

Social-ecological System Approach to Zoning of Mekong Delta

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Abstract: The social-ecological system approach is considered an effective one in regulating the harmonious relationships between man and nature. At the same time, establishing criteria based on the reciprocal relationship between the social-ecological characteristics of a territory will ensure the systematic, scientific, and modern qualities in the implementation of the zoning work - an effective tool in territorial management. The Mekong Delta has diverse ecological and social conditions; the main factors affecting the process of territorial formation are water resources, and river-sea and continental-oceanic dynamics. It is this division that has created a diversity with four sub-regions. Each one has its own functions and solutions for management and utilisation towards the goal of sustainable development. These results have scientific and practical significance, providing a scientific basis for spatial planning for rational utilisation of the Mekong Delta.

Keywords: Zoning, Mekong Delta, social-ecological system.

Subject classification: Sociology

1. Introduction

Zoning is particularly important for the integrated management of the territory in order for rational and effective exploitation and utilisation of development resources by region. It is the territorial division into distinct regions based on a spatial non-repeating character. Depending on the size, approach, and purpose of territorial research, there will be different levels and classification criteria.

The Mekong Delta is the largest delta in Vietnam. It is influenced by the general laws of geography on both the continent and the sea, blessed with great potential and advantages for socio-economic development. At the same time, it is also subject to multiple pressures determined by nature and man. Due to the specificity and importance of the region, various

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different zoning studies have been carried out, but these have mainly been focused on promoting the potential of the natural territory for single-sector development, such as agro-ecological and irrigation zoning. There is little research work based on territorial formation elements of an integrated nature. Therefore, in order to ensure effective exploitation and utilisation of the territory towards the goal of sustainable development, it is necessary to promote integrated approaches in the proposed development framework. The social-ecological system approach based on integrated scientific grounds of the constitutive factors including natural-ecological factors, and integration of human activity and social structures into the system, will be the basis to ensure objectivity and systematicity are integrated into territorial zoning - an effective tool in territorial management.

2. Social-ecological approach

The social-ecological approach is considered a systematic and integrated way to solve challenging problems, minimise risks, promote territorial resources, and especially ensure sustainability in the development process. Within this, the building of modes of development governance that adapts to social systems plays an important role in the decision-making of individuals and organisations (Gorrdard, R. et al., 2016; Fikret, B. et al., 2016; Olivier, B. et al., 2016; Matthew, J. C. et al., 2017; Beichler, S. A., 2017; Juan, R. et al., 2020).

The social-ecological approach to territorial research suggests that a social-ecological system is a geophysical entity combined with complex social characteristics in which a mutual relationship always exists to provide a basis for component factors of capital sources for territorial development. At the same time, it has the ability to self-regulate for continuous hierarchical adaptation in a dynamic equilibrium. According to Ostrom, each social-ecological system consists of the following four key elements: a resource system, a resource unit, a management system, and agents. Related sub-systems will emerge from common elements and their interactions. Each sub-system is influenced by secondary variables such as resource system size, resource mobility, governance level, human knowledge, and so on. The choice of a secondary or deeper level of relevant variables for analysis depends on the specific areas of study, on the spatial and temporal scales of the analysis, or on the transformation of territory that can start from a change in an ecological factor leading to a change in ecosystems, ecosystem services, livelihoods and resource governance. Therefore, when studying the system of territorial constitutive factors, it is possible to find the key point in stimulating development or inhibiting recession (Ostrom, E., 2009; Gorrdard, R. et al., 2016; Matthew, J. C. et al., 2017; Beichler, S. A., 2017).

