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Determining indicator plant species of *Pinus brutia Ten*. Site index classes using interspecific correlation analysis in Antalya (Turkey)

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FOREST ECOLOGY

ABSTRACT

Background: We performed a vegetation study in Antalya, where the Mediterranean climate prevails, in order to determine the indicator plant species of red pine (*Pinus brutia* Ten.). Red pine can be widely distributed from sea level to 1200 meters. Its main distribution is in the main Mediterranean vegetation zone between 500-1000 meters. However, the variation of the habitat factors may be low in this range. Therefore, the productivity relationships of species such as red pine, whose sustainable use is important, cannot be directly explained by environmental variables. In such cases, it is important to determine the indicator plant species. For this reason, indicator plant species of red pine productivity (site index class I) were determined by using interspecific correlation analysis (ICA) in the study. Then, using principal components analysis, the relationship of indicator plant species with the variables of elevation, slope, aspect and soil depth was revealed. In the principal components analysis, the plant species that were determined as an indicator were also added to the graph as a class variable, and the effects of the variables on the indicator plant species were also investigated.

Results: The results of the ICA showed that *Dryopteris flix-mas* (L.) Schott, *Abies cilicica* (Antoine & Kotschy) Carrière, *Cedrus libani* A. RICH and *Colutea cilicica* Boiss. & Bal. species were negative indicators of red pine productivity. On the other hand, *Cistus creticus* L. and *Smilax aspera* L. species were positive indicators of productivity

Conclusions: Interspecific correlation analysis is a useful tool to determine the ecological properties of species that have a local distribution or a vertical distribution in a narrow altitude range. It also offers practical and effective results, especially for species with high commercial value such as red pine.

Keywords: Interspecific Correlation Analysis; Principal Component Analysis; Red Pine; Site Index Value.

HIGHLIGHTS

Determination of indicator species has an important role in areas where variation in environmental variables is low.
Red pine distributes a limited distribution in the Mediterranean region in terms of vertical distribution, except for special areas.
In the present study, the radiation index (correlated with aspect) has a significant effect on red pine productivity.

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INTRODUCTION

Forests are one of the most important components of terrestrial ecosystems and provide various services to people from past to present. This process has brought concepts such as the efficient and sustainable use of natural resources and the protection of biological diversity to the fore (Turner et al., 2007; Supple and Shapiro, 2018). Especially in recent years, due to the increase in anthropogenic effects such as climate crisis, population growth and uncontrolled industrialization, sustainable use has become a necessity for the protection of natural resources (Lotze-Campen, 2011; Satterthwaite, 2009; Ahmadalipour et al., 2019).

