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Ellenberg's indicator values for soil nitrogen concentration and pH in selected swamp forests in the Central Black Sea region of Turkey

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Abstract: Ellenberg developed a system that assigns indicator scores for habitat characteristics of individual plant species. Swamp forests are highly diverse ecological communities and include different plant species, all of which have different ecological requirements. Ellenberg's indicator values (EIVs) were calculated for soil pH and nitrogen (N) concentration in some swamp forest species in the Central Black Sea region of Turkey. In this study, the EIVs for soil pH were usually similar in the swamp forest species studied, while some differences were found with respect to EIVs for soil nitrogen concentration. Tolerance values (TVs) of all of the studied species were higher than those reported in similar studies because EIVs and species abundance were high in the present study compared to similar studies. TVs (soil pH) were higher in Galeriç Forest than in the other 2 swamp forests. The differences among the swamp forest species studied with respect to EIVs might be explained on the basis of soil heterogeneity, even on a local scale.

Key words: Soil pH, soil nitrogen, swamp forests, tolerance values

1. Introduction

Ellenberg's indicator values (EIVs) have been used to estimate the value of a particular environmental factor (such as soil nitrogen (N) and pH) at a particular site by averaging the indicator values for this factor of all species (ter Braak and Gremmen, 1987). They also are used to assign indicator scores for habitat characteristics of individual plant species (McCollin et al., 2000; Diekmann, 2003; Pignatti, 2005; Seidling and Fischer, 2008), and EIVs for a particular species give a synthetic measure of environmental fluctuations in time and space (Dzwonko, 2001). EIVs also allow the assessment of a realized niche of tree species over wide areas according to the main ecological factors (Pinto and Gégout, 2005; Duru et al., 2010).

EIVs enable a rating of basic site qualities such as soil traits and can be assigned a value for each species according to the environmental characteristics by scoring with a scale. The scale for soil nitrogen concentrations ranges from 1 – extremely infertile soils to 9 – extremely fertile soils. The scale for soil reaction (soil pH) ranges from 1 – extreme acidic to 9 – extreme alkaline (McCollin et al., 2000; Seidling and Fischer, 2008).

Although EIVs have been widely used in Central Europe and Britain to show the relationships between environmental factors and species composition (van der Maarel, 1993; Borhidi, 1995; Böhling et al., 2002; Hill et al., 2004), studies related to EIVs in Turkey are rather scarce (Kutbay and Surmen, 2013). Swamp forests are distinctive habitats because they support many plant and animal communities with regard to biodiversity (Calhoun, 1999). They are also known as highly diverse ecological communities with regard to structural and functional attributes (Fickert and Grüninger, 2010). This study aimed (1) to compare swamp forest species with respect to EIVs (soil nitrogen concentration and soil pH) and to find whether there were differences among swamp forest species regarding ecological requirements; and (2) to find probable relationships among EIVs and species diversity and evenness.

2. Materials and methods

2.1. Study area, sampling, and chemical analysis

Three swamp forests were studied in the Central Black Sea region of Turkey (Figure 1). The first forest, known as Hacı Osman Forest (41°18′N, 36°55′E), covers approximately

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Figure 1. Map of the studied swamp forests (Δ: Galeriç Forest, ◊: Çakırlar Forest, □: Hacı Osman Forest).

an 86-ha area that is classified as a unique and endangered world-class alluvial ecosystem (Kutbay, 2001) and is located around Tekkeköy. The second forest is called Galeriç Forest (41°30′N, 36°05′E) and is situated in the western part of Samsun Province in the Kızılırmak Delta. The third forest is called Çakırlar Forest (41°34′N, 35°54′E), and covers a 25.0-ha area around the Kurupelit region of Samsun Province. The studied forests are characterized by hydromorphic alluvial soils (Efe and Alptekin, 1989; Kutbay, 2000, 2001; Huseyinova et al., 2013). Hacı Osman Forest is a protected swamp forest, while the other 2 forests have been heavily disturbed. For example, Galeriç Forest has been subjected to severe disturbance; because of commercial lumber production, its area has receded from 3564 ha to 3106 ha (Table 1) (Demirbaş et al., 2013; Huseyinova et al., 2013).

The cover-abundance values of plant species were estimated according to the Braun-Blanquet scale (Mueller-Dumbois and Ellenberg, 1974). The sizes of quadrats were estimated by means of the minimal-area method (Sağlam, 2013). Twenty floristically and structurally homogeneous plots (400 m^2) were taken from each swamp forest. Soil samples were taken from these plots. From June to November 2011, 20 soil samples of 0–30-cm depth from each swamp forest were collected using an auger. Soil samples were pooled since soil traits were relatively stable and changed very little during the sampling period.

