© 2018 Journal compilation
http://mjbs.num.edu.mn
http://biotaxa.org./mjbs
Volume 16(1), 2018

Mongolian Journal of Biological Sciences

ISSN 1684-3908 (print edition)
MJBS
ISSN 2225-4994 (online edition)

http://dx.doi.org/10.22353/ mjbs.2018.16.08

Original Article

Effects of Scots Pine (*Pinus sylvestris* L.) plantations on plant diversity in Northern Mongolia

Gerelbaatar Sukhbaatar[1,2], Byambagerel Suran[1,2], Baatarbileg Nachin[1, 2] and Dugarjav Chultem[3]

[1]*Institute of Forest, National University of Mongolia 14202, Ulaanbaatar, Mongolia*
[2]*Forest Ecosystem Monitoring Laboratory, National University of Mongolia, 14202, Ulaanbaatar, Mongolia*
[3]*Institute of General and Experimental Biology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia*

Abstract

Key words: species richness, diversity, vegetation cover, plantation, natural forest

Article information:
Received: 20 Sept. 2018
Accepted: 27 Dec. 2018
Published online:
28 December 2018

Correspondence:
gerelbaatar@seas.num.edu.mn

This study was carried out in Scots pine (*Pinus sylvestris* L.) plantations that were previously established in West Khentii Mountains of Northern Mongolia. In this study, species composition, richness, diversity and plant cover changes among planted forests with different plantation ages were analyzed. We found an obvious difference of species composition between natural stands and plantations. Our findings revealed continuous changes in vascular plant composition among plantations by increasing light-demanding species. A number of species from forest and forest-meadow mesophytes were replaced with xerophytes from forest-steppe and steppe. Current profound changes in species composition and a stable existence of invasive plant species from different ecological groups have a tendency to be stored during the initial stage of forest plantation establishment. The strong effect of planted trees on the growing environment appeared rather late, and has intensified since 15 years after the plantation establishment.

Cite this paper as: Sukhbaatar, G., Suran, B., Nachin, B. & Chultem, D. 2018. Effects of scots pine (*Pinus sylvestris* L.) plantations on plant diversity in northern Mongolia. *Mong. J. Biol. Sci*., 16(1): 59-70.

Introduction

Conservation of biological diversity is a key component of sustainable forest management (Jobidon & Thiffault, 2004), and biodiversity provides a broad array of ecosystem services (Wang & Chen, 2010). Biological diversity often becomes a crucial indicator of ecosystem sustainability, therefore, it is important to understand the dynamics and heterogeneity of natural forests (Spies & Barnes, 1985). Therefore, species richness in a region indicates the structural complexity of forest ecosystems and the ability to respond to environmental changes. In addition, Hix and Pearcy (1997) as well as Jenkins and Parker (1998) highlighted that biodiversity is composed of both quantitative and qualitative components, and the interaction of plants with environmental factors determines the distribution and species abundance in the region.

Species composition of vascular plants can be an indicator of environmental changes, and through measuring plant community structure in detail, we can assess the changes of the ecosystem in semi-arid zones (Kawada *et al*., 2005; Vesk & Westoby, 2001). World Bank (2004) reported that, forests in Mongolia have been severely degraded by wildfire, over-exploitation and dramatic changes in climate in recent decades. Distribution of Scots pine forests in Mongolia is very limited, covering only 5% of the estimated 160,000 km^2 of forested area (Tsogtbaatar, 2004). Over the last few decades, most logging activities in Mongolia were concentrated in Scots pine forests and combined with disturbances, such as forest fire, improper commercial logging, overgrazing and damage by pests which caused some part of pine forests to lose its ecological function (Crisp *et al*., 2004; JICA, 1998; UN-REDD, 2018).

Scots pine forests in Mongolia are characterized by xeric sites, which often grow on mountain ridges, where they form the tree-line of the transitional zone to the Central Asian dry grasslands (Dulamsuren *et al*., 2011). Currently, rehabilitation and reforestation are considered the effective tools, which limit deforestation (Brockerhoff *et al*., 2008). Plantations can also play a major role in soil carbon (Farley *et al*., 2004), water quality and quantity (Van Dijk & Keenan, 2007), biodiversity conservation (Buscardo *et al*., 2008; Carnus *et al*., 2006; Stephens & Wagner, 2007) and restoration of forest species (Carnus *et al*., 2006; Cusack & Montagnini, 2004).

A number of studies have showed that plantations positively influence biodiversity conservation when used as reforestation of degraded or deforested areas (Hunter, 1999; Harper & Macdonald, 2002; Carnus *et al*., 2006; Stephens & Wagner, 2007; Brockerhoff *et al*., 2008; Remer & Farley, 2010). Yet, some of them view plantations unfavorably compared to natural forests due to lower biodiversity (Perley, 1994), which includes exotic, native and non-native species. The study in New Zealand (Brockerhoff *et al*., 2001) reported that the replacement of native forest with exotic tree plantations could cause important changes in biodiversity and composition of the plant community. Most studies highlighted those polyculture plantations have more abundant and diverse flora and fauna than monocultures, especially where native species are planted (Carnus *et al*., 2006). Some plantations also provide acute habitat for endangered species, increasing the need to integrate conservation goals into management strategies (Arrieta & Suárez, 2006; Pejchar *et al*., 2005). Furthermore, environmental changes associated with forest edges can negatively affect the plant community present in forests (Harper & Macdonald, 2002; Meiners *et al*., 2002). A number of assessments have shown that closer proximity to a forest edge may result in greater tree mortality rate, which could alter the composition and structure of plant communities (Honnay *et al*., 2002; Jobidon *et al*., 2004). Invasive plants are considered a serious threat to forest ecosystems and are of particular concern in arid and semi-arid regions in Asia (Liu *et al*., 2006). Invasion by exotic grass is related to increasing fire frequency, decreasing biodiversity, reduction in productivity, displacement of native plants and the altering of ecosystem functions in woodlands (Brooks *et al*., 2004; Fridley *et al*., 2007; Milton, 2004).

The objectives of this study were (1) to investigate the species composition, richness and diversity of vascular plants in Scots pine plantations (2) to analyze the changes of plant cover with plantation ages, and (3) to evaluate the community structural changes and plant invasion in the planted forests. We hypothesized that first, plantations can establish a similar species composition as in natural stands of plantation age via forming the viable forest environment, and second, that the very slow growth of plantations is unable to limit plant invasion from other ecological groups.

