Broadleaved regeneration dynamics in the Pine plantation

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ABSTRACT: In an Island of the Netherlands, Pine (*Pinus nigra*) was planted to stabilize the dunes and to protect the arable lands from the blowing sand. This research was conducted to understand the most important environmental factors responsible for a vegetation change in the Pine plantation and effect of this change on the rare orchid population: *Goodyera repens* and *Listera cordata*. Vegetation sampling was carried out according to the Braun-Blanquet phytosociologic method within the three sites of this Island. Twinspan analysis confirmed the definition of three site types and redundancy analysis showed a significant difference between the pure Pine stands and the plots with regeneration. The results revealed that the most significant explanatory variables were litter cover, broadleaved tree cover, and shrub cover indicating the vegetation change under the Pine plantation. The abundance of *Goodyera repens* is strongly associated with the Pine forest and negatively related to broadleaved cover. *Listera cordata* could apparently cope with vegetation change. Controlling the herbaceous layer in the Pine plantation can promote the orchid population but on the contrary, promoting the natural regeneration of broadleaved species might endanger them.

Keywords: broadleaved regeneration; pine plantation; management; orchids; Terschelling

The State Forest Service (SFS) of the Netherlands took initiative to plant Pines, *Pinus nigra*, in the Terschelling Island in 1919. They started the Pine plantation scheme in the western part and finished at the Hoornse Bos (middle part of the Island) by 1939. In a brief discussion with the state forestry service official, it was understood that initially Pines were planted to stabilize the sand dunes and prevent arable lands and human settlements from the blowing sand. Vegetation studies show that the afforestation of dunes modifies the surrounding features. Higher plants, especially trees, reduce wind speed, catch drifting sand, improve the soil aggregation by their roots, promote mycorrhiza and rhizosphere bacteria and stimulate the weathering of soil minerals (Koske, Polson 1984; Forster 1990).

Currently, the management plans in Pine stands are carried out with an objective to increase the biodiversity and for recreational purposes. In the Pine plantation, spontaneous broadleaved species regeneration is taking place and the potential vegetation classes in the course of time are *Betulo-Quercetea* and *Fago-Quercetea* (Sissingh 1977). Three distinct types of forests in the Pine plantation observed are: pure Pine stand, site with natural regeneration and no evidence of management and managed site with felling and ring-barking. The management activities are mainly to increase the canopy opening and the light incident on the soil for broadleaved seedling development.

However, this vegetation change occurs where management by the SFS has opened the canopy, and also where there is no management. The reasons for this change might be related to an increase in organic matter and soil moisture especially in dune valleys. Therefore, regeneration is present and desired to convert the planted forest to an autochthonous deciduous forest. The dune top and valleys of the Hoornse Bos Pine forest appear to have environmental differences that affect the natural regeneration process. The broadleaved species of Oak, Beech, Maple, Holly and Sweet Chestnut frequently occur in the dune valley if they have space and moisture (Ranwell 1972). Consequently, the Forest Service of Terschelling used some management practices to enhance the natural regeneration process of these broadleaved species within this pure Pine stand.

On contrary, this forest conversion process might have impacts on the rare species of orchids and mushrooms, with a net loss of species richness (Hill, Wallace 1989). The two important orchid species: *Goodyera repens* and *Listera cordata* are very common in the Pine forest. These orchids are naturally found in a cool, moist coniferous forest with a mossy component in the understory (Dyrness 1988). The management practices of the Pine stands and natural regeneration of broadleaved species might affect the abundance of these orchids and environmental conditions. So, the environmental variables have impacts on the vegetation and natural regeneration process.

Future management decisions will have to consider the environmental factors that determine the vegetation change from pure Pine stand to broadleaved forest. This study questions what environmental factors are driving the vegetation change in the planted Pine forest of Terschelling. The second research question is to address the concern of the State Forest Service (SFS) regarding the two rare orchid species: are the orchids being influenced by the increase in broadleaved species?

