Influence of border area drainage on the vegetation on the slope of the Ruunasoo bog, South-west Estonia

Mati Ilomets, Laimdota Truus, Raimo Pajula, Kairi Sepp and Elve Lode

Institute of Ecology, Tallinn University, Uus-Sadama 5, 10120 Tallinn, Estonia
Phone: + 372 6566425, fax: +372 6199801, e-mail: mati.ilomets@tlu.ee

Summary
The effect of long-term (over 100 years) drainage on the plant cover of the marginal slope of the Ruunasoo bog (SW-Estonia) was studied. Stable *Vaccinium*-dominated drained bog pine forest has formed close to the marginal ditch. The forest is expanding over the earlier open *S. magellanicum*-dominated bog slope and has even reached the hollow-ridge complex. As a result of the self-drainage, and limited throughfall because of dense tree canopy, the *Sphagnum* carpet is degrading. For the re-naturalization of the plant cover and hydrology of the bog slope, the cutting of trees and closing of ditches are both equally required.

Key index words: bog border drainage, bog slope, peat compression, vegetation succession, water level

Introduction
The bog margin is an important component of a mire landscape. As a rule, bog margins are affected by drainage. Due to deteriorated hydrology, the structure and function of plant cover may change considerably. Commonly open communities are replaced by forest ones. The species composition changes and many species of conservational value, especially birds, characteristic of open mires, may disappear. Therefore it is important to understand more deeply the processes related to drainage of mire margins and to restore actively mire margin communities and habitats before drainage.

Objectives
Drainage of the bog margin may cause, because of the expansion of the tree layer, the self-drainage of a bog. We studied the plant cover of the bog margin using the transect method and measured certain biotic (tree layer cover) and abiotic conditions (depth to water level, bog surface slope). Our aim was to explain the changes in the plant cover structure, which have taken place in the mire margin and to give recommendations to managers for the restoration of the open mire margin.

Materials and methods
Study area
The Ruunasoo bog (ca 200 ha, SW Estonia) is a typical West Estonian plateau-like bog. On the central plateau there predominates the open hollow-ridge complex with wide mud-bottoms. This is surrounded by a narrow (ca 100 m) belt of treed hollow-hummock and pool-ridge complexes. A bog pine forest belt (50–200 m wide) is distributed on the steep bog slopes. A drained forest belt (up to 50 m) borders the bog. During the last century many ditches (with the density of about 2.3 m per 1 m of the bog margin) have been dug on the western margin of the bog.

Description of vegetation
Vegetation was studied along four cross-transects on the bog marginal slope (Fig. 1). On circular sample plots, 10 cm in diameter for the moss layer and 25 cm in diameter for the dwarf-shrub and herb layer, the coverage (%) of every plant species was found. Sample plots (a total of 561 analyses) were selected along transects at each 1 m. The tree layer was described constantly after every 10 m on 10 m x 20 m plots. The depth to the water level was measured in every sampling plot using perforated PVC tubes inserted into the deposit up to 1 m depth. The bog slope was found with the water levelling method developed by Sake van der Schaaf, which is based on the principle of connected vessels.

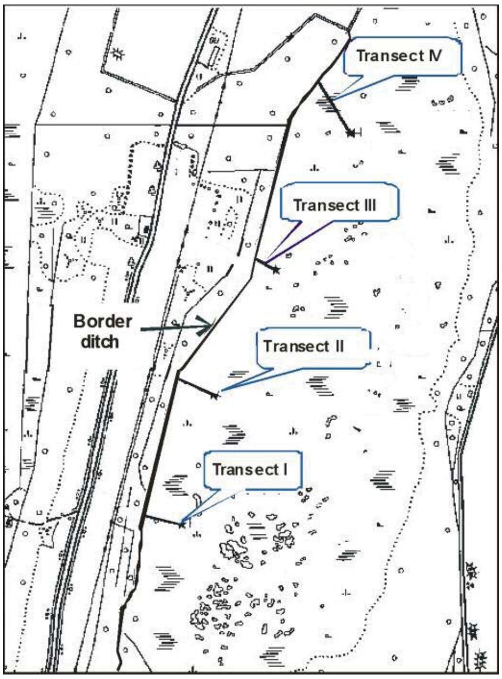

Figure 1. Location of transects I–IV on the western margin of the Ruunasoo bog in SW Estonia.

Peat deposits and mineral subsoil stratigraphy (peat type and degree of the decomposition of every visually distinguishable sequencing peat layer) were studied in at least four points in all transects.