Material and Methods

Seven plots were selected including a natural Scots pine stand and six plantations located in Altanbulag district of Selenge province, in northern Mongolia (50°09’ to 50°15’E latitude and 106°26’ and 106°40’ N longitude). These plots were located at an average altitude of 730 m a.s.l. The study region is dominated by a harsh continental climate, which is characterized by short growing seasons, extended dry and cool periods. Weather in this region also characterized by low precipitation and monthly and diurnal fluctuations in air temperature (Gerelbaatar, 2012). The mean annual rainfall is 276 mm, and the mean annual temperature of the region is low, between -2.0°C and 1.5°C, while the mean monthly temperature ranges from -22°C to 19.0°C. A maximum temperature of 36.4°C has been recorded in June, and a minimum temperature of -40.1°C in January (Regzedmaa, 2008).

According to forest-vegetation zoning in Mongolia, the study region is considered as forest-steppe transitional zone called sub-taiga forests (Mühlenberg *et al*., 2012). The soil in the study area is mainly Haplic Arenosols derived from sandy sediments (JICA, 1998). The sand stratum, which provides the parent materials, is extremely thick, forms in the higher terraces up to 870 m in elevation and is widely observed in the study region. The sand is fine and homogeneous.

The study was carried out in one natural stand of Scots pine (control) and six plantations of different ages. These plantations are characterized by homogeneity of terrains, soil types, and micro-climatic conditions for growth. Moreover, all these plantations were established in clear-cut areas immediately after tree harvesting, which were previously covered by Scots pine. The ground vegetation was quite similar to natural Scots pine forest at the time of each plantation establishment, and similar planting design (4.0 x 1.0 m) and technique were applied. A plough-mounted tractor that dug grooves of 70 cm width and 20-30 cm depth at 4.0 m intervals, primarily dug parallel to counter lines. Then two-year-old Scots pine seedlings were transplanted 1.0 m apart.

In order to compare the changes of plant diversity, vegetation cover and community structure in planted forests with different plantation age, we established sample plots in 9, 12, 15, 18, 21 and 25-year-old plantations, namely Bayanbulag (BB), Tujiin nars (TN), Tsagaan davaa (TS), Gyalaan nuur (GN), Khond (KH), and Gun nuur (GU), respectively. A 65-year-old natural pine forest named Mukhar dukhum (MD) was compared to the plantations. To avoid the disturbance by animals and edge effect, 30.0 x 30.0 m sized sample square plots were established in the central part of each plantation with three replications (21 sample plots). In each sample plot, 2.0 x 2.0 m sized 20 sampling quadratic plots were established randomly along all transects at the 2.0 m interval.

In each quadrat, each plant species and their cover were recorded. These measurements were used to determine the changes in plant community structure, diversity, vegetation cover and evaluate the plant invasion process in planted forests with plantation age. In total, 520 plots were sampled. The total height and stem diameter of planted trees in the plantations were measured using measuring tape and caliper with an accuracy of 0.01 cm. The age of the trees was estimated by calculating the number of nodes and by tree ring counting on disk samples. The crown projection of each tree was measured in four directions. All samples were collected in July 2014.

The point-intersect method was used to assess the percentage of vegetation cover by species according to Walker (1996), and species-specific foliage cover was estimated by Braun-Blanquet (1932) cover class scale. Differences in values among diversity indices in natural and plantations were tested using one-way ANOVA. We applied four indices: species richness, Pielou's evenness index, Shannon-Wiener's and Simpson's diversity index to access plant diversity in plantations.

Species richness is the number of species per plot. Pielou's evenness index was calculated using the formula given by Pielou (1966).

$$e = H'/lnS$$

where: H' is Shannon-Weiner's diversity index, S is the total number of species within a plot and ln(S) is denotes the maximum value of H'.

Shannon-Weiner's diversity index (H') is sensitive to the diversity of common species (Carnevale and Montagnini, 2002; Onaindia *et al.,* 2004).

$$H' = -\sum_{i=1}^{s} P_i * In(P_i)$$

where: Pi is the proportion of individuals that belong to i-th species in the plot and s denotes the total number of species in the same plot.

Simpson's diversity index of dominance (SD) was measured by formula given by Simpson (Simpson, 1949):

$$S_D = \sum_{i=1}^{s} (Pi)^2$$

Jacard's similarity index (J) was used to determine the similarity of plant communities between natural stand and plantations (Porbabaie, 2004).

$$J = \frac{c}{a + b - c}$$

where: J - Jacard's index; c – number of common species in both communities; b – number of species that present in the first community; c – number of species that present in the second community. All plant species growing in sample plots were separated into four categories of ecological groups according to Grubov (2008): alpine, forest, forest steppe and steppe, and four categories of life form: tree, shrub, perennial herb and moss.

Results

Plant species richness and diversity. The main stand characteristics were summarized in Table 1. Our findings revealed that there exists a common trend of relatively slow growth rates of planted trees and crown development, and also gradual reduction of stand density with plantation age (Table 1). From all sites, overall 80 plant species (4 trees, 8 shrubs, 66 herbs and 2 mosses) belonging to 71 genera of 25 families were identified. In the natural stand, a total of 39 species including 3 trees, 2 shrubs, 32 herbs and 2 moss species were recorded. In herbal composition, Compositae (8 spp.) and Gramineae (7 spp.) were dominant families, followed by Leguminosae (4 spp.), Labiatae (3 spp.), Liliaceae (3 spp.) and Rosaceae (3 sp.) (Table 2).

