SPATIAL PLANNING-BASED ECOSYSTEM ADAPTATIONS IN INDONESIA

"Science-based environmental factors, human wellbeing, and sustainable development can be strengthened by applying Spatial Planning-based Ecosystem Adaptations (SPBEAs)".

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Coastal Management: SPBEA Approach

Climate change has significantly impacted the coastal environment. Floods, coastal abrasions, and shoreline retreats are examples of those impacts caused by storm surges, high tides, or sea-level rise which have been triggered by climate change [1]. The impact is aggravated by human behavior in utilizing the existing natural resources. Conversion of coastal ecosystems to extensive agricultural areas or settlements and uncontrolled groundwater discharge are a few examples of human exploitation which could impair the function of the coastal ecosystems. Groundwater discharge is the movement of groundwater from the subsurface to the surface. Controlled groundwater discharge will influence the majority of baseflow. The interaction of groundwater and surface water allows water to flow for maintaining habitat and nutrients to the aquatic ecosystems. Uncontrolled groundwater can influence the changing of people's behavior. Therefore, it is important for people to adapt to climate change for reducing the impact of climate change.

Adaptation is compliance in natural and human system response to climatic stimuli. Ecosystem-based adaptation is a strategy to adapt to climate change that harnesses nature-based solutions and ecosystem services to the adverse effects of climate change [2]. Nature-based solutions in coastal management are a broad concept connecting green infrastructure, natural infrastructure, ecosystem-based adaptation, ecosystem-based mitigation and ecological engineering to ensure the sustainability of coastal environments.

Ecosystem-based adaptation to climate change impacts in coastal spatial planning, particularly shoreline retreats, has been promoted at the international, national, and even local levels. However, scientists' opinions vary on how to implement the adaptation on the spatial-planning practices. Therefore, science-based environmental approaches in addressing concerns on human wellbeing and sustainable development in ecosystem-based adaptation can be strengthened by applying spatial planning-based ecosystem adaptations (SPBEAs).

The SPBEA concept design was carried out hierarchically, starting from the determination of the coastal zone (Fig. 1). The basic spatial data used for the SPBEA model have been fully acknowledged, including land system, land use, soil, slope, climate, water parameters, conservation zone, land ownership, and/or government spatial plans. Meanwhile, the features in SPBEA should at least include the protection zone, greenbelt, ponds, settlements, and infrastructure.

This model was applied in Sayung Subdistrict, Demak and Pekalongan, Central Java, Indonesia [3], and the Mekong Delta in Vietnam [4]. The study areas have experienced massive shoreline retreats. A multicriteria analysis (MCA)

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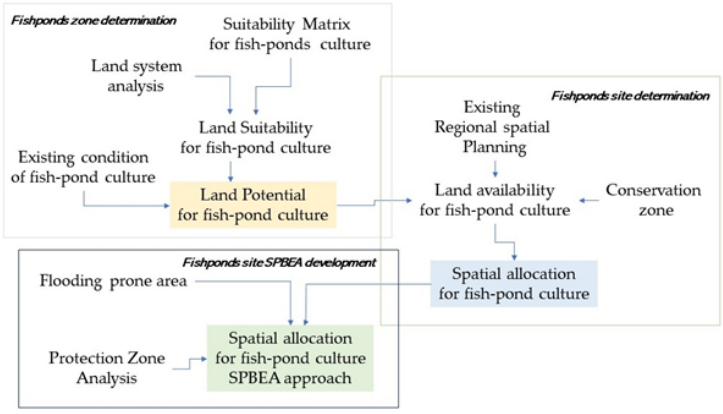

Figure 1. The steps of spatial-planning-based ecosystem adaptation (SPBEA) model development (Source: Dewayani et al. 2021)

method was used for developing the model by using the Geographic Information System (GIS) technique, divided into three steps: 1) the fishpond zone determination, the output of this step was the land potential for fishponds; 2) the fishpond spatial site determination, where the output was the model of spatial allocation for fishponds; 3) SPBEA fishpond site development, with the output being the SPBEA site management planning model. The results show that the SPBEA model is the best practice for combatting shoreline retreats caused by tidal waves and/or sea-level rise. The spatial site management should improve the coastal protection zone and the sustainable fishpond zone by implementing a silvofishery approach.

This spatial analysis structure implements the concept proposed for the spatial planning and management of inland aquaculture. In contrast to spatial suitability analyses that are generally based on AHP, the SPBEA filters the results of the land assessment analysis using the land system data, which basically defines the natural characteristics of the land. The input of the land system in the SPBEA analysis represents an improvement of the ecosystem approach, the characteristics that can be derived from the land system spatial data. Restoring the natural conditions of the ecosystem by zoning can also be applied using spatial information on conservation areas and greenbelts. SPBEA is also conducted in a more detailed spatial arrangement of the site, where ecosystem components must also be part of the fishpond culture zone. The SPBEA concept is a solution to climate change impacts, particularly in coastal areas.