Forests are of great importance in terms of biodiversity. So much so that an important part of terrestrial biodiversity is located in forest ecosystems. From a spatial distribution perspective, 30% (3.8 billion hectares) of the world's land is forested. In Turkey, forests cover 28.6% of terrestrial areas and are 22342935 hectares. Considering the distribution of main forest tree species within these areas, it is known that oak forests have the widest distribution with 5886195 hectares, followed by red pine forests with 5610215 hectares and black pine forests with 4244921 hectares, respectively (GDM, 2021). On the other hand, Turkey has a very rich both in terms of species diversity and ecosystem diversity due to reasons such as hosting different areas in terms of climate, soil characteristics and topographic structure, being at the intersection of the European and Asian continents, and having three phytogeographic regions within its borders (Dönmez and Yerli, 2018; Mısırlıoğlu, 2017; Noroozi et al., 2019). The Mediterranean Basin, in which the study area is located, also contains very rich ecosystems in terms of mentioned properties. Red pine (*Pinus brutia* Ten.), a typical Mediterranean tree, is the most common forest tree species in the study area. It has a distribution starting from the Italian Calabria Peninsula in the west to the Zavita Atrush region in the north of Iraq in the east. Red pine, which spreads as far as the Crimea in the north, can go down to Lebanon and Palestine in the south. This species is most widespread in the east of the Mediterranean basin, especially in Anatolia. Red pine, which has a relatively high temperature demand and avoids continental climates, mainly spreads vertically in the warm Mediterranean vegetation zone (0-500m) and in the main Mediterranean vegetation layer (500-1000m). In addition, red pine can spread in the upper Mediterranean vegetation zone (1000-1500 m) depending on its local microclimatic characteristics (Ketenoğlu et al., 2014). Red pine is the most used main forest tree species in Turkey at the point of satisfying wood raw materials. In this respect, the sustainability of productive red pine are important. Estimating the site index values or identifying the indicators pointing to the productive areas also have a key role in this process. Site index (i.e. the dominant height of the stand at a reference age) is ordinarily used to estimate site quality (Çınar and Gülsoy, 2019). When the studies on the site index of red pine are examined, it is noteworthy that this species has a wide distribution in the Mediterranean basin. Though, in terms of elevation, as stated above, it does not show much distribution at high elevations, except for some microclimate areas. Therefore, due to the low variation in environmental variables in studies performed in local areas, it is not always possible to make a pattern between environmental variables and productivity, in other words, statistically significant relationships cannot be determined (Güner et al., 2011; Keten and Gülsoy, 2020). In these cases, it is of great importance to determine the indicator species to reveal the productivity relations. Because there are many species that are important in terms of species diversity in the areas where red pine is distributed. Among these species, almost all of which are maquis element, *Olea europaea* L., *Erica arborea* L., *Ceratonia siliqua* L., *Cistus creticus* L., *Rubus* fruticosus., *Nerium oleander* L., *Arbutus andrachne* L., *Laurus nobilis* L., *Pistacia terebinthus* l., *Myrtus communis* L., *Quercus coccifera* L. are the most common species. However, the species may differ in the areas where the red pine distributes. While significant differences cannot be observed in areas with low variation in site factors, especially due to reasons such as lack of sample area or working in local areas, there may be differences in terms of plant species on the sub-canopy, shrub, and ground layers. (Keten and Gülsoy, 2020; Kaya, 2020). For this purpose, the indicator plant species of the areas where red pine is productive and non-productive were determined in the study. These results will provide practical and effective outputs at the point of making effective use of the red pine species, which has an economically important value.

MATERIAL AND METHODS

Study area

The study area is located in the Mediterranean Basin, which includes the Western Taurus Mountain range. The elevation in the study area starts from sea level and increases up to 2700 m. However, the highest sample plot recorded data for red pine is 1210 meters. It is stated that the area, where the characteristic Mediterranean climate features are seen, with hot summers and warm and rainy winters, has a humid climate type according to the Thorthwaite climate classification (Özdemir and Özkan, 2016). The representative presentation of the study area in Figure 1.

Statistical analysis

In the present study, data were obtained from 72 sample plots where red pine is distributed. Age and height measurements were carried out on selected plus trees in each sample area using height measuring instrument and tree increment borer. In studies on productivity for tree species (Table 1), measurements are mostly made on plus trees (i.e. trees in the upper height) because they are less affected by silvicultural processes, are more resistant to diseases, are an indicator of growth and development, and represent the yield strength of the area. The upper height values of plus trees may differ according to the age of the stands (Kalıpsız, 1984). Hence, in order to eliminate the age-related bias in the productivity calculation, the age and height values of the 3 plus trees measured in the sample areas were indexed to 75 and the site index values were calculated (Kalıpsız, 1963). By an average of the site index values calculated for the 3 plus trees selected in each sample plot, the average site index value for each sample plot was obtained. By dividing the site index values into 3 groups, the sample plots corresponding to each group were determined. Then, Shapiro-Wilk normality test was applied to the site values.

The Shapiro-Wilk test is a way to tell if a random sample comes from a normal distribution. The test gives you a W value; small values indicate your sample is not normally distributed. This hypothesis is rejected if the critical value P for the test statistic W is less than 0.05 (Royston, 1982). The formula for the W value is [1]. Where $x_{(i)}$ are the ordered sample values and are constants that are generated by the expression [2]. With $m = (m_1, m_2, \ldots, m_n)^T$ being the expected values of the ordered statistics that are independent and identically distributed random variables that follow the standard normal, N(0,1), and V is the covariance matrix of the order statistics.

