of the mangrove ecosystem, where the increasing demand for land has led to logging for agricultural, industrial, port, residential, and aquaculture, where these activities are not balanced with efforts to protect and conserve ecosystem areas mangroves.

Deforestation of mangrove forests causes coastal abrasion in Tangerang Regency because of the loss of the function of mangrove management services, namely as a barrier to abrasion. Intensive logging of mangrove forests also causes accretion, namely changes in the coastline. Abrasion and accumulation in Tangerang Regency caused a threat to population activities due to the erosion of land and the broader sea by scouring water. The abrasion rate on the coast of Tangerang Regency is 15.90 – 40.50 meters per year [17].

Waste originating from industry, agriculture, and households entering the Tangerang Regency's mangrove ecosystem causes environmental pollution that can interfere with mangrove growth. In addition, the waste that enters the mangrove ecosystem causes the death of low-level organisms, so it will indirectly disrupt the imbalance of the ecosystem because it is an interconnected unit. Pollution of the aquatic environment will disrupt the ecological balance and threaten human health. Using mangrove land and land conversion for environmental pollution will cause social conflict for the people of Tangerang Regency due to human factors as resource users. The cause of this social conflict occurs because of disharmony between resource users. The cause of this social conflict arises because of disagreement between resource users.

Problems related to the socio-ecological system of mangrove ecosystem area management that have been identified with the DPSIR approach, the responses or policies that need to be carried out by the Tangerang Regency government are mangrove rehabilitation and restoration, ecotourism development, coastal border conservation, co-management based management, development *wanamina* pond cultivation (silvofishery), development of coastal community development movements and increased public education related to sustainable management of mangrove ecosystems. Rehabilitation and restoration activities are carried out to restore the damaged mangrove ecosystem's condition to carry out its functions properly. Mangrove rehabilitation by replanting is one way to repair or restore part of the mangrove ecosystem [38]. The best stages of the rehabilitation program are to find out the causes of mangrove loss, deal with the causes and process the mangrove habitat.

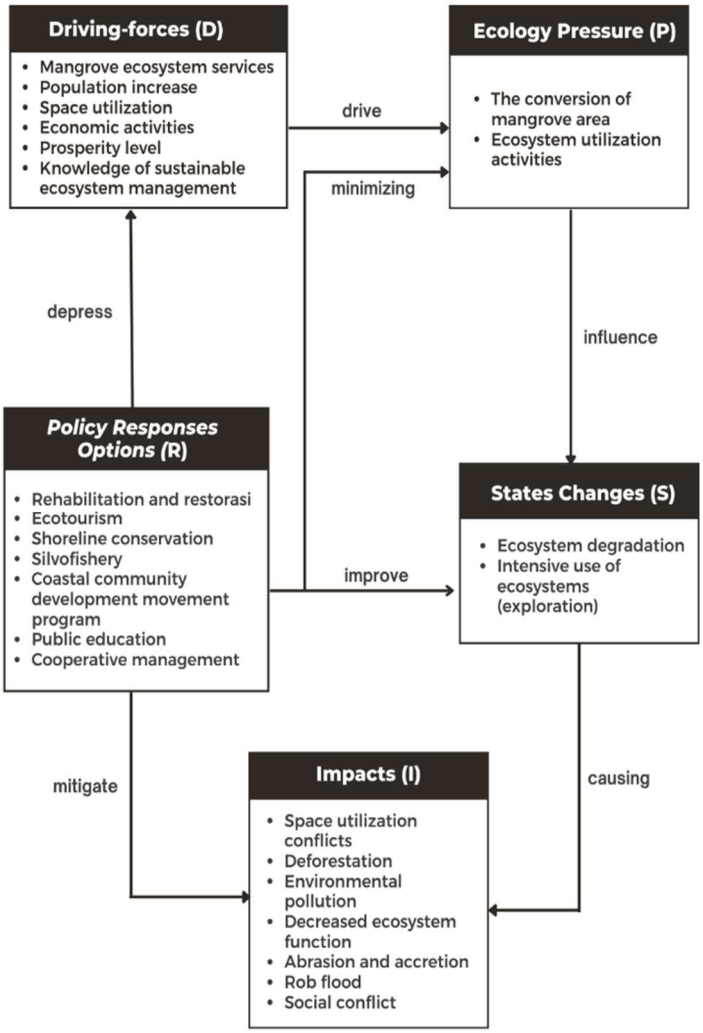

Fig. 3 Conceptual model of the social-ecological system with DPSIR approach in a governance mangrove ecosystem in Tangerang Regency