The soil samples were air-dried and sieved to pass through a 2-mm screen. To determine soil pH deionized water was added to soil samples (1:2.5) and the samples were thoroughly mixed by a shaker and then filtered through Whatman No. 42 filter paper. pH was measured by using an Expandomatic IV digital pH meter (Kacar, 2012). Soil nitrogen (%) was determined by the micro Kjeldahl method (Allen et al., 1976; Balkovič et al., 2012; Kacar, 2012). The taxonomic nomenclature for plant species followed that of Brummitt and Powell (1992) and Güner et al. (2012).

Table 1. General features of study areas.

	Hacı Osman Forest	Çakırlar Forest	Galeriç Forest
Coordinates	41°18′N 36°55′E	41°34′N 35°54′E	41°30′N 36°05′E
Altitude	10 m	11 m	4 m
Total area	86 h	25 h	3564–3106 h
Average annual temperature	13.8 °C	14.46 °C	13.5 °C
Average annual total precipitation	895.2 mm	706.1 mm	672.4 mm
Average maximum temperature	27.7 °C (July)	27 °C (August)	30.1 °C (July)
Average minimum temperature	2.1 °C (January)	3.8 °C (February)	2.9 °C (February)

2.2. Statistical analysis

The mean EIVs were calculated as weighted averages of the species indices based on the cover-abundance of species for each particular plot and they were calculated by using arithmetic means for all species (Obidziński, 2004; Kasprowicz, 2010). EIVs for the swamp forest species studied were calculated by weighted average formula:

$$\text{weighted average} = \sum\nolimits_{i=1}^{n} (\text{rij} \times \text{xi}) / \sum\nolimits_{i=1}^{n} \text{rij}, \quad (1)$$

where r_{ij} is the response of species i in sample plot j, and x_i is the indicator value of species i.

Weighted averages for species tolerance (TV) values for soil pH were calculated using the following equation:

$$\text{Tw} = (\sum\nolimits_{i=1}^{n} \text{Yik}(\text{pHi}-\text{Rk})^2 / \sum\nolimits_{i=1}^{n} \text{Yik})^2, \quad (2)$$

where the variables y and R are species abundance and indicator value, respectively, subscript i stands for relevés (i = 1,. . ., n), and subscript k for plant taxa (k = 1,. . ., p) (Balkovič et al., 2012).

Plant diversity and evenness in the swamp studied forests were calculated by Biodiversity version 2.0 software (McAlleeceet al., 1997). Species diversity was calculated as the Shannon-Wiener index:

$$\text{H} = \sum\nolimits_{i=1}^{s} \text{pi} \times \text{In pi}, \quad (3)$$

where S is the total number of species and pi is the relative cover of the ith species. Shannon-Wiener evenness was calculated as:

$$\text{J} = \text{H'}/\text{Hmax}, \quad (4)$$

where Hmax is maximum species diversity and calculated as $\log_2$ pi.

Species diversity was also calculated as by the Simpson index:

$$\text{D} = 1\sum\nolimits_{i=1}^{s} \text{pi2}, \quad (5)$$

where S is the total number of species and pi is the relative cover of the ith species

$$\text{EP} = \frac{\text{D}}{\text{D max}} = \frac{1}{\sum\nolimits_{i=1}^{s} \text{pi2}} \times \frac{1}{2}, \quad (6)$$

where Ep is the evenness value according to Simpson's index, D is Simpson's diversity index, s is number of species, and pi is relative cover of the ith species (Magurran and McGill, 2011).

Statistical analyses were performed by SPSS version 21.0 (SPSS Inc., 2012). The differences among EIVs and species diversity and evenness values were investigated by one-way ANOVA. Independent variable groups (for species diversity and evenness) were determined using Tukey's HSD test.

3. Results

EIVs for pH were similar in all swamp forest species, while mean EIVs for soil nitrogen (N) concentration showed some differences among the swamp forest species studied (Table 2). TVs in Galeriç Forest were higher than those of the other species in other swamp forests (Table 3).

Swamp forest species in Hacı Osman Forest were separated in 2 groups with respect to EIVs for N and pH (Figures 2 and 3). Group 1 included many different growth forms from tree species, namely *Fraxinus angustifolia* Vahl subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso, *Fraxinus excelsior* L., *Pterocarya pterocarpa* (Michx.) Kunth ex I.Iljink., and *Carpinus orientalis* Mill. subsp. *orientalis* to lianas namely *Clematis vitalba* L. and *Dioscorea communis* (L.) Caddick & Wilkin and some herb species (*Leucojum aestivum* L., *Helleborus orientalis* Lam. etc.); group 2 included nitrogen-fixing species (*Alnus glutinosa* (L.) Gaertn. subsp. *glutinosa*), some tree species (e.g., *Ulmus glabra* Huds.), and the species using ammonia as nitrogen source (*Laurus nobilis* L.).