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \quad (1)$$

$$\left(a_1,\ a_2, \ldots, a_n\right) = \frac{m^T V^{-1}}{\left(m^T V^{-1} m\right)^{1/2}} \quad (2)$$

Since it was determined that it had a normal distribution, analysis of variance, a parametric method, was preferred in order to determine whether there was a significant difference between the site values grouped according to elevation, slope, aspect, and soil depth classes. Then, the plant species that are indicators for red pine in the study area were determined by applying "Interspecific Correlation Analysis (ICA)" (Cole, 1949; Poole, 1974; Özkan, 2002; Özkan, 2008; Güner et al., 2011; Negiz et al., 2013; Gülsoy, Negiz, 2014, Çinar and Gülsoy, 2019). While applying ICA, a 2x2 table was first created (Table 2) and the chi-square () test was performed [3].

$$x^2 = \frac{\left(ad - bc\right)^2 n}{\left(a+b\right)*\left(a+c\right)+\left(c+d\right)*\left(b+d\right)} \quad (3)$$

Then, the c3 coefficient was calculated using the formula given by Cole (1949) and Özkan (2002). The value of c3 coefficient given below is larger or less than 0, representing the type of the indicators. In other words, values larger than 0 represent positive indicator species, and values less than 0 represent negative indicator species. Correlation coefficient (c3) was calculated with the formula [4].

$$c_3 = \frac{4\left(ad - bc\right)}{\left(a+b\right)^2 + \left(b+c\right)^2} \quad (4)$$

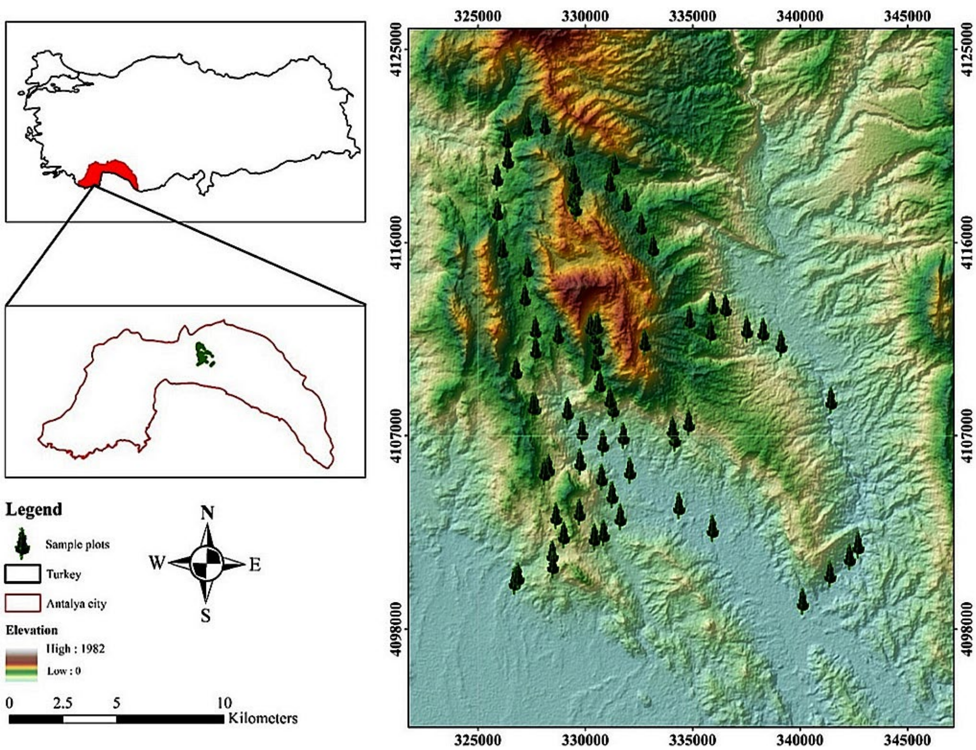

Figure 1: Location map of the study area.

Table 1: Plant types and abbreviations used in the analysis.

