DYNAMICS OF REGENERATIVE SUCCESSION OF AZOREAN PASTURED PEATLANDS

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Introduction

Regenerative secondary succession of vegetation has been documented in a wide range of peatland ecosystems, although the rate of return of peatland species and the dynamics of ecological succession can vary widely (Lavoie et al. 2003), according to the disturbance type, intensity, frequency and duration as well as local environmental conditions. Most frequently, restoration interventions are recommended or even necessary to re-establish natural peatland ecosystem. However, in wetter climates and not so harsh winter, spontaneous revegetation may be more pronounced.

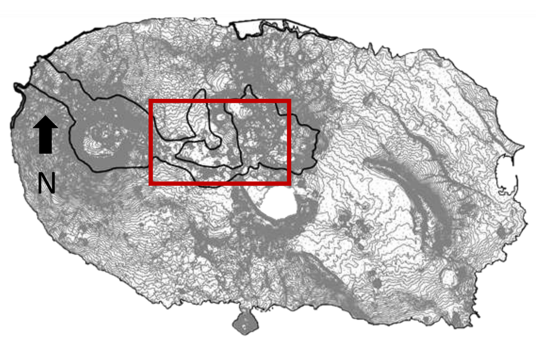
There is, in Azores, a potential distribution of 350 Km^2 of peatlands, less than 30% of the original area persists nowadays and of these, more than 50% are under pressure. Locally, major impacts in peatlands include their use as pasture for cattle. Our study was aimed at analyzing dynamics of vegetation regenerative succession (evaluating the potential use of this strategy as passive restoration) of peatlands that occur on degraded peatland after its abandonment as grazing land and identify which plant species and vegetation types contribute most to the changes.

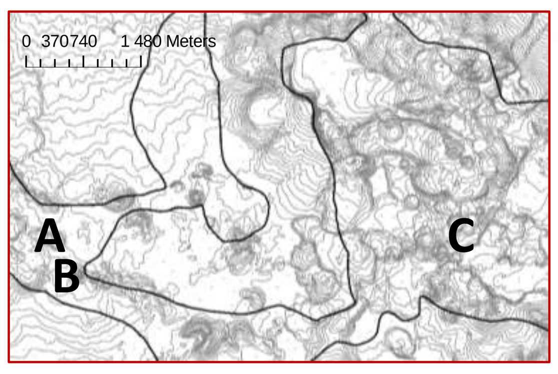
Objectives:

- Analyzing spontaneous return of *Sphagnum* mosses on pastured degraded peatland after its abandonment as grazing land (Study 1).
- Using reference ecosystems, identify which plant species and vegetation types contribute most to the changes of regeneration (Study 2).

Study areas

The study was carried out in Terceira Island, located in the Azores, Portugal. Marked by the coordinates 36°56′ N – 39°42′ N and 25°5′ W – 31°12′ W. Terceira Island, has an area of 402 km^2 and its highest mountain rises to an elevation of 1023 m above sea level (a.s.l). Precipitation ranges from 4109 mm yr-1 at 600 m a.s.l to 13054 mm yr-1 at 980 m a.s.l. (Dias 1996).





A - **A degraded peatland** with 15 ha – a blanket peatland where the grazing pressure was only removed 1 year before the start of this study. Integrated in Nature 2000 as Special Conservation Area (SCA limits defined in previous maps) and Natural Park of Terceira. It was in the past a forested peatland, dominated by *Juniperus brevifolia* (endemic shrub/tree). The area was transformed in a pasture before 1930. After, was extensively grazed. Plowed in the 1980's and used intensively (as pasture) until its abandonment 30 years later, in 2011. With the cease of grazing activities, the Applied Vegetation Ecology Group from Azores University (GEVA) started a research project on dynamics of regeneration. An initial characterization showed that more than 20% of all recorded plants were endemic to Azores or Macaronesia and more than 50% are indigenous (Mendes 2017).