As for EIVs for soil pH, group 2 included only 3 species (*Alnus glutinosa* subsp. *glutinosa*, *Ulmus glabra*, and *Cornus mas* L.), while the other species belonged to group 1 (Table 2). However, all species in Çakırlar and Galeriç forests were in the same group with respect to EIVs because their soil pH and nitrogen concentrations were similar (Tables 4 and 5).

EIVs (N) in the species in Çakırlar and Galeriç forests were higher as compared to the species in Hacı Osman Forest, while the species in Çakırlar and Galeriç forests prefer neutral or slightly acidic soils. However, the species in Hacı Osman Forest were found on moderately alkaline soils and soil nitrogen concentrations were moderate (Figures 4 and 5).

Species diversity was high in Hacı Osman Forest as compared to the other swamp forests. The species in Hacı Osman and Galeriç forests were also more even than the species in the Çakırlar swamp forest (Table 6). There were significant correlations between EIVs and species diversity and evenness. Especially EIVs for soil N concentration and pH were significantly correlated with Shannon-Wiener evenness (Table 7). There were significant differences between the swamp forests according to species diversity and evenness values (Table 8). Moreover, we created groups to compare relationships between species diversity and evenness values and EIVs. Therefore, there were 2 groups for Shannon-Wiener diversity and Simpson evenness and 3 groups for Shannon-Wiener evenness and Simpson richness. As a result, statistically significant differences were found among the EIVs with respect to species diversity and evenness values (Table 9).

Table 2. Mean Ellenberg's indicator values (EIVs) of species in swamp forests studied.

Taxa	EIV pH	EIV N
Acer campestre L. subsp. *campestre*	6*/-**/6***	7*/-**/8***
Agrostis stolonifera L.	6/-/-	8/-/-
Alnus glutinosa (L.) Gaertn. subsp. *glutinosa*	7/-/-	8/-/-
Arum hygrophilum Boiss. *euxinum* (R.R.Mill) Alpınar	6/-/-	7/-/-
Carex capillaris L. subsp. *capillaris*	6/-/6	8/-/8
Carpinus betulus L.	-/6/-	-/9/-
Carpinus orientalis Mill. subsp. *orientalis*	6/6/6	7/9/8
Clematis vitalba L.	6/-/-	7/-/-
Clinopodium vulgare L. subsp. *vulgare*	6/-/-	7/-/-
Cornus mas L.	7/6/6	7/9/8
Cornus sanguinea L.	6/6/-	8/9/-
Crataegus monogyna Jacq.	6/-/-	8/-/-
Euonymus europaeus L.	6/-/-	7/-/-
Fraxinus angustifolia Vahl subsp. *oxycarpa (*Willd.) Franco & Rocha Afonso	6/6/6	7/9/8
Fraxinus excelsior L.	6/6/6	7/9/8
Galium palustre L.	6/-/-	8/-/-
Hedera helix L.	6/6/6	8/9/8
Helleborus orientalis Lam.	6/-/-	7/-/-
Iris pseudacorus L.	6/6/6	8/9/8
Laurus nobilis L.	6/-/6	8/-/8
Leucojum aestivum L.	6/6/6	7/9/8
Ligustrum vulgare L.	6/6/6	7/9/8
Oenanthe silaifolia M.Bieb.	6/-/-	8/-/-
Periploca graeca L.	6/-/-	7/-/-
Primula acaulis (L.) L. subsp. acaulis	6/-/-	7/-/-
Prunus spinosa L.	-/6/-	-/9/-
Pterocarya pterocarpa (Michx.) Kunth ex I.Iljink.	6/-/-	7/-/-
Quercus hartwissiana Steven	6/-/-	8/-/-
Ranunculus repens L.	6/-/-	7/-/-
Rubus hirtus Waldst. & Kit.	-/6/-	-/9/-
Rumex conglomeratus Murray	6/-/-	7/-/-
Ruscus aculeatus var. *aculeatus* L.	6/6/6	7/9/8
Salix alba L.	-/6/-	-/9/-
Smilax excelsa L.	6/6/-	8/9/-
Solanum dulcamara L.	6/-/-	8/-/-
Dioscorea communis (L.) Caddick & Wilkin	6/-/-	7/-/-
Ulmus glabra Huds.	7/6/-	8/9/-
Veronica anagallis-aquatica L.	6/-/-	7/-/-

* species of Hacıosman Forest
** species of Galeriç Forest
*** species of Çakırlar Forest

Table 3. Tolerance values (TVs) of swamp forest species studied for EIVs for pH.

