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Article

Ecological landscape master plan according to landscape characterization in the case of Yalova Çınarcık District

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ABSTRACT

In the case of Çınarcık District, land suitability for settlement, agriculture, forest, and conservation was assessed based on potential, risk, and constraints. An 'Ecological Landscape Master Plan' was developed using GIS-supported Landscape Suitability Analysis (LANDEP) method. Character areas formed by landscape elements influence sustainable and conservation-oriented planning decisions. Natural structure components included 8 parameters, 57 criteria, and numerous sub-criteria. Analyses, synthesis, classification, and zoning were conducted to determine landscape structure. Landscape characterisation identified 7 regions and 92 sub-regions based on topography (19), soil (14), geology and geomorphology (21), hydrology (12), forest cover (9), protection areas (10), and risk factors (8). Approximately 83% of the area is prone to risks such as earthquakes, floods, landslides, and tsunamis. Of the earthquake risk zones, 5% of the area is currently inhabited, 1.8% is suitable with precautions, while 37.1% is unsuitable for settlement. About 4% of settlement areas lie on quaternary sedimentary ground, 2.3% on active fault lines, and 76% are located in coastal plains. The entire 8 km coastline is at tsunami risk. The central settlement sits on problematic young alluvial ground. Notably, 76% of buildings are over four storeys, and 320 are within the active fault line and 500 m protection zone, comprising 12% of all buildings. These risky zones must be classified as 'Exposure Areas,' with evacuation or demolition of vulnerable structures. Reconstruction should be based on microzonation and geological investigations. Notably, 70% of the area includes olive groves and agricultural and forest lands, which should be preserved to ensure sustainability.

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INTRODUCTION

According to the European Landscape Convention, countries are responsible for establishing ecological landscape master plans that prioritize cultural, environmental, agricultural, social and economic policies and planning to reveal the landscape structure and maintain its functions (European Landscape Convention, 2004).

Landscape planning aims to increase the value of landscapes, improve them and ensure integrity in determining future actions in the creation of new landscapes. The sustainability of the landscape's ecosystem services and its nature conservation functions is targeted throughout every stage of this process. The geology, geomorphology, topography, hydrology, soil structure, vegetation, climate structure and current land uses revealed by the natural structure constitute different landscape typologies in the land cover.

This pattern, shaped by unique, varied, and continuous elements within a landscape, defines its distinctive character. Landscape character types may differ across the world, yet remain homogeneous in terms of their intrinsic character. Landscape characters formed by natural components play a crucial role in guiding appropriate land use decisions, especially in determining suitable locations for settlements. Landscape Master Plans with an ecological approach are an effective planning tool in determining the appropriate conservation and utilization patterns for landscape structure at regional, country, city and local planning scales in ensuring nature conservation and sustainability (Uzun et al., 2012).

Çınarcık District, which had not been evaluated within this framework due to its richness of natural structure, diversity of landscape character areas and disaster risks due to its location, was selected as the research area.

MATERIAL AND METHOD

Material

In the literature review, documents such as institutional data, research reports, postgraduate theses, etc. were evaluated and field observations and controls were provided.

- Watershed, stream, wetland and flood boundaries from 1/25.000 scale Map General Directorate (HGM) digital data,
- Elevation, slope, orientation, geomorphological structure and units from 1/50.000 scale Digital Elevation Model (DEM) raster data,
- Soil structure, major soil groups, soil depth from 1/25.000 scale Ministry of Agriculture and Forestry digital soil map vector data format,
- Geology and geological formation from the General Directorate of Mineral Research and Exploration raster data format,
- Disaster and Emergency Directorate 2023 decisions on disaster prone areas,
- Geological structure, geological formation, earthquake zones, degree of erosion, fault lines, soil structure, flood boundaries from XML, PNG and JPEG formatted data from WEB map services of General Directorate of Geographical Information Systems,
- Current land uses were determined according to Land Monitoring Service (2018).

Method

Techniques applied in the process of creating basic base maps:

- Multiple layer operations, surface analysis, digitizing data with AutoCAD 2021 and ArcGIS Pro 3.2.2 software,
- Geographic Information System (GIS) supported analysis and synthesis,
- Obtaining land suitability maps with Optimal Suitability Analysis (LANDEP) method,
- Visual data were edited with Adobe Photoshop 2024 software.

Steps of the research:

1. Data content collection, database creation, scaling,
2. Revealing the landscape structure and attributes to support analysis and synthesis, and developing foundational base layers,
3. Thresholds such as protected and risk areas, protection statuses, restrictions according to natural components,
4. Determination of parameters, criteria and sub-criteria of landscape suitability analysis,
5. Analyzes and synthesizes according to land use suitability,
6. Landscape characterization and zoning based on the results of analysis and synthesis,
7. Categorizing land according to its suitability levels, including classifications such as suitable, unsuitable, precautionary, restricted, and high-risk,
8. Conducting a re-assessment of land cover through overlay analysis based on land use suitability,
9. Identify and draw conclusions,
10. Creating an "Ecological Landscape Master Plan" and making recommendations (Figure 1).

Optimal Suitability Analysis (LANDEP) Method, determination of parameters and criteria:

LANDEP is a comprehensive landscape analysis, synthesis and land-use-optimization system that investigates the most appropriate use of the landscape (Ndubisi, 2002; Tozar, 2006; Tozar et al., 2006; Forman, 2008; Ndubisi, 2014).

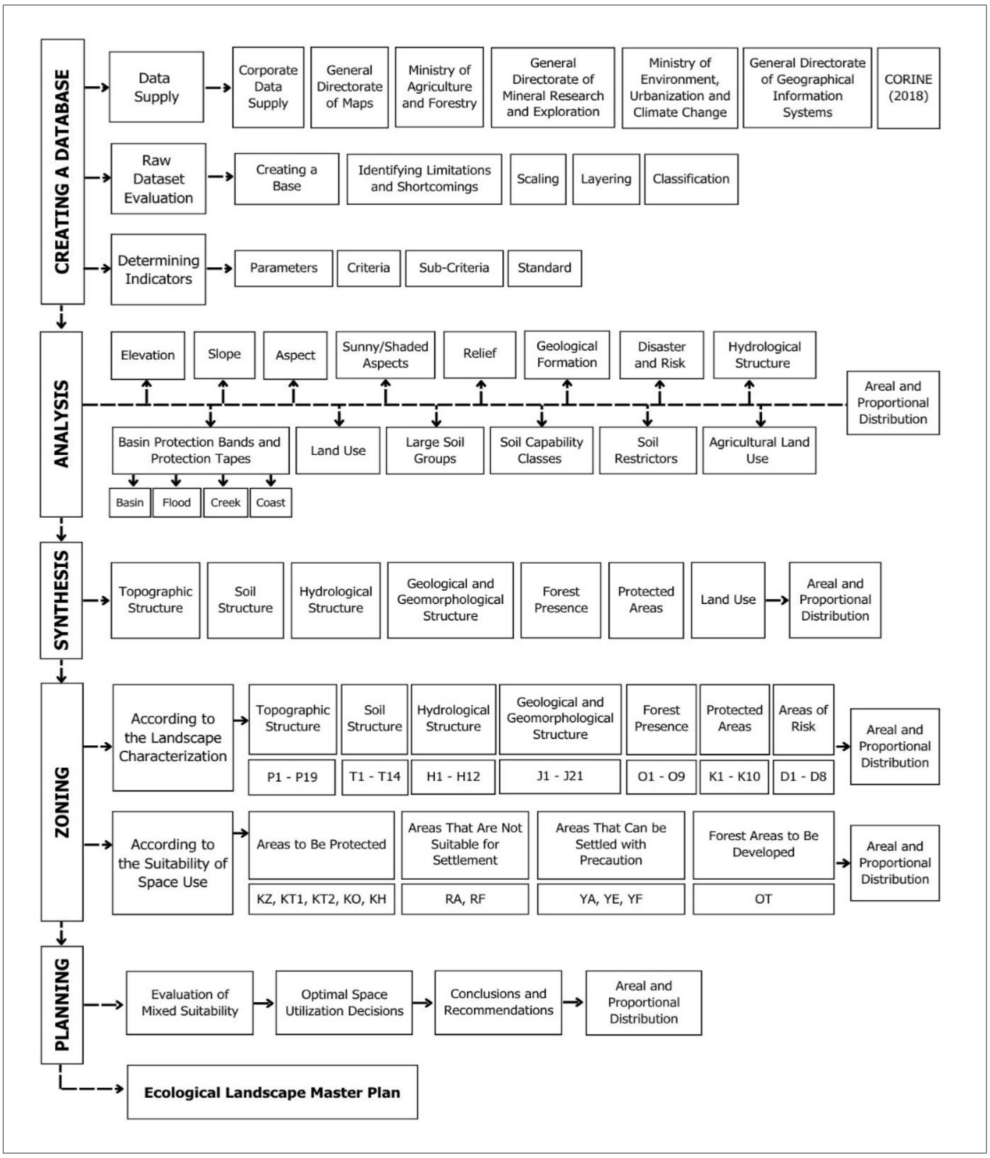

Figure 1. Ecological landscape master plan method scheme.

In ecological planning, it is of great importance to first determine the factors that influence the determination of land uses. Natural components as parameters have been investigated in detail within the scope of approximately 50 studies and 27 literatures according to different specializations.