B - **A semi-natural peatland** with 12 ha - a blanket peatland selected because it was formerly used as a grazing area but abandoned 30 years ago and left to spontaneous regeneration (located close to the degraded peatland); also inside Nature 2000 SCA and Terceira Natural Park). The semi-natural peatland site was, until the end of the 1930's, a grassland maintained by cutting trees and shrubs and by grazing. Extensive grazing stopped in the 1980's, thus 30 years prior to our surveys and analyses. The site was recovering from grazing but had some casual people trampling at a trail crossing it. *Calluna vulgaris* occupies the driest parts and is associated with *Sphagnum* spp. that covers most of the wetter areas. These two species dominate the semi-natural peatland site.
We considered that the historical semi-natural peatlands, where agriculture was practiced decades ago, as representative of an intermediate reference ecosystem against which to assess the recovery of the pastured degraded peatland.

C - **A natural peatland** with 10 ha - a forested peatland located at the base of two volcanic domes dominated by *J. brevifolia* and rich in endemic species. Within Nature 2000 SCA and Natural Park. In this, grazing never occurred. This natural site was never impacted, except indirectly by nearby (around 250 m distant) *Eucalyptus* and *Cryptomeria* plantations. Used as a natural reference ecosystem.

Data collection and analysis

1. *Sphagnum* dispersion dynamics in degraded peatland after pasture cease

The *Sphagnum* spp. distribution on the degraded peatland were mapped on the following dates: (1) aerial photo images of 2006 flight (corresponding to a pasture use situation); (2) photos of Google Earth of 2013 (two years after abandonment); (3) photos obtained by the drone DGI Model Phantom 3 Professional in August 2015 (four years after abandonment). In 2013 and 2015, the cartography was ground truthed with field surveys. The complementary information was based in 100 inventories of all the identified communities made each year, in plots of 1 m x 1 m, previously defined as minimum area size (Mueller-Dombois and Ellenberg 1974).

2. Regenerative dynamics of secondary succession of a degraded peatland after pasture cease

Data collection

48 plots (1 m x 1 m) established randomly in the degraded peatland. For comparison, the vegetation of the semi-natural peatland was surveyed with 10 plots (1 m x 1 m) and likewise in a natural peatland (10 plots). Plots were inventoried three times each year (March, July, and November), from July of 2012 to July of 2015, representing a total of 480 inventories in the degraded peatland, 100 in the semi-natural, and 100 in the natural. In these, all the vascular plants were identified to the species level (taxonomy as in Dias 2016), as well as bryophytes and lichens (taxonomy based on Watson 1981; Gabriel et al. 2005), always using the visual percent cover as the measure. Simultaneously in all 480 plots of the degraded peatland area, vegetation types were drawn using ArcGIS 10.

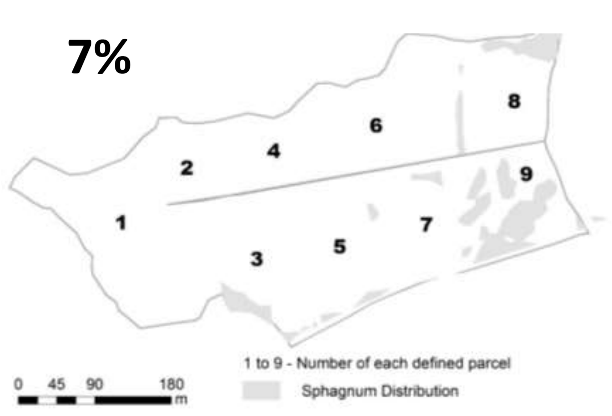
Data analysis

Cluster analysis of reference (after animal removal) inventories to define main communities in the degraded peatland carried out using SPSS Ver. 24 (IBM, Armonk, NY, USA).; PCA ordination analysis of species inventoried in 2012 and 2015 to determine the main tendencies in the flora along a trajectory of regenerative succession, were used (DCA ordination with a gradient length inferior to 4 SD, which indicates that the data has strong linear response and for this reason, the Principal Component Analysis - PCA was used); RDA of vegetation cover and the variable "time" conducted to evaluate the degree of annual variation in the degraded area; A permutation test used to evaluate if vegetation was significantly different between years and which species are associated with the changes in the degraded peatland; For these analyses (PCA and RDA), an annual average of plant cover in each plot was made. All ordinations were made using Canoco 4.5.