Taxa	Hacıosman Forest	Galeriç Forest	Cakırlar Forest	Balkovič et al. 2012
Acer campestre L. subsp. *campestre*	1.33	-	1.50	0.80
Agrostis stolonifera L.	1.39	-	-	-
Alnus glutinosa (L.) Gaertn. subsp. *glutinosa*	0.51	-	-	-
Arum hygrophilum Boiss. *euxinum* (R.R.Mill) Alpınar	1.32	-	-	-
Carex capillaris L. subsp. *capillaris*	1.25	-	1.07	-
Carpinus betulus L.	-	1.38	-	0.46
Carpinus orientalis Mill. subsp. *orientalis*	1.37	1.39	1.43	-
Clematis vitalba L.	1.27	-	-	-
Clinopodium vulgare L. subsp. *vulgare*	1.26	-	-	0.28
Cornus mas L.	0.53	1.45	1.41	-
Cornus sanguinea L.	1.47	1.66	-	-
Crataegus monogyna Jacq.	1.31	-	-	0.67
Euonymus europaeus L.	1.31	-	-	-
Fraxinus angustifolia Vahl subsp. *oxycarpa (*Willd.) Franco & Rocha Afonso	1.33	1.33	1.22	-
Fraxinus excelsior L.	1.29	1.32	1.19	0.67
Galium palustre L.	1.36	-	-	-
Hedera helix L.	1.34	1.34	1.27	-
Helleborus orientalis Lam.	1.30	-	-	-
Iris pseudacorus L.	1.29	1.40	1.24	-
Laurus nobilis L.	1.42	-	1.31	-
Leucojum aestivum L.	1.29	1.34	1.26	-
Ligustrum vulgare L.	1.42	1.55	1.44	0.57
Oenanthe silaifolia M.Bieb.	1.39	-	-	-
Periploca graeca L.	1.41	-	-	-
Primula acaulis (L.) L. subsp. acaulis	1.35	-	-	-
Prunus spinosa L.	-	1.40	-	0.34
Pterocarya pterocarpa (Michx.) Kunth ex I.Iljink.	1.22	-	-	-
Quercus hartwissiana Steven	1.34	-	-	-
Ranunculus repens L.	1.40	-	-	-
Rubus hirtus Waldst. & Kit.	-	1.37	-	-
Rumex conglomeratus Murray	1.30	-	-	-
Ruscus aculeatus var. *aculeatus* L.	1.36	1.49	1.00	-
Salix alba L.	-	1.57	-	-
Smilax excelsa L.	1.34	1.42	-	-
Solanum dulcamara L.	1.39	-	-	-
Dioscorea communis (L.) Caddick & Wilkin	1.11	-	-	-
Ulmus glabra Huds.	0.51	1.47	-	-
Veronica anagallis-aquatica L.	1.24	-	-	-

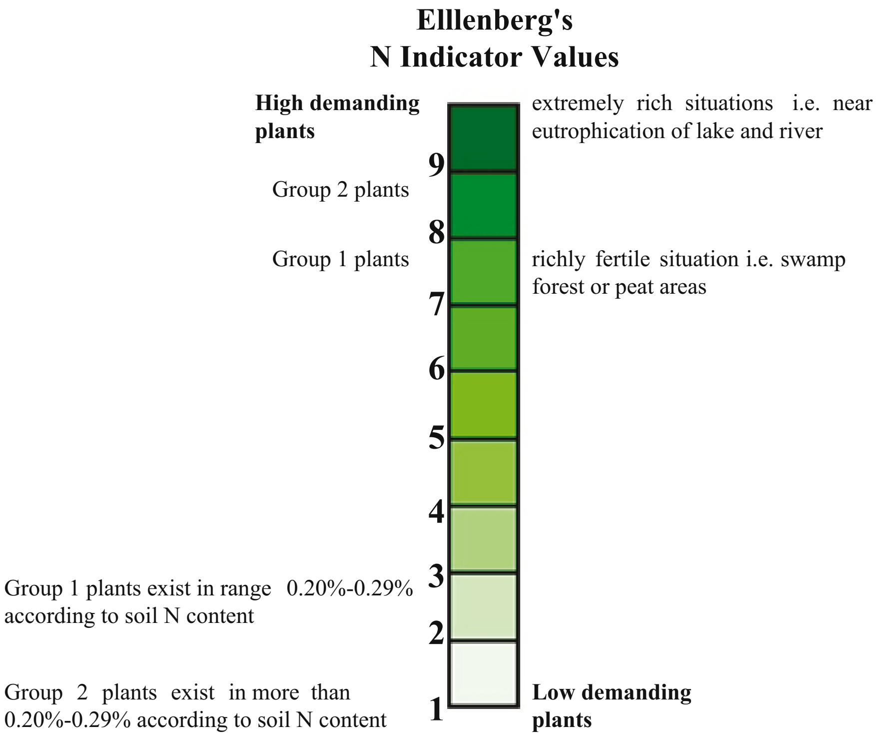

Figure 2. Nitrogen (N) indicator values of plants in Hacı Osman Forest (Figures 2–5 adapted from Dupouey (2010)).