As common assumptions determined in this context, 8 main parameters, 57 criteria, and other sub-criteria, including topographic, hydrological, soil, geological and geomorphological structure, presence of forest area and forest functions, protected areas, land use were determined and evaluated in the research.

The raw data set was created and homogeneous ecological units were revealed through analysis and synthesis. Similar landscape units were grouped and homogeneous landscape character regions were determined (Table 1).

FINDINGS

Research Area Çınarçık District Location and General Characteristics

The research area covers Çınarcık district of Yalova province, Turkey. It is between 29˚12´40´´ and 29˚18'50´´ east longitude, 40˚37´13´´ and 40˚39´55´´ north latitude and its size is 174 km² (Figure 2), (Yalova Municipality, 2024).

The district covers 4 municipalities, 13 neighborhoods and 4 villages, namely Çalıca, Kocadere, Şenköy, Ortaburun, on the Armutlu Peninsula, an extension of the Northern Anatolian Mountains descending towards the west. It borders the Marmara Sea to the north and is 30 meters above the sea (Yalova Governorship, 2025).

The first traces of settlement in the region belong to 3-4 thousand years BC. Phrygians in 1220 BC, Cimmerians in 700

Table 1. Ecological Landscape Master Plan analysis parameters, criteria and sub-criteria.

Parameter	Criteria	Sub Criteria
Topographic Structure	Slope (%)	0 - 20, 20 - 30, 30 and above
	Orientetion	Sunny (S, SW, SE, E, W) more suitable for settlement, Shady (N, NW, NE) less suitable for settlement
Hydrological Structure	Presence of rivers	Stream Protection Band (150 m) Buffer Zone Settlement Prohibited Area
	Catchment boundary and protection zone	1. Absolute Basin Protection Band (0 -300 m) and 2. Short Distance Catchment Protection Zone (300 - 800 m) area prohibited for settlement
	Flood protection area Flood repetition value (Q)	The area within Q 50, Q 100 and Q 500 values and Flood Protection Zone (250 m) is unfavourable for settlement
	Coastal asset	Coastal Protection Band (100 m) Buffer Zone area forbidden for settlement
	Presence of water surface	Dam, Lake, Pond area forbidden for settlement
	Irrigation area and facilities	Canal and canal settlement prohibited area
Soil Structure	Large land groups	Alluvium and Colluvium Soil 1st degree suitable for agriculture
	Land use capability classes (LUCC) Soil limiting factors	Calcareous Brown Forest Soil-Calcareous Brown Forest Soil not suitable for agriculture
		Class I. ECSC 1st degree suitable for agriculture Absolute Agriculture
		II and III class LUCC, 2nd degree suitable for agriculture
		Class IV LUCC restricted, agriculture can be done with precautions
		Class VI and VII LUCC suitable for settlement
		Class VIII LUCC suitable for forest and meadow-pastur
		Erosion (e) problematic soil
		Wetness (w) problematic soil
		Erosion and Salinity (es) problematic soil
		Soil limited, agriculture can be done with precautions
Geological Structure and Geomorphological Structure	Geological formation Soil liquefaction status	Quaternary sediments, Sarısu Volcanite, Fıstıklı Granite, Arslanbey Formation, Young Alluvial objectionable for settlement
	Fault line presence Fault type	Dead Fault (15 m), Dead Fault Protection Zone (150-500 m) Buffer Zone not suitable for settlement
	Erosion degree Earthquake zone	Grade 3 and 4 high severity erosion not suitable for agriculture
	Earthquake zone	1st degree earthquake zone precautionary habitable area
	Geomorphological unit	Coastal plain, coastal plain, low plateau, high plateau, river valley mountainous area
Forest Asset	Woodland zone boundary and functions	Public health, aesthetics, soil, water and nature conservation, recreation and tourism, forest production, non-forest area, treeless forest area use according to function
Areas to be Protected	Forest presence, stand structure and woody species	Coniferous, broad-leaved and mixed forest Stand type, forest, scrub, heathland
	Floristic structure elements	Endemic plant presence not suitable for settlement
	Agricultural land character, Agricultural pattern	Agricultural areas with wet, dry, irrigated, irrigated, natural vegetation, olive grove, pasture area not suitable for settlement
	Protected area presence, Protection status	National Park, Natural Park, Important Plant Area, Urban, Archaeological and Natural Protected Area prohibited area for settlement
Land Use	Land cover	Settlement, agriculture, forest, meadow and pasture area etc.

S: South; SW: Sout west; SE: South east; E: East; W: West; N: North; NW: North west; NE: North east; LUCC: Land use capability classes; ESCS: European Soil Classification System

BC, Vitrinians in 3 BC, Romans in 74 BC and Turks in 1307 BC. There are many historical monuments such as the Obelisk from the Roman Period, Kocadere Castle and dungeons from the Byzantine Period, churches and monasteries from the Greek Period, Çınarcık Great Mosque from the Ottoman Period, aqueducts and tanks (Yalova Governorship, 2024).

Summers in the region are hot and dry, while winters are mild and rainy. It has a transition feature between the Mediterranean and Black Sea climates. The temperature decreases from the sea coast to the inland and higher elevations, and the annual temperature difference of 14.2 °C increases the diversity of vegetation (Dönmez, 1985).

70% of the area is mountainous and the highest altitude is Dumanlı Hill (987 m) and 11% is the rivers and coastal valleys formed by Deveboynu and Soğuksu, Büyükdere and Taşlimanı streams (Yalova Municipality, 2024).

The Armutlu Peninsula, where the site is located, is dominated by Mediterranean and Euro Siberian flora in terms of floristic structure. In forest areas, broad-leaved woody species such as Hornbeam (*Carpinus betulus*), Chestnut (*Castanea sativa*), Beech (*Fagus orientalis*), White Poplar (*Populus alba*), Ash (*Fraxinus angustifolia*), Linden (*Tilia argentea* Desf ex DC.), Sessile Oak (*Quercus petraea*), Eastern Pine (*Platanus orientalis*) and coniferous woody species such as Larch (*Pinus nigra*), Yellow Pine (*Pinus silvestris*), Pistachio Pine (*Pinus pinea* L.) and Red Pine (*Pinus brutia*) (Bilgin, 1967).

The area, which is 1.5 hours away from Istanbul by private car and 1 hour away from Bursa, is accessible by ferry.

The district's appeal is enhanced by attractions such as the historical Pasha Port, Kocadere, Dikilitaş, Dermaz, Baba, Mersin, Kalem, Çalıvere Cape, Osman Uçuğu, and Engerek Bay; its natural beaches; Erikli, Karlık, and Delmece Plateaus; Sudüşen and Erikli Twin Waterfalls; Hersek Lagoon; Büyük Dipsiz Lake and Küçük Dipsiz Lake; the sacred Ayazma springs; Armutlu Hot Springs; historic forest villages. Yalova's top-priority thermal springs and drinking water sources located just 16 km away.

With its tourism potential due to its accessibility, nature and cultural richness, the winter population is 40632, while the population exceeds 500000 in summer (Yalova Governorship, 2024). Between 1992-2007, the settlement areas on the northern coasts of the Armutlu Peninsula have expanded three times and Çınarcık District is one of them (Özdemir & Bahadır, 2008a). In the 7.4 magnitude 17 August 1999 Izmit Gulf Earthquake, the district was significantly affected due to unplanned construction, building construction conditions according to the soil conditions and non-compliance with the coastal law, etc. (Özdemir & Bahadır, 2008b). The number of deaths in eight provinces including Yalova in the earthquake impact area is 17480 people, 362 people died and 6042 people benefited in Çınarcık District. The total of 628 heavily and 558 moderately damaged buildings in Çınarcık District centre is 4.43% (Özmen, 2000).

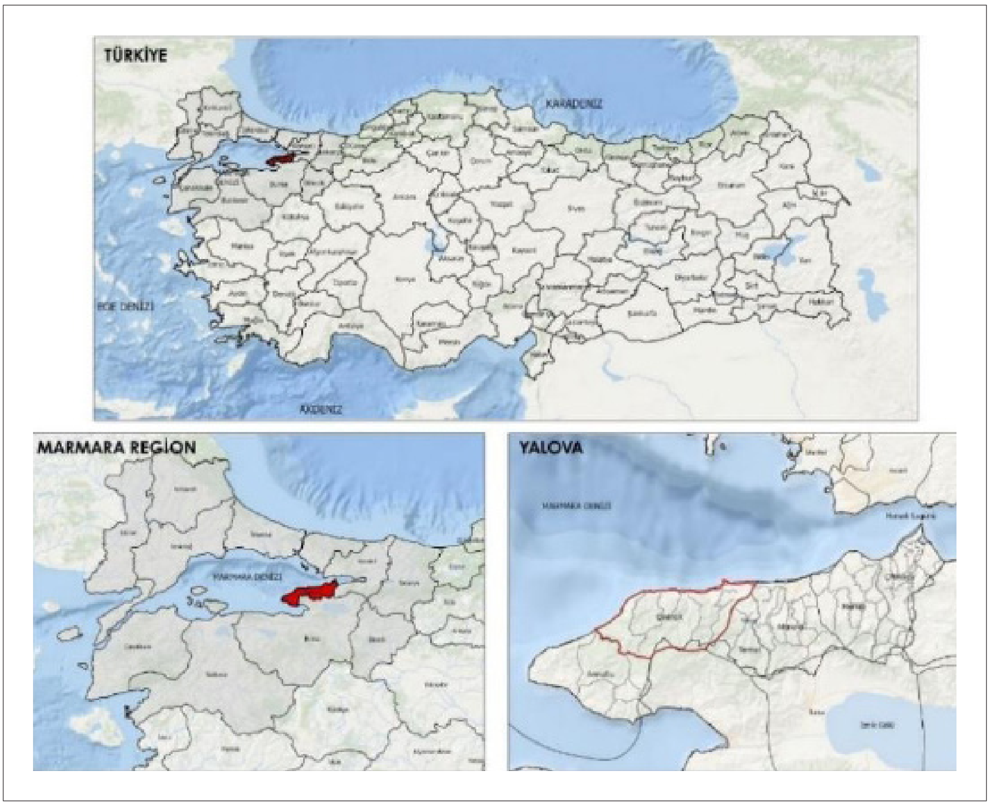

Figure 2. Yalova province and Çınarcık district location.

