Can using CCF help Scottish forests adapt to increased temperatures and drought?

Evidence is weak in this area and it is not possible to make any firm conclusions about how CCF could help forests in Scotland to adapt to increased temperatures and drought.

2.5 Reduced incidence and changed timing of frosts

Definition of the risk

Climate change predictions (Murphy et al., 2009) indicate that there will be an increase in mean temperature across the UK in all seasons, including a reduction in the number of frost days and in the diurnal temperature range in winter. This is likely to advance budbreak date but reduce frost damage in spring (Cannell and Smith, 1986; Murray et al., 1994). However, in autumn although frosts will occur less frequently, they may cause more damage due to generally warmer temperatures and later hardening of shoots. Therefore in general frost will decrease as a problem (Redfern and Hendry, 2002).

Scientific evidence

The maritime climate of Britain has encouraged the commercial use of many non-native species such as lodgepole pine, Sitka spruce and Corsican pine. These commercial species are generally more prone to cold and frost damage than they would be in their native environment, particularly when growing away from the coast. Currently, many commercial species, particularly non-native species, in Britain are affected by cold weather and frost (Redfern and Hendry, 2002). Variation in the native ranges of many of these species provides the opportunity to minimise frost risks by provenance selection.

There is a large body of evidence demonstrating that the presence of an overstorey can reduce frost damage compared to open sites (Nilson et al., 2006; Erefur et al., 2008). Studies have shown that near-ground temperature can be several degrees higher under a shelterwood than in open exposed sites on clear calm nights, reducing frost damage to regenerating seedlings and underplanted trees (Groot and Carlson, 1996; Langvall and Örlander, 2001). In areas where unseasonal frosts may cause damage to young trees, CCF has the potential to reduce damage on young trees, particularly for the more frost susceptible species which may become desirable in future climates.

Population dynamics and infection rates of pests and pathogens are also strongly affected by temperatures, particularly in winter, with frost often being a controlling factor (see section 3.1). Winter chilling and frost are also necessary to break seed dormancy prior to germination in some conifers (see section 3.8).

Can using CCF help Scottish forests adapt to reduced incidence and changed timing of frosts?

Although frosts will decrease in frequency and severity, earlier frosts in autumn may cause increased damage to unhardened non-native species. If these species remain commercially desirable, regeneration (whether by planting or naturally) under a canopy as in CCF will offer an opportunity to minimise frost damage.

Figure 2: the ability of CCF to help mitigate risks of future climate change will depend on the type of structure

3.0 Secondary risks of climate change

3.1 Attack by pests and diseases

Definition of the risk

There is a high probability that climate change will cause an increase in the frequency and severity of attack by pests and diseases (Straw, 1995; Evans et al., 2002; Broadmeadow and Ray, 2005). In particular, warmer winters are likely to increase the period of activity for many pathogens, while in summer trees under drought stress are likely to be more susceptible to attack

(Ray et al., 2008). Wind and storm damage also increase the likelihood of attack by fungal and insect pests by increasing the availability of breeding material in broken and deadwood increases (Schroeder and Eidmann, 1993).

The range of pests and pathogens that affect or have the potential to affect Scottish forests is very wide. In this report we focus on two major pests *Hylobius abietis* (pine weevil) and *Elatobium abietinum* (green spruce aphid), and on two major pathogens, *Heterobasidion annosum* (formerly *Fomes*; butt rot) and *Dothistroma septosporum* (red band needle blight). We also examine the risk of new pests and diseases that may become more prevalent in Scotland under climate change conditions.

Scientific evidence

Hylobius

In Scotland, *Hylobius* reproduce over a two-year life cycle. Under climate change conditions this is likely to shorten, so that weevils emerge and attack transplants during only one season, reducing the fallow period necessary after clearfelling. However, damage rates during this period may be high, as most insects are more active when temperatures are higher.

As the majority of *Hylobius* damage occurs when the adult insects emerge from cut stumps to feed on newly establishing young trees, it is logical that the avoidance of clearfelling should reduce the amount and density of cut stumps available, reduce the availability of planted seedlings and therefore limit *Hylobius* populations and damage. There is evidence from studies in Scandinavia to support this hypothesis (Lof and Madsen, 2000; Pitkanen et al., 2005; Pitkanen et al., 2008). Work currently in progress by Forest Research's Centre for Forestry and Climate Change indicates that *Hylobius* damage levels are reduced in Sitka spruce being transformed to CCF due to a reduction in the number of felled stumps, where the insects develop, and the presence of alternative food resources for the adult weevils (Mason et al., 2004).

Elatobium

Elatobium is the most important defoliator of Sitka spruce, and to a lesser extent Norway spruce, in Britain and populations are limited by a combination of cold winter temperatures and natural predators. Therefore it seems highly likely that populations and damage levels are likely to increase in Scotland due to generally warmer temperatures and fewer winter frosts (Straw, 1995; Day et al., 1998; Evans et al., 2002; Westgarth-Smith et al., 2007). Drought stress is likely to increase susceptibility to *Elatobium* particularly in eastern Scotland, resulting in increased defoliation and reduced volume increment. However, changes in nutritional quality and resistance of spruce foliage and interactions with predators mean that the timing and severity of outbreaks will be difficult to predict. High densities of *Elatobium* and severe defoliation during outbreaks are expected to lead to a progressive decline in the productivity of Sitka spruce (Straw, 1995).

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