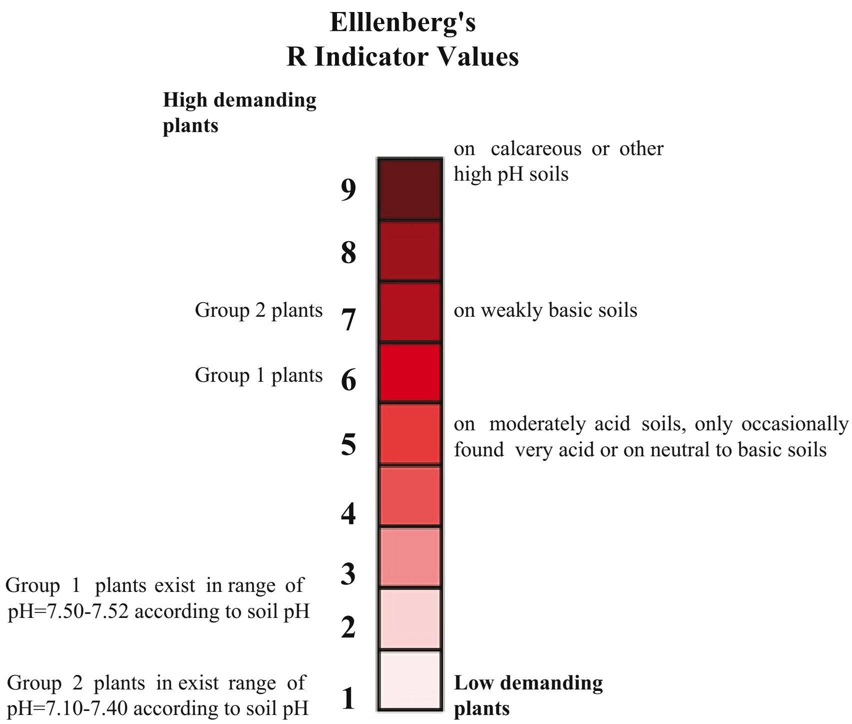

Figure 3. Soil reaction (R; soil pH) indicator values of plants in Hacı Osman Forest.

Table 4. Mean values for soil nitrogen concentrations (%) in swamp forest species studied.

Taxa	N EIV			
	Hacı Osman Forest		Galeriç Forest (0.68%–0.97%)	Çakırlar Forest (0.34%–0.43%)
	Group 1 (0.20%–0.29%)	Group 2 (0.29%–0.45%)		
Acer campestre L. subsp. *campestre*	x	-	-	x
Agrostis stolonifera L.	-	x	x	-
Alnus glutinosa (L.) Gaertn. subsp. *glutinosa*	-	x	-	-
Arum hygrophilum Boiss. *euxinum* (R.R.Mill) Alpınar	x	-	-	-
Carex capillaris L. subsp. *capillaris*	-	x	-	x
Carpinus betulus L.	-	-	x	-
Carpinus orientalis Mill. subsp. *orientalis*	x	-	x	x
Clematis vitalba L.	x	-	-	-
Clinopodium vulgare L. subsp. *vulgare*	x	-	-	-
Cornus mas L.	x	-	x	x
Cornus sanguinea L.	-	x	x	-
Crataegus monogyna Jacq.	-	x	-	-
Euonymus europaeus L.	x	-	-	-
Fraxinus angustifolia Vahl subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso	x	-	x	x
Fraxinus excelsior L.	x	-	x	x
Galium palustre L.	-	x	-	-
Hedera helix L.	-	x	x	x
Helleborus orientalis Lam.	x	-	-	-
Iris pseudacorus L.	-	x	x	x
Laurus nobilis L.	-	x	-	x
Leucojum aestivum L.	x	-	x	x
Ligustrum vulgare L.	x	-	x	x
Oenanthe silaifolia M.Bieb.	-	x	-	-
Periploca graeca L.	x	-	-	-
Primula acaulis (L.) L. subsp. acaulis	x	-	-	-
Prunus spinosa L.	-	-	x	-
Pterocarya pterocarpa (Michx.) Kunth ex I.Iljink.	x	-	-	-
Quercus hartwissiana Steven	-	x	-	-
Ranunculus repens L.	x	-	-	-
Rubus hirtus Waldst. & Kit.	-	-	x	-
Rumex conglomeratus Murray	x	-	-	-
Ruscus aculeatus var. *aculeatus* L.	x	-	x	x
Salix alba L.	-	-	x	-
Smilax excelsa L.	-	x	x	-
Solanum dulcamara L.	-	x	-	-
Dioscorea communis (L.) Caddick & Wilkin	x	-	-	-
Ulmus glabra Huds.	-	x	x	-
Veronica anagallis-aquatica L.	x	-	-	-

Table 5. Mean values for soil pH in swamp forest species studied.