Landscape Characterization and Zoning

In determining the landscape characterisation of the research area, elevation, slope, aspect, orientation, relief, geological formation, disaster and risk status, hydrology, basin protection area, land use capability, large soil groups, soil limiting factors, current land use cover, agricultural land use and forest presence were analysed (Figure 3).

According to land use, 8% is settlement, 5.7% is marginal agriculture, 4.1% is meadow-pasture, 4% is planted agriculture, 2.1% is absolute agriculture, 1.4% is special crop land, 0.1% is water and 80% is forest area. 70% of the area is mountainous and the highest altitude is Dumanlı Hill (987 m).

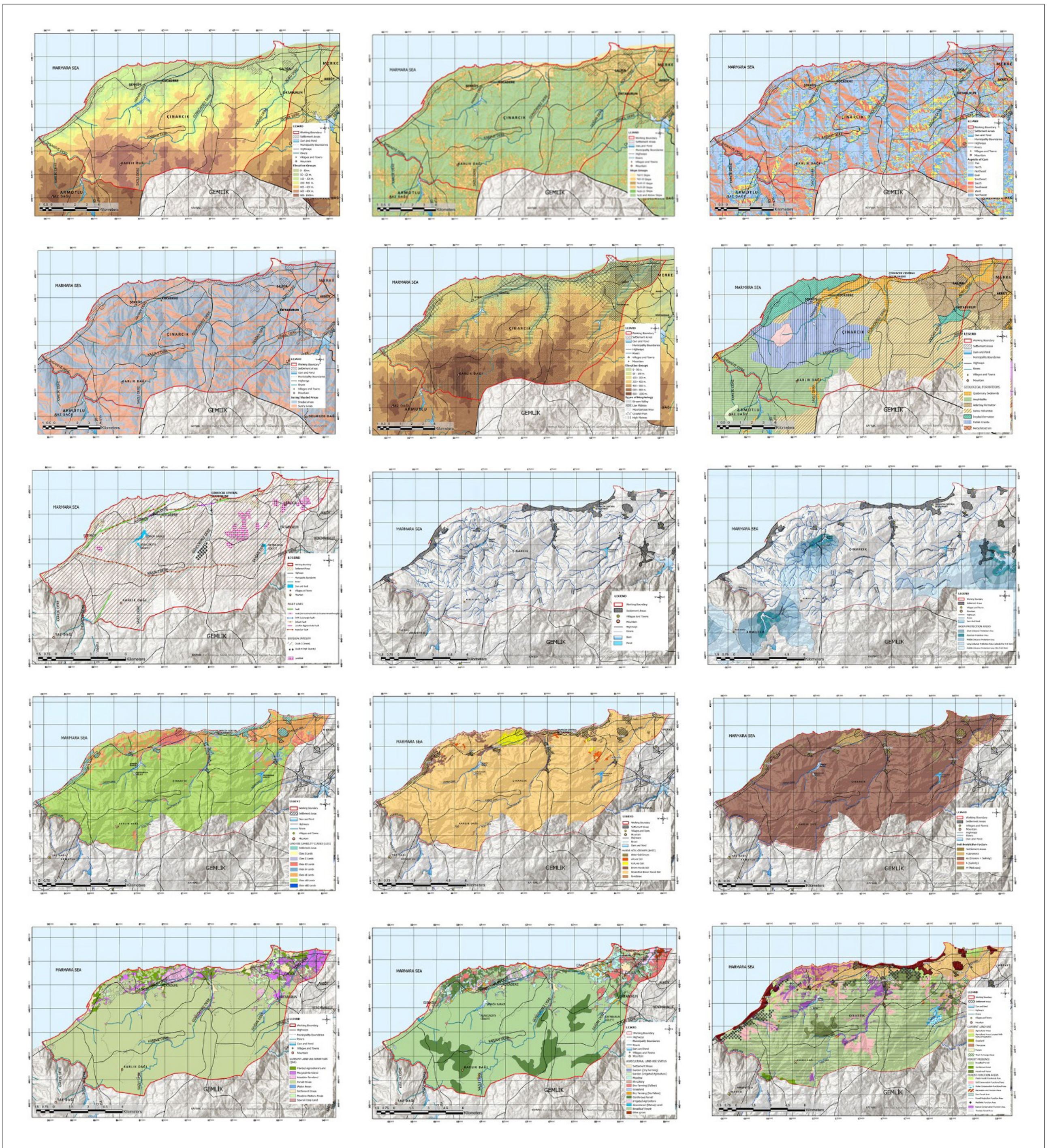

Figure 3. Analysed research area by elevation, slope, aspect, orientation, relief, geological formation, disaster and risk status, hydrology, basin protection area, land use capability, large soil groups, soil limiting factors, current land use cover, agricultural land use and forest presence.*

57% of the area has a slope of over 30%, 11% it is a river and coastal valley formed by Deveboynu and Soğuksu, Büyükdere and Taşlimanı streams. 58% of the settlement area is in coastal plains, plains and valleys at 0-50 m. elevation.

Landscape Characterization and Zoning According to Topographic Structure

Dividing the natural structure into smaller units based on physiographic differences and classifying them in relation to land use, morphology and slope emerge as key parameters. In this context, 19 sub-regions were identified. The P9 region, which comprises 48% of the area, is the largest, characterized by mountainous forest land with slopes over 30%. About 3% of the area corresponds to coastal plain settlements in P1 and P3, 1% to low plateau areas in P14, and 4% to river valley typologies in P3 (Table 2; Figure 4).

Landscape Characterization and Zoning According to Soil Structure

Soil structure is a key parameter in determining the suitability of areas for settlement, absolute agricultural use, and forestry, as well as in identifying appropriate growing environments (T.C. Resmi Gazete, 2005; T.C. Resmi Gazete, 2017).

According to the Handbook on Integration of Geoscientific Data into Planning and Provincial Disaster Risk Reduction Plan Preparation Guide Module 1, soils in Class I, II and III land capability are areas unsuitable for settlement (UOA) (Afet İşleri Genel Müdürlüğü, 2006; İl Planlama ve Risk Azaltma Daire Başkanlığı, 2020).

These areas are "Absolute Agricultural" areas that should definitely be used for agricultural activities. Accordingly, sub-regions were determined by taking large soil groups, land use capability classes and soil limiting factors as criteria in zoning.

Landscape Characterization and Zoning According to Major Soil Groups

In terms of major soil groups, there are 5 different soil types in the area: Alluvial, colluvial, brown forest soils, brown soils without lime and rendzinas.

Brown forest soils develop on calcareous bedrock and are generally found on very steep, rugged slopes. Due to their shallow to very shallow depth, they are prone to severe erosion and stoniness problems (T.C. Resmi Gazete, 2005). They make up 3% of the area and are used as forest, shrubland, and pasture. On suitable slopes, they can also

Table 2. Zoning according to topographic structure, areal and proportional distribution.