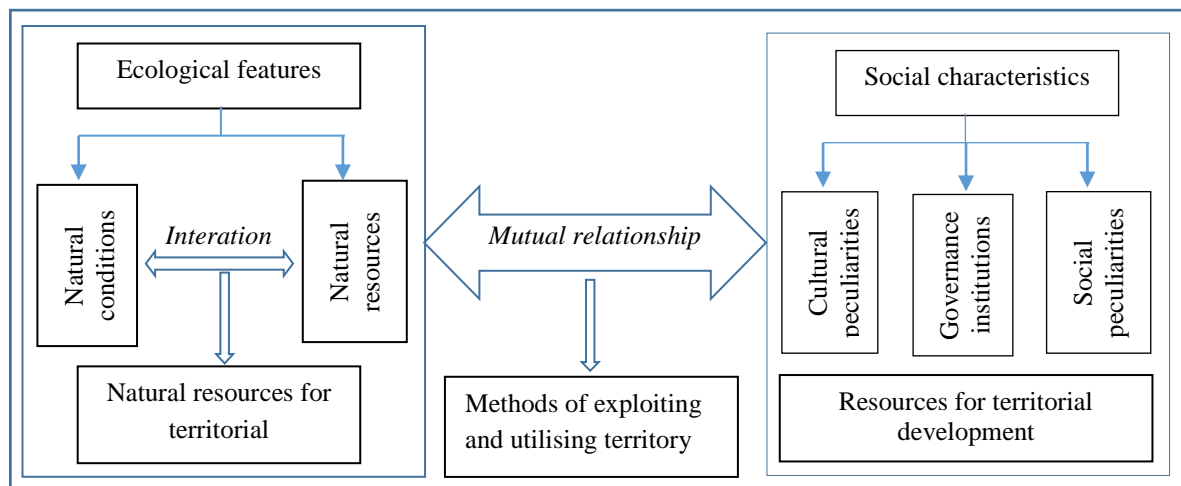
The social-ecological approach contributes to an in-depth analysis of the nature of territorial, inter-territorial, and global potentials and challenges. Greater emphasis is placed on the social nature of a specific territory in the process of proposing and selecting feasible and non-rigid development solutions based on changing ecosystems, ecosystem services

and social systems for livelihoods and welfare of each scale, field and different stages in the direction of respecting the law of development, the distinctiveness of the territory, integrating the epochalism and globalism in the management of the territory (Ostrom, E., 2009; Matthew, J. C. et al., 2017; Fikret, B. et al., 2016; Gorddard, R. et al., 2016; Juan, R. et al., 2020; Trần Thị Tuyết, 2015).

The social-ecological system approach can be widely applied to any subject of territorial research. It is considered an effective territorial zoning approach based on the establishment of social-ecological criteria, as a basis for dividing the territory into different areas, each area ensuring similarities on ecological environmental conditions (geography, natural resources, environment) and socio-economic characteristics, culture, together with institutional system and regional governance. At the same time, there is a reciprocal and interdependent relationship between the natural system and the socio-economic, humanistic, and institutional systems, creating distinct features of the territory (Trần Thị Tuyết & Hà Huy Ngọc, 2020).

Analysis of factors that form and maintain ecosystem services in spatial terms can assist in planning and selecting appropriate solutions for territorial development. At the same time, adapting measures in combination with social-ecological system services can create win-win opportunities, thereby facilitating the implementation of long-term strategies with territorial sustainability (Beichler, S. A., 2017).

Figure 1: Social-ecological System of Mekong Delta



Source: Trần Thị Tuyết, 2015.

Regarding the coastal delta area, the impact of climate change is becoming a challenge for communities that depend on natural resources. Therefore, in order to cope with

abnormal changes, it is necessary to promote local participation in building resilience and adapting to the immediate and long-term impacts of climate change based on overall territorial research results. Thereby a reasonable adaptation framework can be proposed to ensure feasibility by being suitable to the actual situation with low cost, quick adaptability and social acceptability (Westerman, K. et al., 2012).

On the basis of an overall analysis of the social-ecological approach, it is possible to identify the social-ecological system of the Mekong Delta based on specific characteristics of *ecological conditions - a combination of natural conditions and natural resources* interacting with one another forming *natural resources* in a specific space for socio-economic development; *and social characteristics which are determined by means of cultural and social characteristics expressed through the dominant mode of production and utilisation of the territory* (Trần Thị Tuyết, 2015).

3. Principles and criteria for zoning Mekong Delta

Based on the zoning principle of geographical science combined with the social-ecological approach, the Mekong Delta is divided into different sub-regions. Each one has its own social-ecological systems that do not repeat in space, they share the same origin and are relatively homogeneous in terms of a set of features of ecosystems and social systems that mutually affect the creation of specific characteristics for development, regular distribution and characteristics for a combination of resource utilisation measures (Phạm Hoàng Hải et al., 1997; Trần Thị Tuyết, 2015; Beichler, S. A., 2017).

