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CREATION OF A RAISED BOG IN THE BOTANICAL GARDEN OF NEUCHÂTEL: A TOOL FOR RESEARCH, COLLECTIONS AND PUBLIC INFORMATION

Photo credit : The raised bog of the Botanical Garden of Neuchâtel at the beginning of the growing season (march 2016), *Blaise Mulhauser*

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> Keywords PEATLAND'S PLANT COLLECTION
EX SITU CONSERVATION
CLIMATIC EFFECTS ON VEGETATION

02. Abstract

• *Mulhauser Blaise*
• *Mulot Matthieu*
• *Tritz Jérémy*
• *Gueniat Sylvian*
• *Koenig Isabelle*
• *D'inverno Mirko*
• *Mitchell Edward A.D.*

IN SEPTEMBER 2014 WE CREATED A SMALL RAISED BOG OF CA. 100M² IN THE BOTANICAL GARDEN OF NEUCHÂTEL. THE MATERIAL (MARL AND PEAT) WAS COLLECTED FROM A DEGRADED PEATLAND IN AN INDUSTRIAL AREA OF THE REGION. THE BOG WAS PLANTED WITH OVER 30 SPECIES OF MOSSES AND VASCULAR PLANTS COLLECTED FROM BOGS IN THE JURA MOUNTAINS AND FROM EXISTING COLLECTIONS.

This object corresponds to the three missions of the garden : 1) to inform the public as well as students about these unusual, fragile and threatened ecosystems, 2) to present characteristic peatland plants from the Jura Mountains (*Sphagnum*, *Drosera*, *Eriophorum*, *Betula nana*, etc.), and 3) to conduct research projects.

During the winter 2014-15, the snow remained longer on the peatbog that on the adjacent path and meadow, thus providing evidence for a microclimatic effect of the bog. The excessively dry and hot summer 2015 allowed testing the resistance of the newly established bog vegetation. Most plants resisted well, including graminoids *Eriophorum vaginatum*, *Trichophorum cespitosum* or *Carex* sp., *ericaceous* (*Vaccinium oxycoccos*, *myrtillus* and *vitis-idea*) and mosses (especially *Sphagnum*). This living laboratory provides a unique opportunity to inform the public about the characteristics and functions of these ecosystems and the challenges of conserving and restoring them in a warmer world.

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02. Introduction

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Photo credit : The raised bog of the Botanical Garden of Neuchâtel at the beginning of the growing season (march 2016), *Blaise Mulhauser*

PEATLANDS PLAY A MAJOR ROLE IN THE GLOBAL CARBON CYCLE AS THEY STORE CA. 1/3 (CA. 600 GIGATONS) OF ALL SOIL CARBON DESPITE THE FACT THAT THEY ONLY COVER 3% OF THE TOTAL LAND AREA (YU *ET AL.* 2011, MOORE 2002, LIMPENS *ET AL.* 2008).

Regionally they also control hydrology and climate (Mitsch & Gosselink 2000). However in many developed regions peatland have been almost totally destroyed through conversion to agricultural land or peat harvesting. Switzerland is a typical example with a loss of ca. 90% of its initial raised bog surfaces, mostly between the 19th and 20th centuries (Grünig 1994, Joosten & Clarke 2002). For example the 400 km^2 of lowland peatlands (fens) located in the « three lakes » region (between the lakes of Neuchâtel, Biel and Morat) have been converted to agricultural land (Grünig 1994). In 1987 a popular initiative aiming to protect the remaining peatlands of Switzerland - including the largest ones in the Jura Mountains - was accepted by the people.

The challenge today is to preserve the remaining peatlands and to restore damaged ones. Indeed a monitoring program has shown that even the protected bogs are on average suffering from degradation such as reduced moisture, increased nutrient load, encroachment by bushes (Graf *et al.* 2010, Klaus 2007). The main challenges for successful peatland recovery include restoring an appropriate hydrology, hydrochemistry, and microclimate, introducing diaspores of target species and avoiding unwanted invading species (e.g. *Betula, Molinia*) (Gorham & Rochefort 2003, Rochefort & Bastien 1998).

