DETERMINATION OF LANDSCAPE TYPOLOGY WITH REMOTE SENSING TECHNIQUES AND CORRELATION WITH DIFFERENT BIOCLIMATIC CONDITIONS: THE CASE OF BUYUK MENDERES BASIN

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ABSTRACT:

Due to the multidisciplinary nature of landscape research, there are different systems and methods for landscape identification and classification. The methodology of the study is based on landscape characterization, which is based on the pre-selection of geo-ecological and land-use related features of the landscape. For this purpose, landscape character types were identified using climate classes, land use/land cover (LULC), soil and morphological structure. In obtaining the LULC data, which is one of the major inputs of the study, 36-band images were created covering four seasons by producing NDVI (Normalized Difference Vegetation Index); LAI (Leaf Area Index); MSAVI2 (Modified Soil-Adjusted Vegetation Index); fCOVER (fraction of Cover); indices, which are important in determining LULC, together with the basebands in the remotely sensed Sentinel 2 satellite data. LAI is used to determine the amount of leaves per unit area; NDVI is used to determine the green areas in the area; fCOVER is used to determine the ratio of the study area to the area covered by vegetation, MSAVI2 is used to determine the amount of vegetation cover in the study area by using the soil reflectance correction factor (L). The phenological structure of the species was statistically determined with the indices derived from satellite images, and the bioclimatic condition and landscape character type were associated with the species.

1. INTRODUCTION

Identification of features and characters resulting from the interaction of physical and socio-economic factors that make one landscape different from another and evaluation of the importance of ecosystem services are carried out by landscape character analysis. Determining landscape character is an important tool for monitoring landscape change. Landscape character analysis has emerged as a new approach in sustainable land use planning to control and quantify biodiversity loss and landscape change (Van Eetvelde and Antrop, 2009).

According to Simensen et al. (2018), geo-ecological landscape variables landform (95%), vegetation (85%), geology (67%), soil (63%) and hydrography (57%) are the most frequently used parameters to describe the landscape.

To provide a better understanding of climate variables by considering the vegetative structure and land uses of the region, this study was conducted to answer the following questions:
1. How can land cover/land use be improved by analyzing the phenological structure of species with different remote sensing techniques?
2. What are the bioclimatic classes in the region and does the Emberger Bioclimatic classification represent the species?
3.How are landscape typologies affected according to these dynamics?

2. MATERIAL AND METHOD

2.1 Study Area

The Büyük Menderes River is located in the South-Western part of Turkiye, in Western Anatolia (Figure 1). The Büyük Menderes Basin, located at the transition point of the Aegean, Mediterranean and Central Anatolian Regions, has significant climatic variation within different regions of the basin. For example, there are significant differences between the Upper Büyük Menderes Basin at the east and the Lower Büyük Menderes Basin at the west in terms of precipitation, temperature and evaporation.

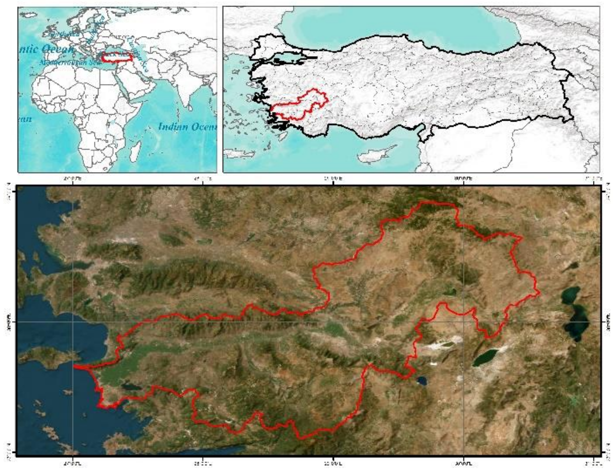

Figure 1. Study area

This study was to evaluate landscape character type in order to find suitable bioclimatic conditions for dominant species. Object-based classification of the Sentinel 2A image was applied after image preprocessing and segmentation. LULC, Morphology, Soil, Climate and Morphology components were overlaid for landscape characterization (Figure 2).