Species richness of each life form of plants was different ($F_{3,04}$=188, P<0.01) between the natural stand and plantations (Fig. 2). In natural forest, Scots pine was the main tree species with broad-leaved trees from Betulaceae *(Betula platyphulla* Sucacz. and *Populus tremula* L.). But, the species composition of plantations differed from the natural forest. A total of 39 plant species from diverse vegetation layers were identified in plantations (trees - 2 spp., shrubs - 5 spp., herbs – 27 spp.), which had not been recorded in natural forest (Table 2). Nevertheless, the number of plant species was just equal in both natural stand and plantations, Jaccard's index indicated that tree species of them were more similar than shrub and herbal species (Fig. 2). Species richness of herbaceous plants was significantly greater than other life forms ranging from 3.17±0.21 to 3.55±0.22 across all plantations. In plantations, species richness was higher for the tree layer in 12-year-old plantation, and for shrub layer in 15-year-old plantation. Moreover, species richness preserved in herbal layer was at a relatively similar level as it was in natural forest (Fig. 1a). The means of evenness, Shannon-Wiener's and Simpson's diversity indeces in tree layer tended to increase until 15-year of age in plantations, and since this period was observed a gradual reduction of evenness, and in shrub and herbal layer evenness was at a relatively close level with small deviations (Fig. 1b, c, d). An ANOVA test showed that there were no significant differences (P>0.05) among diversity, species richness, and evenness indeces in each vegetation layer in natural forest and plantations.

Moreover, Shannon-Wiener's and Simpson's diversities were higher in plantations involving all vegetation layers than in the natural forest (Fig. 1c, d). Jaccard's similarity index showed the most similar values in tree layer, and lower values in shrub and herbal layers. We observed an ever increasing trend of similarity index of plantations with natural forest in tree layer, and gradual reduction in shrub layer with plantation age (Fig. 2).

The existence of stable low value of similarity index for shrub layer with plantation age suggests changes in the plant community structure, and an acceleration of successional stages in plantations in their community structure.

Table 1. Stand characteristics of plantations and natural stands.

Site name	Stand age	Density (tree ha-1)	Mean height (m)*	Mean stem diameter (cm)	Mean crown diameter (m)	Crown basal area (m^2 ha-1)
Bayanbulag (BB)	9	2011	1.44 ± 0.03	3.83 ± 0.06	0.89 ± 0.02	1217.73
Tujiin nars (TN)	12	1477	2.22 ± 0.05	5.21 ± 0.12	1.24 ± 0.03	1779.84
Tsagaan davaa (TS)	15	1444	3.34 ± 0.07	7.25 ± 0.13	1.53 ± 0.03	2558.11
Gyalaan nuur (GN)	18	1555	3.94 ± 0.11	6.54 ± 0.22	1.60 ± 0.04	2499.62
Khond (KH)	21	1077	6.61 ± 0.14	11.39 ± 0.32	2.07 ± 0.06	3628.55
Gun nuur (GU)	25	888	6.14 ± 0.26	12.25 ± 0.53	2.20 ± 0.09	3248.27
Mukhar dukhum (MD)	65	265	17.6 ± 1.12	28.7 ± 1.05	4.35 ± 1.02	6169.12

*mean ± is standard error

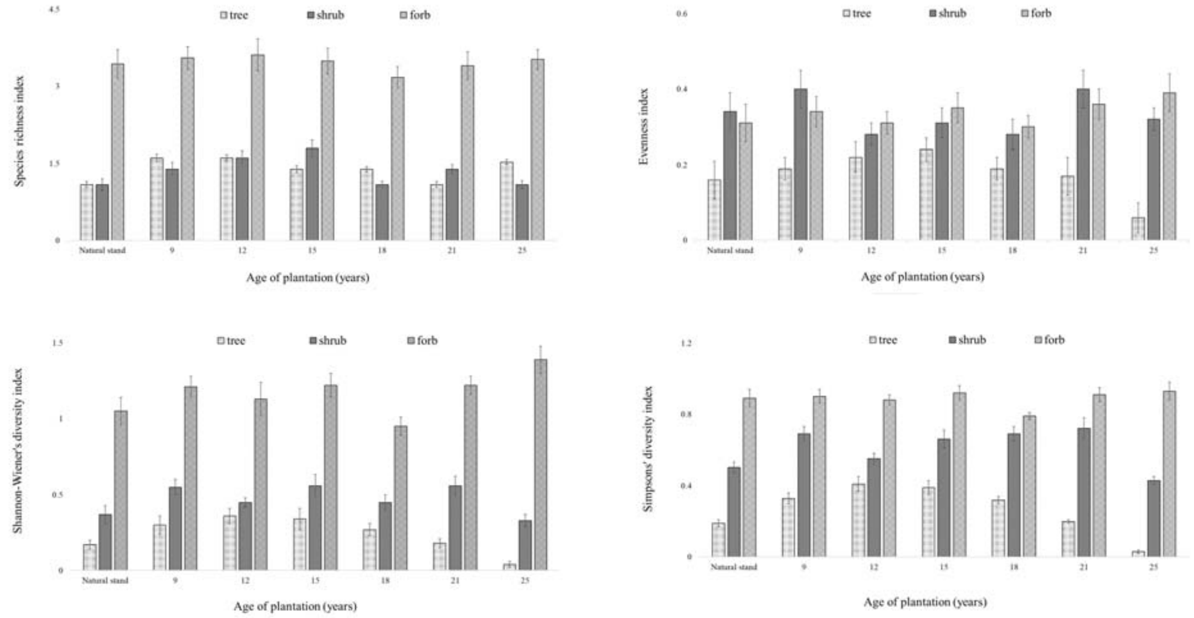

Figure 1. Various indeces of plant species richness, diversity and eveness.

Changes of plant cover with plantation age. Results of ANOVA showed that plant cover of life forms was significantly different (F=17.52; P<0.001) among studied stands. Overall, the tree cover in the plantations is gradually increased with plantation age, where it amounts to 12.17%, 17.79%, 25.28%, 28.99%, 36.28% and 32.48% in 9 (BB), 12 (TN), 15 (TS), 18 (GN), 21 (KH) and 25-year-old (GU) plantations, respectively (Fig. 3).