Climate change and especially extreme climatic event represent a threat to the maintenance of existing peatlands (Bragazza 2008, Pastor *et al.* 2003) as well as to their restoration (Samaritani *et al.* 2011, de Jong *et al.* 2010). Climate-induced lowering of the water table is recognised as a key factor in controlling vegetation changes (Breeuwer et al. 2009), CO_2 balance (Bubier *et al.* 2003, Strack *et al.* 2009) and peat decomposition (Freeman *et al.* 2001).

A further challenge for the conservation and restoration of peatlands is public perception. Peatlands are often considered as useless land and their drainage and conversion to agricultural land is referred to as "improvement". There is therefore a need to educate the general public about the roles of these ecosystems in global climate regulation, local hydrology and climate, as habitat for rare species and as precious archives of past environmental changes and history of human activities (Barber 1993, Warner & Asada 2006,

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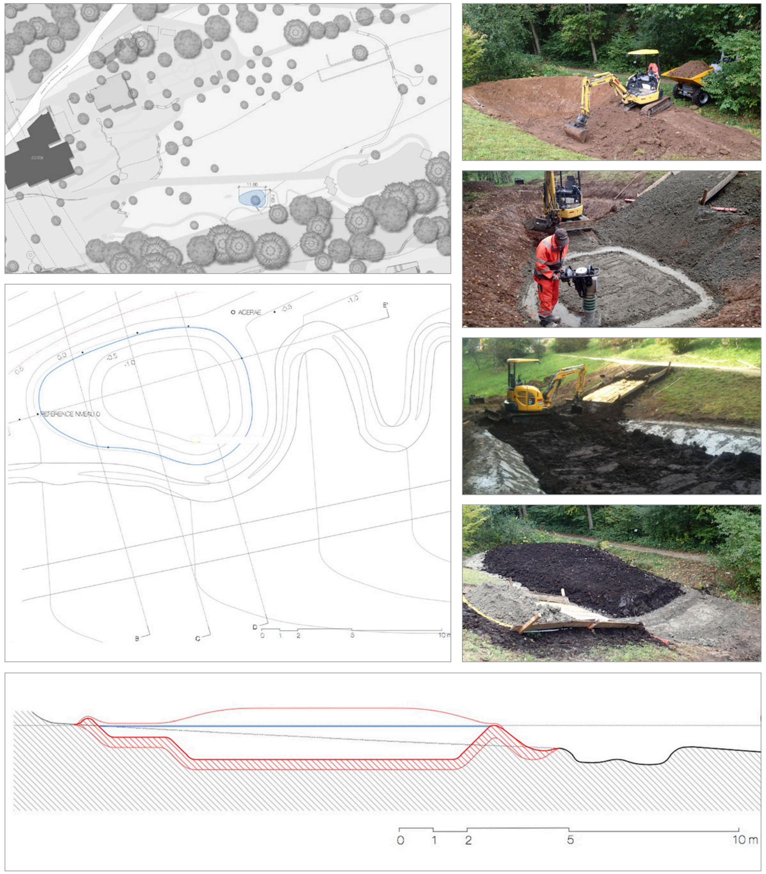
Buckland 1993). The construction in September 2014 of a small raised bog in the botanical garden of Neuchâtel, corresponds to the three missions of the garden: 1) to inform the public as well as students about these unusual, fragile and threatened ecosystems, 2) to present characteristic plants from the Jura Mountains (*Sphagnum*, *Drosera*, *Eriophorum*, *Betula nana*, etc.), and 3) to conduct research projects.

Materials & methods

At the beginning of September 2014 we created a small raised bog of ca. 100m^2 in the botanical garden of Neuchâtel. The map showing the location of the bog and the different stages of construction of the peatland are illustrated in **Figure 1**. First a large (ca. 100m^2) hole was dug. The hole had a maximum depth of 210cm, with one half being deeper and the other shallower gradually reaching the surface of the natural terrain. Then ca. 60m^3 of marl was delivered and brought to the site. This material was distributed homogenously over the surface to produce a 60cm thick impermeable layer over which the peat (also ca. 60m^3) was then deposited. The peat thickness reaches 160cm at the deepest part. The material (marl and peat) was collected from a degraded peatland in an industrial area of the region (town of Le Locle).

