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The effects of afforestation and vegetation conversion on plant diversity: a case study in S-W Syrian Mountains

Lamis Eid[1], Ahmad Haj[2] & Mohammad S. Abido[3*]

[1]Ministry of Agriculture and Agrarian Reform, Damascus, Syria; e-mail: lamis.zena@hotmail.com
[2]University of Damascus, Damascus, Syria; e-mail: hajahmad33@yahoo.com
[3]Arabian Gulf University, Manama, Kingdom of Bahrain; e-mail: mohammedsaa@agu.edu.bh
[*]Corresponding author

ABSTRACT The effect of afforestation and conversion of natural vegetation on plant diversity was investigated in 4 sites in the South-Western Syrian Mountains. Plot and plotless sampling tech-niques were used to assess vegetation parameters within and outside afforested sites. The results of the survey indicated the presence of 80 species belonging to 70 genera and 24 families in the study area. Seventy five percent of the species were of medicinal and forage values where the remaining were of wild relatives of fruit trees. Therophytes and hemicryptophytes dominated plant communities in the all sites. Average species richness was 12.6 in open areas compared to 6.7 in forest tracts. Nine species were limited to forest plantations only. Shannon-Weiner diversity index was 63% greater in open than in afforested areas. Species similarity between open and afforested areas was 47%. Significant differences existed between afforested and open area sites with regard to the number of species and diversity index, however, no significant differences were observed among afforested sites nor among open area sites for measured parameters. It is concluded that afforestation and land conversion effect on the composition and structure of natural vegetation is obvious, however this effect is highly variable. It is recommended that afforestation and land conversion operations be integrated into national strategies for biodiversity conservation in the country to maintain habitats and minimize loss of native species.

KEY WORDS *Pinus*; afforestation; conversion; coniferous; Syria; Mediterranean.

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INTRODUCTION

The Syrian vegetation is heterogeneous due to bio-geographical, historical, climatic, physiognomic, and geomorphological factors (Zohary, 1973; Nahal, 1981; Khouzami & Nahal, 1983; Quezel, 1985; Nahal, 1995; Quézel et al., 1999). These factors contributed to emerging distinctive ecosystems that harbor a number of plant species exceeding 3100 (Mouterde, 1966). Furthermore, vegetation cover is characterized by instability and vulnerability due to anthropogenic activities (Nahal, 1995; Abido, 1999; Ghazal, 2008). Afforestation and conversion of natural forest into forest plantations contribute to this instability and vulnerability. These operations are believed to harm ecosystem biodiversity and interfere with biodiversity conservation goals (Fleming & Freedman, 1998; Maestre & Cortina, 2004; Carnus et al., 2006, Brockerhoff et al., 2008). However, this issue is still under debate due to site locations, modalities of afforestations, ecological context and the definition of biodiversity itself (Allen et al., 1995; Bremer & Farley, 2010). Changes in the composition, decrease of richness and abundance of understory species have been reported after afforestation due to microclimate changes at site level (Elmarsdottir & Magnusson, 2007). The impact also differs according to afforested species, where light penetration through the canopy of trees plays an important role in recruitment of lower vegetation. Broadleaf species allow more light penetration compared to conifers creating better conditions for recruitment of understory species (Pourbabaei et al., 2012; Yang et al., 2014). It has been reported that habitat dependent species are the most affected by afforestation operations (Amici et al., 2012; Calviño-Cancela et al., 2012).

A number of researchers consider conversion of natural forest to plantation yields limited habitats and niches (Bernhard-Reversat, 2001); thus negatively affecting richness of native species (Meers et al., 2010; Pourbabaei et al., 2012). On the other hand, it is well known that original land cover, replaced species, age and density of stands contribute to habitat formations leading to controversial effects of conversion on biodiversity (Brockerhoff et al., 2001; Hartley, 2002; Carnus et al., 2006; Gil-Tena et al., 2007; Brockerhoff et al., 2008; González-Moreno et al., 2011). For instance, decreasing stand density or stand basal area, makes favorable conditions for light demanding species, thus in-creasing understory plant diversity and richness (Bone et al., 1997; Parker et al., 2001; Carnevale & Montagnini, 2002).