Risk Management Tools

Indonesia has been conducted a national adaptation plan to overcome the climate change disasters in coastal areas. Integrated coastal management tools have been implemented to overcome the problems in some areas, such as: 1) coastal protection made from concrete rings, 2) large rock revetment; 3) coastal protection made from geo-tubes along 3 - 4 km; 4) CCSP (Corrugated Concrete Sheet Pile) built by the provincial government; 5) coastal embankment, as well as 6) coastal conservation area (mangrove). The integrated coastal management tools were developed as risk management tools.

As one of the risk management tools, SPBEA can be analyzed using GIS software. GIS is an efficient and effective technique since it can assist in modeling and summarizing complex spatial data into a spatially specific requirement in spatial planning [5,6]. GIS application as a decision-making tool, especially in spatial planning and spatial adaptation modeling, has been widely implemented in various countries. Asian countries such as Indonesia, have also used GIS as a tool for spatial planning decision support system development [5,7].

The development of SPBEA using the GIS technique, on the other hand, cannot rely on a single technique but requires a multicriteria analysis (MCA) which combine spatial analysis techniques, such as buffers and overlays, as well as new algorithm development and the use of surveying and remote sensing for generating input data. However, the spatial data and the GIS technique used may vary depending on the specific spatial requirements for planning. Remote sensing data was also used to analyze and to identify normalized difference water index (NDWI) using the near-infrared (NIR) and shortwave infrared-1 (SWIR-1) bands to assess the tidal flooding into the area. High-resolution remote-sensing image analysis is also used to delineate the existing land use. A visual interpretation is employed for high-resolution remote-sensing images, which classifies the analyzed area into the mangrove, net ponds, fishponds, settlements, gardening/roads, and rivers.

A coastal adaptation of detailed marine spatial planning has to be employed to mitigate the threat from the ocean. An adaptation strategy using risk management tools is needed to manage the environment and aquaculture. In Pekalongan, mangrove development is one of the SPBEA solutions to inhibit climate impacts. In 2021, about 1.05 ha of mangroves were planted around the Mangrove Information Center (Fig. 2). For 2021 - 2023, the government plans to develop a support funding partnership with CSR and NGOs to protect the existing coastal mangrove and develop more coastal mangroves. The mangrove trees stabilize shorelines against erosion by holding the soil in place. Meanwhile, mangrove seedlings that take root on sandbars help stabilize the sandbars over time into small islands [8]. Therefore, the water volume will decrease. By decreasing the water volume, mangroves can inhibit flood and erosion. The mangrove management should be conducted separately and need longer planning time to improve community

Figure 2. Mangrove development in Pekalongan (Source: https://www.khairulleon.com/2017/08/wisata-gratis-di-taman-mangrove.html)

livelihood [6]. Mitigation that is suitable for Pekalongan should be determined by criteria that support coastal resilience, including physical, social and environmental resilience [9].

The Timbulsloko, Sayung Subdistrict, Demak, has implemented a conservation strategy for its coastal areas through a hybrid engineering method using SPBEA as a risk management tool. Hybrid engineering combines technological and ecosystem-based solutions that use a permeable structure as a sediment trap, followed by

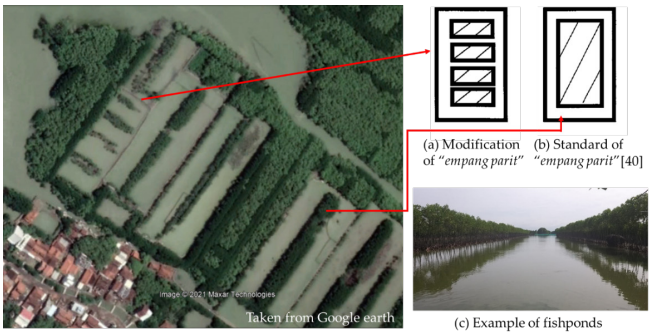

Figure 3. Silvofishery practices and mangrove development management in Timbulsloko, Sayung Distrik, Demak. (Source: Dewayani *et al*. 2021)

mangrove belts planting as a coastal protection ecosystem against the effects of abrasive tidal waves (Fig. 3). The use of mangrove belts is not only for coastal protection but also to manage the fishpond activities of the local community as an ecosystem-based approach.

The key advantages of this integrated spatial planning-based ecosystem adaptation are: 1) erosion can be inhibited by SPBE; 2) drastically reduced costs for coastal maintenance and repair; 3) flood protection; and 4) improved protection for people living immediately near the coastal area. Therefore, mangrove development is the best practice in coastal management that would help people in their adaptation toward climate change hazards.

Way Forward Strategies

As a concept, this study can become a guideline for the implementation of SPBEA issues in the future. Furthermore, site-based SPBEA arrangement requires input from the local community as the direct object of spatial planning. Therefore, a community-based SPBEA approach is needed. However, there is often a weakness in the spatial planning practice, especially in developing countries. This is a realm of government policy, both local and central, that needs further action to achieve sustainable spatial planning and prosperous rural communities. The implementation of spatial planning-based ecosystem adaptations can assist decision-makers to address environmental impacts from a spatial perspective and can make planning decisions more transparent.

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