The bog is divided into two parts, with shallow (30-100cm) and deep (100-160cm) peat. A shallow pool was dug in the centre of each part. Around each pool the surface was divided in six slices half of which were planted (at low density) with over 30 species of mosses and vascular plants collected from bogs in the Jura Mountains and from existing collections (**Table 1**), and the



> **FIGURE 1.**
Map of the botanical garden of Neuchâtel and construction of the peatland.

other half left bare to study colonisation. The two treatments are referred to as "planted" and "non-planted". Plants from the surrounding meadow and forest provide ample sources of seeds, which germinate on the bog. In one half of the 12 surfaces (randomly selected) these plants are left to develop naturally while in the other six surfaces non-bog plants are removed. These two treatments are referred to as "weeded" and "non-weeded". There is thus four combination of these 2x2 treatments and three replicates of each.

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The surface of the peatbog was marked with wooden sticks every meter along perpendicular lines, to delineate ca. 100 plots of 1m². The vegetation of each of these plots is monitored three times a year, in spring, mid-summer and autumn using semi-quantitative estimation of the percentage cover of each species (Londo scale) and with aerial photography done by a drone (**Fig. 2**). A picture is taken from each plot at the time of each vegetation survey. Following this the alien (i.e. "non bog") species are removed in the surfaces corresponding to this treatment. Alien shrubs and tree seedlings which have very successfully germinated on the bare peat (e.g. *Salix*) are also removed from all plots as their development would have excessively large impacts on the bog vegetation in relation to the size of the overall peatland.

> FIGURE 2.

Map of the peatland and pictures taken on 15.06.2015 and 15.09.2015 by a drone.

A dense network of sensors in being installed to monitor micro-environmental conditions (temperature, water table depth, moisture, etc., **Fig. 2**) and will also do regular measurements of other factors including hydrochemistry (pH, macro-nutrients, etc.) and functioning (soil respiration, decomposition, photosynthesis, methane emissions). One of our goals is to assess to what extent such a lowland bog exposed to hot and dry summers is capable to develop a typical bog vegetation and act as a carbon sink. This research ties in with several research projects conducted in Switzerland and other countries in Europe and beyond to which the University of Neuchâtel collaborates.

> TABLE 1.

List of plant species introduced on the peatland of the botanical garden of Neuchâtel

Sampling site - Name of the peatland	Bois-des-Lattes	Bois-des-Lattes	Le Cachot	Le Cachot	Le Cachot	
Place / Lieu-dit	Ancienne zone exploitée	Drain bouché	Gouille du centre	Fossé Pochon	Partie NO	
Sampling date / Date d'échantillage	07/10/14	07/10/14	07/10/14	07/10/14	01/04/12	
Coord N	46'58'21.94''N	46'58'22.02''N	47'0'19.52''N	47'0'16.71''N	47'0'21.63''N	
Coord E	6'42'20.35''E	6'42'45.13''E	6'39'56.20''E	6'39'52.44''E	6'39'50.57''E	
Vascular plants / Plantes vasculaires						**Code IPEN**
Andromeda polifolia L.	●					CH1NEU20140200
Andromeda polifolia L.					●	CH1NEU20140201
Betula nana L.					●	CH1NEU20140202
Calluna vulgaris (L.) Hull	●					CH1NEU20140203
Carex rostrata Stokes			●			CH1NEU20140204
Carex nigra (L.) Reichard*						CH1NEU20140205
Carex rostrata Stokes		●				CH1NEU20140206
Carex rostrata Stokes				●		CH1NEU20140207
Comarum palustre L. (*Potentilla palustris*)				●		CH1NEU20140208
Drosera rotundifolia L.					●	CH1NEU20140209
Dryopteris cristata (L.) A. Gray*						CH1NEU20140235
Eriophorum angustifolium Honck	●					CH0NEU20140210
Eriophorum vaginatum L.	●					CH0NEU20140211
Eriophorum vaginatum L.					●	CH0NEU20140212
Filipendula ulmaria (L.) Maxim.*						CH0NEU20140213
Pinus mugo subsp. *uncinata* (DC.) Domin	●					CH0NEU20140214
Trichophorum cespitosum (L.) Hartm. [s.str.prov]	●					CH0NEU20140215
Vaccinium myrtillus L.	●					CH0NEU20140216
Vaccinium oxycoccos L.					●	CH0NEU20140217
Vaccinium uliginosum L.	●					CH0NEU20140218
Vaccinium uliginosum L.					●	CH0NEU20140219
Vaccinium vitis-idaea L.	●					CH0NEU20140220
Mosses / Bryophytes						
Aulacomnium palustre (Hedw.) Schwägr	●					CH0NEU20140221
Hylocomnium splendens (Hedw.) Schimp	●					CH0NEU20140250
Pleurozium schreberi (Brid.) Mitt.	●					CH0NEU20140222
Polytrichum alpinum Hedw. (=P.strictum)	●					CH0NEU20140223
Sphagnum angustifolium (Russow) C.E.O.Jensen	○					CH0NEU20140224
Sphagnum capillifolium (Ehrh.) Hedw	○					CH0NEU20140225
Sphagnum cuspidatum Hoffm			●			CH0NEU20140226
Sphagnum fallax (H.Klinggr.) H.Klinggr		●				CH0NEU20140227
Sphagnum fallax (H.Klinggr.) H.Klinggr				●		CH0NEU20140228
Sphagnum fuscum (schimp.) H.Klinggr					●	CH0NEU20140229
Sphagnum magellanicum Brid.	●					CH0NEU20140230
Sphagnum magellanicum Brid.					●	CH0NEU20140231
Sphagnum rubellum Wilson	●					CH0NEU20140232
Sphagnum rubellum Wilson					●	CH0NEU20140233
Sphagnum squarrosum Crome*						CH0NEU20140234