The PC-ORD program (McCune and Grace, 2002) was used to classify the circular sample plots by two-way cluster analyses and non-metric multidimensional scaling (NMS) was applied to detect the most important factors affecting the composition of plant species in the field and the surface layer on the marginal slope of the bog. The factors considered were the tree canopy cover, depth to the water level, relative height of microforms and bog surface slope.

Results

Peat coring showed that an open, or with a scarce tree layer, *S. magellanicum*-dominated moss carpet was distributed on the rather wet (with high water level) bog marginal slope (even on its lowermost section) before drainage ditches were dug some 100 years ago. Only in coring sites in the present hollow-hummock complex parts of the transects was the uppermost 2–3 m section of the deposit formed by *Acutifolia* (*S. fuscum* and *S. rubellum*) peat.

Nine clusters were separated (Table 1). *Vaccinium*-dominated clusters 1 and 2 were distributed in the lowermost section of the bog marginal slope under the drained bog forest. The height of the trees is about 15–20 m and canopy cover reached 50%. The importance of *Sphagnum* in the moss layer was very low. The growth of the assemblages dominated by *Vaccinium* species under dense tree canopy was in good accordance with dry conditions, no other factor has affected the species composition significantly. Clusters 3, 5 and 9 were distributed in different sections of the bog forest. Clusters 3 and 5 were more common in the upper part of the marginal slope. Cluster 3 consisted of plots where, because of the deeper water level and denser canopy, the proportion of *Sphagnum* species was quite low and forest moss species were expanding. In cluster 5 *Sphagnum* species still predominated but were affected strongly by tree canopy. The plots dominated by *S. fuscum* and *Rubus chamaemorus* (cluster 9) were affected by tree canopy and depth to the water level, but the distribution of these species was very limited.

The *Calluna vulgaris*-dominated plots (clusters 6) were present only on transect II, where they occurred together with plots dominated by *S. fuscum* + *S. rubella* (cluster 7) on bog hummocks. The depth to the water level affected strongly the composition of *Sphagnum* species in plots of cluster 6. Plots of cluster 4 (*Sphagnum angustifolium* + *Calluna vulgaris*) were found in most parts of the transects, but not in the drained bog forest in the lowermost section of the slope (Figs 2 and 3). The bog surface slope affects markedly the proportion of species in plots of cluster 6.

Clusters 7 and 8 consisted, respectively, of plots from ridges and hollows on the treed hollow-hummock complex. The *S. fuscum* + *S. rubellum*–*Calluna vulgaris* assemblage was the dominant and most stable community on treed bog ridges and hummocks (Masing, 1982). The species composition of plots taken from hollows (cluster 8) was significantly influenced by the bog surface slope. The cover of *S. balticum* increased most in the hollows and wet depressions between hummocks with the rise of the bog slope.