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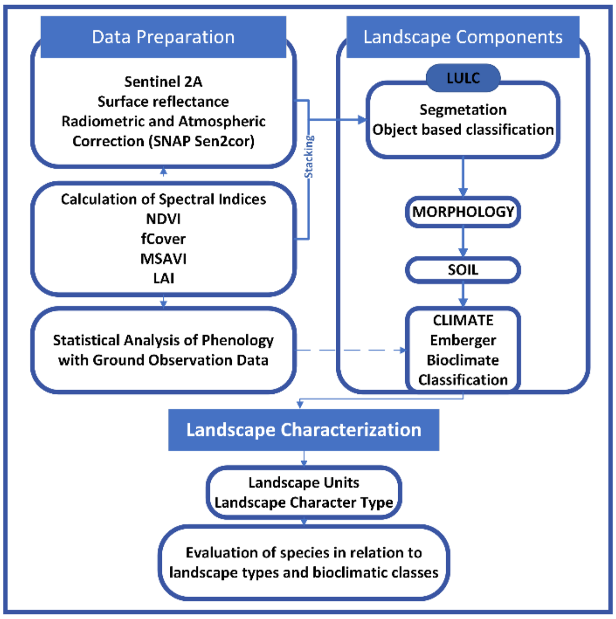

Figure 2. Methodological flowchart

2.2 Preparation of Sentinel-2 Data

Images from four different dates representing different seasons were used in the study.
Image Download Sentinel 2A;
- January 4, 2018
- April 5, 2018
- June 7, 2018
- September 22, 2018

For each date, Red, Green, Blue, Narrow NIR, Red edge, 5 bands and 4 spectral indices were taken for a total of 36 bands (ESA, 2022).

Radiometric and Atmospheric Correction was performed with Sen2cor (SNAP) software (Figure 3). The study area consists of 9 images and has been subjected to atmospheric correction and radiometric normalization for 4 months.

Bands 4,5,6 and 8 of Sentinel-2 data with a resolution of 20 m were converted to 10 m with the High Pass Filter resolution merge (HPF) technique. The process was repeated for 4 months.

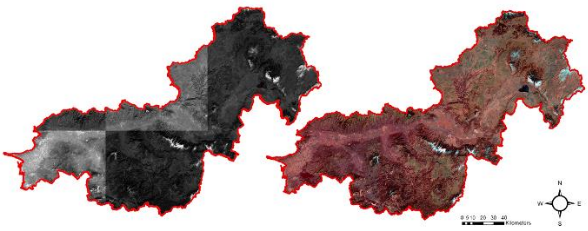

Figure 3. Sentinel 2A raw image and correction image

2.3 Deriving Spectral Indices

The Normalized Difference Vegetation Difference Index (NDVI) is a vegetation index that can be applied on multispectral image data, allowing the detection of green areas and providing information about vegetation cover. The results of the NDVI index calculated using Band 8 (Near Infrared) and Band 4 (Red) of the Sentinel-2 satellite ranged from -1 to 1. Negative or low values represent areas covered by concrete, bare soil, water or ice with no vegetation, while high values represent areas with high vegetation density, such as forests and agricultural areas (Lichtenthaler et al., 1996).

$$NDVI = (NIR - Red) / (NIR + Red), \quad (1)$$

Leaf Area Index (LAI) is an important biophysical component that shows the structural change of the plant canopy, affecting the energy balance, transpiration and the amount of photosynthesis in the plant. LAI can be expressed as leaf area per unit area in the region. Leaf area index (LAI) may vary according to different vegetation and vegetation types. For example, while LAI is "1" in areas that are not rich in vegetation such as deserts, this value can increase to values such as 6-8 in forested areas with abundant rainfall.

$$LAI = (3.618*EVI - 0.118) \quad (2)$$
$$EVI=2.5 * ((NIR - RED) / \quad (NIR + 6 * RED - 7.5 * BLUE + 1))$$

FCover is the index that gives the ratio of the area covered by vegetation. This index shows the size of plant photosynthetic area as well as the intensity of vegetation growth and also the tendency of vegetation growth up to a certain point. "$NDVI_s$" in the index means the normalized vegetation index of the bare soil areas in the area and "$NDVI_v$ means the normalized vegetation cover index of the whole area. (ESA, 2022).

$$FC_{over} = \frac{NDVI - NDVIs}{NDVIv - NDVIs} \quad (3)$$

The Modified Vegetation Index Considering Soil Reflectance (MSAVI2) is used when indices such as NDVI and NDRE provide insufficient data in bare areas with little vegetation cover. The value range of the index result varies between -1 and 1 (Qi et al., 1994).

