International Journal of Engineering & Applied Sciences (IJEAS)
Vol.16, Issue 2 (2024) 104-115
http://dx.doi.org/10.24107/ijeas.1467752
Int J Eng Appl Sci 16(2) (2024) 104-115

Exploring the Spatial Distribution of Coastal Drainage Basins in Türkiye

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Received: 12.04.2024, Revised: 31.05.2024, Accepted: 01.07.2024

Abstract

Coastal regions are vital areas globally, serving as hubs for human habitation and economic activities. Water, being the fundamental resource for life, plays a crucial role in sustaining ecosystems and shaping coastal landscapes. The convergence of river systems in coastal zones underscores their significance in the hydrological cycle and aquatic biodiversity. However, managing these valuable yet vulnerable regions presents multifaceted challenges, necessitating robust management frameworks supported by monitoring and assessment tools. In Türkiye, a country with limited freshwater resources, the management of coastal zones is particularly complex due to increasing pressure on resources and land. This study examines the distribution and characteristics of river and coastal basins in Türkiye. Through spatial analyses on Geographical Information System and basin delineations with watershed modelling program, the study clarifies the regional differences and obstacles encountered by coastal provinces spanning the entirety of Türkiye's coastal borders. The results offer valuable understanding regarding the spatial dynamics of Türkiye's coastal areas with particular emphasis on the significance of Black Sea coastal basins and all coastal provinces. Firstly, river basin systems draining into the Black Sea constitute the majority of Türkiye's surface area. Although the Black Sea region covers only 14% of the total area, more than half of the country's surface area, excluding transboundary and endorheic basins, drains into the Black Sea. Similarly, the analysis of basin types reveals that coastal basins constitute approximately 18% of the drainage areas associated with our coastal waters, nearly one-fifth. This distinction between coastal basin and river basin boundaries differs from the traditional zoning approach in river basin management and coastal area management plans in Türkiye. Consequently, it is anticipated that this spatial evaluation, which has brought a new perspective, will significantly contribute to addressing management challenges, especially the studies that will be evaluated together with population and resource use.

Keywords: River Basin, Coastal Basin, Coastal Zone Management.

1. Introduction

Coastal regions are geographical areas in demand all over the world. As is widely acknowledged, water stands as the most essential resource for sustaining life. During hydrological cycle, water feeds aquatic ecosystems and creates valuable habitats throughout its movement from land to sea. The final regions traversed by the majority of river systems before reaching the oceans are the coastal zones, which have undergone formation and molding processes spanning hundreds of thousands of years. Our planet is a water planet but freshwater content is around 0.4%. Only 1.6% of this amount is river discharges [1]. Despite the relatively low volume transported by rivers, their influence on coastal processes and significance for aquatic life in marine environments is substantial. Coastal areas are very valuable due to the presence of water, the diversity of their resources, and the fact that they are a gateway to the sea that allows trade, most of which is carried out by maritime transport. Ancient cities and ruins prove that coastal zones were always appealing. Water, food, and agricultural natural resources; fisheries and marine transport are significant ones [2, 3].

When we compare the ratio of overall coastal area to total land area and ratio of population of corresponding regions, the result reveals that the coastal population exceeds many folds of

inland regions. More than half of the world population lives near coast from 100 km from the shore [4-8]. Two third of mega cities of the world and most of the capital of countries has a sea border located in coastal zones [2, 7, 9].

All these circumstances complicate the management of these vulnerable and valuable regions. Sound management practices show that; the tools, legislations and different organisational structures needed in coastal zone management. Monitoring and assessment tools are essential to support all these management and decision-making systems, particularly in provinces along the coastline, which encompass extensive coastal areas.

According to the definition, the coastal area is "the land and sea areas bordering the shoreline." This terminological definition, however, did not account for the resources and solutions required for integrated management, it gained a more adaptive / flexible borders in the process until the 1990s. The coastal zone is defined as “The land-sea interface where the land is influenced by marine processes and the sea is affected by terrestrial processes” by the Coastal Engineering Manuel [10]. If the definition of the coastal zone in Coastal Zone Management plans is flexible based on the problem definition and solution focus, integration and ecosystem approach can be achieved. For this reason, the boundaries of the area covered for each project vary in Integrated Coastal Zone Management (ICZM) Plans. There are plans for regional seas and countries, as well as those focused on more specific ecosystem problems. In national plans, administrative boundaries such as geographical regions and provincial borders are considered. Basin management plans typically address large river basins. This may overshadow the importance of coastal basins —the primary region at the land/sea interface where processes impact each other.