Each sub-region has a specific function and can vary depending on changes in structural features over time. This will be the basis for proposing a framework for the sustainable development of the territory. This is because the results of zoning will contribute to clarifying the general rules of structure and function. Combined with the development trend, and the impact of pressures, it can be applicable in the assessment of the territory, thereby choosing the right management solutions, and minimising the influence of competing priorities and less relevant interest groups, especially the impact of climate change. This is because adaptation is a long process requiring strategic development with an appropriate, consistent and iterative roadmap. It is not a simple agreement.

The principle of zoning requires: (1) Respect for objectivity, (2) Ensuring relative uniformity, (3) Suitability for social-ecological functions, and (4) Consistency with management requirements.

Zoning criteria include: (1) Being based on the suitability of ecological conditions and comparative advantages of the sub-region; (2) Being based on the dominant production culture as a result of the process of exploiting and utilising the territory based on cultural values consistent with natural conditions; (3) Being based on social characteristics through indicators of income, urbanisation rate, and the capacity to manage socio-economic risks

and climate change; (4) The ability to link between localities, and between localities and centres (nucleus economic locomotives) and the development of infrastructure connecting localities in the region; and (5) In accordance with the conditions of organisational capacity and territorial management.

The climate change is identified as a factor that increases the volatility of ecosystems and social systems in the area of study. Most of the extreme effects lead to a decrease in the resilience of the ecosystem, increasing serious vulnerability, especially in the condition that the management capacity and response capacity of the government, the community and the people are still limited and dependent on natural and ecological resources. Therefore, in zoning work, it is necessary to update information on the impacts of the climate change with specific characteristics affecting development activities of the region.

4. Specific characteristics in territorial differentiation for Mekong Delta region

The differentiation of ecological conditions from the upstream to the heavily populated coastal areas in the direction of lower terrain has created a specificity in territorial spatial differentiation and the combination of river-sea dynamics has enriched and diversified the research territory's natural landscape. This particularity has regulated the development rhythm of the biological world and man's natural resource exploitation activities. This is fairly evident in the settlement and the dominant production modes associated with topography, the rural population distribution along rivers and roads, the urban population spread throughout the region and mainly distributed in the alluvial soil areas and ridges, and urban centres with a distance of about 60km apart (Vũ Tự Lập, 2004; Ministry of Construction, 2016).

Moreover, continent and sea features are considered the main determinants for the peculiarity of the territory.

- *The continent character* with its dominant delta area and dependence on water sources from the upstream Mekong River has determined many natural characteristics of the study area. The flat terrain, fertile land, convenient irrigation and water-land transportation system have contributed to the formation of an important agricultural economic region in Vietnam. In particular, the coastal plains have become the driving force for marine exploitation. However, at present, due to the impact of climate change and the development of the upstream Mekong River, the region cannot be proactive in water resources management. In particular, hydroelectric dams built in the upstream, have caused abnormal changes in the water cycle in the Mekong River basin, coupled with significantly decreased water levels and increasing depletion of aquatic resources, affecting the development of livelihoods of residents in the region.

The marine character is determined by the length of the coastline relative to the land area, by the surface area of the sea, and by the number of islands and archipelagos. The

Mekong Delta has a coastline stretching 744km, the ratio of the length of the coast to the area of the continent is about $1.8/100\text{km}^2$ which is higher than the national ratio ($1/100\text{km}^2$). On the other hand, there is a sizeable sea area and an expanse of large tidal flats close to fishing grounds and Phú Quốc Island, which has developed a marine character for the Mekong Delta territory. This marine character affects natural features on land and strongly influences the direction of socio-economic development of the study area, especially the advantage of marine economic development. The fact that the marine character provides a source of moisture means the air humidity is often above 80% even in the dry season, causing the whole territory to experience humid conditions, especially on land. The Mekong Delta sea located in the Gulf of Thailand in the Southwest and the East Sea (also known as the South China Sea) in the Southeast is considered to be abundant in natural resources, particularly many types of seafood such as squid, shrimp, crab, blood cockles, etc. In many locations, there are hundreds of thousands of hectares of alluvial plains, which can provide very favourable conditions for wind power development. Maritime traffic is also a strength of the territory because it facilitates connectivity with other regions and territories (Ministry of Foreign Affairs, 2002; Vũ Tự Lập, 2004). Thus, the specificity in territorial differentiation determines the possibility of exploiting and utilising sub-regions for development purposes in accordance with territorial potential. The Mekong Delta area has the potential to develop an integrated economy, typical of land and sea territories, creating linkages and complementarities in the rational organisation, exploitation, and utilisation of resources.