Among these plant life forms, the highest proportion of vegetation cover belongs to herbal plants (max 39.75±3.2%) at the beginning stage of plantation formation, and it was significantly different ($F_{4.96}$=20.7; P<0.05) among plantations. Dominant herbal species with greater plant cover included *Carex pediformis* C.A.Mey. (7.31±0.73% in TN), *Pulsatilla flavescens* (Zucc.) Juz. (6.44±0.97% in TS), *Lespedeza dahurica* (Laxm.) Schindl. (6.44±1.17% in TN), *Bupleurum scorzonerifolium* (Willd.) Koso-Pol. (5.56±0.52% in GN), *Astragalus mongolicus* Bge. (2.90±0.78% in TS) and *Poa botryoides* Besser. (1.38±0.17% in TN), and dominant shrub was *Rosa davurica* Pall. (3.03±0.94% in TS). In the 25-year-old plantation, the plant cover values for shrubs (GU-0.47%; MD-0.37%), herbs (GU -13.9%; MD-8.06%) and mosses (GU-0.52%;

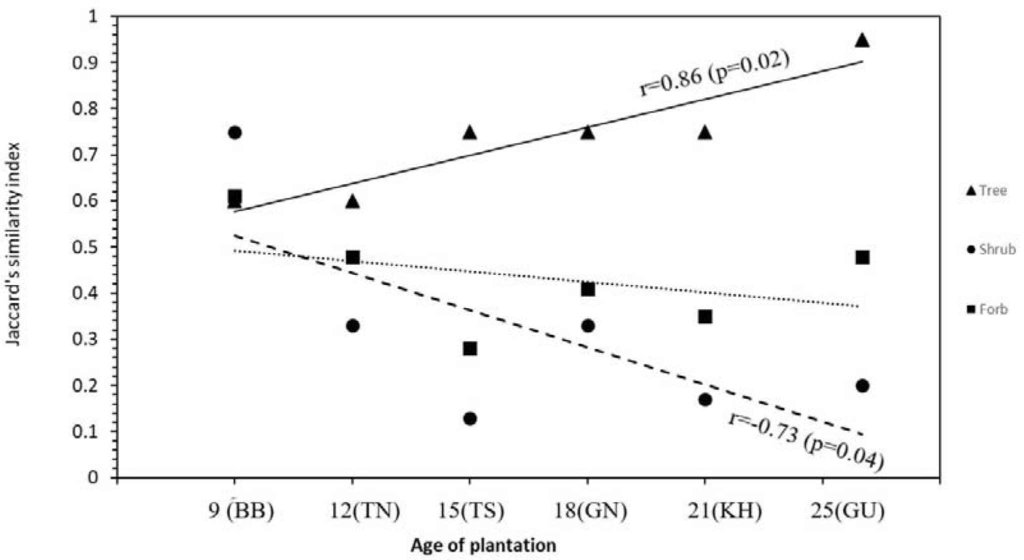

Figure 2. Similarity of plant species in the plantations of different ages.

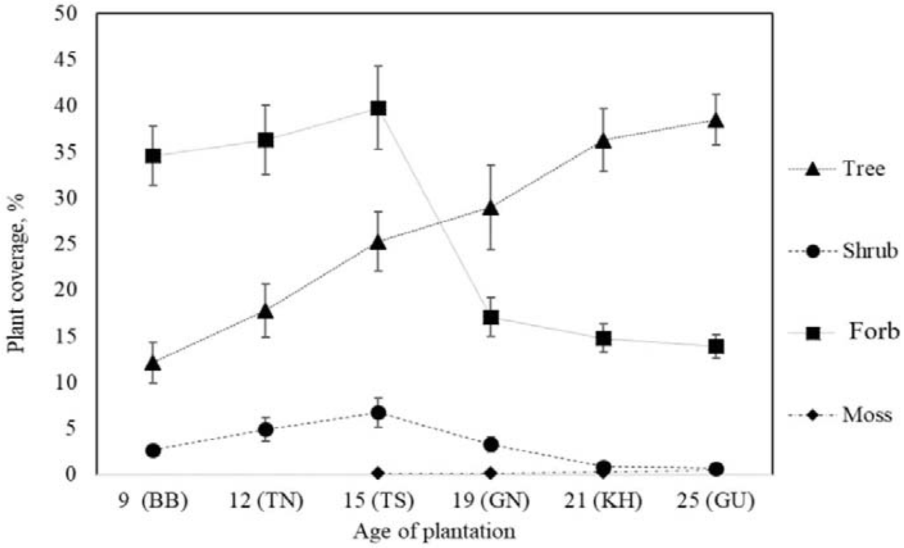

Figure 3. Age-related changes of plant cover by each life form in plantations of different age.

MD-0.75%) were most similar to those in the natural forest.

Community structure and plant invasion. Profound changes were observed in community structure, which was explained by a total of 33 invasive plant species belonging to 15 families from forest meadow (14 spp.), forest steppe (3 spp) and steppe (16 spp.) (Table 2). These invaded plant species were different ($F_{6,94}$=3,07; *P*=0,15) in terms of life-forms. Our findings showed that there were 2 trees, 5 shrubs and 26 herbaceous species, which invaded the plantations. The largest part of them belonged to herbaceous families such as Rosaceae (8 species), Ranunculaceae (4 species), Leguminosae (4 species), Gramineae (3 species) and Compositae (3 species). Overall, these invaded plant species were physiologically drought-resistant herbs and graminoids. Four plant species including *Achillea millefolium* L., *Heteropappus hispidus* (Thunb.) Less., *Phlomis tuberosa, and Thymus dahuricus* Serg. were not registered in all plantations except for natural forest. The seedlings of such tree species as *Salix tenuifolia* Turcz. ex E. Wolf. (BB; TN; TS; GN; KH) *and Ulmus pumila* L., (BB; TN) and their rapid growth were observed in some plantations of early stage development. Total of 6 shrubs (*Salix spp. Vaccinium vitisidaea, Rhododendron dahuricum, Rosa acicularus, Rosa davurica,*

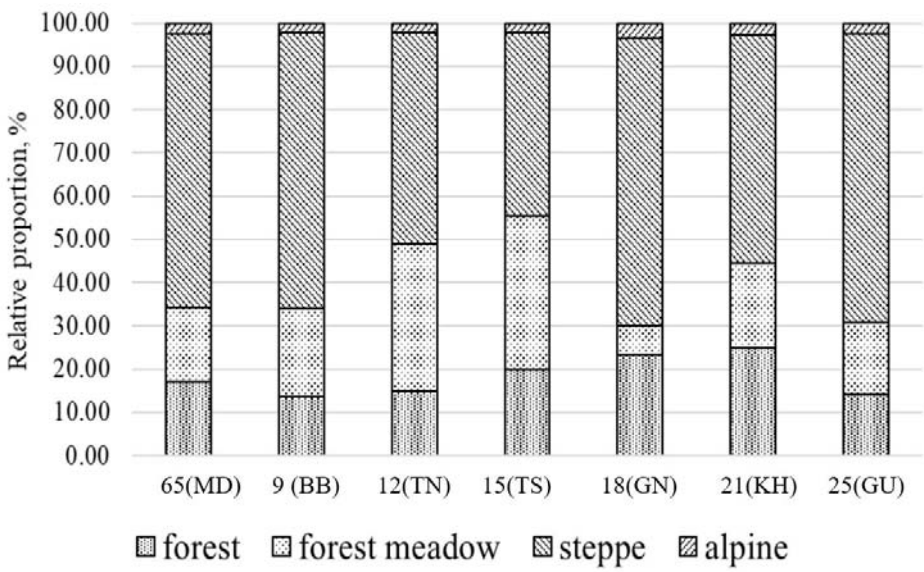

Figure 4. Relative proportion of different ecological groups of plants in various plantations.

