THE EFFECT OF AFFORESTATION ON BIODIVERSITY IN MALATYA, TURKEY

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Abstract. Since 1960s, the Tepehan (Turkey) region had long been suffering from serious soil erosion. Therefore, large-scale afforestation with mainly coniferous species has continued during the past decades in order to control soil erosion and it has yielded quite successful results. However, since it has been unknown how afforestation influences biodiversity so far this study investigated it. Braun–Blanquette method was used to select a plot in each stratum which represents the vegetation characteristic of the whole area of the forest and to assess vegetation parameters. The results of the survey show that 77 species belonging to 58 genera were recorded in different layers including 7 trees, 4 shrubs and 66 herbs in the study area. Diversity index was used for measuring biological diversity and was found consistently and significantly greater in native Quercus forests than in exotic coniferous plantation forests. These results show that afforestation has a negative influence on species diversity. Therefore, it is recommended to develop strategies for biodiversity conservation in afforestation work in the country to maintain habitats and minimize loss of native species.

Keywords: afforestation, biodiversity, biodiversity index, vegetation

Introduction

For 5 to 6 thousand years in our world the delicate balance between soil, vegetation and water has been disturbed in natural environments as a consequence of the removal or destruction of natural vegetation for various reasons. Especially wrong land use with deforestation and erosion in sensitive ecosystems where semi-arid and arid climatic conditions dominated caused the loss of soil and the disappearance of plant species. Afforestation activities have an important role in re-equilibrating the degraded ecosystem as well as reducing the effects of some global disasters and fighting erosion. However, the impact of afforestation with single or several of exotic coniferous species has been discussed without much consideration of the ecological characteristics of the forests.

Whereas some afforestation efforts are believed to harm ecosystem biodiversity and interfere with biodiversity conservation goals (Cao et al., 2009; Calvino-Cassela et al., 2012; Pourbabaei et al., 2012), a large number of studies in many countries has shown that the plantation of forests can provide habitat for a wide range of native forest plants, animals, and fungi and can support a diverse array of native understorey plants (Barbaro et al., 2005; Carnus et al., 2006; Brockerhoff et al., 2008; Juying et al., 2017).

Usually, the used species show rapid growth instead of natural species in afforestation to control soil erosion, accelerate vegetation restoration, and improve ecological environments in Turkey and quite successful results have been obtained. However, the positive/negative impact of afforestation on biodiversity is not discussed so much in Turkey. Whereas it is important to identify the effects of afforestation on biodiversity and the functioning of ecosystems. Biodiversity has been shown to play a key role at all levels of the ecosystem service hierarchy (Mace et al., 2012; Gao et al., 2014). Therefore, the importance of measuring biodiversity increased.

Various diversity indices are used to measure biodiversity. Diversity index is a statistical method which is planned to evaluate the variety of a data group consisting of different types of components. Such as number of existing species (Richness), equal distribution of individuals (Evenness) and total number of existing individuals. Any changes in any of these three features are effectively used to identify changes in a population (M1str et al., 2018).

The study area Tepehan (Malatya-Turkey) is on the southeastern Taurus Mountains where Davis describes in terms of floristic as medium, few or never worked and where studies suggest that the work should be done at a local level and in detail and had long been suffering from serious soil erosion since 1960s. So large-scale afforestation with mainly coniferous species has continued during the past decades in order to control soil erosion and quite successful results has been obtained. However, it has unknown how afforestation influences biodiversity so far. So in this study both inventories have been carried out and the influence of afforestation on the vegetation was assessed by using biodiversity indices.

Materials and methods

Study area

Study was conducted in Tepehan located at 38° 11' 45.3" N and 38° 52' 8.1" E. The first afforestation and erosion control works started here in Malatya in 1962.

In Tepehan and its surrounding, Puturge metamorphic consisting of gneiss, micaschist and amphibolite dominate the terrain. These are the oldest formations in the region and they form the foundation (*Fig. 1*).



Figure 1. The location of the study area

Climate

The climate data of the Puturge Forest Station, which is the nearest meteorological station to the research area, are given in *Table 1*.

