climateXchange

Scotland's centre of expertise connecting climate change research and policy

Climate Change Impacts on Scotland's Forestry Supply Chain

Kate Beauchamp, Forest Research
January, 2018

Summary

Scotland's forestry supply chain has numerous stages, from nurseries, forest management, and timber harvesting, through to transport, and processing. This supply chain needs to develop resilience in the face of climate change. However, climate change will impact on the stages of the chain in different ways, increasing the complexity of the interdependencies between the stages. Scotland's forest sector also has interdependencies with other sectors, including agriculture and construction, which are also expected to be impacted by climate change. These impacts, and changes made in response to them, may have secondary impacts for the forest sector.

Climate change is expected to result in a wide range of socio-economic and political changes which in turn will impact each stage of Scotland's forest supply chain, including end customers, which may change demand across the sector. However, the dynamics of the supply chain are unique due to long forest rotations and the multiple objectives of natural resource management. Standard supply and demand theory doesn't always apply. It is essential that all of these secondary impacts are considered and communicated in order to create a resilient forest supply chain.

This report sets out a theoretical overview of climate change impacts on Scotland's forestry supply chain, with a focus on forest wood products. It looks at impacts on the natural environment including forests, but also on infrastructure such as energy, water, transport and communication, and on business operations.

The lists of impacts are not and will never be exhaustive. The focus is on growers and nurseries, forest management, harvesting, transport, and wood processing. The aim is to provide a framework for discussion with forestry sector experts that:

- identifies climate change impacts on the forestry supply chain, and potential consequences of adaptation practices implemented in response; and
- ensures that lack of adaptive capacity at any stage does not restrict the overall resilience of the sector.

Key findings

- Scotland's forestry supply chain includes forest growers and nurseries, forest management, timber harvesting, transport, and wood processing. Climate change is likely to have **primary impacts** at each step or 'stage' of the forestry supply chain.
- The stages of the forestry supply chain are interdependent, meaning an impact at one stage may have subsequent **secondary impacts** on other stages.
- Businesses, organisations and individuals will need to adapt to reduce climate risk or respond to realised impacts. Adaptation actions taken at one stage may have **tertiary impacts** for other stages.
- Limited adaptive capacity at any stage could reduce the resilience of the sector. Barriers to change at any stage may restrict adaptation actions elsewhere.

Content

Summary 1
Key findings 2
Content 2
1 Introduction 3
2 Climate Change Impacts on a Supply Chain 3
2.1 Primary, Secondary & Tertiary Impacts 3
2.2 Supply & Demand 4
2.3 Failure to Adapt 5
2.4 Resilience 5
2.5 Uncertainty 5
3 Scotland's Forestry Supply Chain 6
3.1 Supply & Demand 7
4 Risks and Opportunities from Climate Change for Forestry in Scotland 7
5 Climate Change Impacts 8
5.1 Primary Climate Change Impacts 8
5.2 Secondary Climate Change Impacts 8
6 Adaptation Actions 11
7 External drivers of change 13
8 Barriers to Adaptation 14
9 Conclusions 14
10 References 16
11 Appendix 1. Summary of Climate Change Impacts on Scotland's Forestry Sector 17
12 References 20

1 Introduction

A business supply chain is a sequence of companies which produce, process, or distribute a product to take it from a supplier to customer. Processes within the chain are known as stages with upstream stages referred to as suppliers and downstream stages and customers as the distribution network. Scotland has a highly valuable forest sector which delivers a wide range of products and services; including timber and other wood products, pulp, paper, biomass, as well as recreation and tourism, contributing almost £1 billion to the economy (CJC Consulting, 2015).

Climate change is expected to have wide ranging impacts in Scotland, including risks to the natural environment (Brown *et al.,* 2016), infrastructure (Dawson *et al.,* 2016) and businesses (Surminski *et al.,* 2016). Adaptation actions are a key element of the strategy to reduce the probability and extent of climate change impacts and to increase resilience in different sectors (Scottish Government, 2014). The Evidence Report for the Second Climate Change Risk Assessment encourages the consideration of both climate change impacts and adaptation actions on business supply chains due to interdependencies between businesses which may result in otherwise unanticipated impacts (Surminski *et al.,* 2016).

Supply chain resilience refers to the 'ability of a supply chain to cope with change' (Wieland & Wallenburg, 2013). The United Kingdom Forestry Standard (Forestry Commission, 2017) defines resilience as: 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change'. These are excellent targets for Scotland's forestry supply chain.