Examining the existing literature reveals a scarcity of studies delving into the significance of coastal basins and their role in different processes. For instance, Simms et al. conducted research on erosion management, where they modelled a small basin in Lake Wollumboola, Australia, to assess soil erosion dynamics. The research highlighted the influence of coastal basin degradation and land use practices on soil erosion dynamics [11].

In the research conducted by another team [12, 13], coastal basins are calculated separately and their impacts are analysed. In the first study, spatial findings similar to those in our research stand out. The calculated spatial coastal basin values here have also been evaluated together with population and other geographical information. In the study, near-coastal unmonitored catchments of Baltic Sea Drainage Basin are presented. 634 sub-drainage basins and their various spatial aggregations are characterized in terms of population; land cover, drainage density, and slope were studied. They indicate that, 13% are is unmonitored near-coastal areas which inhabit 24% of the total basin population. For Sweden, this numbers were calculated as 20% of total catchment area of Sweden with a population of 55% [12]. The second study of the team examined the near-coastal unmonitored drainage basins have impact on coastal water quality conditions. They state that, coastal basins contain a considerable amount of residential areas and population as compared to the inland areas and large river basins. With this study, nutrient and pollutant mass loading to the sea shows a pollution magnitude similar to or greater than monitored river loads. [13].

Another study conducted in South America also reveals the importance of coastal basins. Marquez et al. [14] evaluated the environmental impacts in the basins located on the Atlantic coast of South America. Within the scope of management studies, they evaluated the effectiveness of treating coastal basins as separate geographical units. The study revealed that, apart from the usual river basin management framework, small water resource basin studies can be effective both for determining habitat loss and aquatic ecosystem degradation, and for regaining fauna in economically manageable small basins.

In recent years, there have been many studies in the literature on low elevation coastal zones involving the determination of global warming and its effects. In one study [15], Soboyejo and colleagues emphasizes the importance of drainage basins size selection in the long-term water resource management and planning of coastal basins. Study reveals that the drainage behaviour in these basins is related to the land subsidence, past management practices, and climate variability of the area. The findings of this research suggest that climatological variations and land usage practices have a substantial impact on the drainage patterns observed in coastal basins. Specifically, factors such as precipitation, evapotranspiration, drought occurrences, and water availability exhibit closer correlations in coastal basins compared to inland areas.

Türkiye is a peninsula and has a strategically important location. In addition to its extensive river basins, the smaller riverine discharge basins and coastal basins contribute to Türkiye's water resources, enriching the country's water assets. This is significant considering Türkiye's status as a country with limited water abundance, with an annual average rainfall of 574 mm [16]. This average annual rainfall is less than the world average. Therefore, managing these limited resources in this vulnerable and attractive geographical area poses challenges in Türkiye as well. The pressure on the resources and sectors on the coastal regions of Türkiye is increasing every day. For this reason, the integrated management approach is gaining importance. It is thought that the comparative areal evaluations obtained in the study will shed light on the needs and priorities of our country in the field of coastal zone management. Therefore, water drainage basins, especially coastal small basins are currently receiving attention in terms of management.

In our study, the river and coastal basins in Türkiye were examined according to their sizes, locations and discharging sea area. The spatial evaluation of the coastal basins was also evaluated according to the geographical and marine regions. The coastal basins along the Mediterranean, Aegean, Marmara, and Black Sea shorelines were analysed in terms of their sea discharge. Regional variations were identified and discussed. Furthermore, differences in basin area based on Türkiye's Nomenclature of Territorial Units for Statistics (NUTS) and the corresponding discharging sea areas were delineated.