Subregion	Criteria and Sub Criteria			Area (ha)	Ratio (%)
	Land Use	Morphological Structure	Slope Groups (%)		
P1	Settlement	Coastal plain	0-30	272	2
P2	Settlement	Stream valley	0-30	29	0.2
P3	Settlement	Coastal plain	30 and above	242	1
P4	Agriculture	Coastal plain	0-30	615	4
P5	Agriculture	Stream valley	0-30	825	5
P6	Agriculture	Mountainous area	0-30	414	2
P7	Agriculture	Mountainous area	30 and above	563	3
P8	Forest	Mountainous area	0-30	2523	15
P9	Forest	Mountainous area	30 and above	8002	48
P10	Forest	Stream valley	0-30	322	2
P11	Forest	Stream valley	30 and above	863	5
P12	Forest	High plateau	30 and above	423	3
P13	Forest	High plateau	0-30	242	1
P14	Settlement	Low plateau	0-30	95	1
P15	Agriculture	Low plateau	0-30	642	4
P16	Forest	Low plateau	0-30	308	2
P17	Forest	Coastal plain	0-30	98	1
P18	Forest	Coastal plain	30 and above	113	1
P19	Agriculture	Coastal plain	30 and above	201	1
Total				1679	

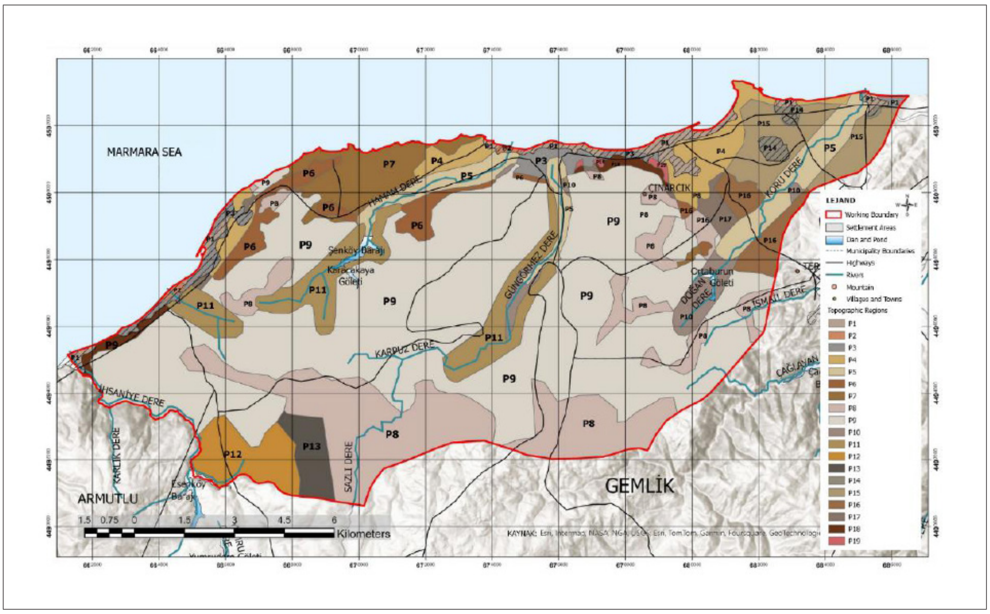

Figure 4. Agricultural land use analysis.

be used for dry farming and fruit cultivation. Brown forest soils without lime, meadow forest lands are transitional soils and generally shallow and shallow soils. The natural vegetation is dominated by forest cover and meadow plants, coniferous forests and meadow formation maquis.

Alluvial soils are deep, flat and nearly flat sloping with little or no erosion hazard. They have good water permeability, rich in mineral and organic matter and fertile. Since they are suitable for growing all kinds of cultivated plants, they have a very high agricultural value It is 19% in the area and is observed in the coastal areas of Çınarcık center settlement, Ortaburun and Esenköy.

Colluvial soils are formed by the accumulation of eroded materials from slopes at the foothills where the gradient decreases. They contain fine materials such as sand, clay and shale in different sizes and have good drainage as they are located in sloping areas. They have agricultural value and can generally be used as dry agricultural land (T.C. Resmi Gazete, 2005). They make up 5% of the area, and the colluvial soils with Class I land capability are considered fertile for agricultural production due to their high mineral content and strong water retention capacity.

Rendzinas are located on medium to high slopes and have low water retention capacity due to the compact nature of the bedrock. Plants can often be damaged by drought, they rapidly lose their organic matter when cultivated and may be subject to severe erosion (T.C. Resmi Gazete, 2005). In the area, these soils are 3 ha and 1% is in Teşvikiye town. In 68% of the area, the land is used as forest and pasture, and agriculture can be practiced on slopes with suitable gradients.

Landscape Characterization and Zoning According to Land Use Capability

In order to ensure the proper use of agricultural lands, soils are classified according to their importance for agricultural use. Land use capability is an important parameter that determines the necessary protection measures and the limits of suitability according to soil cultivation and use patterns. The first four classes of lands have a good soil structure, cultivated plants adapted to the region and forest and meadow plants can be grown well. Class III and IV lands are the last limit of irrigable agricultural lands. They have problems such as erosion and slope, and are less suitable for agriculture compared to Class I and II lands. Especially in sloping areas, problems such as shallowness, stoniness and flooding are noticeable. Class V, VI and VII lands are suitable for the growth of natural vegetation adapted to the region. Some special cultivated plants can also be grown in Class V and VI lands by taking necessary water and protection measures. Class VIII lands are generally lands where there is no or very little soil cover and agriculture is very difficult and uneconomical (T.C. Resmi Gazete, 2005).

The total of the first three classes of land with high productivity in terms of soil capability in the area is 15%. Class I is very limited with 3%, Class II with 1% and Class III with 11%. Soils where crops such as shrubs and trees are grown are class IV land with a rate of 13%. 33% of class VI and 43% of class VII soils are not suitable for agricultural production and are used as forest land

Landscape Characterization and Zoning According to Soil Limiting Factors

In terms of agricultural performance, soil limiting factors erosion, wetness, stoniness, salinity are important parameters. They are the factors that determine the agricultural pattern and agricultural feasibility according to their single and/or coexistence in the soil structure. The soil limiting factor that restricts agricultural activities and is dominant in 87% of the area is erosion-salinity. Erosion factor is effective in Kocadere and Çalıca locations in 4 ha area with a rate of 10%. Wetness factor is in the coastal areas of Şenköy, Çalıca, Koru, Teşvikiye towns and Çınarcık center settlement in 1 ha area. Land use, large soil groups, land use capability classes (LUUC), soil limiting factors were taken as criteria in zoning and 14 sub-regions were determined. T14 region is forest area, non-calcareous forest soil and class VII land and is the largest sub-region with 71%. T13 is the second largest sub-region with 15% of agricultural area, non-calcareous brown forest soil and class VI land. In both regions, erosion and salinity are the major limiting factors (Table 3; Figure 5).

Landscape Characterization and Zoning According to Hydrological Structure

An important parameter related to hydrological structure in the process of making land use decisions is the presence of a watershed. According to the EU Water Directive, the Flood Regulation and the Flood Protection Law, flood risk potential should be determined in river basins and areas exposed to flooding (Water Directive, 2007; T.C. Resmi Gazete, 2021; T.C. Resmi Gazete, 2016). According to the Regulation on Preparation, Implementation and Monitoring of Basin Management Plans, basin areas are water catchment areas. They have the functions of controlling erosion and flooding in the rainfall basin and producing water of good quality and quantity (T.C. Resmî Gazete, 2012). Appropriate land use types and conditions have been determined according to 4 protection distances in the basins. According to İRAP Module 1, water catchment basins and 1st and 2nd degree basin protection bands should be determined in terms of settleability (İl Planlama ve Risk Azaltma Daire Başkanlığı, 2020). 1st Degree Basin Protection Zone: The 'Absolute Protection Area' consists of natural and artificial water bodies used for drinking and utility water supply, and includes a land strip 300 meters wide measured horizontally from the line where land meets water. 2nd Degree Basin Protection Zone: "Short Distance Protection Area" is the land area 700 m wide horizontally from the upper limit of the absolute protection area.

In both protection bands, settlement, agriculture, tourism and mining cannot be carried out in any way except for treatment facilities, and cemeteries cannot be established. Organic agriculture may be allowed in the short-distance protection area under the supervision of the relevant insti-

Table 3. Areal and proportional distribution of zoning according to soil structure.

Subregion	Criteria and Sub Criteria				Area (ha)	Ratio (%)
	Land Use	Large Soil Groups	Capability Class	Limiting Factors		
T1	Settlement	-	-	-	569	3.24
T2	Agriculture	Alluvial	III	Wetness (w)	59	0.34
T3	Forest	Brown Forest Soil	III	Erosion and Salinity (es)	65	0.37
T4	Agriculture	Brown Forest Soil	III	Erosion and Salinity (es))	85	0.48
T5	Agriculture	Colluvial	I	-	16	0.09
T6	Olive grove	Brown Forest Soil	VII	Erosion and Salinity (es)	198	1.13
T7	Forest	Brown Forest Soil	II	Erosion (e)	23	0.13
T8	Forest	Alluvial	II	Wetness (w)	54	0.31
T9	Agriculture	Calcareous Brown Forest Soil	IV	Erosion and Salinity (es)	94	0.53
T10	Agriculture	Colluvial	III	Erosion (e)	247	1.41
T11	Agriculture	Calcareous Brown Forest Soil	III	Erosion (e)	137	0.78
T12	Forest	Calcareous Brown Forest Soil	VII	-	855	4.86
T13	Agriculture	Calcareous Brown Forest Soil	VI	Erosion and Salinity (es)	2.646	15.05
T14	Forest	Calcareous Brown Forest Soil	VII	Erosion and Salinity (es)	12.530	71.28
				Total	17,578	