MATERIAL AND METHODS

Description of study area and selection of Pine stands

The fieldwork of this study was carried out in the Dutch Island of Terschelling in June 2009. After a visit to the forest areas of the Island, the Pine plantation of Hoornse Bos was selected because it has areas representative of the Pine forest dynamics. The forest is dominated by *Pinus nigra* stands. In Hoornse Bos we identified three different types of Pine forest that are representative of the current situation of the planted Pine forests of the Island:

(a) Natural regeneration areas – where natural regeneration of broadleaved tree species and associated species is present and with no signs of active management to promote the occurrence of other species than pine (Fig. 1R);
(b) Managed areas – with regeneration of broadleaves and evidence of management (felling and ring-barking) (Fig. 1M);
(c) Pure Pine stands – with no evidence of regeneration or management (Fig. 1P).

Survey for recording spontaneous tree rejuvenation and orchid abundance

The vegetation sampling was carried out according to the Braun-Blanquet phytosociologic method. In homogeneous plots of 10 m × 10 m the presence/abundance of vascular plant and bryophyte species was recorded using an ordinal scale adapted from the Braun-Blanquet scale (Braun-Blanquet 1964). For each of the three identified forest types eight relevés were made. Distinction in elevation was made for the relevés on the top or in the valley of the dunes (Table 1). In total 24 relevés were made. For each relevé the total cover was assessed in the percentage of the layers of litter, herbs, shrubs, pine trees, broadleaved trees, two orchids and mosses (Table 1). The following parameters were registered: diameter at breast height (DBH) of Pine trees, depth of organic matter (OM), canopy cover with canopy densiometer, organic soil pH and soil moisture (Table 1). Additionally, the orchid presence was recorded using the scale of 1 to 5 (1 = 1–5, 2 = 5–50, 3 = 50–100, 4 = 100–250, 5 = > 250, number of orchids) and a random subsampling of three plots of 1 m × 1 m inside each relevé was made to count the number of individual orchids and seedlings.

Fig. 1. Three different sites of Pine forest in Hoornse Bos, Terschelling Island

Table 1. Data on different environmental parameters of the three sites of Pine forest

