Developing an Aspen – Spruce Mixed Silviculture System In Scotland
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Mixed aspen-spruce forestry in New England

Introduction

Aspen, (Populus tremula) is recognised as a species which has high biodiversity and aesthetic appeal with potential for the production of timber. It is a keystone species within the boreal forest ecosystem. It is a resilient species with a great ability to adapt to a variety of environments. It has a wide tolerance level to a range of soil types and altitude gradients and has the ability to reproduce asexually without significant loss of genetic variation.

Its growth and vigour in more sheltered sites suggest that it was a key component of the woodland ecosystem and its patchy but widespread distribution support the theory that its current distribution is a result of historic land use changes and past and present grazing pressures.

There is no reason why aspen should not again become a major component of Scottish woodlands. Actions needed to bring Aspen back into its rightful place could include planting Aspen into forestry restock areas in sufficient numbers, that aspen becomes a self-perpetuating component of a group of mixed broadleaves which between them would cover 15-25% of the gross area of many upland and lowland conifer forests. (Quelch 2001)

While monocultures might be the simplest approach in commercial forestry, growing intensively managed mixed stands could give higher yields, better wood quality, be more attractive and acceptable, and reduce risk relating to climate, disease, insects, fire and other issues. Trials undertaken by Forest Research at Gisburn Forest using combinations of broadleaved and conifer species demonstrated that overall productivity was greater than for the equivalent single species stands (Kerr 2014).

In the Boreal zone, Aspen occurs naturally within conifer forests where it is the only broadleaved species to compete with Spruce and Pine. Whilst birch also occurs in less dense stands, it is Aspen that matches the height of the conifers (Ern Emmett). Results from testing various Scottish native aspen clones support this, indicating that a mean height of 1.5 – 3.0 m at age 6 can be expected, depending upon site quality (Mason et al. 2002). On suitable sites these growth rates are comparable to that of Sitka spruce during the establishment phase, suggesting that the two species could be compatible in planted mixtures. In addition, it has been observed that the crown form and branching density of improved Sitka spruce results in much more light in the upper canopy in the first twenty years than standard QCI provenance Sitka, providing better conditions for robust mixtures of aspen and Sitka to be established even at relatively intimate spacing (Andrew MacQueen, Personal Communication)

Introducing aspen into commercial conifer plantations would also have benefits for landscape, biodiversity, and soil quality. Potential silvicultural systems could mimic the natural symbiotic relationship between spruce and aspen in the Boreal Forest.

The Natural Spruce-Aspen-Spruce Cycle of the Boreal Forest

1. Spruce and fir produce an acidic soil solution that increases the rate of leaching of nutrient bases and nitrates. Eventually the soil environment is too nutrient-poor to support their seedlings and replacement of older trees ends.
2. As the older spruce die, the canopy opens allowing sun-loving species like aspen to invade. Since aspen are associated with nitrogen-fixing bacteria, they are not limited by the lack of nitrogen in the soil.
3. Aspen come to dominate the community; they build up bases and nitrates in the soil. Increased nutrient levels and the shade of the mature aspen create an ideal habitat for spruce seedlings.
4. Aspen are short-lived and their seeds do not germinate well in shade. As the older aspen die off, *spruce once again come* to dominate (1).
5. The entire cycle takes some 200 years. The spruce-fir community exists through the greater part of this time.

(Radford University)

The Benefits of Aspen in Mixed Forestry Silviculture

- ✓ Increased Soil Nutrient Cycling
- ✓ Soil neutralisation
- ✓ Maintenance of soil mycorrhizal communities
- ✓ Amelioration of Environmental Extremes
- ✓ Control of shrubs, grasses and pests
- ✓ Amelioration of Landscape Impacts
- ✓ Increased Biodiversity
- ✓ Increased site productivity
- ✓ Resistant to pine weevil

Soil Nutrients

Upland soils in Scotland are typically depleted of nitrogen, calcium and organic matter due to the long term removal of sheep and cattle from the hills and the tradition of droving, with cattle being taken to Scottish lowland and English markets (Wood, 2009). The subsequent planting of coniferous trees in the uplands can exacerbate these effects, their litter acidifying the soil over time which reduces further the availability of soil nutrients and reduces microbial activities and communities. Furthermore, acid rain has also contributed to soil acidification.