2. Methodology

In this study, first of all Türkiye's geographical regions were transferred to Geographical Information System (GIS) environment using level information of NUTS of Türkiye. Then, the basin dataset of the regions where Türkiye is located were downloaded from the world Georeferenced global Dams And Reservoirs - Drainage Topology and Catchment database (GeoDAR-TopoCat) data [17,18]. The river basin data of Türkiye were added to our database (DB). Since the river basin data only covers large basins, delineation of smaller basins was made using 30 m resolution Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Digital Elevation Model (DEM) data in those areas. These analyses were performed using the Aquaveo Watershed Modeling System (WMS). The flowchart of the study is presented in Fig. 1.

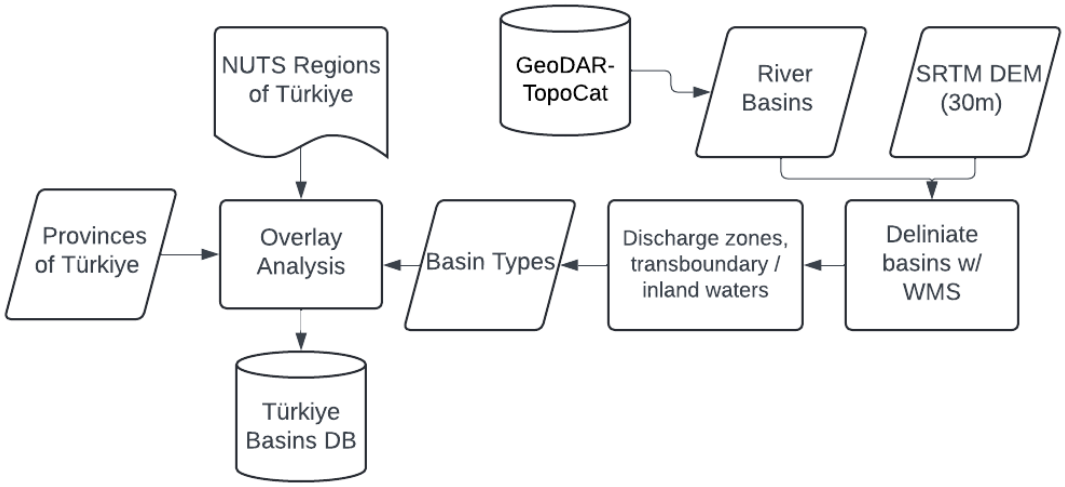

Fig. 1. Study flowchart

After these determinations, the basin areas outside the perennial rivers with continuous flow (intermittent and ephemeral streams) were included in the coastal basins. With this delineation, inland basin regions were also more clearly separated an included into our GIS basin database. After this work, the basins were classed into the seas where they spill into and the geographical regions where they are included in. Therefore, the areal assessments could be possible to complete so that an assessment could be made about the coastal basins and their distribution. Here, analysis criteria were selected to extract river basins of certain sizes. Fig. 2 shows the coastal and river basins of Türkiye and their distribution. The basins indicated in white in the figure are the basins of external/trans boundary waters whose discharge zones are outside our country. The basins in grey are coastal basins and the basins in light grey are the basins of our rivers with a continuous flow regime above a certain size.