$$MSAVI_2 = 1/2 * ((2*(NIR + 1)) - (((2 * NIR) + 1)2 - 8(NIR – RED)) 1/2) \quad (4)$$

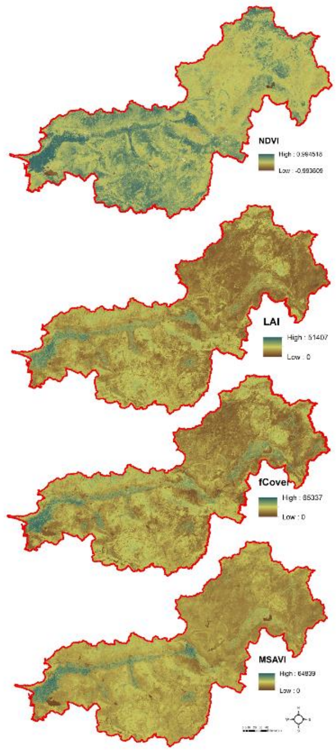

Figure 4. Spectral indices

3. RESULTS

3.1 LULC

LULC classification was performed using object-based approach and Sentinel-2 satellite data. Major classes were handled separately and classified using different techniques and additional data. The major classes are considered as built-up areas, agriculture and forest. For the detailed classification of forest and agricultural areas, phenology was utilized considering the statistical relationship between indices and points data taken from ground observation. The training data set was created for the basis.

LULC map was generated using object-based classification with eCognition software. The segmentation process was applied to the Sentinel-2 image to classify the forest areas. These objects were derived as a result of segmentation. Bareland, maquies and tree species in the image were classified in detail by associating with the forest stand map. Although the stand maps provide detailed species information, the distribution and frequency within the compartments are variable, so the compartments do not provide detailed spatial distribution of the species. For this reason, forest stand types were classified using object-based classification.

As a result of this approach, it was observed that the classification accuracy increased and species pattern realized within the compartments where mixed species took place.

To identify bioclimatic classes and characterize their spatial analysis, CORINE Land Cover (CLC) map and detailed forest stand map were associated with forest and semi-natural areas, agricultural and residential areas. To reveal the crop pattern of the study area, the agricultural areas were digitized, and the different crop types in the area were classified with the help of ground observation data. Settlements data were derived by combining Copernicus-Imperviousness and Urban Atlas Settlement data (Berberoğlu et al., 2019) (Figure 5).

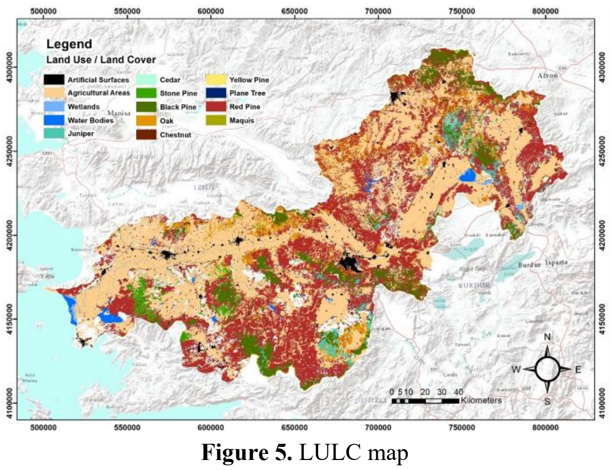

Figure 5. LULC map

3.2 Morphology

Topographic position index (TPI), one of the automated techniques that have become widespread in recent years, has been applied. This technique is based on applying advanced spatial statistics and image processing algorithms to Digital Elevation Model (DEM) data. TPI classifies an area according to both slope status (ridge, valley floor, moderate slope, etc.) and land form (steep narrow canyons, wide valleys, plains, open slopes, etc.) (Figure 6).

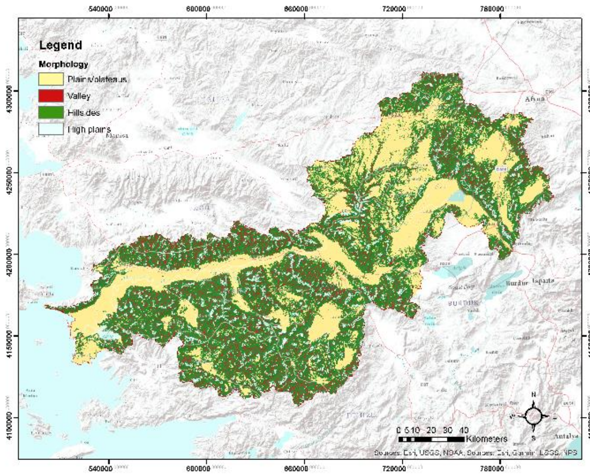

Figure 6. Morphology map

3.3 Soil

Soil classes are specified according to the FAO soil classification called "FAO85-FULL" specified in the European Soil Database. There are 12 different soil classes in the study area. Regosol soil and organic soils constitute the dominant soil type of the study area (Figure 7).