Relevé 10 m × 10 m	TL (%)	SL (%)	HL (%)	ML (%)	LC (%)	BL (%)	Can. cover	Moist.	pH	OM depth (cm)	Veg. count	DBH (cm)	Elev.	Orchid No.		BL Reg.	Pine Reg.	Regeneration site		
														Gd.	*List.*			P	M	R
PA3-T	80	0	10	3	95	0	84.4	15.61	4.28	2.70	6	29.04	2	2	1	1	1	1	0	0
PA2-T	75	0	2	1	95	0	88.56	12.05	4.70	2.63	6	24.12	2	3	1	0	0	1	0	0
PA1-T	75	0	15	2	95	0	84.92	26.89	4.24	4.83	12	43.51	2	4	1	1	0	1	0	0
RA2-T	50	4	30	50	60	10	81.80	19.54	4.80	3.63	12	30.46	2	4	0	1	1	0	0	1
PA4-V	70	0	5	5	90	0	84.66	12.06	4.62	2.13	10	25.22	1	0	0	1	1	1	0	0
PB5-V	60	0	10	5	90	0	76.60	12.29	4.78	2.57	9	21.67	1	3	0	1	0	1	0	0
PB6-T	50	0	20	25	80	0	73.74	8.80	4.71	3.00	12	19.89	2	1	1	1	0	1	0	0
RB6-V	70	5	10	80	30	0	86.74	18.25	4.35	2.97	14	30.13	1	0	1	1	1	0	0	1
RB4-V	40	65	5	5	15	60	87.00	18.25	4.33	4.00	13	30.45	1	3	1	0	1	0	0	1
PB8-V	60	0	25	10	75	0	77.90	15.89	4.66	2.60	8	28.20	1	2	2	0	1	1	0	0
RB3-T	60	0	4	85	5	15	80.50	7.86	4.61	2.53	12	29.88	2	2	3	1	1	0	0	1
RB7-T	70	20	35	75	45	15	89.60	10.45	4.42	2.77	10	26.18	2	1	1	0	1	0	0	1
MA2-V	20	12	2	30	90	25	87.26	16.82	4.32	4.40	15	27.55	1	1	2	0	0	0	1	0
MA3-T	40	30	60	40	70	30	70.62	15.18	4.47	4.70	10	35.45	2	1	1	0	0	0	1	0
RA1-V	50	15	60	60	60	0	85.18	21.01	4.82	3.00	15	30.84	1	3	4	1	1	0	0	1
PB7-V	50	0	20	10	80	0	73.22	17.99	4.93	2.70	11	25.11	1	4	4	0	0	1	0	0
MA1-V	40	1	8	8	90	75	83.36	29.39	4.56	4.50	13	52.83	1	2	3	0	1	0	1	0
RB5-T	60	20	60	10	20	30	81.28	12.72	4.65	2.83	6	30.28	2	2	1	0	1	0	0	1
RA8-V	60	5	60	35	60	50	90.90	19.82	4.76	3.03	16	30.55	1	4	2	1	0	0	0	1
MB4-V	30	10	70	5	30	65	80.50	25.05	4.46	4.13	13	41.96	1	2	3	0	1	0	1	0
MA5-V	35	60	5	30	80	60	72.18	14.55	4.34	4.13	22	32.90	1	3	1	0	0	0	1	0
MA6-T	40	10	10	2	95	70	80.50	9.07	4.19	3.03	6	30.46	2	2	0	1	0	0	1	0
MA7-T	30	10	30	35	65	70	83.36	8.10	4.30	3.20	15	28.36	2	2	1	0	0	0	1	0
MA8-T	20	15	25	80	40	52	88.04	12.16	4.61	2.57	15	23.14	2	2	1	0	0	0	1	0

T = Dune Top; V = Dune Valley; TL = Tree Layer; SL = Shrub Layer; HL = Herb Layer; ML = Moss Layer; LC = Litter Cover; BL = Broadleaved Layer, Can. cover = canopy; Moist. = moisture, OM = Organic Matter depth, Veg. count = vegetation; Elev. = Elevation (1 = medium, 2 = high); Orchid *Goodyera* (*Gd.*) and *Listera* (*List.*) (class number 1 = 1–5, 2 = 5–50, 3 = 50–100, 4 = 100–250, 5 = > 250 number of orchids); BL Reg. = Broadleaved regeneration (1 = regeneration, 0 = no regeneration); Pine Reg. = Pine regeneration; P = pure pine stands; M = managed area; R = regeneration area

Statistical analysis

The data of the relevés was inserted in Turboveg (Hennekens, Schaminee 2001) for Windows and the environmental data in Excel. All data was analysed using Twinspan and Canoco software. In the first instance, the analysis with Twinspan was done to observe a plant community structure development in the Pine plantation. To find a possible causal relationship between the variations in the vegetation and its environment Canoco was used and tested by Monte Carlo Permutation test.

RESULTS

Description of study sites

Regeneration, in this case conversion of Pine forest to broadleaved forest, was assessed by the presence of tree seedlings. Pine seedlings were also found in the study sites, but never a young Pine individual. The same phenomenon was observed for Oaks, since only in the managed sites with regeneration both young and old Oaks were present. These observations could indicate that