Species	Abbreviation	Species	Abbreviation
Pyrus elaeagnifolia Pall.	Pyrela	*Philyleria latifolia* L.	Phllat
Crataegus monogyna Jacq.	Cramon	*Juniperus excelsa* Bieb.	Junexe
Arum dioscoridis Sm.	Arudios	*Phlomis grandiflora* H.S.Thomps.	Phlgra
Origanum onites L.	Orioni	*Rubus fruticosus* L.	Rubfru
Rhamnus oleoides L.	Rhaole	*Fontanesia phillyreoides* Labill.	Fonphi
Platanus orientalis L.	Plaori	*Daphne sericea* Vahl	Dapser
Olea europea var. oleaster L.	Oleeur	*Juniperus oxycedrus* L.	Junoxy
Dryopteris flix-mas (L.) Schott	Dryfli	*Erica arborea* Linneaus	Ercarb
Astragalus spp.	Astspp	*Abies cilicica* (Antoine & Kotschy) Carrière	Abicil
Ceratonia siliqua L.	Crasil	*Vitex agnus-castus* L.	Vitagn
Hedera helix L.	Hedhel	*İnula heterolepis* Boiss.	İnuhet
Thymus thymbra L.	Thythy	*Prunus spinosa* L.	Pruspi
Digitalis davisiana Heywood	Digdav	*Nerium oleander* L.	Nerole
Paliurus spina-christi Mill.	Palspi	*Spartium junceum* L.	Spajun
Calicotome villosa (Poir)	Calvil	*Quercus coccifera* L.	Quecoc
Cirsium arvense (L.) Scop.	Cirarv	*Asparagus acutifolius* L.	Aspacu
Cistus creticus L.	Ciscre	*Quercus infectoria* G.Olivier	Queinf
Pistacia terebinthus L.	Pister	*Myrtus communis* L.	Myrcom
Colutea cilicica Boiss. & Bal.	Colcil	*Cotinus coggygria* Scop.	Concog
Quercus cerris L.	Quecer	*Salvia tomentosa* L.	Saltom
Arbutus andrachne L.	Arband	*Smilax aspera* L.	Smiasp
Cedrus libani A. Rich.	Cedlib	*Cupressus sempervirens* L.	Cupsem
Verbascum sp. L.	Verspp	*Thymelaea tartonraira* (L.) All.	Thytar
Rhus coriaria L.	Rhucor	*Euphorbia characias* L.	Eupcha
Ruscus aculeatus L.	Rusacu	*Styrax officinalis* L.	Sytoff
Teucrium chamaedrys L.	Teucha	*Teucrium polium* L.	Teupol
Poterium spinosum L.	Potspi	*Cercis siliquastrum* L.	Cersil
Fraxinus ornus L.	Fraorn	*Ficus carica* L.	Ficcar
Sambucus ebulus L.	Samebu		

Table 2: 2 X 2 Table for interspecific correlation analysis.

		Species A		
		Presence	Absence	Total
Species B	Number of times presence	a	b	a+b
	Number of times absence	d	c	d+c
	Total	a+d	b+c	a+b+c+d=n

Species with less than 5% presence among the species in the data matrix before the ICA were excluded to avoid bias. Then, the indicator plant species of the areas where the red pine is productive and non-productive were determined as per the data matrix. Here, the site index values are estimated for 3 classes (I., II and III) , and areas with site index value I represent productive areas, while areas with II and III represent non-productive areas. Finally, the indicator plant species of the productive areas were determined by using ICA and sample plots where positive and negative indicator species are found separately or together and where they are absent are classified. Subsequently, in the Principal Component Analysis (PCA) applied together with elevation, slope, aspect, soil depth, and productivity values, sample areas belonging to these groups were represented in different colors. Rstudio software was used for all statistical analyses with packages tidyverse, ggpubr, rstatix, ggplot2, ggridges, FactoMineR, factoextra, corrplot, vegan.

RESULTS AND DISCUSSION

In the present study, Shapiro-Wilk normality test was first applied to determine whether the site data showed a normal distribution before including it in the analysis. The results show that (W=0.989, p=0.831), the p value is larger than 0.05. Therefore, the null hypothesis was failed to reject. In other words, the data show a normal distribution. As of this result, the process continued with one-way analysis of variance (ANOVA), which is a parametric method, in order to determine the relationships between groups of environmental variables prepared as class data.