According to Büyük Menderes Basin soil data;
Brown forest soils cover 21% of the project area. 8,49% of the project area is covered by alluvial soils. In alluvial soils, irrigated agricultural areas constitute the largest area with a rate of 6.05% with an area of 157,894.34 ha. Brown soils have an area of 98.327,27 ha. Dry agricultural land has the highest area in brown soils with a rate of 2.62%.

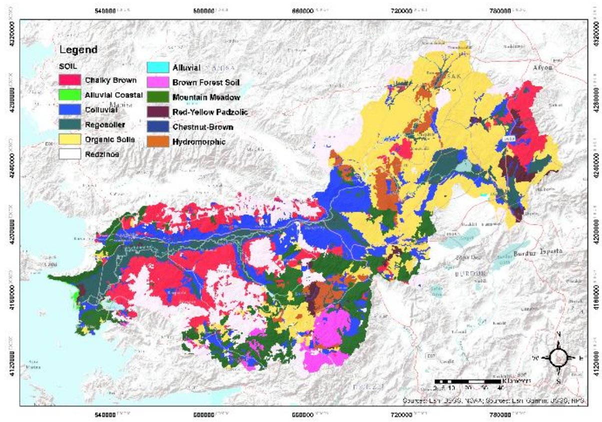

Figure 7. Soil map

3.4 Mediterranean Bioclimatic Layers (Q) (Emberger Pluviothermic Q index)

In this study, bioclimatic layers of Büyük Menderes Basin were determined according to the Emberger Climate Classification using the data obtained from the meteorological stations in the study area over 48 years. Meteorological data were interpolated using ANUSPLIN (Australian National University Spline) software to utilize at the Emberger Climate Classification system in the study area. ANUSPLIN can effectively model the effect of topography as it includes both the horizontal and vertical coordinate system when interpolating precipitation (Hutchinson, 2013).

Spatial analysis was developed with forest stand types and LULC to understand how bioclimatic layers affect these features.

Emberger (1930) classified the Mediterranean climate based on three crucial climatic parameters: precipitation, temperature and evaporation. The precipitation (P) is represented by the annual precipitation (mm). For temperature, the mean of the maximum temperature of the hottest month in the year (M) and the mean of the minimum temperature of the coldest month in the year (m) were considered because vegetation growth is strictly related to these thermal limits.

After determining the summer drought, continentality and precipitation regime, Emberger's precipitation temperature coefficient was applied to determine the Mediterranean bioclimate layers of the stations included in the Mediterranean climate.

Emberger determined the Mediterranean climate limits by using the annual precipitation total and the values of the coldest and hottest extreme months and developed the following equation in order to determine the boundaries of the Mediterranean climate. When “I < 10” is obtained as a result of the formula, it indicates that the calculated station is within the Mediterranean climate limits and the monthly drought index is between 0-10.

$$I=2P / (M+m)(M-m) \tag{5}$$

P = Total precipitation in number of rainy days in the year (mm)
M = Maximum temperature average of the warmest month (°C)
m = Minimum temperature average of the coldest month (°C)

$$Q=2000P / (M+m+564.4)(M-m) \tag{6}$$

Q= Precipitation-temperature coefficient
P= Annual total precipitation (mm)
M= Maximum temperature average of the warmest month (°C)
m= Minimum Temperature Average of the Coldest Month (°C)

Emberger Index	**Precipitation**	**Description**
Q<20	P<300mm	Hyperarid
20<Q<32	300<P<400 mm	Arid
32<Q<63	400<P<600 mm	Semi-arid
63<Q<98	600<P<800 mm	Sub-humid
Q=98	P>1000 mm	Humid

Table 1. Q and P variables

Sub-Mediterranean Bioclimatic Layers (m)
After the data were classified according to the precipitation and temperature coefficients, the Sub-Mediterranean Bioclimatic Layers were determined by using the minimum temperature average (m) of the coldest month (Table 2).