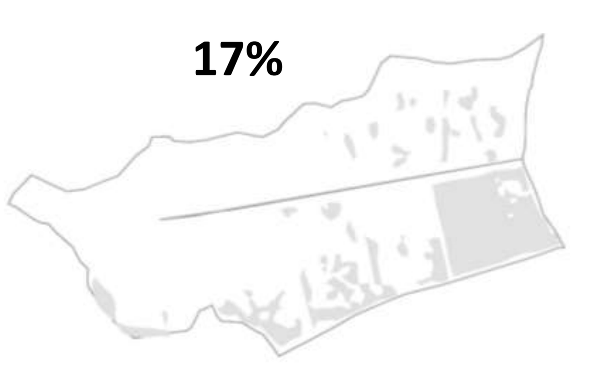
Results

1. *Sphagnum* dispersion dynamics in degraded peatland after pasture cease

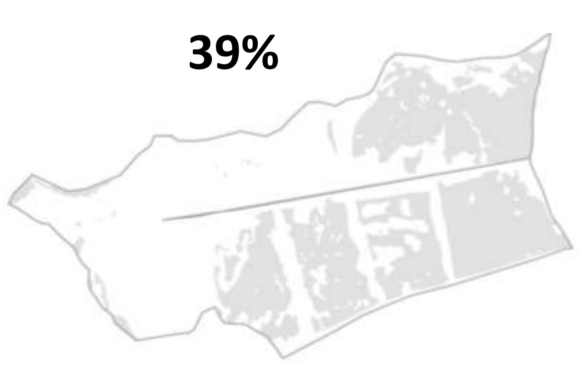
Sphagnum mosses recovered by 65% in the southern parcels compared to 35% in the northern parcels due to environmental (wetness) and floristic factors (presence of aggressive species).