Elevation, slope, aspect and soil depth parameters were transformed into class variables, and the data was arranged in a way to form a group of sample areas corresponding to the classes. Namely, the elevation was divided into 3 classes as Mediterranean vegetation zone (0-500m), main Mediterranean vegetation zone (500-1000m) and upper Mediterranean vegetation zone (1000-1500m) with reference to the studies of Güner and Ekim, (2014) and Özdemir (2022). The slope was calculated in degrees. Those with slope values less than 25° and equal were selected as one class, between 25°-50° as another class, and those with a slope greater than 50° as another class. Aspect was divided into 4 groups as north (0°-45° and 315°-360°), west (45°-135°), south (135°-225°) and east (225°-325°). Finally, the soil depth variable was represented by 4 classes as 0-20cm, 20-50cm, 50-90cm, and 90cm above (Wang et al., 2022; Wu et al., 2022). One Way Anova method was performed to determine whether there is a difference between the site index values corresponding to the variable classes prepared in the stated order (Table 3).

Table 3: Anova test results for the environmental variables.

	Sum Sq	Mean Sq	F value	p
Elevation Class	14.8	14.78	1.234	0.271
Slope Class	8.1	8.086	0.67	0.416
Aspect Class	9.2	9.195	0.763	0.386
Soil Depth Class	0.7	0.68	0.056	0.814

As can be seen from the analysis results in Table 2, there is no class with a p value less than 0.05. In other words, the results indicate that there is no significant difference between the groups. This is due to the fact that there is not much difference between the averages of the site index values of the variable classes. Box plots in Figure 2 also indicate that there is no significant differences in the mean values of site index classes according to the classes of the environmental variables.

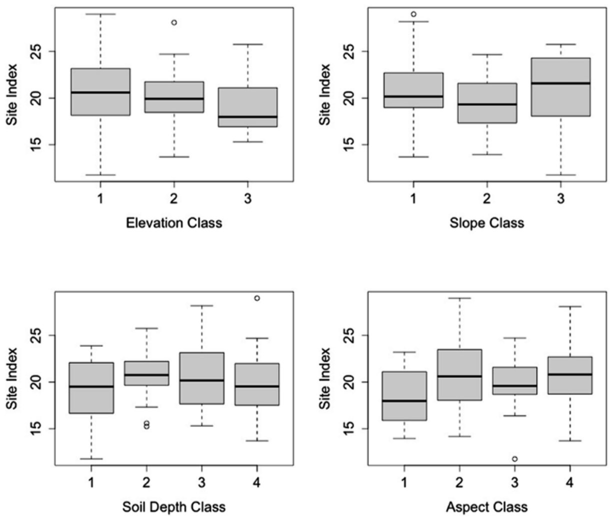

Figure 2: Group averages of site index values belonging to environmental variable classes.

Red pine mostly spreads between 0-1000 m in the study area. 63 out of 72 sample areas are located in mentioned elevation range. In other studies related to red pine (Keten and Gülsoy, 2020; Changjun et al., 2021), it is similarly stated that it is a species that starts from sea level and spreads up to 1500 meters. Therefore, it is an ordinary result that no significant relationship can be found in terms of elevation zones as belonging to this species, which shows a dense distribution in the main Mediterranean and warm Mediterranean vegetation layers (Atalay et al., 2014). For the aspect, it was determined that 52 of the 72 sample areas belonged to the east and south aspects. In terms of slope, it was determined that 61 sample areas had a slope below 50°, and the soil depth was below 25 cm in only 9 sample areas. It was not surprising that there was no significant relationship between the mean of slope angle and soil depth variables. The representations of the percentage ratios of the sample areas corresponding to the environmental variable ranges are given in Figure 3.

As mentioned above, site index values are categorized into 3 classes (I, II and III), and areas with site index value I represent productive areas, while areas with II and III represent non-productive areas. According to this classification, it has been determined that 7 of the sample areas represent site index value I, 18 of them represent site index value II, and 15 of them represent site index value III. The species that are the indicators of productivity in the area were determined according to the c3 coefficients calculated as a result of the ICA applied to the plant species in the area. The results of the ICA revealed that *Dryopteris flix-mas* (L.) Schott, *Abies cilicica* (Antoine & Kotschy) Carrière, *Cedrus libani* A. RICH and *Colutea cilicica* Boiss. & Bal. species were negative indicators of productivity. On the other hand, *Cistus creticus* L. and *Smilax aspera* L. species were positive indicators of productivity (Table 4).