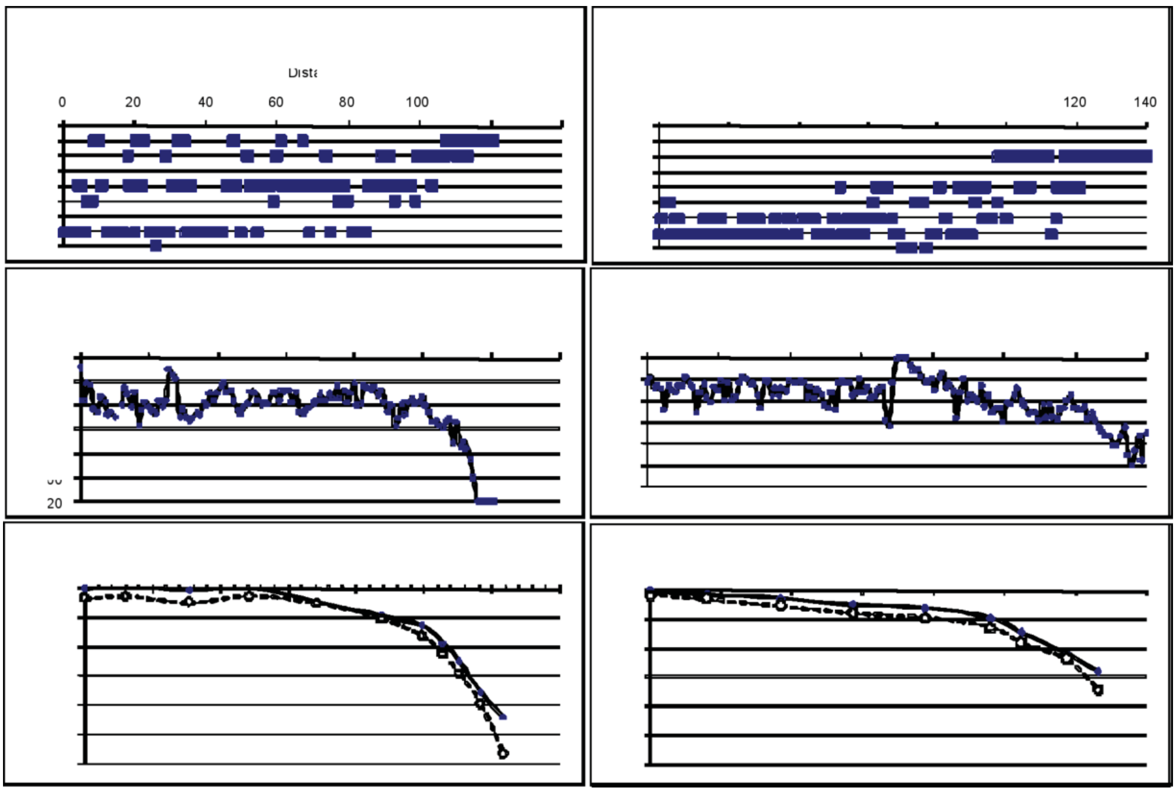

Figure 2. Location of vegetation clusters along transects (A and B), depth to bog water level (C and D) and bog surface declination (E and F) on transects I and II. A and B: for names of clusters see Table 1, distance from the beginning of the transect; C and D: depth to the water level measured after every 1 m on the transect; E and F: solid line – relative height of the bog surface (zero level is the starting point of the transect), dotted line – height of the water level.

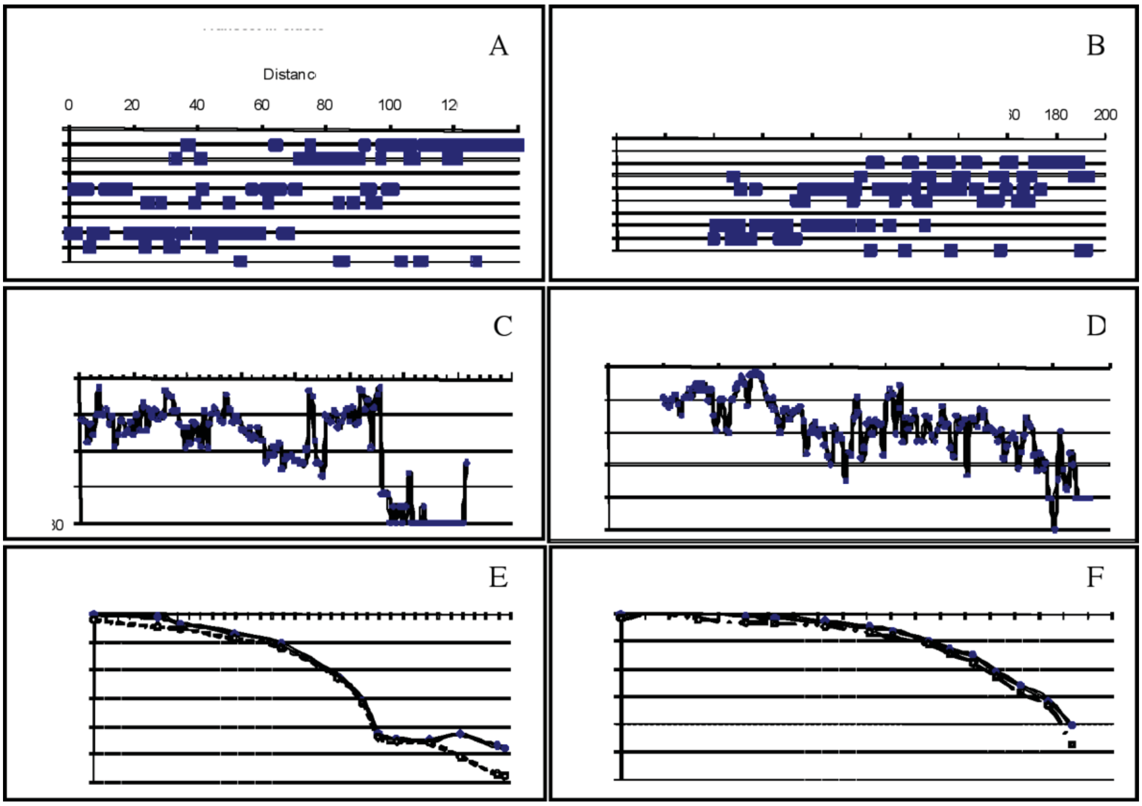

Figure 3. Location of vegetation clusters along transects (A and B), depth to bog water level (C and D) and bog surface declination (E and F) on transects I and II. A and B: for names of clusters see Table 1, distance from the beginning of the transect; C and D: depth to the water level measured after every 1 m on the transect; E and F: solid line – relative height of the bog surface (zero level is the starting point of the transect), dotted line – height of the water level.