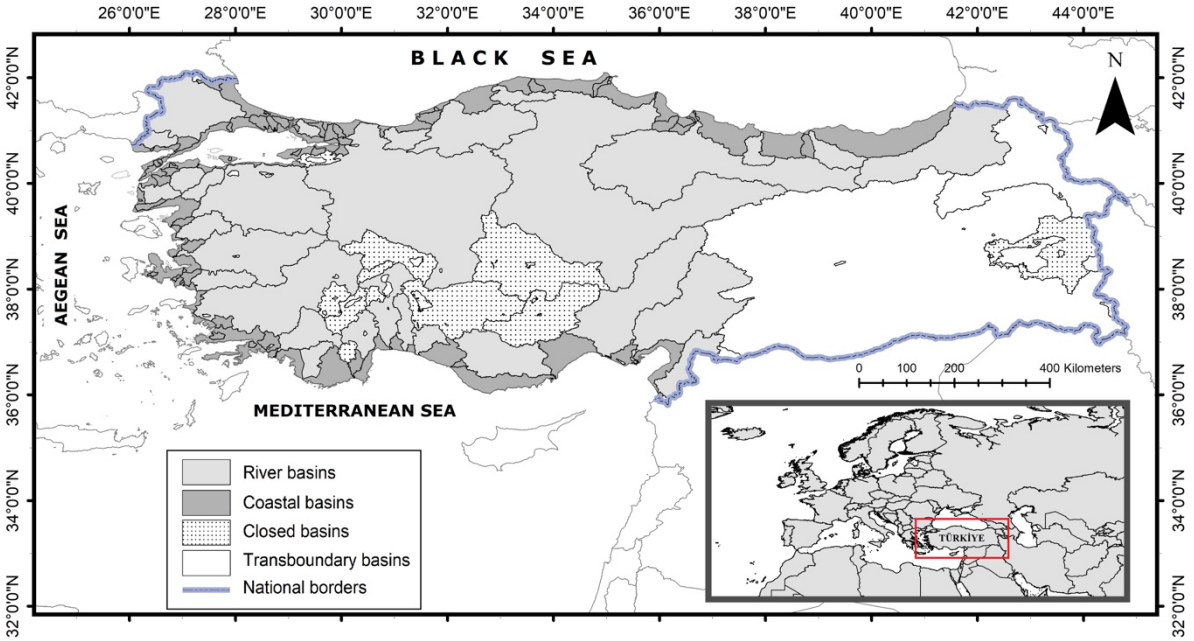

Fig. 2. Study area and basin types

The resulting basin areas were processed in a way to differentiate coastal basins, according to the flow regime. Perennials are distinguished from intermittent and ephemeral streams. The

data produced in the whole study were transferred to the GIS. Corrections for all lake areas, is also obtained from GeoDAR-TopoCat data, were made on the GIS and the lake surface areas were subtracted from basin areas. Each basin was named and various attribute information were entered into the database.

The distribution of the river basins, the boundaries of which were determined and the attributes of which were entered, according to the seas they discharge into, was also determined and it was determined which rivers and coastal basins discharge into which marine areas. For the geographical region evaluations, level 1 and 2 geographical regions of the NUTS regional system, which was adopted by the Council of Ministers Decree dated 2001 were used [19]. Although it is very close to the geographical regions we are used to. Similarly, the distribution of basins included into the coastal provinces was also analysed and the findings are presented in the results section.

3. Distribution of Basins and Their Types

Our country is surrounded by seas on three sides. Evaluations of river basins draining into the sea outside our borders have been provided in tables, but for a clearer understanding of the overall distribution, they have not been color-coded on the maps. These basins include the areas of two major rivers, the Euphrates and Tigris, originating in the eastern parts of our country and flowing into the Persian Gulf, as well as the river basins draining into the Caspian Sea and enclosed/internal basins (

Fig. 3). The total area of these external basins constitutes approximately 27% of our land area. Closed basins and lake basins have also been separately calculated and presented in the tables (Table 1).

Enclosed/internal basins comprise 10% of Türkiye's land area (Table 1). These areas, which also include lake basins, have not been color-coded in Fig. 3.

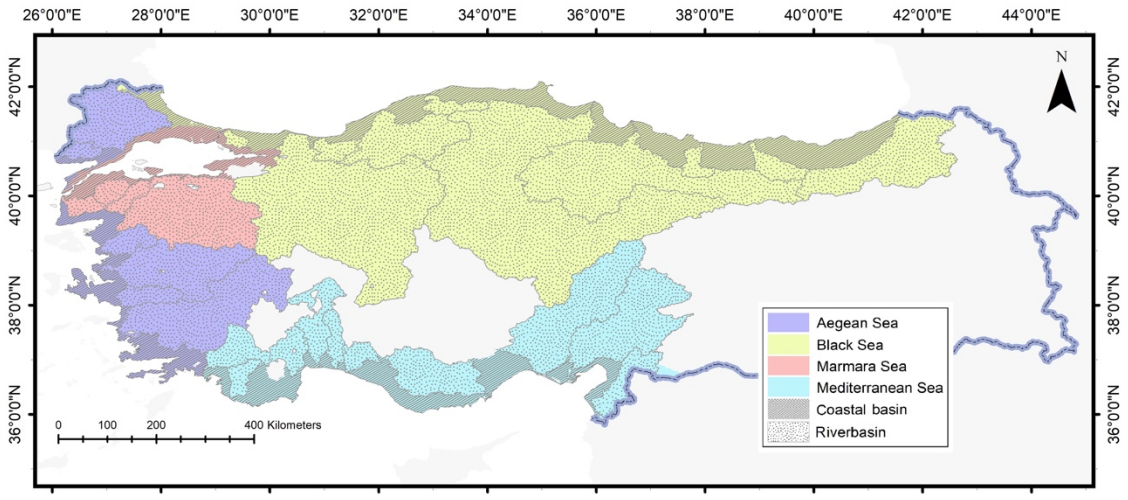

Fig. 3. The distribution of coastal and river basins based on the seas into which they drain