Spiraea media) were recorded in plantations that were absent in natural forest.

The number of plant species was not significantly different (*F*=0.59; *p*=0.72) among stands. In terms of the relative proportion of ecological groups, the steppe plants were dominant in each plantation, with the highest proportion observed in GN (66.6%) and GU (66.6%), and the lowest in TS (42.2%). The proportion of forest and forest meadow plants was relatively little than steppe plants, yet the proportion of forest plants was greater in GN (23.3%) and KN (25.0%), forest meadow plants in TN (34.0%) and TS (35.6%) respectively. We recorded only one alpine species (*Aster alpinus* L.), which was recorded in all stands. Overall, according to ecological groups, forest steppe species made up 57.5%, forest meadow species 28.75%, forest species 12.5% and alpine species 1.25% respectively.

Discussion

Species composition and diversity. All the plantations were made up of 2 year-old seedlings of Scots pine, which is considered the most common indigenous tree species in this region. Our findings of plant species diversity indices showed that Scots pine plantations are more diverse at the beginning stage of plantation establishment than that of natural forest, and species diversity and cover in the older plantations were similar to the natural forest. A number of studies reported that natural forests have more diverse plant species than that of plantations (Carnus *et al*., 2006; Paritsis & Aizen 2008; Gonzales & Nakashizika, 2010; Bremer & Farley, 2010). Contrary, in our case the natural forest was less diverse in plant species than that of plantations. In context of the species richness in plantations, which are younger than 18-year-old was higher (42-46 spp.) than that recorded in natural forest (39 spp.). Several studies highlighted that changes in microclimate after logging, particularly from higher temperatures and lower humidity became a determinant factor of changes of plants species composition in the forest (Sporn *et al*., 2009; Helm *et al*., 2017). Our findings also support this idea and these effects were noticeable for herbaceous species, including forest and forest meadow mesophytes, which were succeeded by xerophytes such as *Artemisia integrifolia* L., *Bromus inermis* Leyss., *Cleistogenes squarrosa* (Trin.) Keng., *Vicia unijuga* A.Br., *Chamaenerion angustifolium* (L.) Scop., *Pulsatilla flavescens* (Zucc.) Juz., *Potentilla fragarioides* L., and *Bupleurum scorzonerifolium* (Willd.) Koso-Pol (Table 2). Besides the rapid development of herbal species, there was an observed natural regeneration mainly by only deciduous tree and shrub species in the previously forested area. Although forest plantations show a positive trend towards restoring of natural flora by creating similar plant cover (Cusack & Montagnini, 2004), this study reports counter results, which showed forest plantations are unable to restore the previous species composition completely. Our first hypothesis was rejected, because of the profound changes, which were found in the community structure can remain stable in studied plantations through time.

Plant invasion and forest succession. Elimination of vegetation, removal of over-story and soil preparation prior to planting activities permit light to reach the understory vegetation and provide good habitat for many herbaceous species (Hardtle *et al.*, 2003). Our findings provide some support for this idea, as intensive forest harvesting and clear cutting in study region have created preconditions for replacement of natural flora with a number of light-demanding invasive species. Due to post logging environmental changes associated with soil moisture and light intensification (Hardtle *et al.*, 2003), several mezophytes (*Achillea millefolium* L., *Heteropappus hispidus* (Thunb.) Less., *Phlomis tuberosa, Thymus dahurica*) were destroyed, and number of light-demanding and xerophyte herbal species invaded plantations. Therefore, a very slow and poor natural regeneration of woody species was observed in all studied stands. Seedlings of Scots pine were recorded only in the natural forest, and relatively low regeneration density (less than 300 stems per ha) of deciduous trees (*Betula platyphulla* Sucacz., *Populus tremula* L., *Salix tenuifolia* Turcz., *Ulmus pumila* L.) that grow by sprouting, and their seeding were found in planted forests. Accordingly, the present results suggested existence of a potential risk of replacement of conifers with deciduous tree species in heavy logged and clear-cut forest areas in study region. Thus, our second hypothesis was supported.

Table 2. Ecological groups and life forms of plant species in study plots.