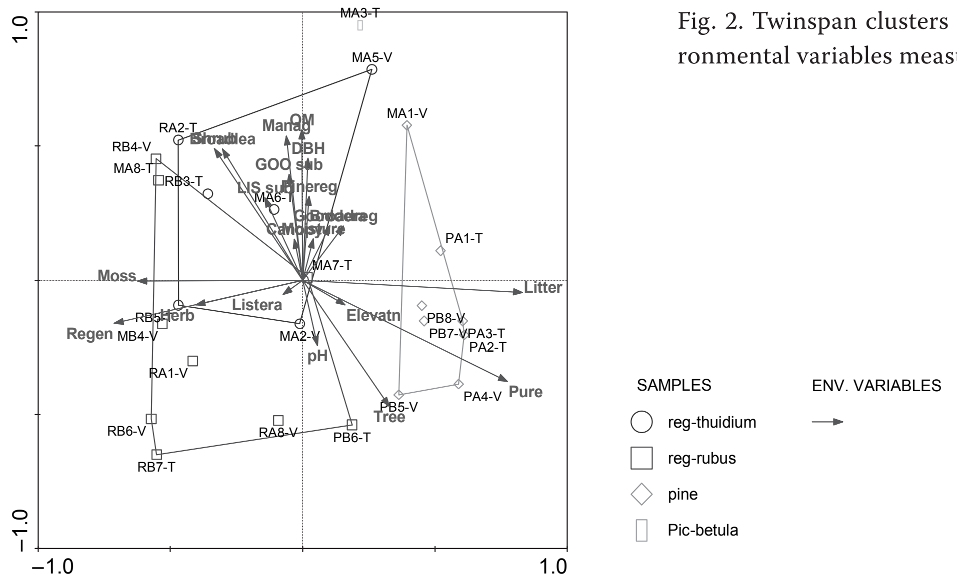

Fig. 2. Twinspan clusters of three sites with all environmental variables measured and samples

the Pine forest is not regenerating in the study sites.

The regeneration sites consist of the first stage of increased herbaceous cover including seedlings, indicating the strong potential for conversion to broadleaved forest. In the managed sites with regeneration, felling and ring-barking of adult Pine trees aim at the canopy opening. Nevertheless, the sites without any management are also under regeneration. Canopy opening is considered to be a determining factor for promotion of regeneration and recruitment of trees. However, in this study canopy is not likely be the main driving factor and statistically it showed no significant difference among the three sites. The edge effect was also reduced as much as possible by choosing the plots in the interior of the forest.

DBH was taken as a factor due to preliminary observations indicating that where regeneration occurred, the Pine trees were thicker meaning that these sites received better light conditions, and where trees were growing better. It was found that higher DBH related to managed sites. This might be a sign that the management choices are following the regeneration patterns by choosing the best areas for light penetration to promote the conversion to broadleaved species.

Another aspect taken into account was the elevation, showing site locations on dune top or in dune valley (Table 1). The observations showed that regeneration occurred preferably in the dune valleys compared to the dune tops. In fact the elevation turned out not to be a significant factor for the vegetation change. On the other hand, pH data