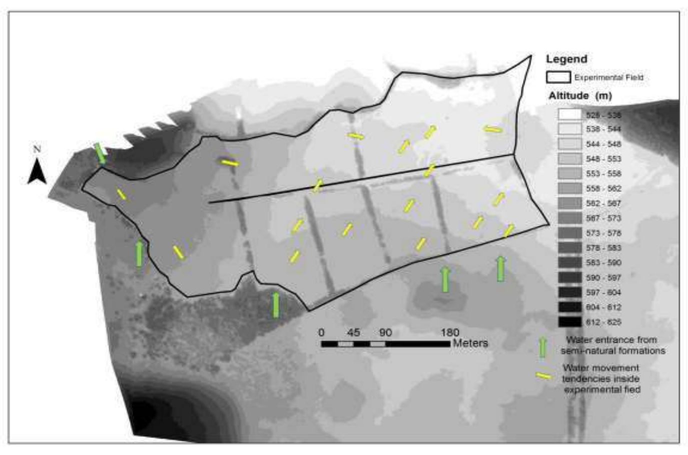
Pastured



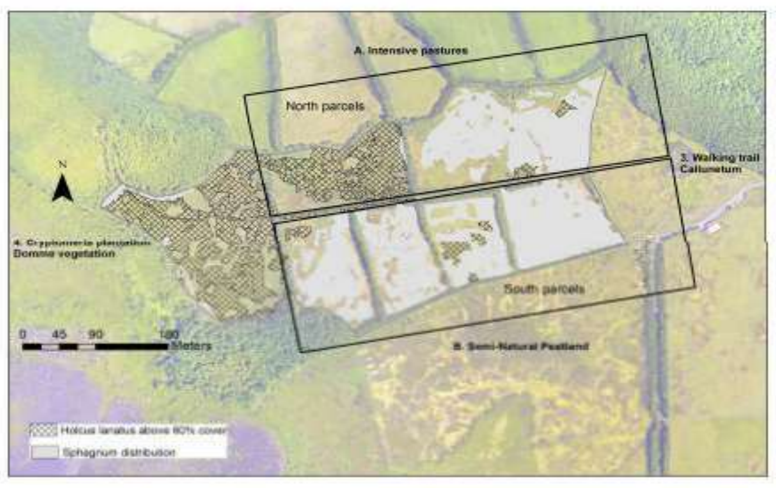
2 years after pasture cease



4 years after pasture cease

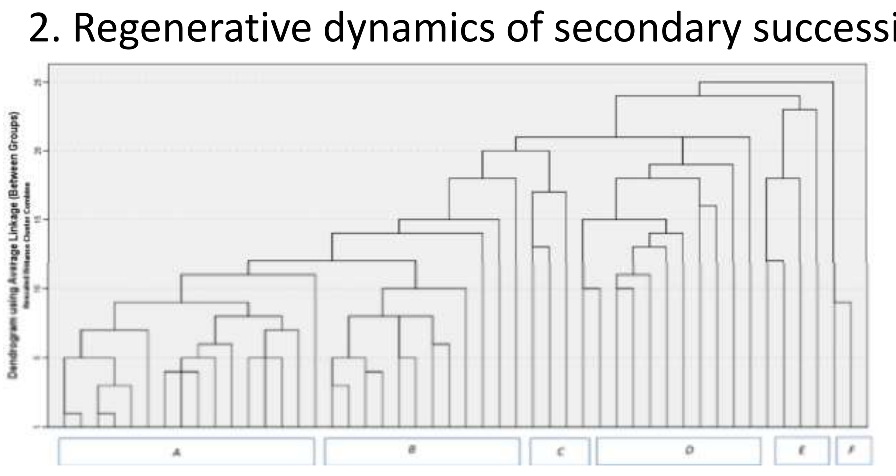


Altitude grid in degraded peatland (DGI Model Phantom 3 Professional analysed in ArcGis 10). Arrows show major tendencies in water direction.



Degraded peatland presenting negative relation between high cover of *Holcus lanatus* (above 60%) and presence of *Sphagnum palustre*.

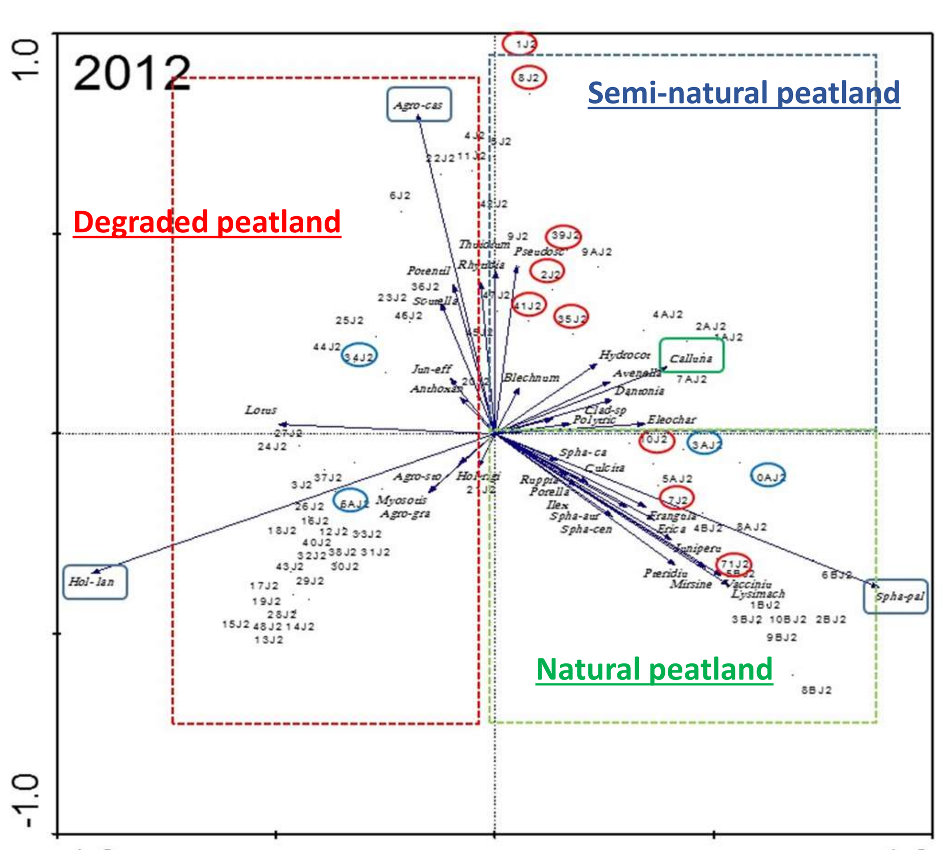
2. Regenerative dynamics of secondary succession of degraded peatland after pasture cease