This report provides a theoretical overview of climate change impacts on a supply chain, and applies this to the forest sector. The focus is on the supply chain for forest wood products, which includes: growers and nurseries, forest management, harvesting, transport, and wood processing. **Primary** impacts of climate change are considered at each stage of the forest supply chain, and how these may have **secondary** impacts at other stages. The ways that adaptation actions may have **tertiary** impacts on other stages of the forest supply chain are explored. In addition, the potential constraints to adaptation are examined, leading to identification of additional research needs, and consideration of how the forest sector can be supported to increase its resilience to climate change. This document provides a framework for further exploration and discussion by the sector of the climate change impacts on the forest supply chain.

2 Climate Change Impacts on a Supply Chain

2.1 Primary, Secondary & Tertiary Impacts

Climate change may have a direct impact on any stage of a supply chain; this is referred to as a **primary impact**. For example, an abnormally long or severe drought period with increased temperatures resulting in extensive forest fires which may cause the loss of timber and forest habitats, and disruption to infrastructure. When an impact at one stage has a subsequent effect on another stage, or even other processes within the same stage, we describe this as a **secondary impact**. To illustrate, the reduced timber availability in the above example may have business implications for the processing sector. It may also result in subsequent increased demand to forest nurseries and may limit access to forest management offices. These concepts are illustrated in Figure 1.

An adaptation action taken by a business to increase resilience to a climate change risk may also have **tertiary impacts** or consequences for others in the supply chain. For example the adaptation actions taken by forest managers in response to increased storm and wind risk, such as shortening rotation lengths, may increase demand on forest nurseries and alter the size and quality of material available for processing.

2.2 Supply & Demand

Climate change may also affect the end customers of a supply chain, either through changing customers demand for products or services, or impacting business function or financial stability. These effects may have secondary impacts on a supply chain, affecting one or more stages or even the entire chain. For example, increased average temperatures may reduce demand for biofuel, reducing demand for small diameter wood. Similarly, adaptation actions taken by the customer may have impacts on the supply chain (Figure 2). For example, a shift towards British grown timber in construction, to reduce reliance on international imports, or substituting timber for other construction materials would increase demand for high quality timber.

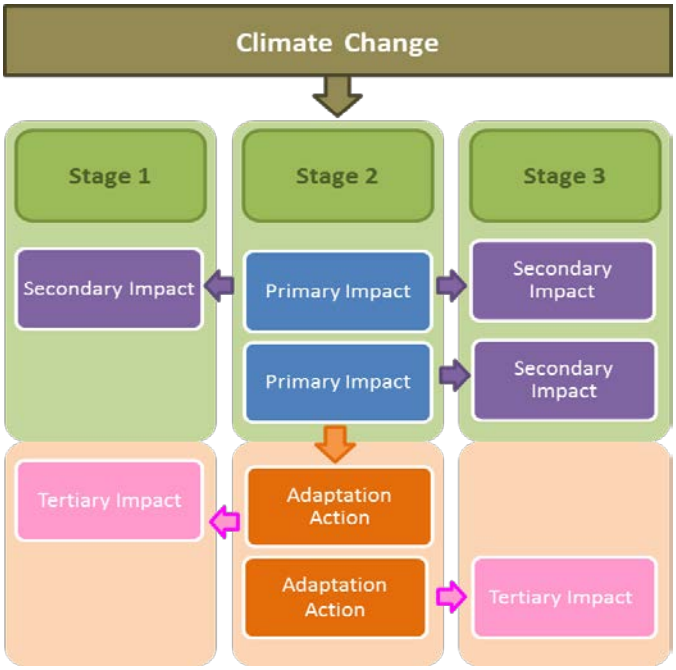

Figure 1: The primary and secondary impacts of climate change on a supply chain (green box), and the tertiary impacts of adaptation actions (orange box).