Thermal variants (m)	
Hyper cold	m>-10
Very cold	-10<m>-7
Cold	-7<m>-3
Cool	-3<m>0
Temperate	0<m>3
Mild	3<m>4.5
Warm	4.5<m>7
Very warm	m<10

Table 2. Thermal variant values

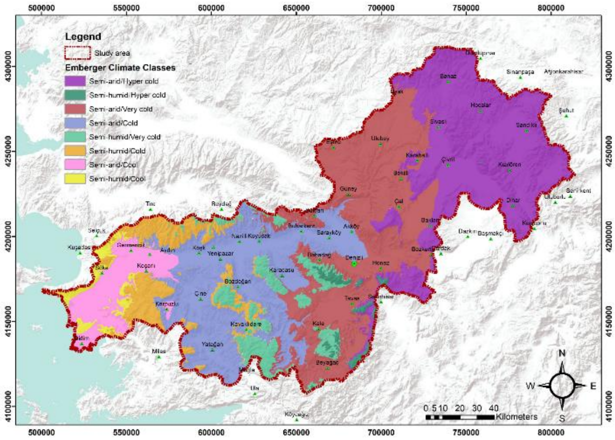

Figure 8. Emberger bioclimatic classification

According to the annual distribution of Q variables in the Emberger climate classification between 1970 and 2018 is seen that the highest mean precipitation during the year is in January. While it is seen that the mean maximum temperature value is highest in July, and the minimum mean temperature value is in December. On the other hand, it was observed that the mean temperature value was the lowest with -4.18 ℃ in January, and the highest month was July with 24.66 ℃.

Emberger Climate indices, were calculated within a GIS environment and 8 climate types were determined in the Büyük Menderes Basin. In the eastern and northeastern parts of the region, semi-arid/Hyper Cold climate type is dominant. While semi-arid/cold and very cold climate types are dominant in the inner and middle parts of the basin, it has been observed that the climate becomes milder towards the coastal areas. It is seen that semi-arid/cool and semi-arid/cold climate type dominates in the areas where agricultural activities are intensively took place in the western and inner parts of the region.

30.21% and 26.28% of the basin is composed of semi-arid/hyper cold and semi-arid/very cold climate types. The least common climate type in the region with 1.57% is Semi-humid/Hyper cold (Table 3).

Emberger Climate Class	**Area (ha)**	**Percentage (%)**
Semi-arid/Hyper cold	893995,00	30,21
Semi-arid/Very cold	777624,00	26,28
Semi-arid/Cold	606649,00	20,50
Semi-humid/Cold	207831,00	7,02
Semi-arid/Cool	189509,00	6,40
Semi-humid/Very cold	161752,00	5,47
Semi-humid/Cool	75451,80	2,55
Semi-humid/ Hyper cold	46467,90	1,57

Table 3. Distrubiton of Emberger Climate Classes in Büyük Menderes Basin

3.5 Landscape Characterization

Landscape character refers to the pattern in which the landscape is formed by elements with different distinguishable characteristics. Land cover/land use, climate classes, soil, and morphology were selected among the most preferred landscape components mentioned in previous studies in this study aimed to make landscape character analysis of Büyük Menderes Basin (Figure 9).

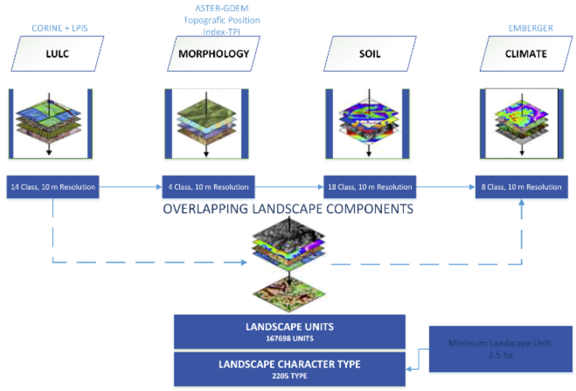

Figure 9. Landscape characterization flow chart

The overlaid landscape components went through a series of elimination processes until the minimum unit was 2.5 ha. In the study, 167698 landscape units and 2205 character types were identified (Figure 10).