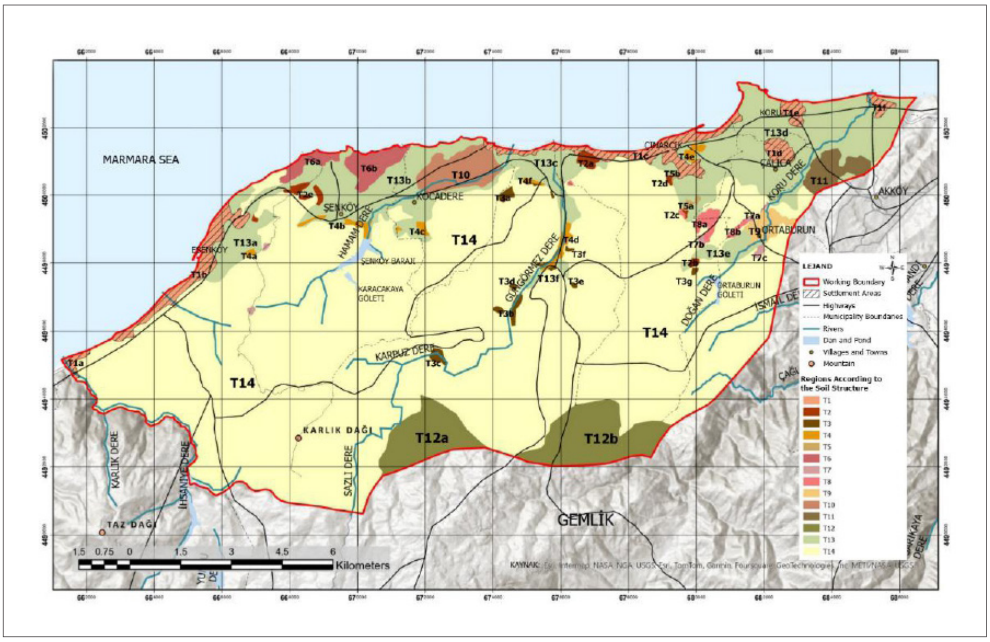

Figure 5. Landscape characterization and zoning according to soil structure.

tution (T.C. Resmî Gazete, 2012). Peak flow and flood recurrence intervals (Q value) are important parameters in determining flood risk areas according to water surface elevations in spatial plans at all levels (Water Directive, 2007; T.C. Resmî Gazete, 2014; T.C. Resmi Gazete, 2021).

Q max. project flow is 10 and headroom is 50 in the fields, 100 and headroom is 500 in villages, 500 and headroom is 1000 in big cities. Once in 100 years, areas subject to very rare and very high probability flooding should be identified (T.C. Resmi Gazete, 2016). River and coastal protection zone (250 m) is another important criterion (İl Planlama ve Risk Azaltma Daire Başkanlığı, 2020).

The coastal protection zone in the area is 32 km, 18 km of which is settlement area. Şenköy Dam (30 ha) is the most important water surface in the area. Basin protection bands cover an area of 16 ha and 10% is absolute protection, 19% is short, 25% is medium and 46% is long distance protection area.

In zoning, 12 sub-regions were determined by taking land use, watershed boundary, watershed, river and coastal protection bands, and irrigation areas as criteria. H10 zone is in forest use and occupies the largest area with 31.4%. H5 and H6 zones with 18% are in watershed protection band and forest area. H1, H4 and H11 zones with 4% are in river and coastal protection band and settlement area (Table 4; Figure 6).

Landscape Characterization and Zoning According to Geological and Geomorphological Structure

In terms of disaster history, 42 earthquakes of magnitude 6.8 and above and 24 tsunamis have occurred in the region since 400 AD (Sancaklı, 2004).

The Çınarcık Trench in the Sea of Marmara and the presence of the North Anatolian Fault Line (NAF), one of the most seismically resilient faults in the world, carry the risk of severe earthquakes and tsunamis (Gazioğlu et al., 2005).

The active fault is the most significant structural feature of the neotectonic formations surrounding the Armutlu Peninsula. It is divided into two branches, north and south, in the Armutlu Peninsula. One branch is located in Yalova region and continues in the Marmara Sea depressions in the east-west direction (Figure 7), (Emre, 1999).

In the area, the upper system of the geological structure belongs to the Cenozoic era, with the system classified as Quaternary, the series as Holocene, and four formations identified: Sarısu Volcanics (Ts), Fıstıklı Granite, Arslanbey Formation (Ta), and Alluvium (Qal). According to the proportional size of the geological formations, Sarısu Volcanites dominate with 44% and Fıstıklı Granite with 25%. The Arslanbey and Alluvium formations, which cover 13% of the area, are prone to liquefaction and are considered unsuitable for settlement. Alluvial soils contain clay, silt and sandstone, the most liquefaction prone soils are fine sands and silty sands. In general, clay soils are not susceptible to liquefaction, but they lose their strength during earthquake shaking and move to the surface with liquefying sands (Koç, 2007). Areas with liquefaction potential are defined as areas that are not suitable for settlement due to disaster hazards (UOA) and require detailed geological-geotechnical survey (DGI) and microzonation (İl Planlama ve Risk Azaltma Daire Başkanlığı, 2020). Approximately all of the built-up area in the area is on young alluvial soils and are areas with precautionary conditions and problematic areas such as swelling, settlement, liquefaction etc. where precautions can be taken.

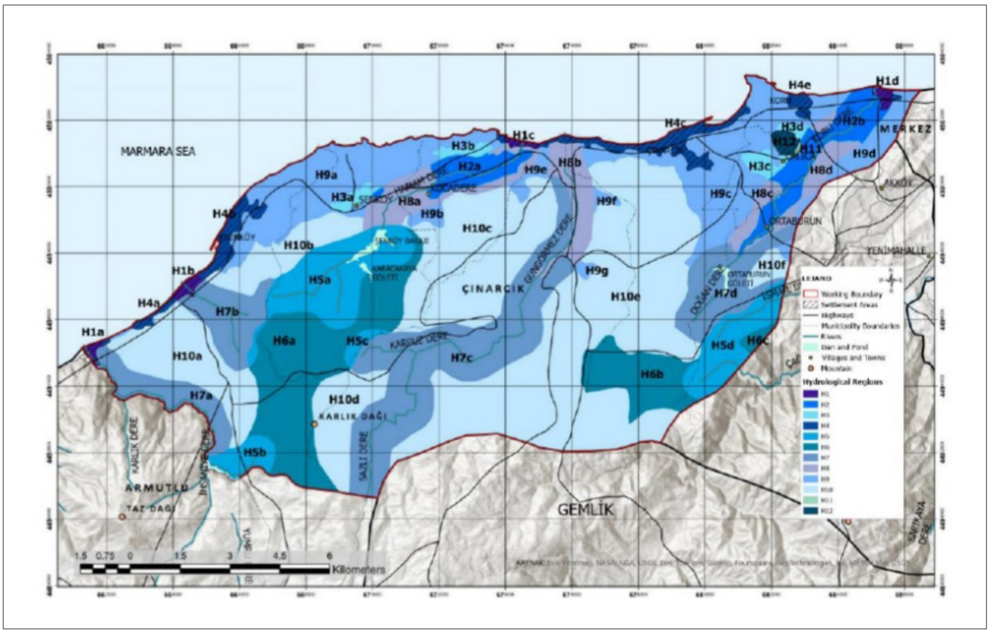

Figure 6. Landscape characterization and zoning according to soil structure.

Sarısu volcanics are widespread in the central part of the Armutlu Peninsula and are volcanic stacks consisting of andesitic lavas and agglomerates. This formation starts with a sedimentary level usually 5-10 m thick on metamorphic rocks. It consists of lithologies such as conglomerate, mudstone, sandstone and limestone and is problematic in terms of settleability (Yılmaz et al., 2010). Fıstıklı granite contains granitic rocks with different mineralogical compositions and is therefore suitable for settleability (Dereköy, 2006). Merkez Neighbourhood and Koru town are located on young alluvial soil and coastline with liquefaction potential. With over 4 storeys high-rise building stock and high ground magnification values, these are the neighborhoods that will be most affected by a possible major earthquake.

In the zoning process, 21 sub-regions were identified based on criteria including land use types such as settlement areas, forests, and agricultural lands; landslide risk zones; geological formations such as Quaternary deposits; erosion risk areas and their severity; and the presence of fault protection

Table 4. Zoning according to hydrological structure, areal and proportional distribution.

Subregion	Criteria and Sub Criteria					Area (ha)	Ratio (%)
	Land Use	Basin Protection Band	Stream Protection Band	Coastal Protection Band	Irrigation Area		
H1	Settlement		+	+		100	0.57
H2	Settlement		+		+	815	4.63
H3	Agriculture				+	199	1.13
H4	Settlement			+		469	2.67
H5	Forest	+	+			1353	7.70
H6	Forest	+				1834	10.43
H7	Forest		+			2933	16.69
H8	Agriculture		+			996	5.67
H9	Agriculture					3300	18.77
H10	Forest					5520	31.40
H11	Settlement		+			5	0.03
H12	Settlement					54	0.31
Total						17578	

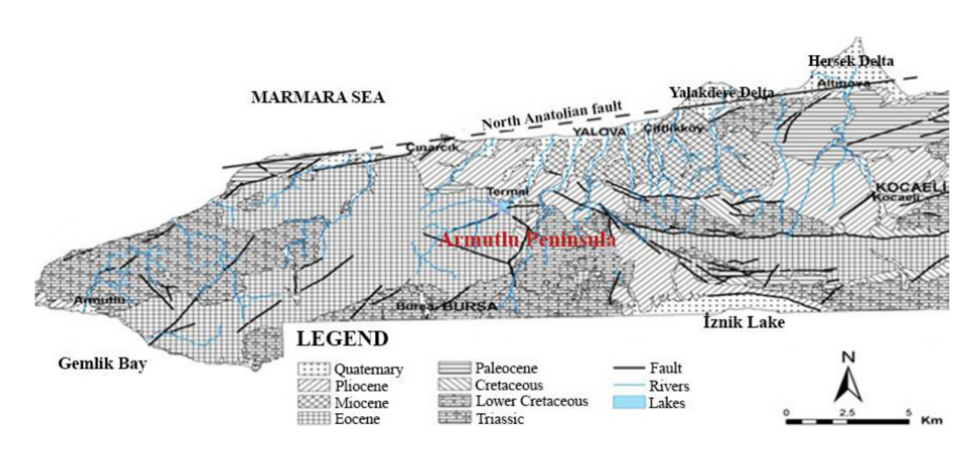

Figure 7. Geological map of Armutlu Peninsula (Özdemir & Bahadır, 2008a).

zones. J5 region covers 69.6% of the area and is the largest region with forest area and 3rd degree erosion risk. J1, J2, J4, J14, J16 and J19, which cover 5% of the area, are built-up areas, quaternary sediments, 3rd degree erosion or fault protection zone and earthquake risk areas. J20 zone is 1.2% of the area and is a landslide risk area. Ortaca Village settlement area is in this landslide risk zone (Table 5; Figure 8).