The benefits of deciduous trees generally on soils, landscape and biodiversity as long been accepted however the specific impacts of individual species has only recently been studied.
It is well known that aspen is one of the key pioneer species however, new research has crystallised this further. For example, it has found that aspen although not leguminous, can fix atmospheric nitrogen. A large community of endophytic bacteria resides in the stem tissue of aspen. Among these endophytes, several diazotrophic (nitrogen-fixing) bacteria have been identified. (Georg von Wuehlisch, 2011)

The role of above ground aspen trees as a nutrient sink for calcium has also recently emerged from several other studies. Unlike most tree species, it has been well documented that aspen take up large amounts of calcium from the soil pool and retains this nutrient in the perennial tissues of the plant. (U.S. Dept of Agriculture, 2009)

Clearly therefore, aspen as a valuable role to play in restoring upland soils following periods of overgrazing and nutrient depletion. In addition, aspen can mitigate some of the impacts on soils from softwood forestry when grown in an intimate mix.

The leaf litter generated from a relatively small amount of aspen in conifer dominated stands will significantly slow the development of moss and the development of a mor humus. This will likely maintain soils with higher soil temperature and nutrient cycling compared to soils covered with mosses. These different soil conditions could also have a significant effect on present and future site productivity. (University of Alberta, 2007)

Aspen provides both short- and long-term nutritional benefits to forest sites. It takes up large quantities of nutrients and stores them in woody tissues, thus retaining nutrients within the ecosystem. In addition to calcium mentioned above, it is also particularly efficient at retaining sulphur, and zinc, especially in the bark, which has photosynthetic capability. Aspen foliage is shed annually, but it decomposes rapidly and tends to be efficiently cycled within the forest ecosystem. (Simard, 2001)

Soil Mycorrhizal Fungi

The importance of mycorrhizal fungi to tree growth is increasingly being realised. Mycorrhizal fungi are an important component of natural soil ecosystems and form a symbiotic relationship with plants, forming a crucial link with their surrounding soil environment. Effectively forming a secondary root system, they allow for increased nutrient uptake (up to 700%), improved water status, pathogen protection and improved soil structure. Some forms of mycorrhizae (arbuscular mycorrhizae) which penetrate root cells require a continuity of host plants, if the symbiosis is to remain effective. Studies in North America have shown that the practice of clear felling can have a devastating effect on soil mycorrhizae communities which can then hamper regrowth. The retention of hardwood species such as aspen across a clear fell area provides an inoculum source for the fungi when successive softwood crops are planted. Mixed silviculture and Continuous Cover Forestry practices can preserve the soil ecosystem leading to a more productive forest overall.

Scots Pine before adding mycorrhizal fungi and after (Dr David Read, Plant Health Care Inc.)

Recent research also suggests that trees growing in species-rich forests produce more wood than those surrounded by same species stands (Fichtner 2018). Interrelations of a tree with its immediate neighbours induce higher productivity of the entire stand, and that these interactions explain more than 50% of the total stand productivity. It is thought that competition is less prevalent in species-rich forests which have improved microclimatic conditions and more positive soil mycorrhizal fungi interactions.

Developing A Mixedwood System of Aspen and Spruce

There are a number of different ways in which aspen and spruce can be integrated in a mixed silviculture system. There has been much study of how aspen can be used as a nurse crop for spruce whereby established aspen woodland is under planted. This method has been found to facilitate the growth of spruce through the amelioration of environmental extremes, and control of shrubs and grasses. The prevalence of pests can also be controlled to some degree through for example reducing the damage to young spruce and pine trees by pine weevil by the overhead shading provided by the aspen. It is also logical that alternating spruce with fallow periods of disease resistant broadleaf species such as aspen will reduce the infestation of pests and diseases.

There is growing interest in Mixedwood Silviculture in North America primarily comprising quaking aspen and white spruce. In Alberta, Spruce-aspen mixedwood forests now make up 20% of the actively managed forested area. In Nordic countries, managing mixed stands is a common method for producing conifers with high timber quality and for harvesting pulpwood or biofuel from the young broad-leaved stands and subsequently producing conifer pulpwood and timber through conventional management. Aspen (Populus tremula) is the key broadleaved species in such systems.