Motoonological data Daried		MONTHS											
Meteorological data	renou	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Total rainfall (mm = kg \div m ²)	2	72.7	24.75	53.6	57.95	117.3	25.25	3	1.55	6.3	42.65	51.6	32.4
Maximum rainfall (mm = kg \div m ²)	2	22.9	12.95	15.75	22.3	35.8	10.4	1.8	0.55	4.6	20.15	13.9	12.15
Avarage temperature (°C)	2	-1.85	0.8	6.05	10.1	13.6	19.3	24.25	24.7	21	12.6	5.6	2
Maximum temperature (°C)	2	6.15	10.55	16.65	21.5	25.35	32.3	34.6	34.4	31.4	23.25	15.95	9.8
Minimum temperature (°C)	2	-9.85	-8.05	-4.25	-2.2	5.6	8.05	12.75	14.75	10.35	1.8	-5.05	-6.1
Average wind speed (m÷sn)	2	2.3	2.6	3.2	3.15	2.6	2.8	3.15	2.95	2.45	2.4	1.85	2.25

 Table 1. 2017-2018 data of Puturge forest meteorological station (MGM, 2019)

Table 1 is to show that the average annual temperature is 11.51 °C, the annual rainfall is 489.05 mm and the average annual relative humidity is 47.01%. In terms of temperature regime, it is a summer season of 4-months between June and September, a winter season of about 4.5-months between November and late March and the spring and fall seasons of about 1.5-2-months.

According to the WALTER method, ombrotermik climate (precipitation-temperature) diagrams of Puturge was seen (*Fig. 2*).



Figure 2. Ombrotermik climate (precipitation-temperature) diagrams of Puturge

Figure 2 shows that a drought period of four months has been from the end of May to the end of November.

Vegetation

According to Davis (1965-1988), the research area is located at the B7 Iranian-Turonian floristic region that is characterized with dwarf trees, grasses and meadow at a high rate although the number of tree species that is relatively few. Walter (1976) described the zonal vegetation as climate zone "Temperate arid- Step forest Zone", and Zohary (1973) classified it as "Persian xenophile Quercus brantii forest". These dry forests, which are generally pure oak communities constituted a narrow rung among Hakkâri, Malatya and Kahramanmaraş where the spreading of the oak-juniper forests continued on the slopes of the west and central Taurus (Louis, 1939; Mayer and Aksoy, 1998).

The current vegetation of the research area consists of oak-bush communities, steppe communities with secondary characters created along with the anthropogenic influences for years, pine and cedar communities established with afforestation in 1962 (*Fig. 3*).



Figure 3. A view of the vegetation of the study area

Vegetation sampling

Sample plots were randomly selected in the field and Braun–Blanquette method was used to select a plot in each stratum which represents the vegetation characteristic of the whole area of the forest and vegetation studies was carried out in 9 plots of 20×20 m during periods of optimum development of the vegetation in 2018 (*Table 2*).

No	Name of plant community	Geographical location (WGS 84)	Altitude (m)
1	Pinus nigra afforestation area (Pn1)	477151-4220072	1500
2	Native Quercus sp. forest (Q1)	477164-4220086	1500
3	Pinus nigra afforestation area (Pn2)	475820-4220064	1510
4	Native Quercus sp. forest (Q2)	475799-4220076	1515
5	Pinus sylvestris afforestation area (Ps1)	478215-4219536	1575
6	Cedrus libani afforestation area (C1)	479417-4218245	1540
7	Mixed forest (M1)	477067-4222421	1280
8	Pinus nigra afforestation area (Pn3)	477670-4222935	1190
9	Native Quercus sp. forest (Q3)	477696-4222942	1200

Table 2. Geographical locations of the plots

The limit value of vegetation cover was determined according to Scamoni (1963) and showed *Table 3* (Aksoy, 1978).

Table 3. Limit values of vegetation layer according to Scamoni (1963)

> 5 m	T tree layer
50 cm – 5 m	S shrub layer
< 50 cm	H herb layer

According to Braun–Blanquette, the abundance-cover (density) scale is:

r: One species, the cover condition is ambiguous,

- +: Species abundant, but cover is weak, cover is 1-5%,
- 1: Species abundant, but cover grade weak, cover 5-25%,
- 2: Species cover is between 25-50%,
- 3: Species cover is between 50-75%,
- 4: Species cover is between 75-100%.

Measuring plant diversity

There are some common diversity indexes. However, Shannon-Wiener index are most widely used for measuring biological diversity. When used species richness and species evenness together, the diversity of the community can be expressed and compared to other communities.

