Restoration and Reclamation Review
Student On-Line Journal
Vol.4, No.2, Spring 1999
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Restoration of Ericaceous (Shrub) Dominated Wet Heathlands in The Netherlands

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Wet heathlands, dominated by shrubs that are members of the heath family, Ericaceae, have been declining since the middle of the century. Changing agricultural practices have been one of the greatest influences causing the increase and then and decline of ericaceous (also called heather species) shrublands in the Netherlands. Shrub and woodlands once covered most of the Netherlands. The shift from woodlands into heather shrublands began as early as 2500 BC when nomadic farmers used methods of burning and cutting that led to an increase in grasslands and shrub dominated areas rather than woodlands (Waterbolk 1954 as cited in Aerts and Heil 1993). Because the soil was too poor to sustain agricultural practices over a long time, large ericaceous shrublands, encompassing smaller patches of grasslands, became prominent with the abandonment of agricultural practices. These areas became known as the heathlands.

Throughout the centuries, farmers realized that in order to successfully farm the heathlands, large areas of land consisting of approximately 9 ha of heathland and 2 ha of grassland were necessary to maintain 1 acre of agricultural land. The heathlands and grasslands served as nutrient collection areas for farmland. Sheep were allowed to graze on the heathland and then were brought back to a sheep cote, an area set aside for the collection of sheep dung. The farmers cut sod from the grasslands and incorporated the dung and sod together and applied it as a fertilizer to their fields (De Smidt 1979 as cited in Aerts and Heil 1993). This was a fairly sustainable method of agricultural that preserved species-rich communities in the heathland. However, with the advent of artificial fertilizers, farmers were able to increase the amount of land they could farm. The increase in farmland lead to the reduction in the number and size of heathlands throughout the Netherlands. In addition, the introduction of artificial nutrients into a once nutrient poor environment contributed to a decrease in the species-rich heathland (Aerts and Heil 1993). As heathlands declined, there was an increase in monoculture grasslands of *Molinia caerulea*.

Beginning in 1980, the Dutch government began supporting regeneration of ericaceous species in the heathlands throughout the Netherlands. Since then, there have been many studies to learn more about heathland processes and dynamics. A better understanding of the nutrients, pH, toxic metals, competitive relationships between species, and seed banks from these studies have provided a basis on which restoration work can be successfully explored and implemented (Aerts and Heil 1993).

Characteristics of Species-Rich Heathlands

The species-rich wet heathlands are mainly dominated with *Erica tetralix* (and a few other Erica sp.) In habitats of moderate moisture status, or humid heath, *Calluna vulgaris*, (noted for its abundance of purple flowers) is often co-dominant with *E. trexalis* (De Smidt 1979). However, where soil aeration occurs less frequently, as in the wet heath complex, *C. vulgaris* is quite reduced (Specht 1979). Since humid and wet areas often occur in proximity to each other, some properties of *C. vulgaris and E. trexalis* co-dominant complexes will overlap with more of the wet *E. trexalis* heath complexes. Other plants within wet heathlands, in smaller quantities than *E. trexalis,* include herbaceous plants such as, Sundew *(Drosera rotundifolia*), Marsh Gentian (*Gentiana pneumonanathe*), Bog Asphodel (*Narthecium ossigragum*), Bog clubmoss (*Lycopodium inundatum*), and Tufted bullrush (*Scirpus caespitosus*) (Aerts and Heil 1993; Berendse and Aerts 1984).

Ericaceous heathlands are found predominantly on soils that are nutrient poor. Many of these soils include a humus podsol where the top layer of soil is humus rich. These soils are formed on top of iron deficient parent material. The humus podsol is extremely acid and base deficient (Aerts and Heil 1993). Although most of the topsoil is acidified throughout the wet heathlands, areas where underground buffered seepage and buffered water streams flow become less acidic (Cals et al.1993 as cited in Roelofs et al.1996). Places that are slightly buffered due to groundwater seepage enable certain plant species to develop and survive in the heathland that normally could not withstand some of the more extreme acidic conditions. The mixture of the slightly buffered areas and non-buffered areas creates the heterogenous environment of a species-rich, wet heathlands (Roelofs 1986).

Effects of Nutrients in Wet Heathlands

Many formerly species-rich, shrub dominated areas are now dominated by the grass *M. caerulea.* There are many factors involved in the shift from ericaceous species to *M. caerulea*. Because monocultures of grass*, M. caerulea* are clearly replacing formerly ericaceous areas, research was undertaken to determine the cause of the invasiveness of *M. caerulea* in the heathlands. One hypothesis, developed by Berendse and Aerts (1988) was that *E. tetralix* disappears from nutrient-rich, well-aerated sites because *M. caerulea* is able to out-compete *E. trexalis* under these conditions. *M. caerulea* is less competitive on extremely poor, water-logged sites. By comparing the growth of *M. caerulea* and *E. tetralix* in monocultures and grown together, Berendse and Aerts concluded that nutrient poor sites where *E. tetralix* most frequently occurs and where it does not experience optimum growth will be the best place for it to survive when in competition with *M. caerulea*. In well-aerated, high nutrient areas, *M. caerulea* would be too strong a competitor for *E. trexalis* even though *E. trexalis* may experience optimum growth in these conditions. From their findings, Berendse and Aerts suggested efforts should be made to reduce nutrients and restore water-logged soils that had been altered due to agricultural practices.

Within recent decades, artificial fertilizers have made a large contribution to the increase in nutrients in the heathlands. Some of these nutrients, primarily nitrogen and sulphur, are also being atmospherically deposited over the heathland. The source of these elements is from heavily manured pastures and fields surrounding the heathland (van Breemen et al.1982 as cited in Aerts and Berendse 1988).