5. Result of territorial zoning of Mekong Delta

With the above-mentioned principles and criteria, together with the conjugate analysis of component maps, characteristics of exploitation and utilisation of resources, features of development dynamics, relationships and interactions between elements and components, it is possible to form integrated climate change scenarios for 2020.

According to the 2020 climate change scenario for Vietnam, the temperature has tended to rapidly increase in recent decades. Under the RCP4.5 scenario, by the mid-century, the increase would reach about 1.3°C in all sub-regions. By the end of the century, the temperature will increase by about 1.7°C , and three-quarters of sub-regions will experience an increase of more than 1.7°C , while only the coastal sub-region will face an increase of less than 1.7°C .

Annual rainfall tends to increase over the whole region, but this rise will be lower than that in other coastal areas of Vietnam such as the Red River Delta, the North Central Coast and the Mid Central Coast. Specifically, according to scenario RCP4.5, annual rainfall in the middle and the end of the century will increase by 15.3%, in which the mid-century will witness an increase of about 15%, with a fairly uniform distribution in terms of spatial and regional territories. At the end of the century, the growth rate will fluctuate between

sub-regions, in which the Long Xuyên Quadrangle sub-region will experience the highest growth rate of over 17%, with about 14% for the remaining sub-regions. Notably, the fluctuations in the two periods between the middle and the end of the century of the sub-regions tend to differ. Those sub-regions that see an increase include the Long Xuyên Quadrangle with about 1.4% and the Đồng Tháp Mười with 0.1%. The remaining sub-regions experience a decrease by about 0.1% to 0.5%, corresponding to the Central and Coastal sub-regions.

Sea level rise can be detected by the fact that the sea level in the Mekong Delta coastal area is higher than the national average. According to scenario RCP4.5, the average rise in sea level for the whole coastal strip of Vietnam by 2050 is 23cm (13cm÷31cm), and by 2100 is 53cm (32cm÷76cm), and the coastal area from Cape Cà Mau - Kiên Giang is 54cm (33cm÷78cm), about 1cm to 2cm higher than that in the northern and central coastal areas.

Along with research work on territorial factors such as geomorphology, soil, ecology, and socio-economic statistics (Tôn Thất Chiêu et al., 1991; Vũ Tự Lập, 2004; Ministry of Construction, 2016; General Statistics Office, 2021; University of Social Sciences and Humanities, 2018; Ministry of Natural Resources and Environment, 2021), the research area is divided into four social-ecological sub-regions. These are:

- The Đồng Tháp Mười sub-region occupies 16.1% of the territory, distributed mainly in Đồng Tháp, Long An and part of Tiền Giang Provinces at a topographic elevation of >1.5m with the low-lying ground and new alluvium. The soil mainly belongs to an alkaline soil group accounting for 70%, while alluvial soil is distributed along the Cambodian border and adjacent to the Southeast region. The sub-region is characterised by high floods where water has difficulty draining away, with inundation levels as high as 3-5m; it is less affected by salinity intrusion, it has advantages of developing rice production, aquaculture and freshwater waterfowls. The main mode of production is agricultural cultivation across an area accounting for over 22%, contributing nearly 20% to total income. The rate of urbanisation is the lowest in the region, at about 17%. The climate change will increase and worsen the impact of droughts, abnormally hot temperatures, localised heavy rainfall, river bank erosion, and reduced flood and inundation. The sub-regional development orientation is associated with the enhancement of water storage capacity in combination with water drainage measures during the flood season. Economic activities lead to resource use associated with the protection and development of the Melaleuca forest ecosystem, agricultural production in the flood season, the formation of a modern rice-growing area with a large-scale production model linking farming households with enterprises according to the product value chain; development of the economic chain of trade in services within the region, especially linking areas rich in raw materials in the region with other regions, ensuring flexible and inter-regional transportation with the Southeast region, and the axis of border-gate economic linkage with Cambodia by waterways and roads.