There is increased focus on Scottish forestry on landscape and biodiversity and alternative silviculture systems. For example: The natural choice: securing the value of nature (2011); Forests and Landscapes; UK Forestry Standard Guidelines (2011); The Scottish Forestry Strategy (2006); FC Info Note 29 Continuous Cover Forestry (1999). However as far as we are aware there has been little of any focus on mixed forestry silviculture. With the increased occurrence of tree diseases in the UK and the growing number of species affected, we believe that it is time to consider such a system. Eadha has been working to develop a National Aspen Clone Collection which will provide the basis of a national supply chain. We are now confident that aspen can now be available in sufficient quantity and of a sufficient genetic range to be considered in extensive planting schemes. Based on our researches outlined above, we believe that aspen is the ideal broadleaved species for mixed forestry systems and we believe that models in both North America and Scandinavia which are based on aspen and spruce are replicable in Scotland's Sitka dominated commercial forestry sector.

Research shows that depending on stand attributes such as species composition, density and tree sizes, the relationship between spruce and aspen can range from mutually beneficial to neutral to competitive. However if managed correctly, mixtures of these species can yield more than pure stands of conifers. A modelling study based on data collected in boreal forests of north-eastern British Columbia suggests that mixed forests of aspen and spruce will produce greater biomass over several rotations that pure spruce forests of the same density. (Simard et al 2001)

Silvicultural Systems

There are many considerations with the management of mixed stands which can often be more challenging that single species stands. This is particularly the case when both species are planted for productive use rather than as a sacrificial nurse crop. Competition between species is at its greatest in random or intimate mixtures yet these look the most natural. In reality there will be trade-off between

the ease of management i.e. flexibility to intervene and thin/remove either species independently of the other, and landscape impact.

In North America, one mixed forestry system employed is the underplanting of existing stands of 40-60 year old aspen with spruce. This method has delivered high survival rates and good growth rates for the spruce. In Scotland there are very few mature aspen stands and where these exist, they are highly valued and usually protected sites. Underplanting would therefore be unacceptable.

The alternative method would be to plant a nurse crop of aspen. The maturing aspen wood would be subsequently underplanted with conifers and the aspen harvested when the spruce reach a certain age. This method may be appropriate where soils conditions are particularly poor and require some amelioration before a commercial softwood crop is established.

The planting of aspen following conifer harvesting has advantages in terms of reducing pests, in particular pine weevil which will avoid feeding on aspen even in no-choice situations (Mansson & Schlyter 2004). Aspen can therefore be successfully established through planting or regeneration following harvesting without chemical treatments. The aspen can then be used as a nurse crop for subsequent underplanting with conifers once the pine weevil population has declined to acceptable levels.

Alternatively the Shelterwood Method practiced in Nordic countries can be employed whereby an initial mixed stand of aspen and spruce can be developed, with the aspen progressively thinned as the spruce develop. This would applicable for both new forests and harvested blocks within established forests.

Where existing stands of conifer exist, a fringe of aspen could be planted around the perimeter, as a shelterbelt softening the forest edge to provide landscape and biodiversity benefits. Following harvesting of the adjacent conifers, the aspens will begin to colonise the cleared areas through suckering.

Subsequent restocking of conifers can take place mixed with any regenerated aspen as with the shelterbelt method. The aspens will spread progressively through the conifers following successive harvests. Felling regimes can then be designed to exploit both species, by mimicking natural cycles of aspen and spruce dominance outlined above. Fringe areas of aspen can be either retained or selectively harvested.

There are no doubt other potential systems and models which could be developed and this is not an exhaustive list. However all these ideas are conjectural in a Scottish context until field trials with aspen and sitka spruce are developed, and Eadha is putting out a call to public, private and 3rd sector forest owners and managers to embrace the possibilities outlined in this report and to develop some pilot projects in partnership with Eadha.

Eadha can provide the following services:

- ✓ **Woodland design**
- ✓ **Advice on clonal mixes**
- ✓ **Aspen supply**
- ✓ **Management Plans**
- ✓ **Development of partnership community aspen nurseries**

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