Mediterranean natural forests and woodlands are habitats for a wide spectrum of native species (Naveh, 1975; Proença et al., 2010; Bergner et al., 2015). Meanwhile, they provide humans with many products as well as environmental and cultural services (Croitoru, 2007). To this end, the South-Western Syrian Mountains form an ecotone where the Mediterranean, Irano-Turanian biogeographic regions meet (Zohary, 1973; Cohen et al., 1981, Abido, 2000). With its unique climate and topography the area supports Eu-Mediterranean vegetation type of rich plant diversity; making its conservation a priority (Abido, 1999; Chikhali, 2000; Ghazal, 2008). However, large tracts of these mountains have been subjected to extensive afforestation and land conversion operations. The current study explores vegetation structure and composition of the area and the effect of afforestation and the conversion of natural forests into plantations on plant diversity.

MATERIAL AND METHODS

Study site

The study area is composed of three adjacent sites where, afforestation and conversion of natural forests have taken place since the 1980s (Table 1, Fig. 1). In these sites, pine plantations replaced degraded natural vegetation that composed mainly of evergreen and non-deciduous trees and shrubs of less than 20% coverage. Native cover species include *Amygdalus communis* L., *Crataegus azarolus*, *C. monogyna* Jacq., *Quercus calliprinos*, *Q. infectoria*, *Prunus cerasus* L., *P. mahaleb* L., *P. microcarpa*, *P. ursina* Kotschy, *Pyrus syriaca* and *Poterium spinosum* L. Soil is terra rosa of 20-30 cm deep on limestone. The climate is sub humid Mediterranean type of meso-thermo variant (Nahal, 1981; Quezel, 1985) with monthly averages precipitation and temper-ature of 500 mm and 14 ºC respectively. Drought period extends to 6 months a year (Fig. 2).

Methods

Three 10x10 m quadrates were taken randomly in and outside each of the three plantations.

Figure 1. Location of the study area: S-W Syrian Mountains.

Site	Latitudes	Altitude (m)	Physiography	Anthropogenic activities	Stand
Wadi Barada (Nabi Habeel)	33º 36" N, 36º 22" E	1310	Gentle to steep slopes (30-35%) North, South, West	Afforestation - grazing	*Cedrus libani, Cupressus arizonica, C. sempervirens.*
Dimas (Dier Ashaer)	33º 35" N, 36º 24" E	1250	Steep slopes (45%) North, East, South	Afforestation - land clearing	*P. brutia, Cupressus sempervirens.*
Zabadani (Jebel Saeeda)	33º 36" N, 36º 31" E	1246	Moderate slope (20-30%); North, East, West	Afforestation - Reforestation - grazing – tourism - collection of medicinal and aromatic plants	*Pinus brutia, Cupressus arizonica, C. sempervirens.*
Rawda (Zarzar)	33º 37" N, 36º 01" E	1210	Gentle slopes (15-20%); North, East, South	Grazing- wood cutting, - collection of medicinal and aromatic plants	Natural landscape (Maquis)

Table 1. Study site attributes: S-W Syrian Mountains.

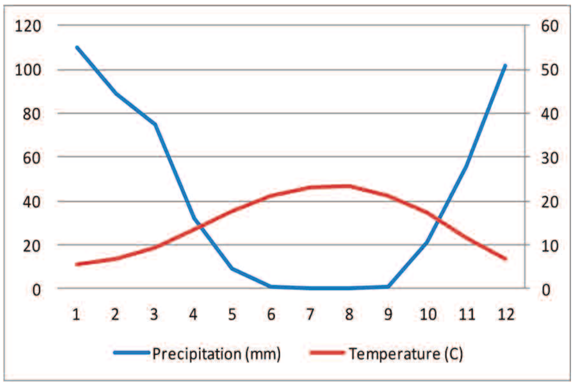

Figure 2. Average annual rainfall, temperature and dry period.

The basal area of the stands was estimated by measuring diameter at breast height (DBH) of all trees in the forested plots using diameter tape (Husch et al., 2003). Height of 6 trees representing dominant, co-dominant and medium height were measured using clinometers. Basal area and overall density of trees were calculated and expressed in hectares. Relative coverage, density, frequency and importance value of species for outside plots were calculated using a 60 meter- line transect laid along the edge of each quadrate (Mueller-Dombois & Ellenberg, 1974; Magurran, 1988). Shannon-Weiner diversity index (H') was calculated (Mueller-Dombois & Ellenberg, 1974) as:

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

where S is Number of unique species, Pi is the proportional abundance of species i and In Pi = the natural logarithm of the proportional abundance of species i.