Table 1. Distribution and percentage area coverage of basin types across various sea regions being drained

	Closed Basins	Transboundary Basins	River Basins	Coastal Basins	%Sea Region Poured
Aegean Sea	0	0	**15.8**	**18.9**	**10.3**
*coastal ** *				13.1	1.5
*stream channel **	0	0	15.8	5.8	8.8
Black Sea		**0.1**	**56.2**	**43.2**	**34.0**
*coastal ** *	0	0	0	37.1	4.3
*stream channel **		0.1	56.2	6.1	29.7
Marmara Sea	0	0	**7.4**	**11.7**	**5.2**
*coastal ** *				7.7	0.9
*stream channel **	0	0	7.4	4.0	4.3
Mediterranean Sea		**0.5**	**20.7**	**26.3**	**13.8**
*coastal ** *	0	0	0	25.2	2.9
*stream channel **		0.5	20.7	1.1	10.9
Inland	**100**	0	0	0	**10.2**
closed basin	100				10.2
Caspian Sea	0	**14.1**	0	0	**3.8**
stream channel		14.1			3.8
Persian Gulf	0	**85.3**	0	0	**22.8**
stream channel		85.3			22.8
Grand Total	**100**	**100**	**100**	**100**	**100**

** Perrenials streams*

*** Ephemeral and intermittent streams*

The distribution of basin types across various sea regions in terms of percentage area coverage is presented in Table 1. In the Black Sea, is the largest area of sea being drained, river basins make up 56% and coastal basins 43%, totaling 34% overall. In the Mediterranean Sea, river basins cover 21%, coastal basins 26%, totaling 14%. For the Aegean Sea, river basins account for 16%, coastal basins for 19%, totaling 10%. The Marmara Sea has 7% coverage from river basins, 12% from coastal basins, totaling 5%. The Persian Gulf is dominated by transboundary basins, Euphrates and Tigris, covering 85%, totaling 23% of Türkiye. The Caspian Sea shows 14% coverage from transboundary basins, totaling 4%. Upon refining our analysis and omitting inland basins and rivers that do not discharge into the sea from our borders, it becomes evident that 54% of Türkiye's total surface area drains into the Black Sea region. In the context of coastal basins, 37% of the surface area lies along the Black Sea coasts, followed by 22% along the Mediterranean coasts.

The provided Table 2 shows the distribution of various basin types across NUTS regions. Central Anatolia has the highest proportion of closed basins, accounting for 62%, followed by Eastern Anatolia at 17%. In terms of transboundary basins, Eastern Anatolia is predominant, with these basins comprising 81% of the region and 58.8% of all transboundary basins in Türkiye, primarily due to the Euphrates and Tigris river basins. The Mediterranean region has the highest percentage of river basins at 14%, encompassing 65% of the region. In the Aegean Region, river basins and coastal basins cover 75% and 15% of the area, respectively. Over one-third of Türkiye's coastal basin area is located in the Black Sea region (37%), where the topography features mountains running parallel to the sea. The Black Sea region accounts for only 14% of Türkiye's total surface area. However, when excluding transboundary and

endorheic basins, it is evident that more than half of the country's surface area drains into the Black Sea.

Although the Mediterranean and the Marmara regions account for 11.4% and 12.5% of Türkiye's total area respectively, it is evident that they collectively encompass half of Türkiye's coastal basin area. Together with the Black Sea region, these three regions host 85% of all Turkish coastal habitats, underscoring their significance. Overall, the Table 2 demonstrates a diverse distribution of basin types across various NUTS regions, with each region contributing proportionally to both the total area of each basin type and the total area of the region. In the table, basin types are evaluated numerically in two distinct columns. The column marked with a right arrow shows the percentage distribution of each basin type within that geographical region. The column indicated by the downward arrow presents the ratios of the basin type surface area within that geographical region to the total surface area of all basin types.