Landscape Characterisation According to Forest Areas and

Table 5. Zoning according to geological and geomorphological structure, areal and proportional distribution.

Subregion	Criteria and Sub Criteria					Area (ha)	Ratio (%)
	Land Use	Landslide Risk Area	Geological Formation	Erosion Degree	Protection Band		
J1	Settlement		Quaternary	3		35	0.2
J2	Settlement				+	24	0.1
J3	Forest			4		74	0.4
J4	Settlement		Quaternary		+	390	2.2
J5	Forest			3		12460	69.6
J6	Forest			3	+	187	1.0
J7	Forest	+		3		374	2.1
J8	Forest		Quaternary	3		368	2.1
J9	Agriculture		Quaternary			277	1.5
J10	Agriculture		Quaternary	3	+	33	0.2
J11	Agriculture			3		149	0.8
J12	Agriculture		Quaternary	3		821	4.6
J13	Agriculture	+		3		1735	9.7
J14	Settlement		Quaternary			209	1.2
J15	Agriculture			3	+	264	1.5
J16	Settlement			3	+	190	1.1
J17	Settlement					181	1.0
J18	Agriculture					86	0.5
J19	Settlement			3		32	0.2
J20	Settlement	+				15	0.1
J21	Agriculture	+				4	0.02
					Total 17907.30		

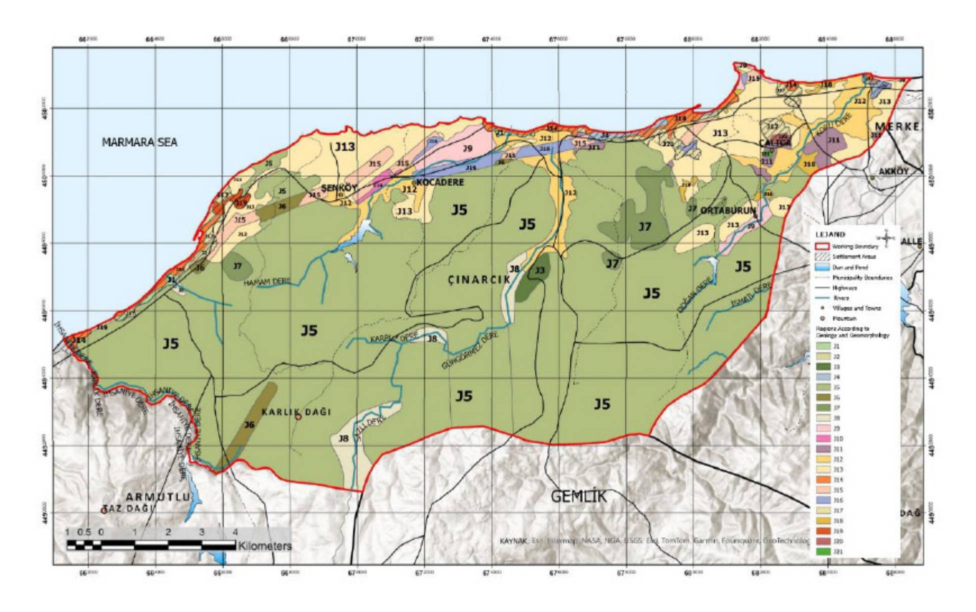

Figure 8. Landscape characterisation and zoning according to geology and geomorphological structure.

Functions 15% of the forest areas are in agriculture and olive grove production function and 3% of them have 16 endemic plant species.

The treeless forest area is located in Esenköy; the water protection zone surrounds the Ortaburun Pond; forests with agricultural-aesthetic functions are found around the central settlement; and the ecotourism area lies within the Armutlu district boundary.

In zoning, 9 sub-regions were determined according to land use and endemic plant species. The O3 region, which covers 58% of the area, is the largest area harbouring endemic species. O4 and O9 are agricultural areas covering 3% of the area and harbouring endemic species (Table 6; Figure 9).

Landscape Characterisation and Zoning According to Protected Areas

In the zoning, 10 regions and 26 sub-regions were determined according to land use, hydrology, protection bands and area criteria.

In the protected areas, 38% of the K4 region is under forest land use and covers the largest area.

Sub-region K1a is the only protected area with Şenköy Grade II Archaeological Site (Table 7; Figure 10).

Landscape Characterisation and Zoning According to Risk Factors

According to the disaster regulations and guidelines with

Table 6. Areal and proportional distribution of forest areas according to their functions.

Subregion	Criteria and Sub Criteria		Area (ha)	Ratio (%)
	Land Use	Endemic Species Presence		
O1	Forest	-	841	5
O2	Agriculture	-	2080	12
O3	Forest	+	9862	58
O4	Agriculture	+	90	1
O5	Forest	-	1455	9
O6	Agriculture	-	418	2
O7	Olive grove	-	196	1
O8	Forest	-	1737	10
O9	Agriculture	+	261	2
Total			1690	

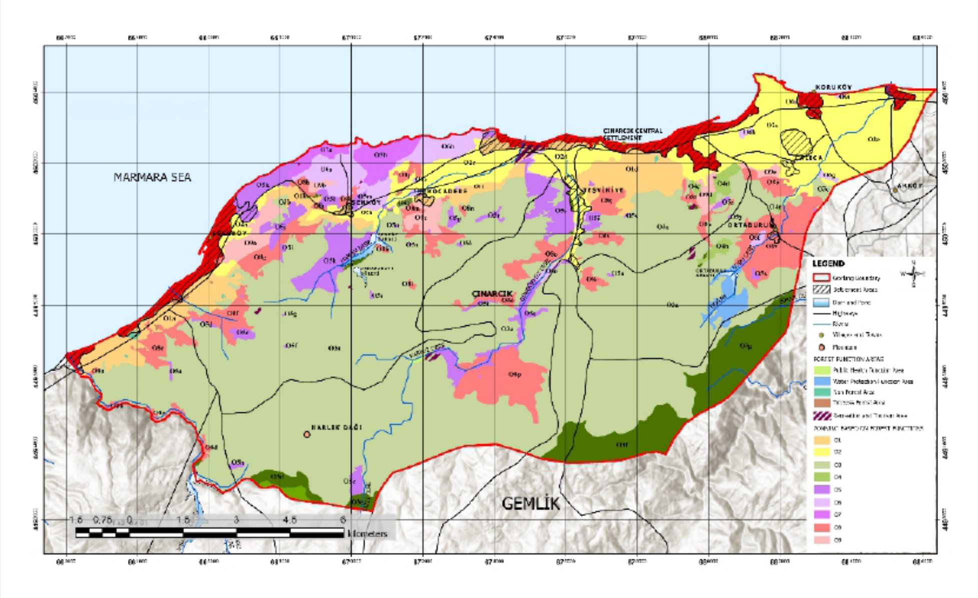

Figure 9. Landscape characterization and zoning of forest areas according to their functions.

the definition of 'Critical Area', lands within 15 m distance to fault lines, having geological structure that will increase earthquake intensity or having liquefaction potential cannot be subject to priority or intensive development (İstanbul Büyükşehir Belediyesi, 2002; Japon Uluslararası İşbirliği Ajansı, 2004; T.C. Resmî Gazete, 2007; İstanbul Valiliği, 2014; Afet ve Acil Durum Yönetimi Başkanlığı, 2023).

According to the maps of live fault lines, the areas within 15 m from the fault lines are determined as fault protection bands and are considered as areas unsuitable for settlement (Maden Tetkik Araştırma Müdürlüğü, 2019).

In terms of settleability, areas with slopes above 18-20% are problematic and precautionary areas. In terms of another type of disaster, there is a regional landslide risk in the zones dominated by geological formations with high slopes and suitable for weathering, low slopes and rich in alluvial sediments (İl Planlama ve Risk Azaltma Daire Başkanlığı, 2020).

Areas at risk of disaster are areas that are not suitable for settlement (UOA) and require detailed geological-geotechnical survey (DGI) and microzoning (MBA) (T.C. Resmî Gazete, 2014).