Søerensons similarity index (ISs) was calculated according to Mueller-Dombois & Ellenberg (1974); Boyce & Ellison (2001).

$$IS_s = \frac{2C}{A+B} \times 100$$

where, C is the common species between paired plots, A and B are a number of encountered species in each plot. Species' life form was classified according to Raunikiaer (1934).

Analysis of variance between sites was conducted at 5% level using CoHort Statistical Package. Furthermore, cluster analysis for sites was implemented using Multi-Variable Statistical Package (MVSP). Uses of species were acquired from Louhaichi et al. (2009), Al-Oudat & Qadir (2011). Species were identified according to Mouterde (1966) and Tohmé & Tohmé (2007).

RESULTS AND DISCUSSION

The outcomes of the study showed the presence of 80 species belonging to 70 genera and 24 families in the study region (Table 2). This reflects a species genera ratio of 1.14 and the genera, families ratio of 2.92. Forty percent of the surveyed species

Scientific name	Family name	Life form class	Open areas	Forest land	Wild relatives	Medi-cinal	Forage
Acer hermoneum (Bornm.) Schwer.	Aceraceae	Ph	+	-	*	*	
Achillea falcata L.	Asteraceae	Ch	+	-		*	
Achillea membranacea (Labill.) DC.	Asteraceae	Ch	+	-		*	
Achillea santolina L.	Asteraceae	He	+	-		*	
Aegilops sp.	Gramineae	Th	+	+			*
Allium paniculatum L.	Liliaceae	Ch	+	-		*	
Amygdalus orientalis Miller	Rosaceae	Ph	+	-	*	*	*
Anagallis arvensis phoenicea Vollm.	Asteraceae	Th	-	+			
Anchusa strigosa Retz.	Boraginaceae	Th	+	-		*	
Anthemis cotula L.	Asteraceae	Th	+	+			
Artemisia herba-alba Asso	Asteraceae	Ch	+	-		*	
Asphodeline lutea (L.) Reichenb	Asteraceae	Cr	+	+			*
Asphodelus microcarpus Salzm. et Viv.	Asteraceae	Ch	+	-			
Bromus tectorum L.	Gramineae	Th	+	+			*
Capparis spinosa L.	Capparaceae	Ch	+	-			*
Capsella bursa-pastoris (L.) Medik.	Brassicaceae	Th	+	-			*
Carduus pycnocephalus L.	Asteraceae	He	+	-		*	
Caucalis tenella Delile	Caryophyllaceae	Th	+	-			*
Centaurea iberica Trevir. et Spreng.	Asteraceae	Th	+	-			
Cichorium pumilum Jacq.	Asteraceae	Th	-	+		*	
Cirsium libanoticum DC.	Asteraceae	He	-	+		*	
Cirsium phyllocephalum Boiss. et Blanche	Asteraceae	He	+	+			
Colchicum brachyphyllum Boiss. et Hausskn.	Liliaceae	Cr	+	+		*	
Coronilla scorpioides (L.) Koch	Fabaceae	Th	+	-			
Crataegus azarolus L.	Rosaceae	Ph	+	+	*	*	*
Descurainia sophia (L.) Webb ex Prantl.	Brassicaceae	Th	+	-			*
Ecballium elaterium (L.) A. Rich.	Cucurbiaceae	He	-	+		*	
Echinops viscosus Rchb.	Asteraceae	He	+	+			
Erodium hirtum (Forssk.) Willd.	Geraniaceae	He	+	-			*
Eryngium creticum Lam.	Umbellifera	He	+	+		*	*
Euphorbia macroclada Boiss.	Euphorbiaceae	He	+	-		*	
Fibigia clypeata (L.) Medik.	Brassicaceae	He	+	-		*	
Fritillaria libanotica (Boiss.)	Liliaceae	He	+	-			
Gundelia tournefortii L.	Asteraceae	He	+	-			
Haplophyllum fruticulosum G.Don	Rutaceae	He	+	-			
Hordeum bulbosum L.	Gramineae	He	+	+			*
Koeleria cristata (L.) Roem. et Schult.	Gramineae	Th	-	+			*
Lactuca orientalis (Boiss.) Boiss	Asteraceae	Ch	+	-		*	
Linum strictum L.	Linaceae	Th	+	-			
Malva sylvestris L.	Malviaceae	He	+	-		*	

Table 2/1. Life forms and uses of species found in open and afforested areas. Ph: Phanerophyte, Ch: Chamaephyte, Th: Therophyte, Cr: Cryptophyte, He: Hemicryptophyte, +: presence, -: absence (continued).