Taxa	pH EIV			
	Hacı Osman Forest		Galeriç Forest (6.75–7.33)	Çakırlar Forest (6.90–7.44)
	Group 1 (7.50–7.52)	Group 2 (7.1–7.40)		
Acer campestre L. subsp. *campestre*	x	-	-	x
Agrostis stolonifera L.	x	-	-	-
Alnus glutinosa (L.) Gaertn. subsp. *glutinosa*	-	x	-	-
Arum hygrophilum Boiss. *euxinum* (R.R.Mill) Alpınar	x	-	-	-
Carex capillaris L. subsp. *capillaris*	x	-	-	x
Carpinus betulus L.	-	-	x	-
Carpinus orientalis Mill. subsp. *orientalis*	x	-	x	x
Clematis vitalba L.	x	-	-	-
Clinopodium vulgare L. subsp. *vulgare*	x	-	-	-
Cornus mas L.	-	x	x	x
Cornus sanguinea L.	x	-	x	-
Crataegus monogyna Jacq.	x	-	-	-
Euonymus europaeus L.	x	-	-	-
Fraxinus angustifolia Vahl subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso	x	-	x	x
Fraxinus excelsior L.	x	-	x	x
Galium palustre L.	x	-	-	-
Hedera helix L.	x	-	x	x
Helleborus orientalis Lam.	x	-	-	-
Iris pseudacorus L.	x	-	x	x
Laurus nobilis L.	x	-	-	x
Leucojum aestivum L.	x	-	x	x
Ligustrum vulgare L.	x	-	x	x
Oenanthe silaifolia M.Bieb.	x	-	-	-
Periploca graeca L.	x	-	-	-
Primula acaulis (L.) L. subsp. acaulis	x	-	-	-
Prunus spinosa L.	-	-	x	-
Pterocarya pterocarpa (Michx.) Kunth ex I.Iljink.	x	-	-	-
Quercus hartwissiana Steven	x	-	-	-
Ranunculus repens L.	x	-	-	-
Rubus hirtus Waldst. & Kit.	-	-	x	
Rumex conglomeratus Murray	x	-	-	-
Ruscus aculeatus var. *aculeatus* L.	x	-	x	x
Salix alba L.	-	-	x	-
Smilax excelsa L.	x	-	x	-
Solanum dulcamara L.	x	-	-	-
Dioscorea communis (L.) Caddick & Wilkin	x	-	-	-
Ulmus glabra Huds.	-	x	x	-
Veronica anagallis-aquatica L.	x	-	-	-

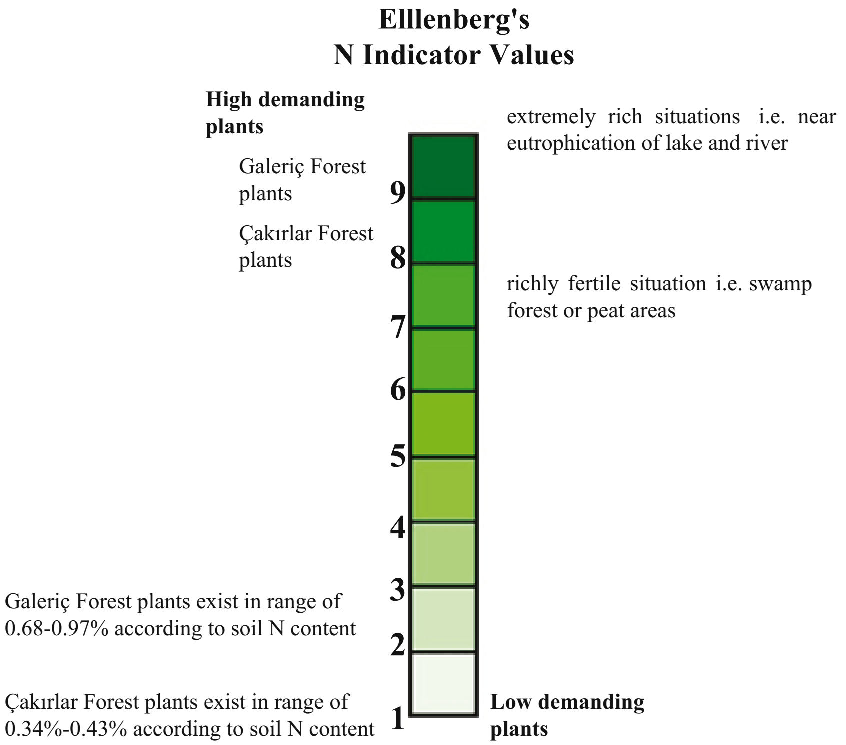

Figure 4. Soil nitrogen (N) indicator values of plants in Galeric and Çakırlar forests.