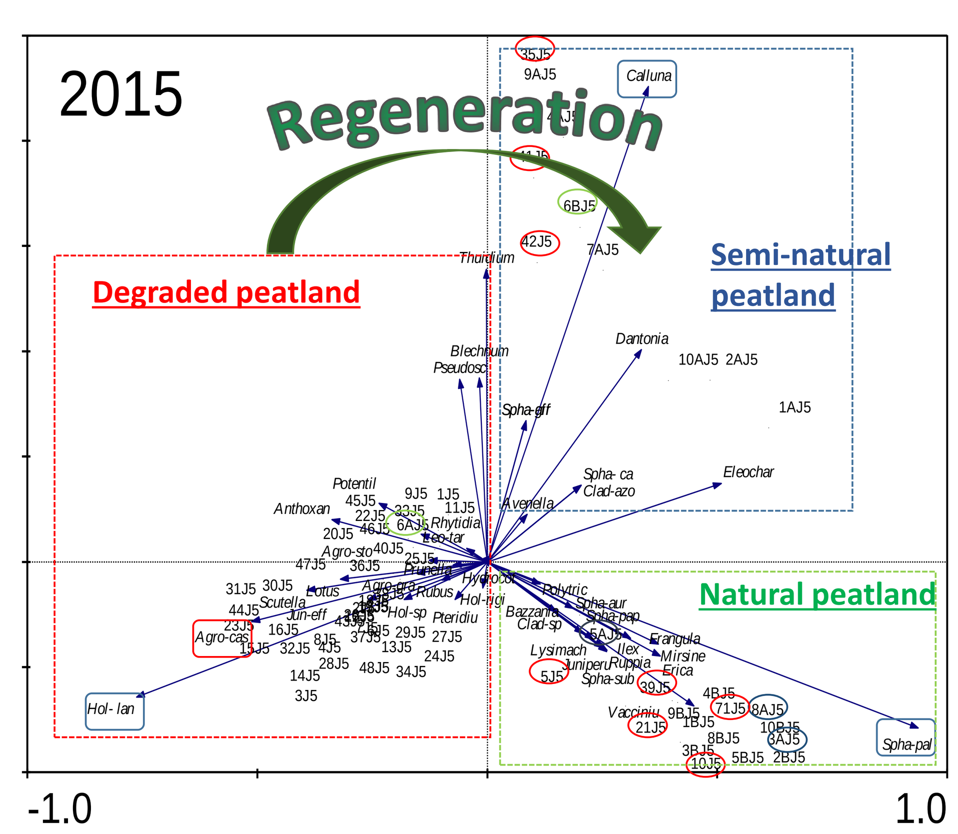


Communities in the degraded peatland: A - *Holcus lanatus* pure grassland, B - *Holcus lanatus* with *Agrostis* sp. grassland, C - *Agrostis* sp. grassland with a moss carpet, D – *Agrostis* sp. grassland; E – *Calluna vulgaris* peatland. F – *Sphagnum* peatland.