Scientific name	Family name	Life form class	Open areas	Forest land	Wild relatives	Medi-cinal	Forage
Marrubium vulgare L.	Lamiaceae	He	+	-		*	
Notobasis syriaca (L.) Cass.	Asteraceae	Th	+	+		*	
Ononis natrix L.	Fabaceae	Ch	+	-		*	
Papaver syriacum Boiss. et Bl.	Papaveraceae	Th	+	+		*	
Salvia triloba L. fil.	Lamiaceae	Ch	+	+		*	
Pistacia atlantica Desf.	Anacardiaceae	Ph	+	-	*		
Pisum sativum L.	Fabaceae	Th	+	-		*	
Poa bulbosa L.	Gramineae	Ch	+	+			*
Poa sinaica Steud.	Gramineae	Ch	+	+			*
Prunus microcarpa C.A.Mey	Rosaceae	Ph	+	-	*	*	*
Pterocephalus plumosus (L.) Coulter	Dipsacaceae	Th	+	-		*	
Pyrus syriaca Boiss.	Rosaceae	Ph	+	-	*	*	
Quercus calliprinos Webb.	Fagaceae	Ph	+	-	*		
Quercus infectoria Olivier	Fagaceae	Ph	+	-	*		
Ranunculus arvenis L.	Ranunculaceae	Th	+	-		*	
Salvia pinardi Boiss.	Lamiaceae	He	+	+		*	
Sarcopoterium spinosum (L.) Spach	Rosaceae	Ch	+	-		*	
Scabiosa prolifera L.	Dipsacaceae	Th	+	-			
Scolymus hispanicus L.	Asteraceae	Th	-	+		*	
Scolymus maculatus L.	Asteraceae	Th	+	+		*	
Scorzonera parviflora Jacq.	Asteraceae	He	+	+		*	
Scrophularia libanotica Boiss.	Scrophulariaceae	He	+	+			*
Senecio sp.	Asteraceae	Th	+	+			*
Serratula kurdica Post	Asteraceae	He	+	+		*	
Silene latifolia Poir.	Caryophyllaceae	He	+	-		*	
Sinapis alba L.	Brassicaceae	Th	+	+			*
Sinapis arvensis L.	Brassicaceae	Th	+	-			*
Stachys nivea Labill.	Lamiaceae	Ch	+	-			*
Stipa barbata Desf.	Gramineae	He	+	+			*
Taraxacum syriacum Boiss.	Asteraceae	He	+	-		*	*
Teucrium polium L.	Lamiaceae	Ch	+	+		*	
Thymus syriacus Boiss.	Lamiaceae	Ch	+	-		*	
Tragopogon latifolius Boiss.	Asteraceae	He	+	-		*	
Trifolium campestre Schreb.	Fabaceae	Th	+	+			*
Trifolium purpureim Loisel.	Fabaceae	Th	+	+			*
Trifolium stellatum L.	Fabaceae	Th	+	+			*
Trigonella spinosa L.	Fabaceae	Th	+	+			*
Turgenia latifolia (L.) Hoffm.	Umbellifera	Th	+	-			
Vaccaria segetalis (Neck.) Garcke ex Asch.	Caryophyllaceae	Th	+	-		*	
Vicia sp.	Fabaceae	Th	-	+		*	*

Table 2/2. Life forms and uses of species found in open and afforested areas. Ph: Phanerophyte, Ch: Chamaephyte, Th: Therophyte, Cr: Cryptophyte, He: Hemicryptophyte, +: presence, -: absence.

were of medicinal value, 35% forage species and 9 wild relatives of fruit trees. The area was dominated by Therophytes (38%), Hemicryptophytes (30%), followed by Chamaephytes (20%) which reflects the dryness of the area and the prevailing of low temperature in winter months. Figure 3 presents the percentage of plants in each category of life forms in open and forested areas.