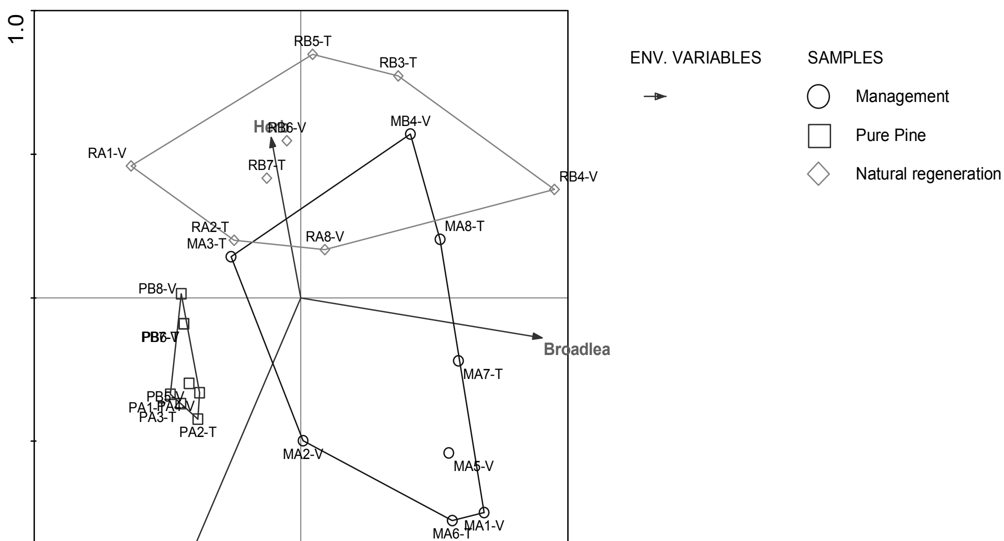

Fig. 3. Clusters with only significant environmental variables clearly defining the three study sites separately

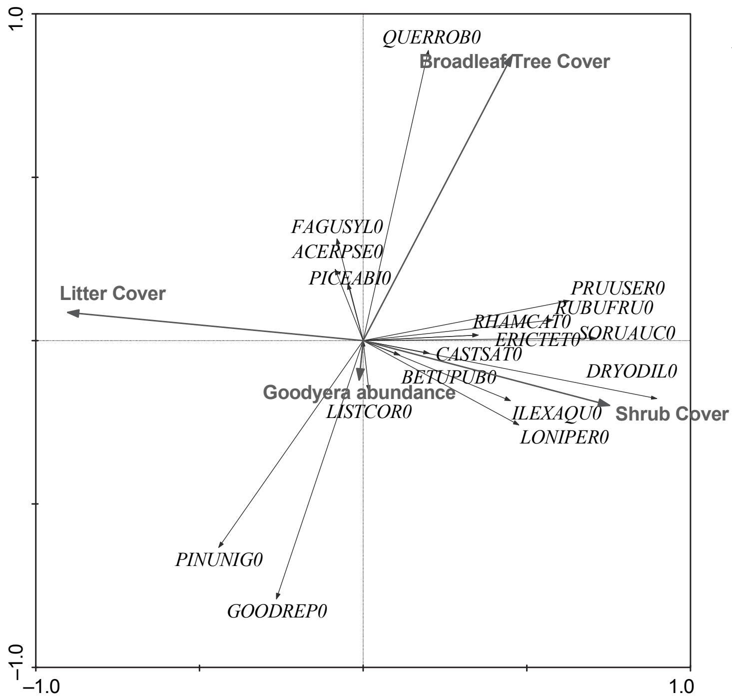

Fig 4. Graph showing significant environmental variables correlated with the presence of plant species

showed no significant results among the three site types (Table 1).

Analysis of regeneration and orchid abundance

From the Twinspan analysis, groups of plant communities were created (Fig. 2). Each of the four clusters in the Twinspan analysis was characterised by open habitat and broadleaf woodland species (Fig. 2). The main regeneration of the woody genus *Rubus* was present in several relevés and forms a different big cluster in Fig. 2. Pine and mosses (*Thuidium*) also form two different clusters in the Twinspan analysis, and the shrubs (*Betula*) form a small cluster in Fig. 2. Twinspan clusters matched with the classification of the study sites made a priori, grouping the natural regeneration sites (R), managed sites (M), and pure Pine stands (P). The

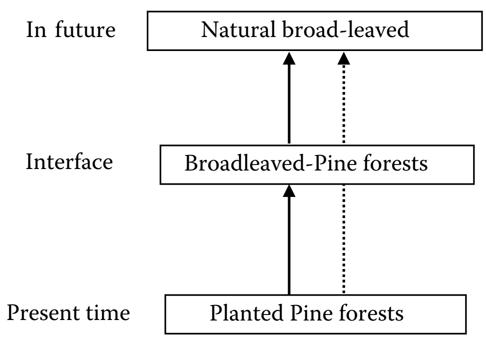

Fig. 5. Situations for future natural broadleaved forests developing from pine plantations on acidic sand soils of Hoornse Bos (the Netherlands)

environmental factors that are driving these clusters were not clear. Therefore, in the following analysis variables were selected so that only the significant ones would be included.