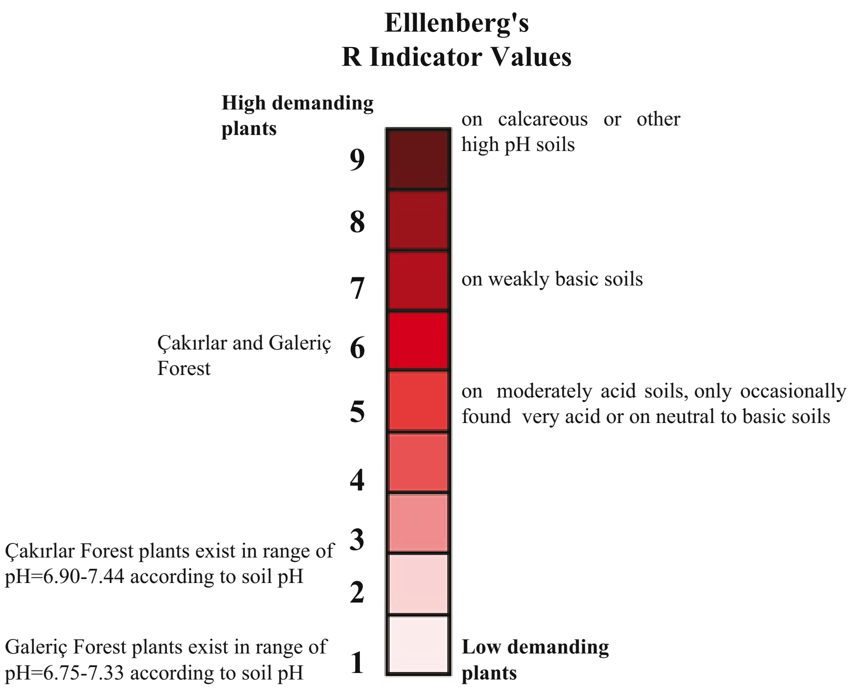

Figure 5. Soil reaction (R; soil pH) indicator values of plants in Galeric and Çakırlar forests.

Table 6. Plant diversity and evenness in swamp forests studied.

	Hacı Osman Forest	Çakırlar Forest	Galeriç Forest
Shannon-Wiener Richness	1.265 ± 0.038	0.788 ± 0.032	0.912 ± 0.048
Simpson richness	0.046 ± 0.004	0.153 ± 0.011	0.114 ± 0.013
Shannon-Wiener evenness	0.978 ± 0.002	0.941 ± 0.005	0.957 ± 0.004
Simpson evenness	23.437 ± 2.081	6.697 ± 0.462	9.596 ± 1.28

Mean ± standard error (SE).

Table 7. Pearson correlation coefficients between EIVs and Shannon-Wiener and Simpson diversity and evenness.

	Çakırlar Forest		Galeriç Forest		Hacı Osman Forest	
	pH EIV	N EIV	pH EIV	N EIV	pH EIV	N EIV
Shannon-Wiener diversity	−0.228	0.594*	0.585*	0.067	0.351	0.488
Simpson diversity	0.393	−0.350	−0.549*	−0.036	−0.442	−0.551*
Shannon-Wiener evenness	0.228	−0.859**	0.697*	−0.011	0.715**	0.634*
Simpson evenness	−0.461	0.373	0.682*	0.108	0.348	0.459

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
Mean ± standard error (SE).

Table 8. Mean diversity and evenness values of swamp forests. Means followed by the same letters are not significantly different at the 0.05 level using Tukey's HSD test.

	Shannon-Wiener diversity	Shannon-Wiener evenness	Simpson richness	Simpson evenness
Hacı Osman Forest	1.264 ± 0.038a	0.978 ± 0.005a	0.046 ± 0.014c	23.437 ± 6.582a
Galeriç Forest	0.912 ± 0.048b	0.957 ± 0.011b	0.114 ± 0.033b	9.596 ± 3.388b
Çakırlar Forest	0.778 ± 0.073b	0.940 ± 0.011c	0.153 ± 0.028a	6.697 ± 1.131b

Table 9. Statistically significant differences among the EIVs and species diversity and evenness values using one-way ANOVA (P < 0.001).

	Shannon-Wiener diversity	Shannon-Wiener evenness	Simpson richness	Simpson evenness
	P value			
N EIV	0.000	0.000	0.000	0.000
pH EIV	0.000	0.001	0.001	0.000

Mean ± standard error (SE).