After determining the indicator species for productive and nonproductive classes of red pine, principal component analysis (PCA) was applied between site index values and environmental variables using their real values. However, a change has been made in the aspect here. Because including the aspect in the analysis as its real value (degree), it may cause errors. For instance, while the values of 1 degree and 359 degrees both represent the north aspect, there is a 359-fold difference between them when considered numerically. One of the most common solutions preferred to eliminate this error is to use the radiation index instead of the aspect. The radiation index is estimated according to the equation

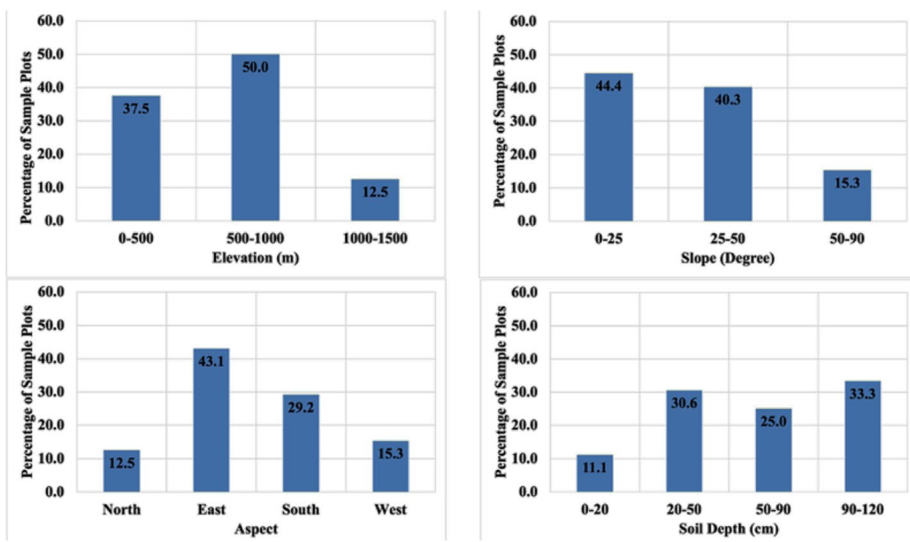

Figure 3: Percentages of sample plots corresponding to variable classes.

[5]. In the equation, Q represents the aspect value. Radiation index values range from 0 to 1. While the areas in the north-northeast direction, which is the coldest and rainiest, converge to 0, the values approach 1 towards the hotter and drier south-southwest direction (Moisen and Frescino, 2002; Aertsen et al., 2010; Özdemir, 2022). Therefore, radiation index is included instead of aspect in the principal component analysis. The eigenvalue and variance percentages of the components obtained from the PCA result are given in Table 5.

$$Radiation\,Index = \frac{1-\cos\left(\left(\frac{\pi}{180}\right)*(Q-30)\right)}{2} \quad (5)$$

Table 4: Ressults of ICA for site class I of red pine.