Soil Acidification and Related Problems

Sulphur deposition contributes to soil acidification, which complicates the survival of heather and related herbaceous species in the heathlands. If an increase in acidification occurs on a sediment layer that is carbonate-free (unbuffered), submerged macrophytes will disappear (Roelofs 1986). In addition, acidifying precipitation leads to a decline in the numbers of other plant species. Herbaceous species that are naturally present in small quantities are some of the quickest to succumb to increased acidity (Roelofs 1986). As sulphur is deposited, primarily through rainfall, it acidifies the soil. At the same time atmospheric deposition of nitrogen occurs, often as ammonium sulfate. Ammonium can accumulate in acidic soils leading to more favorable conditions for *M. caerulea* to out-compete ericaceous species (Roelofs 1986).

Indirectly, soil acidification can play a role in removing base cations and mobilizing toxic metal ions such as aluminum, which can also lead to species decline in heather dominant heathlands (Ulrich 1983 as cited in Houdjik et. al 1993). Although aluminum toxicity is not the primary cause of species loss in the heathlands, it could become a bigger problem if soil acidification in the Netherlands continues to intensify.

Restoration Measures – Managing Nutrients

One of the primary restoration methods for reducing nutrients in the heathlands is sod-cutting. Although sod-cutting was practiced by farmers in past centuries, it is now primarily done by mechanical means to control nutrients. Sod-cutting is the removal of all aboveground biomass, which includes the removal of the litter layer and humus layer. Managing nitrogen levels by sod-cutting is quite effective and is recommended at intervals of approximately 25 years (based on the original management regimes at the turn of this century) (Diemont et al. 1982 as cited in Aerts and Heil 1993). However, as nutrients become more abundant in the Netherlands sod-cutting may need to be applied as a management tool more often than 25 years. This increase in the intervals between sod-cutting can increase management and expenses making other alternatives look more attractive. Other methods of nutrient removal such as mowing, burning and simply letting domestic animals graze on the heathland may also be used in management practices in the Netherlands, but are not described in great detail in the literature or are always favored when compared with sod-cutting for removal of nutrients. Although sod-cutting is a good way to remove nutrients, its expense makes it unrealistic for all heathland management plans (Bobbink and Heil 1993; Aerts and Heil 1993). A combination of nutrient removal methods is likely to be most feasible.

Restoration Measures - Restoring pH

Soil acidification and aluminum toxicity can be controlled by increasing the amount of base cations in the system (Jansen et al.1996; Houdijk et. al 1993). One way to accomplish this is to incorporate lime into the soil or to apply it after sod-cutting when nutrient levels have been reduced. However, lime application in wet heathland areas is problematic because in wet situations lime may become distributed unevenly or be carried away from where it was applied. In areas such as humid heath or even dry heath, lime can be incorporated into the soil, but in wet heathlands restoring hydrology to encourage the flow of buffered groundwater may prove to be more beneficial than liming.

Starverden, located in the central part of the Netherlands, was the site of a restoration study that showed the benefits of soil pH and nutrient reduction over the course of several years (Jansen et al. 1996). At Starverden, pre-existing, artificial hydrologic patterns previously used for afforestation purposes were reversed by filling trenches and ditches. The restored hydrologic pattern reestablished groundwater seepage that increased base cations. Coupled with sod-cutting to reduce nutrients, Starverden became a favorable area for heather and related herbaceous species to become reestablished and more abundant (Jansen et al. 1996).

Restoration Measures - Regeneration by Seed

Although restoring wet heathland hydrology and nutrients is a complex process, reestablishing ericaceous species also requires a source of propagules, in this case seeds. Because much of the success from these restoration efforts often relies on sod-cutting techniques and removing the topsoil layer, precautions must be taken regarding how deep to cut the sod. Both heather species *C. vulgaris* and *E. textralis* have large persistent seed banks in the organic layer of soil. *M. caerulea* seeds are also persistent in the seed bank, but in smaller quantities than *C. vulgaris* and *E. trexalis* (Bruggink 1993). When sod-cutting is used to reduce nutrients, the cut must be made just above the mineral layer of the soil. This practice removes much of the nutrients, but leaves enough seeds for ericaceous species to regenerate. Other less time consuming and less expensive management practices such as mowing and removal of the litter layer will help eliminate *M. caerulea* seeds, but leave a seed bank that is able to regenerate ericaceous species (Bruggink 1993).

Conclusion and Summary of Restoration Events in the Wet Heathlands

With the support of the Dutch government, restoration efforts throughout the Netherlands are likely to continue to preserve unique heathlands, particularly wet heathlands. Obstacles to heathland regeneration that need to be monitored and addressed include nutrient abundance, atmospheric nutrient deposition, soil acidification, hydrological changes, competition between plant species, and regeneration of ericaceous species. Heathland restoration efforts have been fairly successful in the short-term. Research in the last couple of decades has provided information that enables us to understand processes and relationships between plants in competition, nutrients and plant productivity and chemical concentrations with respect to improving or hindering desired plant species. Given the uncertainty, it appears that restoration and preservation of wet heathlands in the Netherlands will require long-term management and monitoring.

Suggested management practices of heathlands are still being gathered and evaluated. Sod-cutting is suggested as a part of a management regime at regular intervals of 25 years (based on original regimes of management at the beginning of this century) (Diemont et al. 1982 as cited in Aerts and Heil 1993). Whether this frequency will be enough to reduce nitrogen and other nutrients at their current levels is still unclear. Berendse and Aerts (1996) conducted restoration efforts using sod-cutting and hydrological measures as effective methods of preventing the continuous build up of nitrogen. They concluded that the long-term impact of these experiments are still unknown. Because much of the information and experimentation regarding heathland restoration has been done within the last decade and a half it is likely that we will not know the level of impact of our restoration efforts for at least another decade, if not longer.

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