Ecotourism development in the mangrove area is a unique attraction in Tangerang Regency. Ecotourism is a journey to quiet natural places where activities are carried out in an environmentally responsible manner to enjoy and appreciate the mangrove ecosystem [39]. It is a form of responsible tourism that is fair in contributing to the tourism sector worldwide so that it has a low impact on socio-cultural aspects and natural resources [40]. Fishing is the most popular activity in the mangrove forest ecotourism of Muara Village [31].

Mangrove ecosystem management policies through coastal border conservation by protecting areas along the coast have significant benefits for protecting coastal areas from activities that disrupt the preservation of the mangrove ecosystems that grow in coastal areas. The coastal border of the Tangerang

Regency is administratively located in 8 coastal sub-districts, namely Kronjo, Mekar Baru, Mauk, Kemiri, Sukadiri, Pakuhaji, Teluknaga, and Kosambi.

The pond cultivation business on the coast of Tangerang Regency affects the mangrove ecosystem environment, so it must be carried out considering the principles of sustainable development that do not hurt the mangrove ecosystem area. Pond space as a green open space with silvofishery needs to be developed to protect the mangrove ecosystem. Silvofishery is an effort to preserve mangrove plants while still providing results in aquaculture. This concept is an option because it is ecologically profitable and can offer economic benefits [41], [42]. Currently, the silvofishery pattern is being developed in Muara Village with the embankment trench model by maintaining the presence of mangroves in the pond area between 60 – 80%. In contrast, the *komplangan* model is carried out by planting mangroves alternately with a ratio of 2 hectares of ponds must maintain 8 hectares of mangroves around the pond.

The coastal community development movement program is a coastal community economic empowerment program carried out by Tangerang Regency. The program is intended to improve the quality of community welfare and build quality coastal areas, which are expected to help solve problems faced by coastal communities, including the management of sustainable mangrove ecosystem areas to support the improvement of community welfare.

Increasing public education regarding the importance of knowledge of socio-ecological systems in realizing sustainable management of mangrove ecosystems needs to be carried out by the Tangerang Regency Government. Community education aims to foster a sense of responsibility and increase public awareness of protecting and preserving mangrove ecosystems. Mangrove ecosystem management must not exclude local communities but must open access to the distribution of benefits directly or indirectly. The regional community development approach assumes that community change can occur optimally through broad participation from a wide spectrum of communities at the local level in setting goals and actions.

The co-management approach (cooperative management) is implemented in the direction of mangrove ecosystem areas in the Tangerang Regency. This approach is based on togetherness and partnerships between the government, communities, and other stakeholders to achieve sustainable management through sustainable management collaboration to achieve their respective interests. Stakeholders in the co-management framework are all parties who influence or are affected by the policies, decisions, and actions of the system to be built where there are at least four critical stakeholders in the collaborative management concept, namely resource utilization actors, government, other stakeholders, and agents change [43].

IV. Conclusion

Socio-ecological system problems in managing mangrove ecosystems with the DPSIR (Driving-force, Pressure, State, Impact, Response) approach in Tangerang Regency are driven by the mangrove ecosystem services, population growth, welfare levels, economic activities, patterns of space utilization, and community knowledge. These driving factors cause pressure on the mangrove ecosystem because of the conversion (conversion) of land and activities of ecosystem utilization, causing environmental degradation conditions and the increasingly intensive use of mangrove ecosystems (ecosystem exploitation). These conditions cause impacts on the socio-ecological system, namely the decline in ecosystem functions, deforestation, abrasion and accretion, environmental pollution, tidal flooding, spatial use conflicts, and social conflicts so that these impacts can be suppressed, mitigated, repaired, and minimized through ecosystem management policies. Mangroves include rehabilitation and restoration, ecotourism development, coastal border conservation, co-management-based management, silvofishery ponds, coastal community development movement programs, and increasing public education.

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