To calculate vegetation profiles, Braun–Blanquette scores were transformed to relative cover (r: 0.01; +: 0.02; 1: 0.04; 2: 0.15; 3: 0.375; 4: 0.625; 5:0.875) prior to analysis (Fontaine et al., 2007).

Species richness

Species richness is the actual number of species present in a community (Atlas, 1984; Patrick, 1949):

D = S

where D = species richness, S = number of species in the community.

Shannon-Wiener index

Shannon-Weiner diversity index (H') was calculated (Shannon and Weaver, 1949) as:

$$H' = -\sum_{i=1}^{s} P_i \text{ In } Pi$$

where S = total number of species, Pi (Ni/N) = proportional abundance of species i, In Pi = the natural logarithm of the proportional abundance of species i. Values of H' can range from 0 to 5.

Species evenness

From the formula above we obtain Shannon evenness index J (Pielou, 1966) as

$$J = \frac{H'}{\ln S}$$

where J: Pielou Regularity Index, H: Shannon-Weaner Diversity Index, S: Number of species, J ranges from 0 to 1.

Results

Vegetation analysis

9 samples were established and 77 species belonging to 58 genera were recorded in the study area in different layers including 7 trees (T), 4 shrubs (S) and 66 herbs (H) (*Table 4*). Within the study area, there were important differences between exotic coniferous plantations and native species plots with respect to structural development. Exotic coniferous plantations had significantly greater numbers of planted tree species, higher stem density and crown cover, greater mean tree heights and stem diameters than native Quercus. On the other hand, the plant community in Quercus forest varied in structure and composition among sites due to physiographic and anthropogenic pressures. The density of grasses in the native forest is clearly a reflection of favourable light conditions. Species richness and species diversity correlated negatively with crown cover.

	Plot area no	Pnk1	Q1	Pn2	Q2	Ps1	C1	M1	Pn3	Q3	
	Area (m ²)	400	400	400	400	400	400	400	400	400	
	Altitude (m)	1500	1500	1510	1515	1575	1540	1280	1190	1200	
		•	Cov	ver of la	yer		•	•			
	T Layer (%)	70	30	80	25	80	70	60	90	40	CE
	S Layer (%)	10	30	3	30	-	5	15	10	50	EN
	H Layer (%)	10	90	15	95	15	30	60	10	80	IST
		•	Vege	tation he	eight		•	•			EX
	Tree layer (m)	8-10	68	16-18	6	20	12	12-15	12	6	
	Shrub layer (m)	3	3	2.5	3	-	2.5	2.5	3	3	
	Herb layer (cm)	30	50	40	50	30	50	30	10	50	
		•	Distin	guishing	g taxa		•	•			
Т	Pinus nigra	3		4	1		•	2	4		5
Т	Quercus cerris	2	2	+				1	•	2	5
Т	Cedrus libani	1			•	•	4	3	1	•	4
Т	Quercus infectoria subsp. boissieri	•	1	•	2	•	•	•	•	2	3
Т	Robinia pseudoacacia				1				2	1	3
Т	Quercus libani		r		•				•	+	2
Т	Pinus sylvesteris		•	1	•	5	•		•	•	2
S	Quercus cerris	1	2	•	1	•	•	1		3	5
S	Quercus infectoria subsp. boissieri	•	2	•	2		•	1	•	2	4
S	Crataegus aronia subsp. aronia			1	1		1	1			4
S	Pinus nigra	1						1			2
S	Rosa canina				r			1			2
S	Cedrus libani				•				1	•	1
S	Quercus libani			•					•	1	1
S	Crataegus monogyna subsp monogyna							+			1