Species	Chi Square	p	c3	Species	Chi Square	p	c3
Pyrela	1.744	0.187	0.119	Palspi	0.001	0.980	-0.004
Phllat	1.295	0.255	0.225	Spajun	0.240	0.624	0.064
Cramon	0.594	0.441	-0.162	Calvil	0.240	0.624	0.064
Junexe	1.667	0.197	-0.173	Quecoc	0.121	0.728	0.051
Arudios	0.026	0.871	-0.032	Cirarv	0.361	0.548	-0.093
Phlgra	0.736	0.391	0.150	Aspacu	1.681	0.195	0.273
Orioni	0.055	0.815	0.045	**Ciscre**	**5.042**	**0.025**	**0.355**
Rubfru	0.121	0.728	-0.051	Queinf	1.210	0.271	0.139
Rhaole	0.220	0.639	0.097	Pister	1.527	0.217	0.257
Fonphi	0.484	0.487	0.148	Myrcom	0.516	0.473	0.137
Plaori	0.001	0.971	0.004	**Colcil**	**4.048**	**0.044**	**-0.259**
Dapser	0.691	0.406	-0.135	Concog	0.317	0.547	0.120
Oleeur	0.196	0.658	-0.091	Quecer	1.210	0.271	0.139
Junoxy	1.076	0.300	-0.163	Saltom	0.038	0.845	0.042
Dryfli	**5.344**	**0.021**	-0.280	Arband	0.756	0.348	0.182
Ercarb	1.623	0.203	0.172	**Smiasp**	**5.696**	**0.017**	**0.414**
Astspp	0.472	0.492	0.096	**Cedlib**	**9.296**	**0.002**	**-0.282**
Abicil	**4.306**	**0.038**	-0.167	Cupsem	1.945	0.163	0.287
Crasil	0.495	0.482	0.143	Verspp	0.082	0.775	0.059
Vitagn	0.285	0.549	0.084	Thytar	1.429	0.232	0.215
Hedhel	0.890	0.346	-0.079	Rhucor	0.495	0.482	0.076
Inuhet	0.660	0.417	-0.106	Eupcha	0.233	0.630	-0.091
Thythy	2.212	0.137	0.150	Rusacu	0.758	0.384	0.128
Pruspi	1.744	0.187	0.119	Sytoff	0.432	0.511	-0.136
Digdav	0.495	0.482	0.076	Teucha	0.771	0.381	0.149
Nerole	0.385	0.535	0.130	Teupol	0.059	0.809	0.051
Potspi	1.744	0.187	0.119	Cersil	1.429	0.232	0.215
Fraorn	0.660	0.417	-0.106	Ficcar	0.240	0.624	0.064
Samebu	0.001	0.971	0.004				

While evaluating the PCA results, the eigenvalues of the axes are expected to be higher than 1% and the variance higher than 10%. It was observed that only axis 1 and axis 2 comply with these conditions, and the total variance explanation rate of these two axes was 53.63%. Therefore, the evaluations were made only according to axis 1 and axis 2. The correlations of the variables with the axes and the PCA graph are given in Table 6 and Figure 4, respectively.

Table 5: Results of PCA.

	Eigenvalue	Percentage of variance	Cumulative percentage of variance
Axis1	1.55699	31.13990	31.13990
Axis2	1.12470	22.49392	53.63381
Axis3	0.97051	19.41016	73.04397
Axis4	0.72628	14.52556	87.56953
Axis5	0.62152	12.43047	100

Table 6: Correlations between variables and axes.

	Elevation	Radiation Index	Slope	Soil Depth	Site Index
Axis1	0.608	0.129	0.782	-0.737	-0.122
Axis2	-0.467	0.680	0.135	-0.225	0.613

PCA graph was created for environmental variables and site index values. While creating the PCA graph, sample areas (s) with only positive indicators (Pos), areas with only negative indicators (Neg), areas with both positive and negative indicators (All), and areas without any indicators (Na) were combined into the PCA graph as separate class variables. In the figure, sample areas with positive indicators are represented by red color, and sample areas with negative indicators are represented by gray color. Sample areas without any of the indicator species are shown in blue, and sample areas with both positive and negative indicators are shown in yellow.

The site index has the highest correlation with axis 2 (p = 0.613). It was observed that the variables with high correlation with axis 2, except for the site index, were altitude and radiation index. Of these variables, radiation index has a positive correlation with axis 2 (p=0.680), similar to the site index, while there is a negative correlation between elevation and axis 2 (p=-0.467). The results of the radiation index indicated that productivity is higher in the south and southwest aspects of the study area. On the other hand, while the elevation has the highest relationship with axis 1, the site index has a negative relationship with axis 1. It reveals that as the elevation increases in the study area, the site index value decreases. In fact, it is noteworthy that the sample areas, which are represented by red color in Figure 4 and have positive indicators of productivity, are positioned in the opposite direction from axis 2 with elevation.

Other variables with high correlation with axis 1 are slope and soil depth. The slope has a positive correlation with elevation, while soil depth has a negative correlation. According to these results, when an indirect interpretation is made, it can be said that the site index has a negative relationship with the slope and a positive relationship with the soil depth. However, the small vertical elevation range within the study area is an important consideration when evaluating these results.