The results from the RDA analysis for the samples and factors show a significant difference between the pure Pine stands and the plots with regeneration. Among the selected factors, the most significant ones to explain the vegetation change are litter cover, broadleaved tree cover, and herb cover which were tested using the Monte Carlo test (Fig. 3).

The Pine plots are determined by the litter layer, which negatively correlates with the shrub layer. On the right side, the presence of broadleaved seedlings defines the managed sites, while the regeneration site is dominated by the herbaceous cover (Fig. 4).

The abundance of *Goodyera repens* is strongly associated with the Pine forest and negatively related to the cover of broadleaved species regeneration. And the influence of shrub layer in the natural regeneration sites is visible from this analysis, showing two stages of regeneration with high oak cover in contrast with high shrub and herbaceous cover. *Listera cordata* is not influenced by the vegetation change very much, since it can survive in a mixed forest of conifers and broadleaves (Hapeman 2000).

DISCUSSION

In sandy soil, nutrient availability in the organic layer is one of the most important factors for regeneration or plant growth (Ellenberg et al. 1991). Accordingly, in this study the litter layer (decomposed to OM) played a significant role for regeneration patterns of Hoornse Bos Pine forest (Fig. 3) and it also reflects a general trend of regeneration in Central Europe (Ellenberg et al. 1991; Zerbe 1993). However, the canopy cover improves the soil water balance in climates where summer drought is very pronounced (Joffre, Rambal 1993; Lookingbill, Zavala 2000) by lowering radiation levels and creating microclimatic conditions that are more favourable for germination and establishment of natural regeneration, as is the case of this study. Therefore, the tree crown and its position could be the main factor influencing the establishment of regeneration of broadleaved species in the Pine forests. This trend of the strong ability of broadleaved species to grow in managed and natural pine stands was suggested as the future development of oak-beech natural forests in Hoornse Bos (Fig. 5); similar results were reported by Leuschner et al. (1993) and Zerbe (2002).

According to Ashton et al. (1997), *Pinus sylvestris* can be considered as a nurse for facilitating the establishment of oak and beech (broadleaved species) in the Menzer Heide, Germany. In this study, the herbaceous and broadleaved cover, as the measure for the regeneration of broadleaved species in the Pine plantation, gave significant results among the three types of sites indicating that the management choices are following the regeneration patterns by choosing the already best areas to promote conversion to broadleaved species.

In the cluster analysis, some environmental parameters such as soil moisture, OM, pH, elevation and DBH did not give any significant results. The apparent explanation might be that the decomposition of pine litter was very slow and the elevation of dunes did not vary too much. In addition, most of the areas of this Island are situated below or near the sea level. The presence of broadleaved species in the tree layers of pine plantations on sites very poor in nutrients enhances understory vegetation (Krausch 1970; Knapp 1990), as is the case of *Listera cordata* in this field research. However, the future intensive study will require more intensive and concluding results about some environmental parameters.

CONCLUSION

From the results of data analysis, three forest types were selected: (*i*) pure Pine stand with high litter cover and higher abundance of *Goodyera repens*, (*ii*) intermediate regeneration with species-rich high herbaceous cover, and (*iii*) advance regeneration with high cover of broadleaved species mainly *Quercus robur.* Interestingly, there seems to be a conflict in management strategies. To increase biodiversity the regeneration of broadleaved species should be promoted and to protect the rare orchid, *Goodyera repens*, the pure Pine stand must be promoted. *Listera cordata* could apparently cope with the change in vegetation from pure Pine stand to a mixed forest of conifers and broadleaved species. Finally it may be concluded that controlling the herbaceous layer in the pure Pine plantation should promote the orchid population but on the other hand, promoting the natural regeneration of broadleaved species will suppress them significantly. However, the increasing number of samples and future intensive research could improve the results of the study.

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