Table 2. The distribution of basin types across geographical regions

	% Coverages									
	Closed Basins		Transboundary Basins		River Basin		Coastal Basins		Region/TR Area	
NUTS Regions	↓*	→**	↓	→	↓	→	↓	→	↓	Total →→
The Mediterranean	9.5	8.5	0.8	1.8	14.4	65.0	24.4	24.6	11.4	100
Eastern Anatolia	17.0	8.9	58.8	81.1	3.7	9.9	0.1	0.1	19.3	100
Aegean	10.2	9.1	0.0	0.0	16.8	75.6	15.2	15.3	11.5	100
Southeastern Anatolia	0.0	0.0	35.6	96.1	0.7	3.9	0.01	0.01	9.9	100
Central Anatolia	61.9	29.7	4.7	5.8	26.6	64.4	0.2	0.1	21.3	100
Black Sea	0.0	0.0	0.1	0.2	19.1	69.8	36.7	30.0	14.1	100
Marmara	1.4	1.1	0.1	0.3	18.6	76.9	23.4	21.7	12.5	100
Total ↓↓	100		100		100		100		100	

*↓ Spatial proportion among basin types
**→ Basin type ratio of geographical region

The drainage basins that contribute to the Black Sea's hydrology extend into the Central Anatolia, Aegean, and Marmara Regions of our territory. Conversely, within the Aegean and Mediterranean Regions, hydrological inputs primarily arise from local catchment areas. Notably, the contributing drainage basins to the Black Sea stem from Türkiye's prominent rivers, namely the Kızılırmak, Yeşilırmak, and Sakarya Rivers, with their respective spatial extents illustrated in Fig. 4.

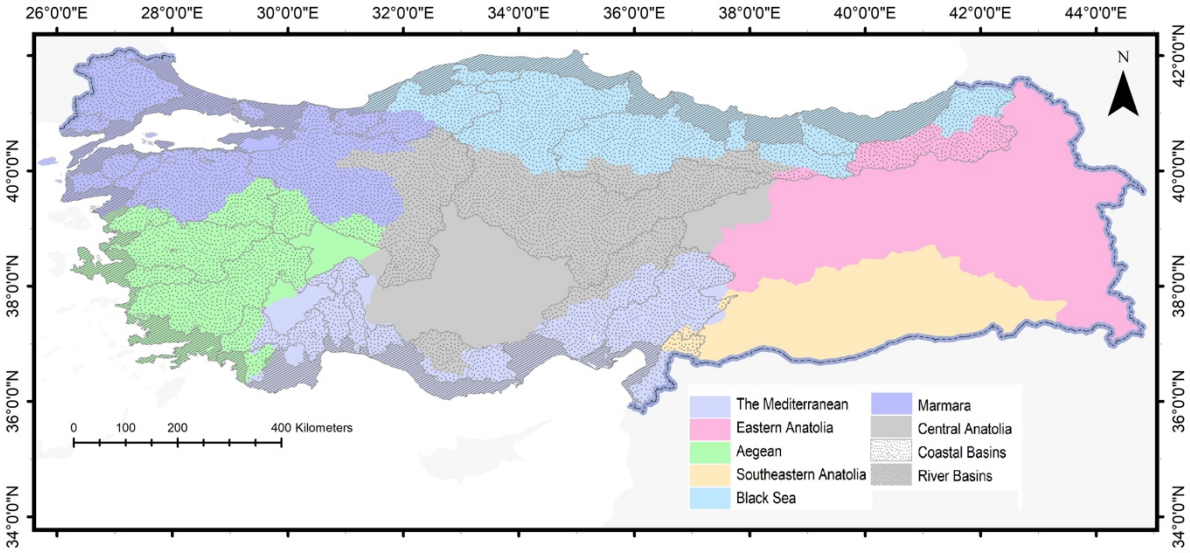

Fig. 4. The distribution of river and coastal basins according to NUTS geographical regions