Families	Species	Ecological group	Life form	Natural forest	Age of plantation					
					9	12	15	18	21	25
PINACEAE	*Pinus sylvestris L.*	FS	TR	+	+	+	+	+	+	+
BETULACEAE	*Betula platyphulla Sucacz.*	FS	TR	+	+	+	+	+	+	+
SALICACEAE	*Populus tremula L.*	FS	TR	+	+	+	+	+	+	+
	Salix tenuifolia Turcz.	FM	TR	-	+	+	+	+	+	-
ULMACEAE	*Ulmus pumila L.*	ST	TR	-	+	+	-	-	-	-
CAMPANULACEAE	*Youngia tenuifolia (Willd.)Babc.et Stebbins.*	ST	HE	+	+	−	+	+	+	+
CARYOHEYLLACEAE	*Dianthus versicolor Fisch.*	ST	HE	−	−	−	+	−	−	−
COMPOSITAE	*Achillea millefolium L.*	FM	HE	+	-	+	-	-	-	-
	Artemisia commutata Bess.	ST	SS	+	+	+	-	+	+	+
	Artemisia integrifolia L.	FM	HE	-	+	+	-	-	-	-
	Aster alpinus L.	AL	HE	+	+	+	+	+	+	+
	Chrysanthemum Zawadskii Herb.	FM	HE	+	+	+	+	+	+	+
	Crepis praemorsa (L.) Tausch.	FM	HE	-	-	-	+	-	-	-
	Filifolium sibiricum (L.) Kitam.	ST	HE	+	+	+	-	+	-	+
	Heteropappus altaicus (Willd.) Novo-pokr.	ST	HE	-	-	+	-	-	-	-
	Heteropappus hispidus (Thunbg.)Less.	ST	HE	-	-	-	+	-	+	+
	Leontopodium leontopodioides (Willd.) Beauvd.	ST	HE	+	+	+	-	-	-	+
	Leuzea uniflora (L.) Holub.	ST	HE	+	+	+	-	+	+	-
	Scorzonera radiate Fisch.	FS	HE	-	-	-	-	+	+	-
	Orostachys malacoHEylla (Pall.) Fisch.	ST	HE	-	-	+	+	+	-	+
	Sedum aizoon (L.)	FM	HE	-	-	-	+	-	-	-
	Carex pediformis C. A. Mey.	ST	HE	+	+	+	+	+	+	+
DIPSACACEAE	*Scabiosa comosa Fisch.*	ST	HE	+	+	-	-	-	+	+
ERICACEAE	*Rhododendron dahuricum (L.)*	FS	SH	-	-	-	+	-	-	-
	Vaccinium vitis-idaea (L.)	FS	SS	-	-	-	+	-	+	-
GENTIANACEAE	*Gentiana macrophylla Pall.*	FM	HE	-	-	-	+	-	-	-
GRAMINEAE	*Agrostis Trinii Turcz.*	FM	HE	-	-	-	+	-	-	-
	Bromus inermis Leyss.	ST	HE	-	+	-	-	-	-	-
	Bromus Pumpellianus Scribn.	FM	HE	+	+	+	-	-	-	-
	Cleistogenes Kitagawae Honda.	ST	HE	+	-	-	-	-	+	+
	Cleistogenes squarrosa (Trin.)Keng.	ST	HE	-	+	-	-	+	-	-
	Elymus sibiricus L.	FM	HE	+	+	+	+	-	+	+
	Festuca lenensis Drob.	ST	HE	-	-	-	-	-	-	+
	Festuca valesiaca Gaud.	ST	HE	+	+	-	+	-	-	-
	Poa botryoides Trin.	FM	HE	+	+	+	-	+	+	+
	Stipa baicalensis Roshev.	ST	HE	+	-	-	-	-	-	+
	Trisetum sibiricum Rupr.	FS	HE	+	+	+	+	-	+	+

Table 2. (continued)

IRIDACEAE	*Iris flavissima Pall.*	ST	HE	+	+	-	-	+	-	+
	Iris ruthenica	FM	HE	-	-	-	+	-	-	-
LABIATAE	*Phlomis tuberosa (L.)*	ST	HE	+	-	-	-	-	-	-
	Schizonepeta multifida (L.) Brig.	ST	HE	+	+	+	-	+	-	+
	Thymus dahuricus Serg.	ST	SS	+	+	-	-	-	-	-
LEGUMINOSAE	*Astragalus mongolicus Bge.*	ST	HE	+	-	+	+	-	+	-
	Lathyrus humilis (Ser.) Spreng.	FM	HE	-	-	+	+	-	+	-
	Lespedeza dahurica (Laxm.) Schindl.	ST	HE	+	+	+	-	+	-	+
	Medicago falcata (L.)	ST	HE	-	-	-	-	-	+	-
	Thermopsis lanceolata (L.)	ST	HE	-	+	-	-	+	-	-
	Trifolium lupinaster (L.)	ST	HE	+	+	+	+	-	+	-
	Vicia cracca (L.)	FM	HE	+	+	+	+	+	-	-
	Vicia unijuga A. Br.	ST	HE	-	-	+	+	-	+	-
LILIACEAE	*Allium bidentatum Fisch. ex Prokh*	ST	HE	+	-	-	-	-	-	+
	Allium lineare L.	ST	HE	-	-	-	+	-	-	-
	Hemerocallis minor Mill.	FM	HE	+	+	+	+	-	-	+
	Polygonatum odoratum (Mill.) Druce.	FS	HE	+	+	+	+	+	+	+
ONAGRACEAE	*Chamaenerion angustifolium (L.) Scop.*	FM	HE	-	+	+	+	-	+	+
PLANTAGINACEAE	*Plantago major (L.)*	FM	HE	-	-	+	-	-	-	-
RANUNCULACEAE	*Thalictrum minus (L.)*	FM	HE	-	-	-	-	-	-	+
	Pulsatilla flavescens (Zucc) Juz.	ST	HE	-	+	+	+	+	+	+
	Pulsatilla Turczaninovii Kry. ex Serg.	ST	HE	-	-	-	-	-	+	-
	Aconitum barbatum Pers.	ST	HE	-	+	-	+	-	-	+
ROSACEAE	*Chamaerhodes erecta (L.) Bge*	FM	HE	-	-	+	-	-	+	+
	Fragaria orientalis Losinsk.	FM	HE	-	-	-	+	-	-	-
	Potentilla acaulis (L.)	ST	HE	+	+	-	-	+	-	+
	Potentilla bifurca (L.)	ST	HE	-	-	-	-	-	-	+
	Potentilla fragarioides (L.)	FM	HE	-	+	+	+	-	+	-
	Potentilla nivea (L.)	FS	HE	-	-	-	-	+	-	-
	Potentilla tanacetifolia Willd. ex Schlecht.	ST	HE	+	+	+	-	+	+	+
	Rosa acicularus Lindl.	FM	SH	-	-	+	+	-	-	-
	Rosa davurica Pall.	FS	SH	-	+	+	+	-	+	+
	Rubus saxatilis (L.)	FS	HE	-	-	+	-	-	-	-
	Sanguisorba officinalis (L.)	FM	HE	+	-	+	+	-	-	-
	Spiraea media F. Schmidt.	ST	SH	-	-	+	+	-	+	-
RUBIACEAE	*Galium boreale (L.)*	FM	HE	-	-	+	+	-	-	-
	Galium verum (L.)	ST	HE	+	+	+	-	-	-	+
SCROHEULARIA-CEAE	*Veronica incana (L.)*	ST	HE	+	+	+	+	+	-	+
UMBELLIFERAE	*Bupleurum scorzonerifolium Willd.*	ST	HE	-	+	+	+	+	+	+
	Peucedanum vaginatum Ldb.	ST	HE	+	+	+		+	+	+
VALERIANACEAE	*Patrinia rupestris(Pall.) Dufr.*	ST	HE	-	+	+	+	+	+	+
DICRANACEAE	*Dicranum congestum*	FS	MS	+	-	-	+	-	+	-
RHYTIDIACEAE	*Rhytidium rugosium*	FS	MS	+	-	-	-	+	-	-