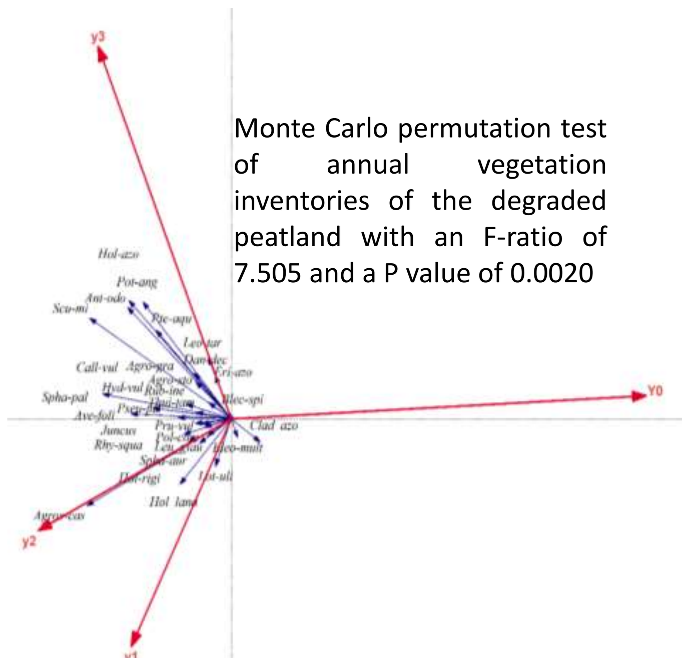
Vegetation community	Additional species	% Plots in 2012	% Plots in 2013	% Plots in 2014	% Plots in 2015
A) H. lanatus pure grassland	No relevant additional species	38	29	21	15 ↓
B) H. lanatus with Agrostis sp. grassland	Lotus uliginosus, A. castellana, A. stolonifera	23	17	8	4 ↓
C) Agrostis sp. grassland with a moss carpet	A. castellana, A. stolonifera, Holcus lanatus, Thuidium tamariscinum, Scleropodium purum and Rhytidiadelphus squarrosus	21	17	21	15 ⇔
D) Agrostis sp. grassland	A. castellana, A. stolonifera, Calluna vulgaris, Sphagnum palustre	8	6	6	4 ↓
E) Calluna vulgaris peatland	Sphagnum palustre, Danthonia decumbens Avenella foliosa	6	13	15	19 ↑
F) Sphagnum peatland	Sphagnum spp., Holcus azoricus, Eleocharis multicaulis	4	15	23	44 ↑

Communities presence (in %) in the 48 plots implemented in the degraded peatland and its evolution throw regenerative succession.





Dynamics of regenerative succession in degraded peatland, after pasture cease



Monte Carlo permutation test of annual vegetation inventories of the degraded peatland with an F-ratio of 7.505 and a P value of 0.0020

In the two first years, the most relevant species were *H. lanatus* and *A. castellana* (introduced). In the final period of this study, the most important species were *S. palustre*, *C. vulgaris* as well as *H. azoricus* (indigenous and endemic).

Conclusions

Dynamics associated with pastured peatlands regeneration:

- Decrease cover of introduced herbaceous species communities
- Increase of endemic herbaceous species communities
- Increase of *Sphagnum* cover
- Increase of *Calluna vulgaris* cover
- In the degraded peatland there was an increase of species richness, native and peatlands species, indicating regenerative succession in the studied area.

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