Table 3. Basin type percentage distributions of coastal provinces

Area Distribution %	Closed Basins	Trans-boundary Basins	River Basin	Coastal Basins	Coastal Province Area %
Adana	0	0	**2.99**	1.89	**1.76**
Antalya	1.74		**2.16**	**11.51**	**2.62**
Artvin	0	0.1	1.69	0.66	0.97
Aydın			**1.84**	0.72	1.03
Balıkesir	0	0	**2.96**	2.75	**1.84**
Bartın			0.05	2.4	0.3
Bursa	1.26	0	**2.16**	0.76	1.33
Çanakkale			1.26	5.09	1.24
Düzce	0	0	0.53	0.42	0.32
Edirne			1.41	0.64	0.8
Giresun	0	0	0.76	4.5	0.91
Hatay		0.09	0.85	2.16	0.71
İstanbul	0	0	0.2	5.15	0.7
İzmir			**1.74**	5.71	**1.56**
Kastamonu	0	0	**2.51**	3.28	**1.67**
Kırklareli		0.13	1.12	1.88	0.83
Kocaeli	0.02	0	0.11	3.28	0.44
Mersin	0.35		**1.93**	**8.68**	**2.03**
Muğla	0	0	1.26	**8.5**	**1.63**
Ordu			0.53	4.24	0.76
Sakarya	0	0	1.11	0.4	0.62
Samsun			1.18	5.62	1.26
Sinop	0	0	0.62	3.53	0.73
Tekirdağ			1.08	2.15	0.8
Trabzon	0	0	0.01	5.17	0.6
Yalova	0.02			0.86	0.1
Zonguldak	0	0	0.39	1.8	0.41
Rize			0.02	4.25	0.5
Percentage of Basin Types in Coastal Provinces Relative to Türkiye's %	**3.4**	**0.32**	**32.49**	**97.98**	**28.49**

The evaluation results conducted on a coastal province basis using overlay analysis are presented in Table 3. In this table, coastal province area gives the percentage of coastal provinces' land area compared to the total land area of Türkiye. Similarly, the values in basin type columns indicate the percentage of these basin types within coastal provinces relative to their total areas across Türkiye. Upon examining the values therein, it is evident that while the percentage distribution of river basin areas is relatively small, coastal provinces exhibit a notably higher distribution of coastal basin areas. Coastal provinces constitute 28% of the total surface area of Türkiye. The proportion of river basin area in coastal provinces to the total river basin area of Türkiye is 32%, whereas the proportion of coastal basin area in coastal provinces to the total coastal basin area of Türkiye naturally stands at 98%. The provinces with the largest river basin area proportions are Adana, Balıkesir, Kastamonu, and Antalya, respectively. In terms of coastal basin proportions, the ranking is as follows: Antalya, Mersin, Muğla, İzmir, Samsun, Trabzon, and İstanbul. In Table 3, data bars are gradient-filled to enhance the readability of the table. Here, in addition to the importance of Antalya, Mersin and Muğla provinces as we know, it has been revealed that they are important coastal provinces in terms of coastal basins. In the studies to be conducted in these provinces in terms of coastal zone management, it is seen that small coastal basins are more important than the river basin considered in traditional management practices.

4. Discussion

Coastal zones have become increasingly important since the 1970s due to on-going destruction and anthropogenic pressures. Efforts in coastal zone management and river basin management aim to mitigate these adverse impacts. While river basin management primarily focuses on water resources, ICZM necessitates a more specialized management approach due to its dependency on various resources. Coastal zones are characterized by diverse uses and denser populations compared to inland areas worldwide. Establishing such smaller coastal catchments/ basins defined in this study can facilitate more effective governance.

When we look at the scope of the ICZM spatial plans or basin-based plans carried out in Türkiye, it is seen that coastal basins are not specifically mentioned. In these plans, it is seen that a framework is determined according to administrative units or regions or basins. Basin management plans consist of 26 basins delineated according to the hydrological characteristics of the major river basins and their surrounding regions. The plans rely on existing structures for decision-making systems, avoiding the need for specialized legislation and new management infrastructure. However, according to the principles of integrated and ecosystem-based management, dynamic and unique coastal regions require flexibility and adaptability in decisions.