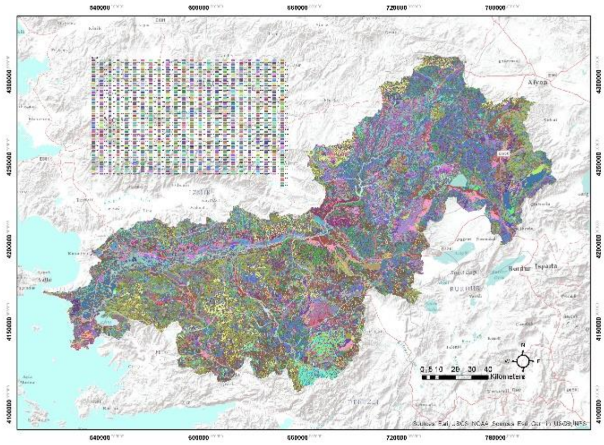

Figure 10. Landscape character types map

3.6 Evaluation of Dominant Species

The results can be drawn from Table 4, which shows how Emberger classes in dominant forest stand classes in the basin are distributed can be summarized as below:

It was observed that the species diversity is high in the region in the Semi-arid/Hyper cold climate class. Red Pine and Black Pine communities are growing at 1000-1500 m in the Semi-arid/Hyper cold climate class. The Oak species are dominant in this altitude after Red and Black Pine.

Although the Semi-arid/Very cold class is the most widespread climate type in the region after the Semi-arid/Hyper Cold climate class, where species diversity is low. Black Pine, Juniper and Oak species growing at 2000 m and above dominate the Semi-arid/Very cold climate class.

In the western parts of the region where the coastal zone effects are seen, Black Pine communities were found in Semi-arid/Cool and Sub-humid/Very cold climate classes.

The distribution of maquis in the Semi humid-cool climate class coincides with the physiological demands of this vegetation type as well as Red Pine communities that grow mainly at 0-500m.

In the Sub-Humid/Hyper Cold climate class, in addition to the Maquis and Red Pine communities growing at 0-500 m, similar to the Sub-Humid/Cool climate class, Oak and Stone pine were also seen (Table 4).

Emberger Climate Classes	Altitude	Forest Stand Type	Percentage (%)
Semi-arid/Hyper cold	1000-1500 m	Black pine	22,21
	1500-2000 m	Black pine	5,94
	500-1000 m	Cedar	0,10
	1000-1500 m	Cedar	1,53
	1500-2000 m	Cedar	0,22
	500-1000 m	Juniper	0,13
	1000-1500 m	Juniper	4,63
	1500-2000 m	Juniper	3,49
	1500-2000 m	Maquis	0,12
	1000-1500 m	Oak	10,50
	1500-2000 m	Oak	0,40
	1000-1500 m	Red pine	40,21
	1500-2000 m	Red pine	9,67
	2000 m >	Red pine	0,81
	1000-1500 m	Yellow pine	0,01
	1500-2000 m	Yellow pine	0,03
Semi-arid/Very cold	2000 m >	Black pine	28,50
	2000 m >	Juniper	50,86
	2000 m >	Oak	18,92
	1500-2000 m	Stone pine	1,72
Semi-arid/Cold	500-1000 m	Black pine	1,80
	500-1000 m	Maquis	10,12
	1000-1500 m	Maquis	5,25
	500-1000 m	Oak	10,26
	500-1000 m	Plane tree	0,01
	500-1000 m	Red pine	72,55
Semi-humid/Cold	0-500 m	Maquis	31,08
	0-500 m	Oak	5,51
	0-500 m	Plane tree	0,02
	0-500 m	Red pine	59,03
	0-500 m	Stone pine	4,35
Semi-arid/Cool	1000-1500 m	Stone pine	100,00
Semi-humid/Very cold	500-1000 m	Stone pine	100,00
Semi-humid/Cool	0-500 m	Maquis	59,32
	0-500 m	Oak	0,25
	0-500 m	Red pine	39,42
	0-500 m	Stone pine	1,01
Semi-humid/Hyper cold	0-500 m	Maquis	39,62
	500-1000 m	Maquis	1,26
	0-500 m	Oak	0,04
	500-1000 m	Oak	0,01
	0-500 m	Red pine	51,50
	500-1000 m	Red pine	5,96
	0-500 m	Stone pine	1,61

Table 4. Dominant forest stand types and their climate classes in the Büyük Menderes basin

In the study, optimal areas were determined by considering the growing conditions of dominant species within the scope of previous studies (Baylan and Ustaoglu, 2020 ; Atalay, 2011; Le Hourou, 1959; Sauvage, 1961; Nahal, 1962; Vessella and Schirone, 2013).
The most suitable areas were selected by applying zonal statistics at the scale of landscape character types. (Figure 11).