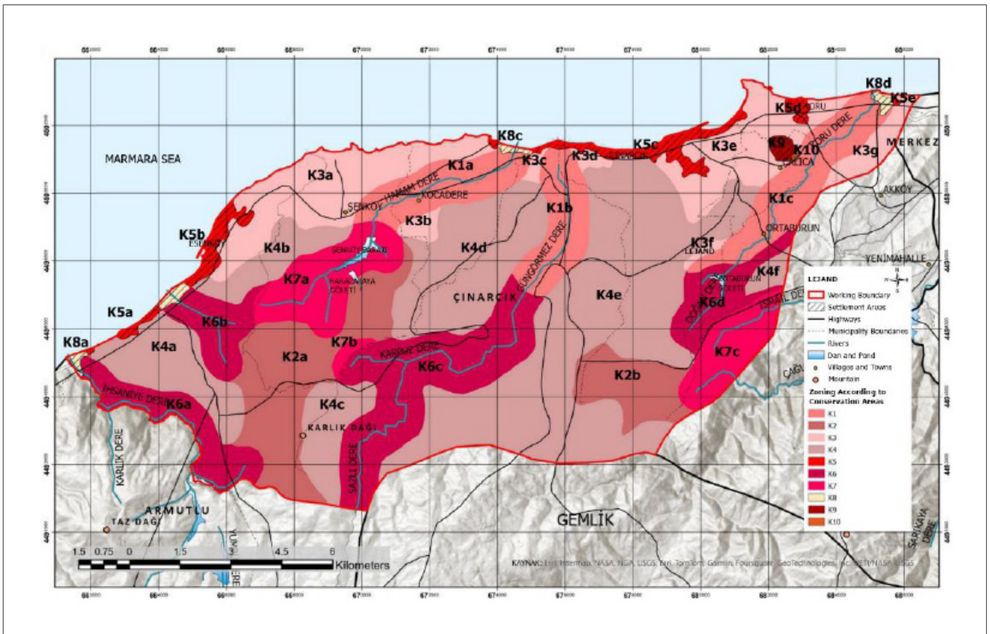

Figure 10. Landscape characterisation and zoning according to protected areas.

Table 7. Zoning, area and proportional distribution by protected areas.

Region	Subregion	Land Use	Areas to be Protected				Area (ha)	Ratio (%)	Ratio (%)
			Hydrological Protection Bands	Forest Area	Agriculture Area	Protection Site			
K1	K1a	Agriculture	Stream	-	+	+	310	1.76	5.67
	K1b	Agriculture	Stream	-	+	-	261	1.48	
	K1c	Agriculture	Stream	-	+	-	425	2.42	
K2	K2a	Forest	Basin	+	-	-	1158	6.59	10.43
	K2b	Forest	Basin	+	-	-	676	3.85	
K3	K3a	Agriculture	-	-	+	-	1573	8.95	18.26
	K3b	Agriculture	-	-	+	-	62	0.35	
	K3c	Agriculture	-	-	+	-	37	0.21	
	K3d	Agriculture	-	-	+	-	43	0.24	
	K3e	Agriculture	-	-	+	-	1240	7.05	
	K3f	Agriculture	-	-	+	-	31	0.18	
	K3g	Agriculture	-	-	+	-	224	1.27	
K4	K4a	Forest	-	+	-	-	552	3.14	38.50
	K4b	Forest	-	+	-	-	426	2.42	
	K4c	Forest	-	+	-	-	412	2.34	
	K4d	Forest	-	+	-	-	1350	7.68	
	K4e	Forest	-	+	-	-	3908	22.23	
	K4f	Forest	-	+	-	-	120	0.68	
K5	K5a	Settlement	Coastal	-	-	-	40	0.23	2.47
	K5b	Settlement	Coastal	-	-	-	112	0.64	
	K5c	Settlement	Coastal	-	-	-	236	1.35	
	K5d	Settlement	Coastal	-	-	-	40	0.23	
	K5e	Settlement	Coastal	-	-	-	5	0.03	
K6	K6a	Forest	Stream	+	-	-	561	3.19	16.51
	K6b	Forest	Stream	+	-	-	430	2.45	
	K6c	Forest	Stream	+	-	-	1463	8.32	
	K6d	Forest	Stream	+	-	-	448	2.55	
K7	K7a	Forest	Basin, Stream	+	-	-	741	4.22	7.31
	K7b	Forest	Basin, Stream	+	-	-	50	0.28	
	K7c	Forest	Basin, Stream	+	-	-	494	2.81	
K8	K8a	Settlement	Coastal, Stream	-	-	-	21	0.12	0.54
	K8b	Forest	Coastal, Stream	-	-	-	32	0.18	
	K8c	Settlement	Coastal, Stream	-	-	-	18	0.10	
K9	K9	Forest	-	-	-	-	49	0.28	0.28
K10	K10	Settlement	Stream	-	-	-	6	0.03	0.03
Total 1758									

In the zoning, 8 sub-regions were determined according to land use and disaster risk factors. In terms of risky areas, D3 sub-region in the river and basin protection band is the largest area with 40% and D5 sub-region with 3rd degree erosion risk is the largest area with 10% in terms of settlement, forest and agricultural areas.

Sub-region D7 is the second largest area with 38% of forest area and 3rd degree erosion risk. D1 sub-region is in the built-up area and this area, which is in the quaternary sediment and fault line protection band, is objectionable in terms of geological formation, has a rate of 1% (Table 8; Figure 11).

ÇINARCIK DISTINCT ECOLOGICAL LANDSCAPE MASTER PLAN

In terms of landscape characterisation, there are 7 regions and a total of 93 sub-regions determined according to topographic structure (19), soil structure (14), geology and geomorphological structure (21), hydrological structure (12), forest presence (9), protection area (10) and risky areas (8). Within the scope of the Ecological Master Plan, these areas are evaluated under 4 sub-headings as areas to be protected, unsuitable for settlement, areas that can be settled with limited-precaution and areas where forest presence will be developed, and land use decisions and recommendations are made according to their ecological suitability.

Areas to be Protected in Çınarcık District (K)

Five sub-regions were determined according to land use, soil structure and basin protection band criteria and it is the largest region of the area with 60.8%.

KZ Zone: It consists of T6 and O7 sub-regions and covers 1.1% of the area. T6 region has the characteristics of brown forest soil, class VII soil, erosion and salinity factor. Existing agricultural land use will continue, but soil limiting problems need to be improved. O7 is an olive grove area, and its agriculture and nature conservation function should be maintained.

KT1 Region: It consists of T5, T9 and T10 sub-regions covering 2.03% of the area under agricultural land use. T5 region is colluvial soil and class I soil. T9 region is non-calcareous brown forest soil, class II soil, erosion and salinity problematic. T10 region is colluvial soil, class III soil, erosion problematic. Agricultural activities should be continued in the region by eliminating soil problems, non-agricultural activities should not be allowed and it should be protected as an absolute agricultural area.

KT2 Region: It consists of T2, T4, T11 and T13 sub-regions covering 16.6% of the area under agricultural land use. T2 region agricultural area is alluvial soil, class III soil and the limiting factor is wetness. T4 region is agricultural area, brown forest soil, class III soil and limiting factors are erosion and salinity. T11 zone, agricultural area, brown forest soil without lime, class III soil and erosion is problematic. T13 zone, agricultural area, non-calcareous brown forest soil, class VI soil and erosion and salinity are problematic. The region is suitable for agricultural activities by eliminating soil limiting problems in terms of agricultural performance.

KO Region: It covers O1, O3, O5 and O8 sub-regions in forest land use. It is the largest area with 23% and forest protection status will continue.

KH Region: It is in forest land use and in the catchment protection band and covers H5 and H6 zones and 18.1% of the area. Protection status in terms of soil and water functions and ecosystem services (Table 9; Figure 12).

Unsuitable Areas for Settlement

The Unsuitable Areas for Settlement (UOA) Region consists of two sub-regions covering 37.1% of the area. It carries hazards such as earthquake, landslide, flood and tsunami due to geology, geomorphology and hydrological structure. The region is an area of exposure in terms of disaster risks and is not suitable for settlement (Table 9; Figure 12).

Table 8. Zoning according to risk factors, areal and proportional distribution.

Landscape Character Zones	Criteria and Sub Criteria		Area (ha)	Ratio (%)
	Land Use	Risk Factor		
D1	Settlement	Geological formation quaternary sediment Fault line protection zone	197	1
D2	Forest	Landslide risk area	350	2
D3	Settlement, Forest, Agriculture	Stream protection zone Basin protection zone	7016	40
D4	Agriculture	Fault line protection zone	589	3
D5	Forest, Settlement, Agriculture	3rd degree erosion risk area	1759	10
D6	Olive grove	Absolute protection required area	188	1
D7	Forest	3rd degree erosion risk area	6674	38
D8	Forest	-	782	4
Total 17555				

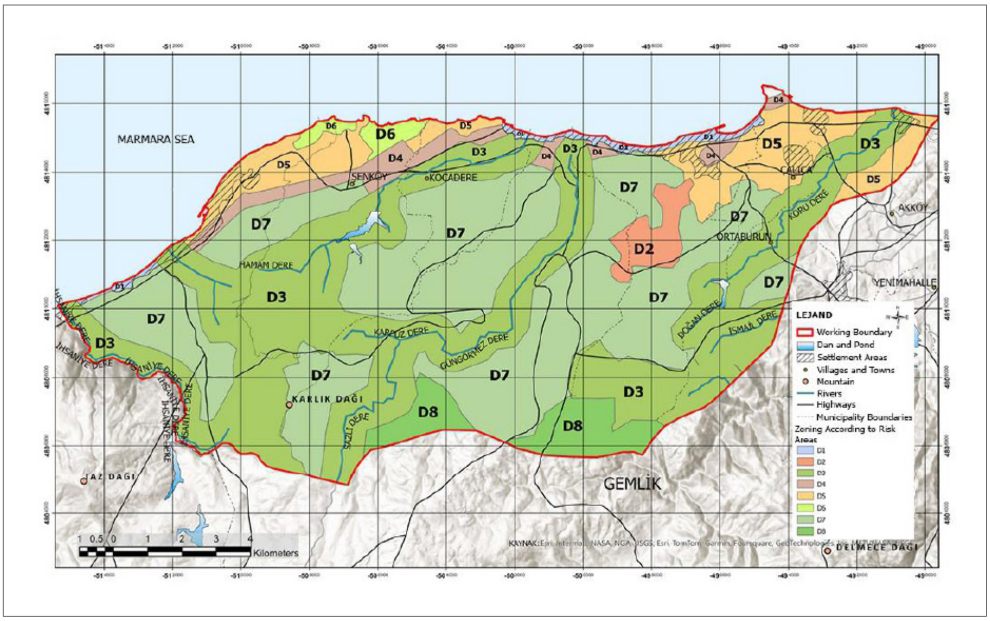

Figure 11. Landscape characterisation and zoning according to risk factors.