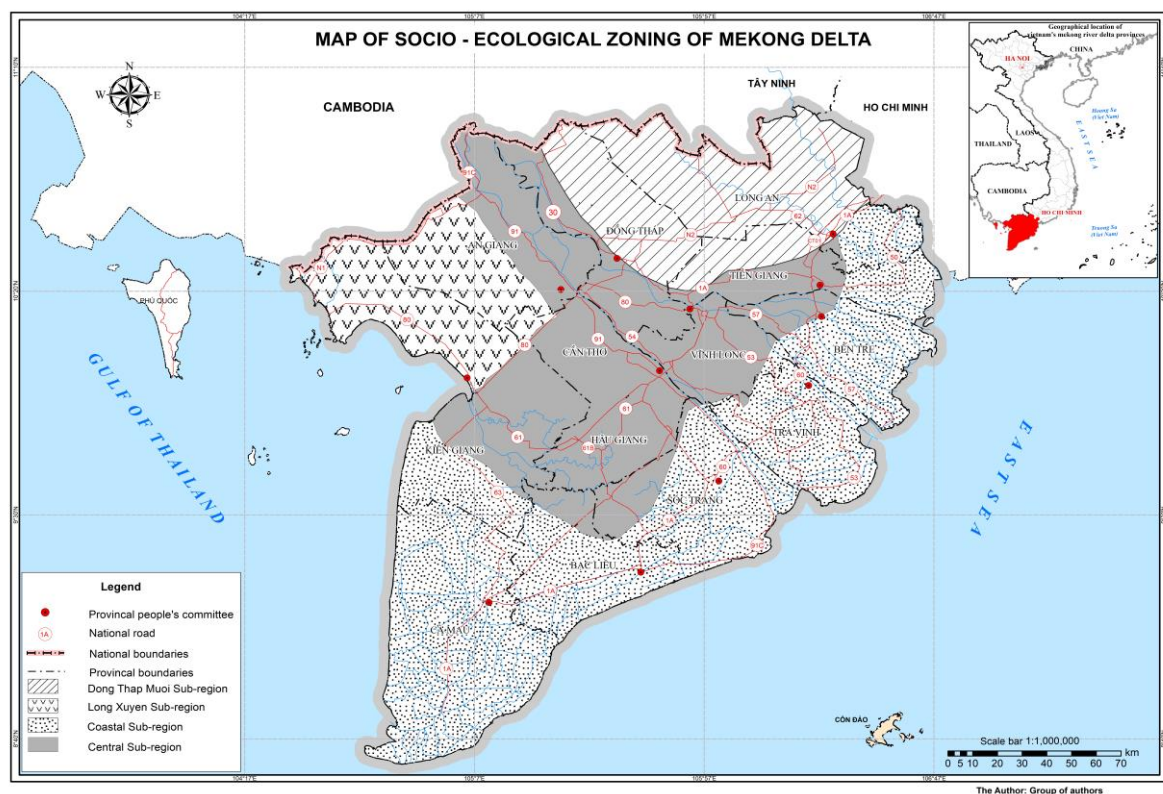
- The Long Xuyên Quadrangle sub-region occupies 10.8% of the territory, located within the administrative boundaries of An Giang and Kiên Giang Provinces, at a topographical elevation of 1.6m to 2m with alkaline soil predominance; the area is overwhelmed by annual floods with inundation levels between 3m and 4.5m. The coastal area of Kiên Giang Province, affected by salinity intrusion with a salinity level of 0-12g/l, has the advantage of developing integrated economic activities of rice cultivation and a marine economy. Agricultural production and aquaculture contribute about 23% to income; the development industry combined with service industries, has contributed to accelerating the urbanisation process, reaching the rate of 30%, ranking it second in the region. The climate change causes flooding and salinity intrusion in the western coastal area (Kiên Giang), increasing drought and reducing floods in An Giang Province. Development orientation should ensure the ability to store water, prevent the accumulation of saltwater, prioritise to the development of livelihood models suitable to freshwater and saltwater ecological conditions. It is necessary to promote conservation and development of Melaleuca forest ecosystems on wetlands, forests on rocky mountains, limestone mountains and marine ecosystems. It is important to develop inter-regional economic trade and service chains through border-gate economic links and sea-coastal connectivity.