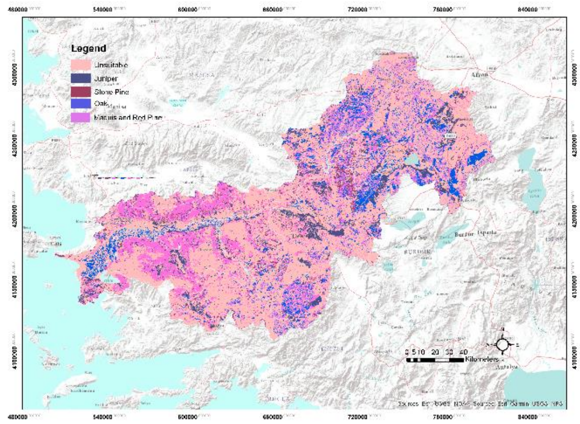

Figure 11. Suitability of dominant species according to landscape typology

4. CONCLUSION

In the study, with the help of remote sensing techniques, image pre-processing, spectral indices and object-based classification enabled an important improvement in landscape character analysis. By including morphology, soil and Emberger bioclimate classes, landscape typology was revealed. The dominant species in the area were analysed on the basis of landscape typology and suitable areas were determined. This study emphasized that the geographical conditions of the dominant species are important in reforestation areas.

Although it is different in terms of scale, it has been observed that studies conducted in areas with similar vegetative characteristics are compatible with this study. In addition, similar studies in other river basins play an important role in developing holistic river basin management plans.

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REFERENCES

Atalay, İ., 2011: *Türkiye İklim Atlası*, İnkılap Kitabevi Baskı Tesisleri.

Baylan, K. A., Ustaoğlu, B., 2020: Emberger biyoiklim sınıflandırmasına göre Türkiye’de Akdeniz biyoiklim katlarının ve alt tiplerinin dağılışı. *Ulusal Çevre Bilimleri Araştırma Dergisi*, 3(3), 158-174.

Emberger, L., 1930: *Sur une formule climatique et ses applications en botanique*. CR Hebd Acad Sci Paris 191:389–391

ESA, 2022. Europe's Copernicus programme-European Space Agency Access: https://scihub.copernicus.eu/dhus/#/home

Hutchinson, M. F., 2013. *ANUSPLIN Version 4.4*. A: https://fennerschool.anu.edu.au/research/products/anusplin

Le Houerou, H.N., 1959: *Recherches écologiques et floristiques sur la végétation de la Tunisie Méridionale*. Alger: Institut de Recherches Sahariennes,2 vol. 227 p.

Lichtenthaler, Hartmut K. et al., 1996: Detection of vegetation stress via a new high resolution fluorescence imaging system. *Journal of Plant Physiology* 148 599-612.

Nahal, I., 1962: Le Pin d'Alep (Pinus halepensis Miller). *Étude taxonomique, fitogéographique, écologique ve sylvicole*. Annales de l'École National des Eaux et Forêts 19: 1–207.

Qi, A. Chehbouni, A.R. Huete, Y.H. Kerr, S. Sorooshian, 1994: A modified soil adjusted vegetation index, *Remote Sensing of Environment,* Volume 48, Issue 2, Pages 119-126, ISSN 0034-4257,
https://doi.org/10.1016/0034-4257(94)90134-1.

Sauvage C. 1961: *Recherches géobotaniques sur les subéraies marocaines*, Rabat, Institut Scientifique Chérifien, coll. Travaux de l'Institut , 462 p.,

Simensen T., Halvorsen R., Erikstad L., 2018: Methods for landscape characterisation and mapping: A systematic review, *Land Use Policy*, Volume 75, Pages 557-569, ISSN 0264-8377.

Van Eetvelde V., Antrop M., 2009: Indicators for assessing changing landscape character of cultural landscape in Flanders (Belgium). *Land Use Policy*, 26: 901-910.

Vessella F., Schirone B., 2013: Forest Conservation and Restoration Using the Emberger Index: Cork Oak as Study Case. *Forests* 2022, 13, 252. https://doi.org/10.3390/f13020252