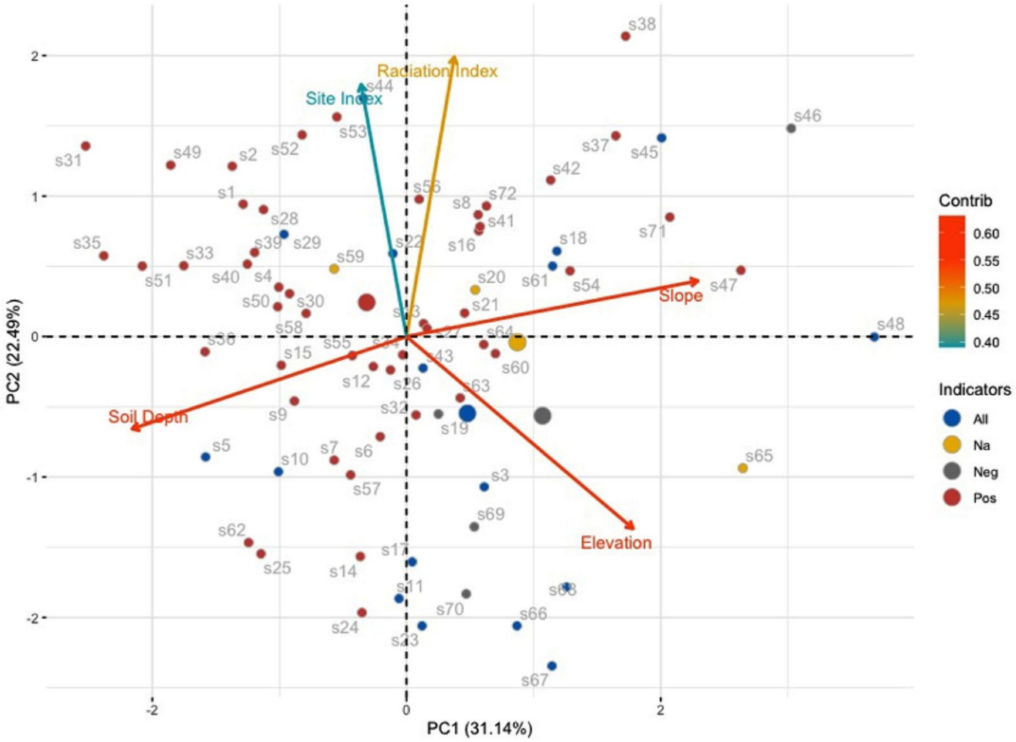

Figure 4: PCA plot of axis 1 and axis 2.

When all these results were evaluated, it was seen that the results obtained for the productivity of red pine have similar characteristics to the previous studies. For instance, Altun et al. (2007) revealed a positive relationship between the productivity of red pine and the slope classes in their study. Researchers could not detect a significant relationship between elevation and site index in the study. This is due to the small vertical elevation range (950-1150m). Additionally, in the aforementioned study, a positive relationship was determined with southern aspects similar to our result.

Another study revealing the relationships between red pine productivity and environmental variables was carried out by Özkan and Kuzugüdenli (2010), and altitude was determined as the most important factor affecting red pine productivity. In the study, in which a negative relationship with altitude was revealed, site index values were divided into both 3 and 5 classes and analyzes were made. In the study, it was stated that the results obtained regarding the site index values, which were divided into 3 classes, were more explanatory. This result shows that dividing the productivity of red pine into three classes is more meaningful than dividing it into five classes. For this reason, we divided the site indexes into 3 classes and included them in the analysis.

CONCLUSIONS

The results of the study show that there is no direct significant relationship between productivity and environmental factors in studies on species that do not have much sample plot data, were carried out in local areas or were found in limited areas in terms of horizontal and vertical distribution. However, by determining the indicator plant species of the areas where the target species are productive or not, useful information can be obtained for the mentioned target species. In order to ensure the sustainable use of species with high commercial use such as red pine and to determine the most productive areas, the inclusion of indicator plant species in the decision-making processes of natural and artificial regeneration of these species will provide significant benefits.

AUTHORSHIP CONTRIBUTION

Project Idea: SÖ

Funding: SÖ, TÇ

Database: SÖ

Processing: SÖ, TÇ

Analysis: SÖ, TÇ

Writing: SÖ, TÇ

Review: SÖ, TÇ

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