- The Central sub-region occupies 30.5% of the territory. This includes multiple provinces and cities along the Tiền and Hậu rivers upstream with 100% of Cần Thơ, Hậu Giang, Vĩnh Long Provinces, and part of An Giang, Đồng Tháp, Tiền Giang and Kiên Giang Provinces. These are distributed at topographic elevations from 1.4m to 2.4m with alluvial soil predominance, inundated due to the impact of floods and high tides with inundation levels of 1m to over 5m, affected by salinity intrusion with salinity levels of around 0-8g/l, favourable for the diversified development of agricultural livelihoods according to the water season and freshwater aquaculture. Planting forests to prevent river bank erosion in this region is deemed necessary. The dominant production method is agricultural cultivation, fruit tree farming with well-known fruit granaries in Southwest Vị Thanh, Southeast Cần Thơ and the land ridge between Tiền and Hậu Rivers. The sub-region has the highest urbanisation rate in the area of approximately 40%, with the centre being Cần Thơ City and the urban centres of An Giang Province. The climate change worsens the impacts of drought, and river bank erosion and salinity intrusion. Prioritising water-saving livelihood models, linked production, processing and consumption of agricultural products in the region, and inter-regional road networks and river transportation are necessary for this region.

- The Coastal sub-region occupies most of the territory (42.6%), distributed along the coast across eight provinces from Long An to Kiên Giang, notably characterised by sand dunes and mangroves with an average topographic elevation of 0.7m to 1.2m, in a lower direction from along the Cambodian border to the coastal area (0.3m to 0.7m). Common soil groups include saline and sandy soils, with an inundation level of less than 1m due to tidal influences, and are directly affected by salinity intrusion with a salinity level of 20g/l. According to the climate change scenario 2020, if sea level rise by 100cm and there are no

response solutions, about 47.29% of the Mekong Delta area will be at risk of being inundated. The provinces facing the greatest risk of inundation include Cà Mau in the Coastal sub-region with 79.62% of the provincial area, and Kiên Giang in the Coastal sub-region and the Long Xuyên Quadrangle with 75.86% of the provincial area. Endowed with coastal characteristics and great potential for aquaculture development, in recent years the localities have promoted and exploited the industry, accounting for nearly 70% of the total aquaculture surface area of the whole region and a large proportion of sub-region's agricultural income. However, with about 22% the urbanisation rate of the area is low, which, while higher than that of the Đồng Tháp Mười sub-region, is lower than that of the other two sub-regions. The development orientation gives priority to strengthening the coastal protection forest system-soft dykes to prevent coastal erosion, preserve land, and conserve ecological diversity. At the same time, it promotes the aquaculture model in terms of available capacities of each region thereby supporting the development of the marine economy, ensuring favourable marine traffic and providing key export-led aquatic and seafood products.

Map 1: Map of Socio-ecological Zoning of Mekong Delta



Source: Authors.

Table 1: Features of Social-ecological Sub-regions in Mekong Delta

No.	Sub-regions	Area (km ²)	Characteristic values								
			Ecological characteristics				Social characteristics				
			Topographic elevation (m)	Soil	Inundation levels (m)	Salinity level (g/l)	Dominant production method	Rate of agricultural production area (%)	Ratio of aquaculture area (%)	Rate of agricultural income (%)	Urbanisation rate (%)
1	Đồng Tháp Mười	6324.3	>1.5	Alkaline soil, alluvial soil	3-≥ 5 (inundated by floods), difficulty draining away	0-4	- Agricultural production, rice, freshwater aquaculture - Industry: Long An	22.1	2.03	19.6	17.6
2	Long Xuyên Quadrangle	4269.7	1.6-2	Alkaline soil, mangrove soil	3-4.5 (inundated by floods)	0-12	- Agricultural production, rice: An Giang, Kiên Giang - Seafood: Kiên Giang - Urbanisation rate is high	28.5	20.57	23	30