The plant community in open areas varied in structure and composition among sites due to physiographic and anthropogenic pressures. The community was dominated by a mixture of evergreen and deciduous species, of which *Amygdalus* spp., *Crataegus* ssp., *Poterium spinosum*, *Quercus calliprinos* and *Prunus* spp. were the prominent species. The community was stratified into two strata as dwarf trees (up to 4m) with average density of 500 tree ha^{-1} are dispersed among herbaceous and shrubby vegetation.

The following species with their importance values (IV) were observed outside plantation plots: *Coronila scorpioides* (29%), *Crataegus azarolus* (26%), *C. monogyna* (15%), *Poterium spinosum* (29%), *Sinapis arvensis* (19%), *Euphorbia macrocloda* (18%), *Stachys nivea* (17%) and *Prunus microcarpa* (6%). Other species of lesser IVs like *Asphodehine aestivus*, *Centaurea iberica* and *Salvia pinardi* were registered. The slopes of the study area were dominated by different woody species according to their water requirement. *Quercus calliprinos* dominated eastern slopes with 39% importance value, whereas northern slopes were occupied by *Crataegus azarolus* (25%) and *Prunus microcarpa* (8%). Meanwhile, southern slopes were occupied by *Asphodelus microcarpus*

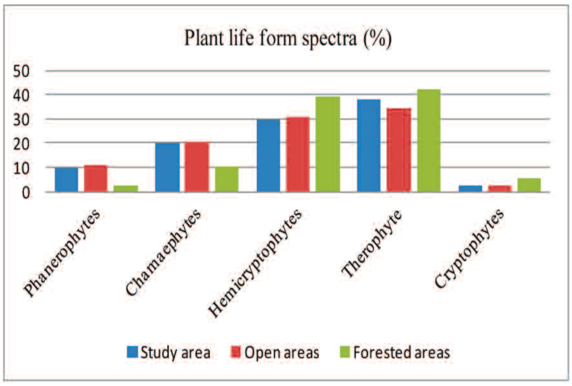

Figure 3. Plant life forms in open and afforested areas.

	Plot	Zabadani (BA: 24 m^2)			Wadi Barada (BA: 18 m^2)			Dimas (BA: 10 m^2)			Rawda (Natural landscape)		
Plot		1	2	3	1	2	3	1	2	3	1	2	3
Zabadani (BA: 24 m^2)	1	100.00											
	2	76.35	100.00										
	3	94.73	71.43	100.00									
Wadi Barada (BA: 18 m^2)	1	94.68	71.39	99.95	100.00								
	2	82.54	66.67	87.28	87.24	100.00							
	3	91.49	84.55	86.23	86.55	79.00	100.00						
Dimas (BA: 10 m^2)	1	86.28	64.04	91.52	91.48	96.40	78.29	100.00					
	2	90.27	67.37	95.52	95.57	91.85	81.91	95.75	100.00				
	3	94.14	70.89	99.41	99.46	86.79	85.70	91.02	95.24	100.00			
Rawda (Natural landscape)	1	56.51	39.12	60.88	60.92	64.89	49.85	68.09	64.74	61.38	100.00		
	2	70.67	50.46	75.57	75.61	79.99	63.08	83.47	79.83	75.92	83.76	100.00	
	3	43.00	28.93	46.67	46.71	50.08	37.52	52.84	49.96	47.10	81.98	66.78	10

Table 3. Similarity index among plots based on number of species and diversity index .

Source	df	Number of species				Shannon-Weiner **diversity index**			
		Type III SS	MS	F	P	Type III SS	MS	F	P
Blocks	2	32	16	0.71	0.53 ns	1.27	0.64	3.76	0.09 ns
Trt.	3	509.67	169.89	7.53	0.02 *	4.02	1.34	7.91	0.02 *
Error	6	135.33	22.56<-			1.02	0.17<-		
Total	11	677				6.31			

Table 4. ANOVA for number of species and Shannon-Weiner diversity index among the study sites.
*Significant at 5% (LSD 0.05 = 9.49 for number of species and 0.82 for diversity index).