Note: "+" – presence; "–" absence;

Similarity of plant cover and woody species composition. Mongolian conifer forests are grown under frequent droughts and water deficits (Dulamsuren *et al.*, 2011), and are sensitive to climate change and anthropogenic disturbance impacts (UN-REDD, 2018). Furthermore, the effects of plantations on understory species diversity and plant cover may change due to different ages of the stands (Nagaike, 2003), and since canopy closure increase as stands get older. The strong effect of planted trees on the growing environment appeared rather late, and has intensified since 15 years after the plantation establishment, which has explained the continuous reduction of plant cover in shrubs and herbal layers and the first appearance of mosses (0.16±0.13 in GN) in planted forests. Clearly, this would also depend on the increase of tree height and the crown dimensions and their shading effect, which may adversely affect the development of light-demanding plant species and their cover. Our results of the assessment concur with other studies that show high similarity of woody species composition between the natural forest and plantations (Alem & Woldemariam, 2009; Tecimen *et al.,* 2017). The highest similarity between the natural forest and the plantation only in terms of plant cover and woody species composition was found in 25-year-old plantation. Finally, the findings from this study suggest an importance of the polyculture plantation establishment and update of present initial planting design in planting strategies in order to improve the conservation status of the endemic forest plant species and their abundance in Mongolia.

Acknowledgements

This project was funded by PEER Science Cycle 2 grant #296 'Building research and teaching capacity to aid climate change and natural resource management at the National University of Mongolia. We thank Mr. D. Byambaa, director of the Tujiin Nars National Park for accessing permission in national park area and other technical supports. A special gratitude goes to Dr. G. Tsedendash, who had done plant survey and consulted plant identifi cation in the field. A great appreciation to our field crew.

References

Arrieta, S. & Suárez, F. 2006. Scots pine (*Pinus sylvestris* L.) plantations contribute to the regeneration of holly (*Ilex aquifolium* L.) in mediterranean central Spain. *European Journal of Forest Research,* 125(3): 271–279.

Braun-Blanquet, J. 1932. The study of plant communities. *Plant Sociology* New York: Hafner Pub. Co., 1972 pp.

Bremer, L. L. & Farley, K. A. 2010. Does plantation forestry restore biodiversity or create green desert? A synthesis of the effect of land-use transitions on plant species richness. *Biodiversity Conservation,* 19: 3893–3915.

Brockerhoff, E. G., Ecroyd, C. E. & Langer, E. R. 2001. Biodiversity in New Zealand plantation forests: policy trends, incentives, and the state of our knowledge. *New Zealand Journal of Forestry,* 46: 31–37.

Brockerhoff, E. G., Jactel, H., Parrotta, J. A., Quine, C. P. & Sayer, J. 2008. Plantation forests and biodiversity: oxymoron or opportunity? *Biodiversity Conservation,* 17(5): 925–951.

Brooks, M. L., D'antonio, C. M., Richardson, D. M., Grace, J. B., Keeley, J. E., DiTomaso, J. M., Hobbs, R, J., Pellant, M., Pyke, D. 2004. Effects of invasive alien plants on fire regimes. *BioScience* 54(7): 677–688.

Buscardo, E., Smith, G. F., Kelly, D. L., Freitas, H., Iremonger, S., Mitchell, F. J. G., O'Donoghue, S. & McKee, A. 2008. The early effects of afforestation on biodiversity of grasslands in Ireland. *Biodiversity Conservation,* 17(5): 1057–1072.

Carnevale, N. J. & Montagnini, F. 2002. Facilitating regeneration of secondary forests with the use of mixed and pure plantations of indigenous tree species. *Forest Ecology and Management,* 163(1): 217–227.

Carnus, J. M., Parrotta, J., Brockerhoff, E., Arbez, M., Lastel, H., Kremer, A., Lamb, D., O'Hara, K., Walters, B. 2006. Planted forests and biodiversity. *Journal of Forestry* 104(2): 65–77.

Cusack, D. & Montagnini, F. 2004. The role of native species plantations in recovery of understory woody diversity in degraded pasturelands of Costa Rica. *Forest Ecology and Management,* 188(1): 1–15.

Dijk, A. I. J. M. van & Keenan, R. J. 2007. Planted forests and water in perspective. *Forest Ecology and Management,* 251(1): 1–9.

Dulamsuren, C., Hauck, M., Leuschner, H. H. & Leuschner, Ch. 2011. Climate response of tree-ring width in Larix sibirica growing in the drought-stressed forest-steppe ecotone of northern Mongolia. *Annals of Forest Science,* 68(2): 275–282.

Farley, K. A., Kelly, E. F. & Hofstede, R. G. 2004. Soil organic carbon and water retention after conversion of grasslands to pine plantations in the Ecuadorian Andes. *Ecosystems* 7(7): 729–739.

Fridley, J. D., Stachowicz, J. J., Naeem, S., Sax, D. F., Seabloom, E. W., Smith, M. D., Stohlqren, T. J., Tilman, D. & Von Holle, B. 2007. The invasion paradox: reconciling pattern and process in species invasions. *Ecology* 88(1): 3–17.

Gerelbaatar, S. 2012. The features of formation of Scots pine (*Pinus sylvestris* L.) plantation. *Ph.D thesis,* National University of Mongolia, Ulaanbaatar, 117 pp. (In Mongolian)

Gonzales, R. S. & Nakashizuka, T. 2010. Broad-leaf species composition in Cryptomeria japonica plantations with respect to distance from natural forest. *Forest Ecology and Management,* 259: 2133–2140.

Grubov, V. I. 2008. Key to the Vascular Plants of Mongolia. Ulaanbaatar, Gan Print CO., Ltd. (in Mongolian)

Hardtle, W., Oheimb, G. V. & Westphal, C. 2003. The effects of light and soil conditions on the species richness and soil conditions of the ground vegetation of deciduous forests in northern Germany (Schleswig-Holstein). *Forest Ecology and Management,*182(1): 327-338.