4. Discussion

Nitrogen is known as the most important macronutrient in terrestrial ecosystems (Diekmann, 2003). EIVs for soil N concentration are a good indicator of productivity and nutrient availability and also refer to the degree of mobilization of accumulated nitrogen in the soil (Duru et al., 2010; Wehenkel, 2011). More nitrogen-demanding species belonged to group 2 in Hacı Osman Forest. *Alnus glutinosa* subsp. *glutinosa* was also included in the nitrogen-demanding species group (group 2) although this species is a nitrogen-fixing species. It has been stated that continued N_2 fixation may lead to high senescent leaf N concentrations and rapid ecosystem incorporation of fixed N and N fixation can control the nitrogen budget at the ecosystem level (Uliassi and Ruess, 2002; Vitousek et al., 2010). Group 2 also includes some herb species like *Carex divisa* Huds. This species exhibits a ruderal strategy according to Grime's CSR classification. It has been found that nitrogen-demanding species usually exhibit the ruderal-type strategy (Dupouey et al., 2002; Huseyinova et al., 2013; Kutbay and Surmen, 2013). Soil pH values were lower in Galeriç and Çakırlar forests, and the species in these forests were more acid-tolerant. Hédl (2004) found a similar situation in beech forests. pH values for the studied species ranged from 6 to 7, whereas soil nitrogen values ranged from 7 to 8. EIVs for soil N concentration and pH in the present study were similar to those reported for other swamp forests (Slezák et al., 2012). The studied species were indicators of weakly acid to weakly basic and indicated fertile soils with high bioactivity and alkaline and near neutral pH (Vallet et al., 2008).

Soil pH values of the swamp forest species studied ranged from 6.75 to 7.52. It may be concluded that swamp forest species had wide amplitude regarding soil pH (Pitman et al., 2014). Cicek et al. (2010) found that swamp forest species, especially canopy species in swamp forests (*Fraxinus angustifolia* subsp. *oxycarpa*) studied, can tolerate higher soil pH, although it grows better in more open soils with a lower pH. Soil pH has a great effect on the availability of soil nutrients. For example, phosphorus availability declines with both decreasing and increasing soil pH. The soils in the Central Black Sea region are low in available phosphorus and this is probably due to soil pH (Kutbay, 2001; Niinemets and Kull, 2003).

It has been found that the species in Galeriç and Çakırlar forests occurred on soils rich in available nitrogen. Seidling and Fischer (2008) reported that shade-tolerant species were found on soils rich in available nitrogen. It has also been reported that alluvial hardwood forest species are found on flooded but well-drained and fertile soils (Schnitzler, 1994; Košir et al., 2013). This is particularly true for group 2 plants in Hacı Osman Forest. However, Galeriç and Çakırlar forests were heavily disturbed as compared to Hacı Osman Forest and the species in these forests contained soils that were rich in soil nitrogen. Seidling and Fischer (2008) also reported that the original mean EIVs for soil traits are closely related to measured soil parameters in regional studies and may change due to spatial heterogeneity.

TVs for the species were rather high as compared to those in similar studies (Balkovič et al., 2012). First of all, the same species in similar studies were found in a submontane forest, whereas the present study was carried out in swamp forests. High TVs are probably due to the high species abundance and high EIVs (soil pH) in the swamp forests studied. Significant correlations between species diversity and evenness and EIVs emphasized the importance of species abundance for indicator values. Mölder et al. (2008) found significant correlations between EIVs and species diversity and evenness. There were significant positive correlations between the Shannon-Wiever index and the EIVs for N in Hacı Osman Forest, while this correlation was negative in Galeriç Forest. This was probably due to the degree of disturbance, and Galeriç Forest was heavily disturbed (Huseyinova et al., 2013; Mullerova et al., 2013). Swamp forest species in Galeric Forest had high mean EIVs and species abundance and as a result of this they also had higher TVs.

It has been found that EIVs for soil nitrogen and pH were subjected to spatial heterogeneity. Soil is a very heterogeneous ecosystem and soil traits may change even within local areas (Kutbay and Surmen, 2013). In temperate zones, succession is strongly dependent on various local factors, for example soil traits, and these traits usually culminate in forest vegetation as the climax state. EIVs may also be used to indicate successional stages and the forests studied form the climax phase of hydrosere (Kutbay, 2001; Wehenkel, 2011).

In summary, we found that there were some differences among the swamp forest species studied with respect to EIVs for soil N concentration. The differences among species regarding EIVs for soil traits might be due to the differences in plant species diversity and evenness. For example, the distribution in species in Hacı Osman Forest was more even than in the other swamp forests and these differences lead to habitat heterogeneity in the soil in swamp forests studied (Rodríguez-Loinaz et al., 2008). Zelený and Schaffers (2012) and Huseyinova et al. (2013) found that using mean EIVs in ecological studies leads to more significant results than using external ecological information and they may be used to classify the species with respect to preference for soil traits in a particular ecosystem. Further studies are required for a better characterization of swamp forest species over local and global scales with respect to EIVs. This will be very helpful for sustainable management of such distinctive ecosystems.

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