The novelty of this study is to reveal the findings that will pave the way for the special structure of coastal basins to be included in monitoring and decision-making processes. Analysing the distinctions of coastal basins within the context of provincial, drained, or geographical regions reveals deficiencies in current approaches. The primary issue is the need to conduct monitoring studies on carrying capacities and environmental pollution in coastal basins. Conducting detailed studies on a larger geographical scale or on a river basin basis in coastal areas with population and pollution pressures, as demonstrated by Marquez et al., may enhance efficiency in terms of both time and cost.

This distinction is becoming more apparent in various monitoring and evaluation aspects of coastal zone management studies worldwide. The proportion of coastal basins to the total surface area in our country is significant, close to one-fifth at 18%, when assessed together with the streams drained into our seas. In the study of the Baltic Sea [12], which is an inland

sea like the Black Sea, the spatial percentage of coastal basins shows a similarity with Türkiye. The separate evaluation of coastal basins in terms of environmental effects reveals pressure discrepancies previously unnoticed. Considering population distribution and densities in coastal regions, similar pressure situations are evident in our country [20, 21]. This study sheds light on overlooked areas in future planning and strategy studies, or adaptive renovation of former projects. Monitoring and decision-making processes are successive processes. It has also been seen in literature that these coastal basins, which appear smaller compared to the basin and provincial areas, do not participate in the monitoring evaluation processes in the usual processes in the world.

Management entities are tasked with assessing and mitigating the utilization of resources, pollution, and pressures, especially concerning water resources. However, in the basin management plans made in our country [22], it is not investigated how coastal basins have an impact on environmental degradation [23]. When we look at the Integrated Coastal Zone Plans of Directorate General of Spatial Planning of Ministry of Environment, Urbanisation and Climate Change [24], it is seen that the plans do not go far beyond spatial planning. National strategic plan studies conducted for water quality monitoring between 2012-2023, as well as those conducted for compliance with the implementation of the water framework directive, are observed to have insufficient focus on coastal basins. The examples presented in the literature have shown both the difference of water resource dynamics in coastal basins and the fact that environmental pressures can be as intense in coastal basins as in inland ones [11, 13, 14, 15].

5. Conclusions

The coastal regions of our country, strategically positioned and bordered by seas on three sides, face escalating pressure on their resources and sectors. This heightened importance underscores the growing significance of adopting an integrated management approach. Comparative analyses between coastal and inland areas starkly reveal the substantial difference, with coastal populations far exceeding those of inland regions. A closer examination of coastal basins' areal coverage emphasizes the criticality of addressing coastal management issues in provinces directly affected. The comparative spatial assessments garnered from the study are anticipated to illuminate the needs and priorities of our country in coastal zone management.

For instance, the Mediterranean coastlines alone occupy 24% of Türkiye's land area, accommodating diverse human activities and ecological habitats. Particularly, the Black Sea basin receives runoff from approximately 54% of the country's total surface area, underscoring the significant role of rivers such as the Kızılırmak, Yeşilırmak, and Sakarya in the region's hydrological dynamics. Considering the Black Sea region, which is adjacent to an environmentally vulnerable inland sea and its critical habitats, a coastal basin perspective clarifies regional environmental pressures and hazards such as erosion and flooding, while also emphasizing the importance of addressing marine pollution within broader river basin management efforts. Excluding inland and transboundary basins, the proportion of coastal basins to the total surface area is 18%. Therefore, The Mediterranean and Marmara regions are notably more important as their percentages of coastal basins exceed their surface area proportions. This highlights the need for attention to settlements at coastal area, population dynamics of the coastal regions, and carrying capacity determinations in these regions.

Further provincial-level analysis unveils the disproportionate contribution of coastal provinces to coastal basin coverage compared to river basins, with these areas often extending significantly into provincial borders. Notably, provinces like Antalya, Mersin, Muğla, İzmir,

Samsun, Trabzon, and Istanbul emerge as pivotal centers, boasting the largest populations and economic activities. This comprehensive assessment offers valuable insights into Türkiye's coastal zones' hydrological dynamics and management challenges, guiding future strategies for sustainable coastal development and resource management. Adopting an integrated coastal zone approach and tailoring decisions to specific regional needs will undoubtedly yield more effective outcomes when addressing the management issues of these provinces.

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