* *In the botanical garden of Neuchâtel before 2012, from "vallée des Ponts-de-Martel" (Bois-des-Lattes or Marais rouge)*

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02. Results

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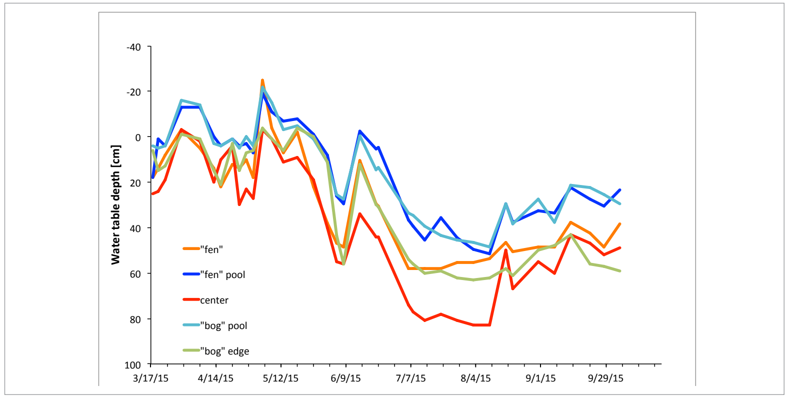
After one year of development some preliminary results can already be shown, including the thermal inertia of the peatland, the resistance of the plants to the heat wave and drought of the summer 2015 and the colonisation of herbaceous plants on the bare peat surface.

> **FIGURE 3.**

The peatland on 24.02.2015 with snow still on the surface.

1. THERMAL INERTIA

The first observation is the thermal inertia of the peat body relative to the surrounding mineral soil. This was very obvious during the winter after a period of snowfall. The thickness of the snow and the duration of snow cover were measured from November to March on the peatland and on the adjacent path and meadow. The water-saturated peat body froze during the winter and the snow remained longer than on the adjacent well-drained mineral soil that heated up much faster as soon as air temperature increased (**Fig. 3**). Thus once the peat body has cooled it remains colder than the surrounding land. These temperature patterns will be more precisely monitored in the future once temperature loggers are installed.

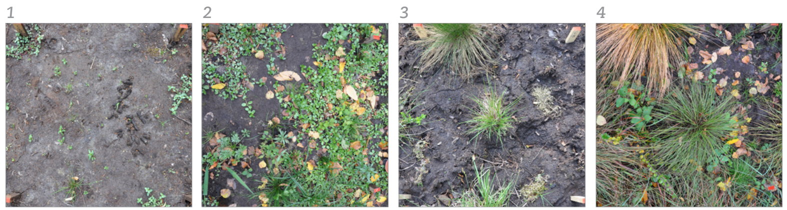


> **FIGURE 4.**

Patterns of water table depth [cm] measured in five spots on the bog (colors are the same than Piezometer of Fig. 2).