Table 4. Vegetation analysis

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S	Robinia pseudoacacia				r		.	.	.		1
S	Colutea cilica	•		•			•	•		r	1
Н	Poa bulbosa	2	1	2	3	1	2	2	1	2	9
Н	Lotus gebelia var. gebelia	1	2	1	2	+	+	1		•	7
Н	Muscari comosum	+	2	1	2		2	•	r	1	7
Н	Trifolium arvense var. arvense	1	5	1	3	•	1	3	•	1	7
Н	Ziziphora capitata	1	1	1	1		•	+		1	6
Н	Trifolium boissieri	1	2	•	4		1	3	•	2	6
Н	Astragalus sp.	•	1	•	1	+	+	1		1	6
Н	Pilosella piloselloides	•	r		1	+	+	1	+	•	6
Η	Rumex acetellosa	•		<u> </u>	1	1	•	1	1	1	5
Н	Hypericum scabrum	1	1	+	2		•	•		1	5
Н	Trifolium pilulare	•	r	•	2		•	2	2	4	5
Н	Astragalus altanii	+	1	•	1	+	•	•	•	1	5
Н	Bunium paucifolium var. brevipes	•	r	+	1	+	+	•		•	5
Н	Lotus gebelia	•	1	•		•	+	•	2	1	4
Н	Astragalus cephalotes var. brevicalyx	+				+	•	1		2	4
Н	Achillea bieberstenii		+		2	+	•	1			4
Н	Tragopogon longistris subsp. longistris		+		1	+				1	4
Η	Phlomis kurdica	•	r		1		r	1		•	4
Н	Galium spurium subsp. ibecinum		+	+	+		•	•	+	•	4
Н	Ranunculus cuneatus	1		1		2	1	•			4
Н	Pinus nigra	1		1	+		•	•			3
Н	Senecio vernalis	+		+		+	•	•		•	3
Н	Arenaria serpylifolia	•	•	1			1	•	•	1	3
Н	Alyssum szowotsii	•	1	•		+	•	•	•	1	3
Н	Astragalus angustifolius subsp anatolicus	•				+	•	•	+	1	3
Н	Cerastium dicthomum subsp. dicthomum	•					+	•	+	1	3
Н	Crepis cf. alpina			•			+	•	+	1	3
Н	Helichrysum armenium subsp. araxinum				1		+	1		•	3
Н	Geranium tuberosum	•		+		r	+	•		•	3
Н	Lactuca serriola		+	•	+			•	+		3
Н	Onosma sericeum		+	•	1			+		•	3
Η	Quercus cerris	+		+			•	•	+		3
Η	Veronica bozakmanii	•		+		+	+	•			3
Η	Anthemis sp.	•	1					•		1	2
Η	Torilis leptophylla	•					r			1	2
Н	Crataegus aronia var. aronia	•		+			r	•		•	2

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Н	Myosotis stricta				1		+				2
Н	Sanguisorba minor subsp muricata	•			1		+	•	•		2
Н	Leontodon asper var. setulosus	•			+		•	•	•	+	2
Н	Vicia sativa subsp. nigra var. nigra	•	1		1		•	•			2
Н	Vicia cracca subsp. stenophylla					r				2	2
Η	Viola occulta					r	+	•			2
Η	Bromus japonica				1			•		1	2
Η	Cedrus libani						1	+			2
Н	Tripleurospermum oreades			+	+						2
Н	Verbascum sp.							+		+	2

Single repetition taxa: Picnomon acarna +, Bromus tectorum + (Pn3), Teucrium polium +, Papaver dubium +, Briza humilis +, Cerastium dicthomum subsp. inflatum +, Cyanus depressa +, Trifolium purpureum + (Q3), Myosotis refracta +, Valerianella coronata + (Q2), Crupina crupinastrum +, Euphorbia cf. macroclada +, Eryngium campestre var. virens +, Salvia multicaulis +, Opopanax hispidus +, Taeniatherum caput-medusae subsp. crinitum 1(2) (M1), Lecokia cretica +, Ophrys frigida r (Pn2), Geranium rotundifolium r, Crepis sancta +, Centaurea virgata +, Potentilla argentea +, Erysimum kotschyii + (C1), Cnicus benedictus subsp. benedictus r (Q1)

Biodiversity measurement

The sample which were the highest in species richness were also found to have the highest species diversity or Shannon-Wiener Index value (*Table 5*).

Sampling plots no.	Pn1	Q1	Pn2	Q2	Ps1	C1	M1	Pn3	Q3
Shannon-Wiener Index (H')	2.27	2.47	2.29	3.01	1.69	2.46	2.88	2.02	3.08
Species richness	15	26	21	35	20	27	28	17	36
Species evenness	0.84	0.76	0.75	0.85	0.57	0.75	0.86	0.71	0.86

Table 5. Biodiversity measurement in sampling plots

Species diversity

Results show that Q3 plot has the highest plant diversity as compared to other plots, followed by Q2 and M1 plots as the second and third most diverse respectively. Ps1 plot was the least diverse among all 9 plots (*Table 5*). Shannon-Weiner diversity index was 62% greater in native Quercus forest than in exotic coniferous plantations (pine and cedar) areas as a diversity index of 2.85 and 1.79 for the native Quercus forest and afforested areas was registered consecutively.