No.	Sub-regions	Area (km ²)	Characteristic values								
			Ecological characteristics					Social characteristics			
			Topographic elevation (m)	Soil	Inundation levels (m)	Salinity level (g/l)	Dominant production method	Rate of agricultural production area (%)	Ratio of aquaculture area (%)	Rate of agricultural income (%)	Urbanisation rate (%)
3	Central	12003.6	1.4-2.4	Alluvial soil, alkaline soil	1-≥ 5 (inundated by floods and tides)	0-8	- Agricultural production, rice: Đồng Tháp - Fruit trees: Southwest Vĩ Thanh, Southeast Cần Thơ, the high strip of land between Tiền and Hậu Rivers - Industry	26.7	8.4	19.8	31.8
4	Coastal	16745.6	<1	Mangrove soil, alkaline soil, sandy soil	≤1 (inundated by tides)	≥ 20	- Seafood - Coastal protection forest - Agricultural production, fruit trees	22.9	69	28.5	22

Source: Aggregated results of the authors.

The results of territorial zoning based on an integrated approach of the main factors of the territory from the specific ecological and social characteristics that reflect the capacity of the territory, combined with the analysis of the territorial divergence and dynamics of both maritime and continental characters, will make an effective tool in territorial management, especially in the context of regions severely affected by the climate change, including increased drought and salinity intrusion occurring on a large scale with increasingly serious impacts, adversely affecting production activities. The root causes include the decrease in water resources and the lack of moisture reserves leading to the degradation of resources that serve as the main basis for people's livelihood activities. This especially applies to the rural population which is easily affected by, but difficult to recover from, natural disasters because of limited drought-adaptation resources and conditions, making it difficult to change livelihoods, and giving rise to challenges affecting the results of such national target programmes as sustainable poverty reduction, building new rural areas, etc. The results of zoning combined with the orientation of sectoral and territorial development will be the basis for planning a reasonable development space, ensuring harmony with nature and laws that governing daily life consistent with the sub-regions. Therefore, the main solutions to be considered to ensure the sub-regional functions are as follows:

- Protect and develop forest ecosystems, especially mangrove ecosystems to increase territorial protection and conserve biodiversity.
- Develop economic sectors on the basis of exploiting resources on the continent, focusing on economic development associated with agricultural products and developing marine economic sectors (aquaculture, maritime transport, seaports, tourism).
- Promote economic models that address dual goals (i.e. conservation and development), to ensure protection as a result of the ecological system and integrated economic development.
- Provide a reasonable space for the development of the residential system, and agricultural production associated with the product value chain.

4. Conclusion

The social-ecological system is considered an effective approach by a huge amount of research into territorial specificity combined with the comparison of similarities and differences with other territories, applied by many scholars in territory research in order to regulate the harmonious relationship between man and nature. At the same time, establishment of criteria based on the dominant reciprocal relationship of the social-ecological characteristics of the territory will ensure systematic, scientific and innovative implementation of zoning - an important tool in territorial management.

The territory of the Mekong Delta is Vietnam's southernmost region. It experiences diverse ecological conditions creating a specificity in exploitation and utilisation for the development of the integrated economy. This is a combination of the development of various economic sectors based on exploiting resources on the continent, focusing on the economic development associated with the agricultural products and the development of marine economic sectors (i.e. aquaculture, maritime transport, seaports, tourism, and so on).

The main factors that greatly affect the natural differentiation of the Mekong Delta territory include water source, the simultaneous impacts of the sea-ocean process combined with the dependence on the water source upstream of the Mekong River, the yearly rainfall in the Mekong Delta, the exploitation and utilisation of the territory from upstream to coastal areas leading to the peculiarity of the territorial divergence and differentiation. It is the differentiation of social-ecological characteristics that creates this diverse territory formed of four sub-regions: the Đồng Tháp Mười, the Long Xuyên Quadrangle, the Central and Coastal areas. Each sub-region has its own functions, hence different management and utilisation solutions are needed towards the goal of sustainable development of the study area.

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