RA Zone: It covers sub-regions H2, H5, H7 and H8 in the river protection band and 34.7% of the area. H2 zone is agriculture and irrigation area, H5 zone is forest area, basin and river protection band, H7 zone is forest area and river protection band, H8 zone is agriculture area and river and coastal protection band.

RF Zone: J2 and J4 sub-regions on the live fault line and in the fault line protection band and covers 2.4% of the area. J2 zone is in built-up area and fault line protection band. J4 zone is built-up area, geological formation is quaternary sediment and fault line is in the protection band.

Areas Suitable for Settlement in Limited Conditions with Precautions (PSA)

According to the risk factors, the precautionary settlements areas (PSA) zone consists of four sub-zones covering 1.8% of the area. In these areas, microzonation and drilling data, soil structure and liquefaction analyses, etc. should be carried out to determine new construction conditions. The region covers areas that are limitedly inhabitable and require Detailed Geological Investigation (DGI) (Table 9; Figure 12).

YA Region: It is built-up areas and is in the river and coastal protection band. It covers H1 sub-region and 0.5% of the area.

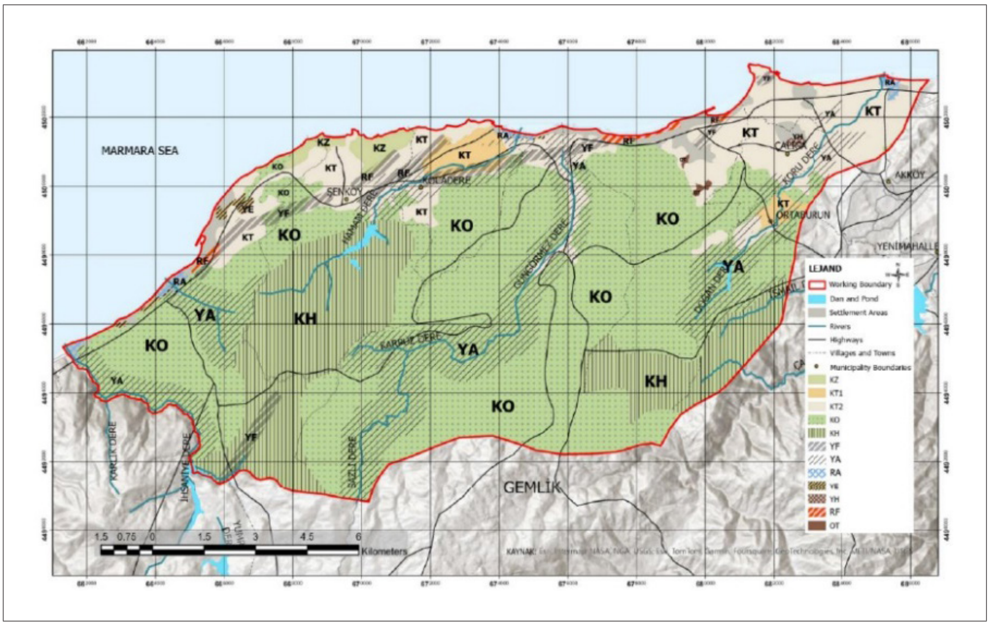

Figure 12. Ecological Landscape Master Plan according to land use suitability zoning.

Table 9. Land use suitability zoning and distribution of parameters.

Zones	Subregion	Criteria	Subregions	Area (ha)	Ratio (%)
Area to be protected (K)	KZ	Agricultural area	T6	198	1.1
		Forest area Olive grove use	O7		
	KT1	Agricultural area	T5, T9, T10	357	2.03
	KT2	Agricultural area	T2, T4, T11, T1	2927	16.6
	KO	Forest area	O1, O3, O5, O8	4037	23
	KH	Settlement area Basin protection band	H5	3187	18.1
		Forest area Basin protection band	H6		
Total				10706	60.8
Unsuitable areas for settlement (UOA)	RA	Agricultural area Stream protection band	H2, H8	6098	34.7
		Forest area Stream protection band	H5, H7		
	RF	Settlement area Fault protection band	J2, J4	414	2.4
Total				6512	37.1
Residential area with precaution (PSA)	YA	Settlement area Stream protection band	H1	100	0.5
	YE	Settlement area Erosion risk area	J1, J20	50	0.3
	YH	Agricultural area Landslide risk area	J21	4	0.02
	YF	Settlement area Fault protection band	J16	190	1
Total				344	1.8
Forest area to be developed (OT)	OT	Forest area status Treeless forest soil	T5	16	0.09
Total				16	0.09

YE Zone: Built-up areas with erosion risk, covering J1, J20 sub-regions and 0.3% of the area. J1 region is quaternary sedimentary and has earthquake risk and 3rd degree erosion problem. J20 zone is at risk of landslide.

YH Zone: It has landslide risk and is in agricultural use. J21 zone covers 0.02% of the area.

YF Zone: 3rd degree erosion risk, in fault line protection band and in settlement use. J16 landscape character sub-region covers 1% of the area.

Treeless Forest Land to be Developed

It is treeless forest land (OT) and there is no vegetation cover on it, but it is a forest area and has a protection status. OT Zone: The lands in this region are colluvial soil and class I land use capability. It covers the T5 landscape character sub-region and 0.09% of the area. In terms of land use, this area is 16 ha and it is an area to be developed by afforestation (Table 9; Figure 12).

CONCLUSION AND RECOMMENDATIONS

Çınarcık District has disaster potentials in terms of risk factors such as earthquake, flood, landslide, tsunami and erosion in 83% of the survey area: Almost all of the inhabited area of the district center is on young alluvial soils. Construction conditions are limited, controlled and problematic areas with swelling, settlement, filling, etc. that require precautions. Areas with liquefaction potential are unsuitable for settlement (UOA) due to disaster hazards, and detailed geological-geotechnical survey (DGI) and microzonation are required in terms of seismicity.

58% of the settlement is in coastal plains, coastal plain and river valleys at 0-50 m elevation. Unsuitable for settlement area (UOA) accounts for 37.1% of the area. For effective management of tsunami, flood and flood risk in these areas, hazardous areas should be analyzed in detail according to topographical, hydrological, climatic and other relevant factors. Flood susceptibility maps should be created with accurate geographical information and indicators and necessary measures should be taken in flood vulnerability areas. It is necessary to declare the risky areas determined according to the disaster situation as "Disaster Vulnerability Areas" and urgently evacuate the risky buildings according to the building stock. It is of great importance to determine the reconstruction conditions of the buildings that have expired through microzonation and detailed geological surveys.

Decentralization to suitable areas in terms of settleability is necessary according to the size of the population that may be affected in areas exposed to risks. However, the most important problem in the district in this respect is the natural constraints set forth by the physiography and the lack of suitable locations and sufficient areal size for new construction or reserve areas in terms of disaster.

As a result, the natural thresholds of the district prevent and limit the horizontal growth and development of the urban macroform. Accordingly, the building stock can be renewed by determining new construction conditions through planning within the scope of urban transformation in the built-up area. For this settlement where disaster and other urban risks are high, avoidance planning should be made and risk mitigation measures should be taken in the plans.

Within the scope of the research, land use suitability of the district in terms of other land uses was determined. Accordingly, 70% of the area is olive grove, absolute agricultural area, agriculture, forest and protected areas. According to sustainability and nature conservation criteria, the current use of these areas should be preserved and maintained.

Areas with absolute agricultural performance in terms of suitability for agriculture should never be used for purposes other than agricultural activities. Soils with high agricultural productivity and biomass production capability should be declared as absolute agricultural areas and should not be used for non-agricultural purposes.

In order to create sustainable, safe, livable, disaster prepared and resilient living environments, methods and approaches that take disaster hazards and risks into account should be integrated with the planning system and construction process. It is aimed to identify hazard and risk sources in settlements, to obtain input data, to determine hazards at country, regional and urban scales, to define, analyse and zone risks (Kentleşme Şûrası, 2018).

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