2. RESISTANCE OF THE BOG VEGETATION TO THE HOT AND DRY SUMMER 2015

The summer 2015 was especially hot and dry. We therefore feared that the newly planted bog vegetation would not survive such extreme conditions. However we observed that almost all plants survived. Deep rooted vascular plants such as *Carex* ssp., *Eriophorum* ssp., *Trichophorum caespitosum* and ericaceous shrubs all survived well (see especially difference between pictures of **Fig. 2**). Likewise the mosses including *Sphagnum* were still mostly alive. The only exception was the bog pool species *Sphagnum cuspidatum* that died in the dried out pools. This general good resistance of bog plants may be explained by the fact that, although the summer was indeed especially hot and dry the spring had been quite wet, with high water table recorded from March to June (**Fig. 4**). The development if the vegetation in two 1m² plots representative for two of the four treatments is illustrated in **Figure 5**.



> **FIGURE 5.**

Vegetation development of two 1m² plots of the bog corresponding to two treatments: **1:** non-planted & non-weeded (plot C-6). **2:** planted & non-weeded (plot B-8). **3:** July 8th 2015. **4:** October 16th 2015.

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3. DEVELOPMENT OF PLANTS ON OPEN PEAT SURFACES

We left 50% of the bog surface totally bare to study the primary colonisation by diaspores from the surrounding plants. Given the extreme climatic conditions of the summer we wondered how successful this colonisation would be. Interestingly a high number of plants germinated on the peat. These were however mostly plants from the adjacent meadow and forest while bog plants seemed to have colonised these surfaces from vegetative lateral growth (especially clear for *Vaccinium oxycoccos*, **fig. 6**).

> FIGURE 6.

Development of *Vaccinium oxycoccos* on the bare peat surface from an adjacent vegetation patch during the summer 2015. (Grey pieces are IPEN labels with name of plants introduced)

Discussion

The peatbog of the Botanical Garden of Neuchâtel, created at low elevation (ca. 500m) and in a region with moderate rainfall (ca. 900mm/yr) is primarily useful to understand the evolution of such an ecosystem under apparently unfavourable climatic conditions. After only one year of observations it is clearly too early to draw any firm conclusions on the long-term development of this peatland. However the drought and heat wave that lasted from May to September 2015 already provided the opportunity to evaluate how the plants reacted to a long-lasting hydric stress. We were pleasantly surprised to see how well the vegetation had survived and indeed the comparison of the two aerial images (**fig. 2**) and the images of the two plots (**fig. 5**) clearly show the strong growth of the vascular plants. The mosses may not have grown much but mostly seem to have survived as well. The exceptions are the smallest patches or isolated moss plants and the characteristic *Sphagnum* species of bog pools (*S. cuspidatum*) that died in the dried up pools. The peatland therefore already represents an invaluable object for scientific research.

The second advantage of this peatland is that the characteristic plants of this unusual ecosystem can now be present in their "natural" context rather than in suboptimal small surfaces. Having these plants growing on a massive peat body also offers a higher chance of maintaining these plants over a long period, as attested by their good survival during the stressful conditions of the summer of 2015. This peatland already is proving very useful to the public inform about the value and fragility of peatland ecosystems. The peatland thus also clearly serves educational purposes.

This peatland also offers opportunities to test the growth conditions of rare and endangered peatland plants, of multiplying them with the goal of re-introducing them in some newly restored peatlands in the region without having to samples in fragile natural populations. As 90% of the remaining peatlands in Switzerland have been damaged directly or indirectly by human activities there is now a good potential for conducting ecological restoration projects and indeed many ambitious projects are in progress. In many cases

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it would be desirable to re-introduce the characteristic plants of these ecosystems and here the peatland of the Botanical Garden of Neuchâtel can be useful both to experiment growth conditions and to multiply characteristic plants. The peatland thus also serves conservational purposes.

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