Harper, K. A. & Macdonald, S. E. 2002. Structure and composition of edges next to regenerating clear-cuts in mixed-wood boreal forest. *Journal of Vegetation Science,*13(4): 535–546.

Helm, N., Essl, F., Mirtl, M. & Dirnböck, T. 2017. Multiple environmental changes drive forest floor vegetation in a temperate mountain forest. *Ecology and Evolution,* 7: 2155–2168.

Hix, D. M. & Pearcy, J. N. 1997. Forest ecosystems of the Marietta Unit, Wayne National Forest, southeastern Ohio: multifactor classification and analysis. *Canadian Journal of Forest Research,* 27(7) 1117–1131.

Honnay, O., Verheyen, K. & Hermy, M. 2002. Permeability of ancient forest edges for weedy plant species invasion. *Forest Ecology and Management,* 161(1): 109–122.

Hunter, M. L. 1999. Maintaining biodiversity in forest ecosystems. Cambridge university press, Cambridge.

Tecimen, H. B., Sevgi, O., Akkaya, M., Sevgi, E., Hancer, C. K. & Cakir, E. A. 2017. Comparison of species richness and diversity at natural stands and plantations of stone pine (*Pinus pinea* L.). *Pakistan Journal of Botany,* 49(5): 1743-1748.

Jenkins, M. A. & Parker, G. R. 1998. Composition and diversity of woody vegetation in silvicultural openings of southern Indiana forests. *Forest Ecology and Management,* 109(1): 57–74.

JICA. 1998. The forest resources management study in Selenge province, Mongolia. *Final Report,* 116 pp.

Jobidon, R., Cyr, G. & Thiffault, N. 2004. Plant species diversity and composition along an experimental gradient of northern hardwood abundance in Picea mariana plantations *Forest Ecology and Management,* 198(1): 209–221.

Kawada, K., Vovk, A. G., Filatova, O. V., Araki, M., Nakamura, T. & Nayashi, I. 2005. Floristic composition and plant biomass production of steppe communities in the vicinity of Kharkiv, Ukraine. *Grassland Science* 51(3): 205–213.

Liu, J., Dong, M., Miao, S. L., Li, Z. Y., Song, M. H. & Wang, R. Q. 2006. Invasive alien plants in China: role of clonality and geographical origin. *Biological Invasions* 8(7): 1461–1470.

Meiners, S. J., Pickett, S. T. & Handel, S. N. 2002. Probability of tree seedling establishment changes across a forest–old field edge gradient. *American Journal of Botany* 89(3): 466–471.

Milton, S. J. 2004. Grasses as invasive alien plants in South Africa. *South African Journal of Science*, 100: 69-75.

Mühlenberg, M., Appelfelder, J., Hoffmann, H., Ayush, E. & Wilson, J. 2012. Structure of the montane taiga forests of West Khentii, Northern Mongolia. *Journal of Forest*

Science, 58(2): 45–56.

Onaindia, M., Dominguez, I., Albizu, I., Isabel, A., Carlos, G. & Ibone, A. 2004. Vegetation diversity and vertical structure as indicators of forest disturbance. *Forest Ecology and Management,* 195(3): 341–354.

Paritsis, J. & Aizen, M. A. 2008. Effects of exotic conifer plantations on the biodiversity of understory plants, epigeal beetles and birds in Nothofagus dombeyi forests. *Forest Ecology and Management,* 255: 1575–1583.

Pejchar, L., Holl, K. D. & Lockwood, J. L. 2005. Hawaiian honeycreeper home range size varies with habitat: implications for native Acacia koa forestry. *Ecological Applications* 15(3): 1053–1061.

Perley, C. 1994. Biodiversity, sustainability and a land ethic. *New Zealand Forestry, 39:* 2–3.

Pielou, E. C. 1966. Shannon's formula as a measure of specific diversity: its use and misuse. *The American Naturalist,* 100(914): 463–465.

Porbabaie, H. 2004. Applying of statistic science in ecology. Gilan University Press, Gilan. 428 p.

Regzedmaa, M. 2008. Climate resources and changes: References of meteorological dates of Selenge province. Sukhbaatar, Mongolia, 11–25. (In Mongolian)

Alem, S. & Woldemariam, T. 2009. A comparative assessment on regeneration status of indigenous woody plants in *Eucalytus grandis* plantation and adjacent natural forest*. Journal of Forestry Research,* 20(1): 31-36.

Simpson, E. H. 1949. Measurement of diversity. *Nature*, 163: 688.

Spies, T. A. & Barnes, B. 1985. Ecological species groups of upland northern hardwood-hemlock forest ecosystems of the Sylvania Recreation Area, Upper Peninsula, Michigan. *Canadian Journal of Forest Science,* 15(5): 961–972.

Sporn, S. G., Bos, M. M., Hoffstätter-Müncheberg, M., Kessler, M. & Gradstein, S. R. 2009. Microclimate determines community composition but not richness of epiphytic understory bryophytes on rainforest and cacao agroforests in Indonesia. *Functional Plant Biology,* 36: 171-179.

Stephens, S. & Wagner, M. R. 2007. Forest plantations and biodiversity: a fresh perspective, *Journal of Forestry* 105(6): 307–313.

Tsogtbaatar, J. 2004. Deforestation and reforestation needs in Mongolia. *Forest Ecology and Management* 201(1): 57–63.

UNREDD, 2018 Mongolia's Forest Reference Level submission to the UNFCCC. National Programme, Ministry of Environment and Tourism, Ulaanbaatar, Mongolia, 61 pp.

Vesk, P. A. & Westoby, M. 2001. Predicting plant species' responses to grazing, *Journal of Applied Ecology,* 38(5): 897–909.

Walker, M. D. 1996. Community baseline measurements for ITEX studies. *ITEX Manual Copenhagen*: Danish Polar Centre, 39–41.

Wang, S. & Chen, H. Y. H. 2010. Diversity of northern plantations peaks at intermediate management intensity. *Forest Ecology and Management,* 259(3): 360–366.

World Bank, 2004. Mongolia Forestry Sector Review. Ulaanbaatar, Mongolia, 71 pp.

*****