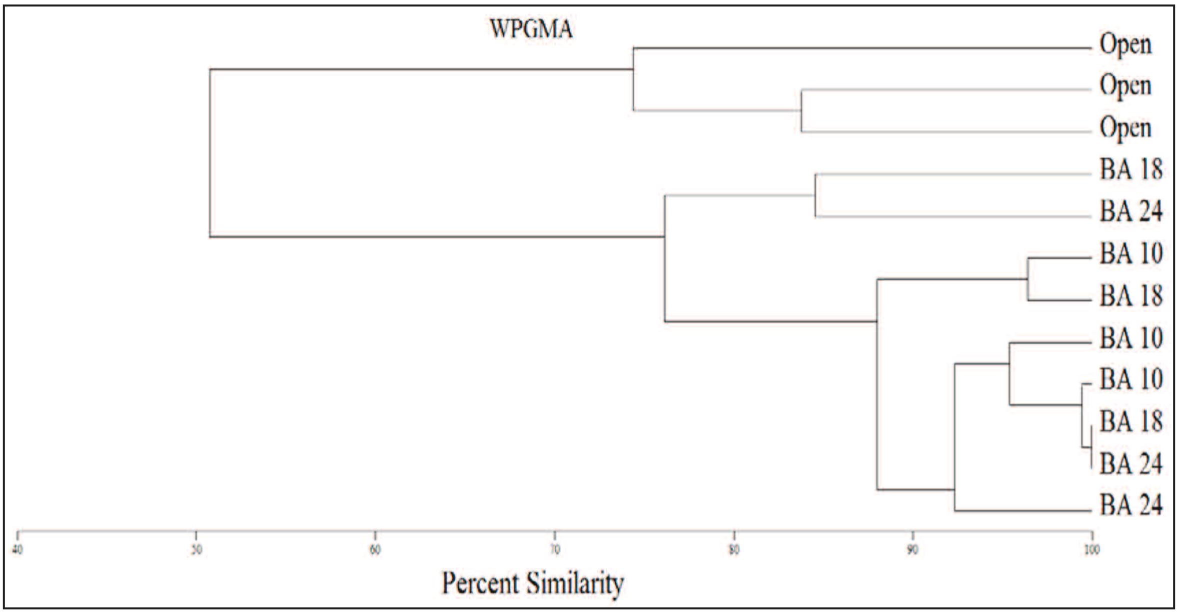

Figure 4. Cluster analysis among plots based on number of species and diversity index .

(72%) and *Poterium spinosum* (35%). Other herbaceous species existed on the slopes with lesser IVs. The dominance of *Poterium spinosum* and *Asphodelus microcarpus* indicates degradation of plant community as free ranging animals are roaming the site (Naveh, 1975; Thirgood, 1981; Giourga et al., 1998; Abido, 2000).

There were 73 species outside forested areas belonging to 24 families compared to 35 species related to 11 families in closed forest tracts. Forty five species were only found outside forest area, which represent 52% of the total species. Species richness was higher in open areas than in afforested areas, where average species richness was 12.6 in open areas compared to 6.7 in forest areas. Nine species were limited to forest plantations as height of trees were in the range of 10-15 meters. In the meantime, density and BA of trees ranged from 500 to 816 ha -1 and 10 to 24 m^2/ha consecutively. Shannon-Weiner diversity index was 63% greater in open than in afforested areas as a diversity index registered 3.92 and 1.46 for the open and afforested areas consecutively. This result is line with Sattout & Caligari (2011) where they related forest diversity with stand age, density and site history. Species similarity between open and afforested areas was 47%. Figure 4 and Table 3 illustrate the results of cluster analysis among plots with regard to the number of species and diversity index.

Significant differences existed between afforested sites and open area sites with regard to the number of species and diversity index, however, no differences were observed among afforested nor among open area sites for measured parameters (Table 4). This result is in line with the findings of a number of researchers where highlighted the negative effects of afforestation on species diversity (Andrés & Ojeda, 2002; Cao et al., 2009; Pourbabaei et al., 2012).

CONCLUSIONS

The Natural vegetation of the study area represents a relic of natural forest with various degradation states as indicated by the presence of remnant of old natural forests as well as pioneer species in all sites of the study area forming a steppe vegetation. Afforestation and land conversion effect on the composition and structure of natural vegetation is obvious as the number and diversity of species were lower in afforested sites. However, this effect is highly variable as physiographic, anthropogenic activities and the structure and composition of afforested sites themselves contributed to this variability.

It is very important to incorporate afforestation and land conversion into national strategies for the conservation of biodiversity in the country in order to maintain habitats and native species.

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