Species richness

It shows that Q3 plot has the highest plant diversity as compared to other plots, followed by Q2 and M1 plots as the second and third richest, respectively. Pn1 plot was the least rich (*Table 5*). Species richness was higher in native afforested areas than in

afforested areas, where average species richness was 32.3 in native and mixed areas compared to 21.3 in exotic coniferous plantations (pine and cedar) areas.

Species evenness

It shows that Q3 plot has the highest as compared to other plots, followed by M1 and Q2 plots as the second and third most even, respectively. Ps1 plot was the least even (*Table 5*). We can see from our results that evenness in the native Quercus forest are much higher than in plantation area. But some samples with the most species (highest species richness) and species diversity did not have the highest species evenness.

Discussion and conclusion

Since the Şiro River Basin is risky in terms of erosion, studies were started in 1962 to protect soil in the basin to prevent the arrival of sediment to the Karakaya Dam. Soil conservation and afforestation activities have been achieved and it has been observed that sediment in the dam basin has been largely prevented. And in order to improve the distorted coppices in Tepehan, more regular and highly productive forests were created in terms of establishment characteristics as a result of plantation of oak seeds and afforestation of open and gradient areas.

However, the pine afforestation in this area can be anticipated for possible negative effects): (i) in pine plantations the dense and thick layer of needle litter represent a serious risk for uncontrolled, severe wildfires (*Fig. 4*); (ii) the change of the structure of these afforested heathlands means the loss of this dense scrubland vegetation type for its associated fauna; (iii) Leaves of quercus sp. constitute part of the diet of goats and sheep (*Fig. 5*). They are among the less resistant woody species in pine-tree stands and individuals lose foliage and are, subsequently, no longer valuable as food source for goats and sheep. This not only means an actual loss of resources, but also implies an increase of browsing by these large herbivores on adjacent open heathland stands, which would have negative consequences if that increase exceeded the heathland's carrying capacity (Andrés and Ojeda, 2002) and (iv) biological adaptation disorders such as resistance to biotic and abiotic pests.



Figure 4. A view of the pine afforestation in the research area



Figure 5. A view of the Quercus tree and shrub in the research area

The general conclusion from the case studies clearly indicates that afforestation affects species richness of different functional groups in different ways. Especially the number of species of vascular plants is negatively affected by afforestation. Shade tolerant plant groups had replaced the original heathland communities.

On the other hand, this study shows that the species diversity (Shannon-Wiener index, H') followed very similar correlation for species richness, however, for species evenness it did not. All the same, diversity index was found consistently and significantly greater in native Quercus forests than exotic coniferous plantations forest. This result is in line with the findings of a number of research studies where the negative effects of afforestation on species diversity was highlighted (Andrés and Ojeda, 2002; Pourbabaei et al., 2012). Because species richness of vascular plants is affected by exotic coniferous species. This difference is mainly due to the amount of light which reaches the forest floor. Similarly, understorey biomass is related to the amount of light. So shade tolerant plant groups replace the original heathland communities. Namely, there is a negative correlation between tree coverage and grass density in afforestation areas. As the coverage of the tree layer increases, the degree of coverage of the shrub and grass decreases and the coverage of the shrub layer increases, the degree of coverage of the grass decreases. This situation has a negative effect on vegetation composition and species diversity. The number of endemic taxa decreased in subsamples under coniferous species compared to native broadleaved forests.

Another important finding of this study was that high species richness did not always indicate plant density. In other words, forests with a greater number of species were found to have less tree density were also found to have more shrub and grass density as compared to forests with low species richness in similar area size.

While the afforestation results appear favourable to stop erosion, it is very important to develop strategies for the conservation of biodiversity in afforestation. New forests must be designed in such a way that they conform to the other elements and the character of the landscape. With exotic and monocultural plant species, full coveraged and sharp, straight borders should be avoided. It is also important to maintain open areas within the forest, which will be largely successful in creating a dynamic and sustainable environment in terms of biodiversity in the arid and semi-arid region.

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