Discussion

Over 100 years ago the western marginal slope of the Ruunasoo bog was almost treeless and *S. magellanicum* formed a dense carpet. About a century ago the first low ditches were dug under the bog slope to keep the water level deeper in the marginal lagg area. In the 1950s the deep border ditch between the bog and the marginal lagg area was excavated. Another deep ditch was dug in the middle part of the slope.

As a result the growth conditions for the tree layer ameliorated in the close vicinity (under the bog slope) of ditches. The *Sphagnum* carpet withdrew and *Vaccinium* species, mainly *V. myrtillus* expanded rapidly as tree canopy became denser. Another consequence of the mire margin drainage was that the bog surface on the slope broke down and was compressed as the water level decreased and the *Sphagnum* carpet regressed. Pine trees expanded upwards on the slope and the bog pine forest belt developed on the almost open slope with the *S. magellanicum* carpet. This phenomenon can be characterized as self-drainage of the bog. As the trees grow taller the canopy cover increases and throughfall to the surface decreases. Evapotranspiration may

TABLE 1. Clusters of plant cover plots on transects I–IV, mean depth to the water level of clusters and their correspondence with mire site types on the western marginal slope of the Ruunasoo bog. Clusters are named after the dominant plant species.

No.	Cluster	Water level ± St. Dev. (cm)	Site type
1	*Vaccinium*	68±30	drained peatland forest
2	*Pleurozium schreberi–Vaccinium myrtillus*	52±18	drained peatland forest
3	*Dicranum berger–Polytrichum strictum–Rubus chamaemorus*	44±20	pine bog forest
4	*Sphagnum angustifolium–Calluna vulgaris*	34±10	treed hollow-ridge bog and pine bog forest
5	*S. magellanicum + S. angustifolium + Aulacomnium palustre-Rubus chamaemorus*	31±13	pine bog forest
6	*Calluna vulgaris*	32±12	pine bog forest
7	*S. fuscum + S. rubellum–Calluna vulgaris*	28±10	treed hollow-ridge bog
8	*S. cuspidatum + S.tenellum*	10±8	treed hollow-ridge bog
9	*S. fuscum–Rubus chamaemorus*	37±30	pine bog forest

TABLE 2. Number of analyses and species and mean cover by layers in clusters (for cluster names see Table 1). Factors strongly affecting plant species structure were found by NMS ordination. WL = depth to water level, HL = height of hummock .

Cluster	No of analyses	Strong factors	Number of species					Mean cover, %				Tree canopy cover,%
			Total	Dwarf-shrub and herb	Mosses: Total	Mosses: *Sphagnum*	Mosses: Others	Dwarf-shrub and herb	Moss: Total	Moss: *Sphagnum*	Moss: Others	
1	52	no	18	10	8	5	3	15	5	3	2	50
2	106	no	24	12	12	5	7	32	56	10	46	55
3	12	canopy, WL, HL	16	11	5	1	4	17	58	16	42	45
4	113	slope	23	12	11	5	6	30	64	60	4	30
5	44	canopy	24	14	10	5	5	22	80	69	11	35
6	35	WL	15	8	7	5	2	40	39	38	1	20
7	149	no	24	12	12	6	6	28	82	81	1	15
8	25	slope	13	9	4	4	0	11	80	80	0	5
9	14	canopy, WL, HL	14	8	6	5	1	15	44	42	2	45

also increase. The *Sphagnum* carpet degrades in shade and less humid conditions and is replaced by forest moss species, mainly *Aulacomnium palustre* and *Pleurozium schreberi*. The rate of the process may be considerable as the bog pine forest belt has expanded over 100 m upwards on the slope during the last 50–60 years. In transect I the bog pine forest is expanding over the slope and reaching the bog plateau.

We concluded that to bring up the water level, clear-cutting of the tree layer is as important as closing the ditches. Even these measures are not sufficient for restoring the pre-drainage situation with the open *S. magellanicum*-dominated carpet as the bog slope has changed.

Acknowledgements

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