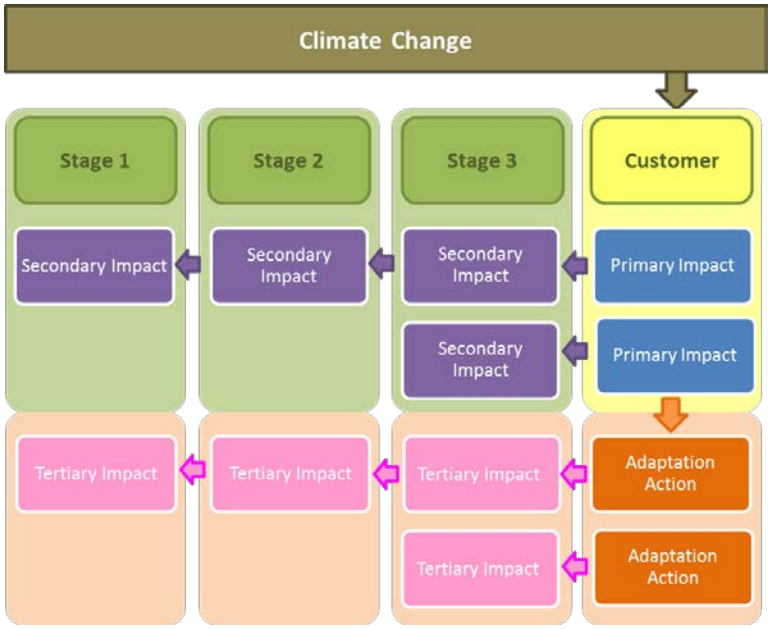

Figure 2: Primary climate change impacts on supply chain customers (yellow box), and subsequent secondary (green box) and tertiary impacts (orange box) on the supply chain.

2.3 Failure to Adapt

The failure of any one stage of a supply chain to implement a climate change risk management strategy, or to successfully adapt to reduce climate change risk, could create vulnerability for other parts of the supply chain. In a worst case scenario, failure at one stage could disrupt the entire chain. Impacts on the supply chain will vary depending on the extent of the primary impact, but also on the adaptive capacity of the affected stage and adjacent up- and downstream stages. The degree of disruption and recovery time will be affected by factors such as available financial reserves, the level of reserve material, flexibility in supply and distribution networks, national and international customer base, as well as the degree of contingency planning at each stage.

2.4 Resilience

In order to develop a resilient supply chain it is essential that all of the primary and secondary impacts of climate change and the tertiary impacts of adaptation actions are considered when assessing risk. To achieve this, awareness of the vulnerability throughout the supply chain is necessary, which can be achieved through communication between those involved in the stages of a supply chain.

Supply chain resilience extends beyond the adaptive capacity of any one stage or business. The ability of the sector to respond to change, the flexibility within the supply chain, the ability to work together, and to communicate at all levels (from policy to practice) will be critical for the degree of resilience of a supply chain.

Certain themes and topics require greater exploration as they extend across a supply chain and reaching a resolution which satisfies all stages will be fundamental to building a resilient supply chain.

2.5 Uncertainty

The degree of certainty relating to climate change impacts varies largely. Whilst there is sufficient certainty about many projections to adopt 'no regrets' actions, in some cases the uncertainty is so large that further time and research are needed to address the unknowns before adaptation actions are implemented. When considering secondary impacts the degree of uncertainty may be higher, adding an additional challenge to risk assessments.

Uncertainty increases further when considering potential adaptation actions and subsequent tertiary impacts, due to the wide range of adaptation options and the uncertainty which surrounds human action. The concept of tertiary impacts is included to illustrate how impacts at one stage can have wider impacts throughout the supply chain, and to encourage communication between the stages of the supply chain to reduce any negative impacts of adaptation.

3 Scotland's Forestry Supply Chain

Scotland forest sector is estimated to contribute almost £1 billion to the economy each year and employs some 25,000 people (CJC consulting, 2015). This includes both forestry and timber production which add £771 million and recreation and tourism which contribute £183 million. Understanding the potential impacts of climate change and how the sector can adapt is therefore of huge economic importance. This report focuses on forest and timber production, from seed to processing but doesn't extend to recreation and tourism. This is sometimes termed the "forest wood chain", but throughout this document we refer to it as the **forestry** (or forest sector) **supply chain** for consistency.

A basic supply chain for the forest sector is presented in Figure 3. There are four stages: the nursery providing the seedling, forest management, harvesting and haulage, and primary processing. Included in the nursery stage is the sourcing of seed from seed stands. If natural regeneration is used to establish a stand the first stage will be absent and included under forest management. The forest management stage includes planting, establishing and growing the stand and may include thinning and protection from pests, pathogens and herbivores. Forest harvesting and haulage includes felling, extraction and transport to the primary processor. The final stage includes primary processing and the production of sawn wood products, panels, fencing and woodfuel; and secondary processing into a wide range of wood products for many different customers is also included in this stage. Figure 4 illustrates the final three stages of the forest supply chain. This excludes the nursery stage but expands processing into primary and secondary to illustrate a wide range of products.

Figure 3: A simplified forestry supply chain

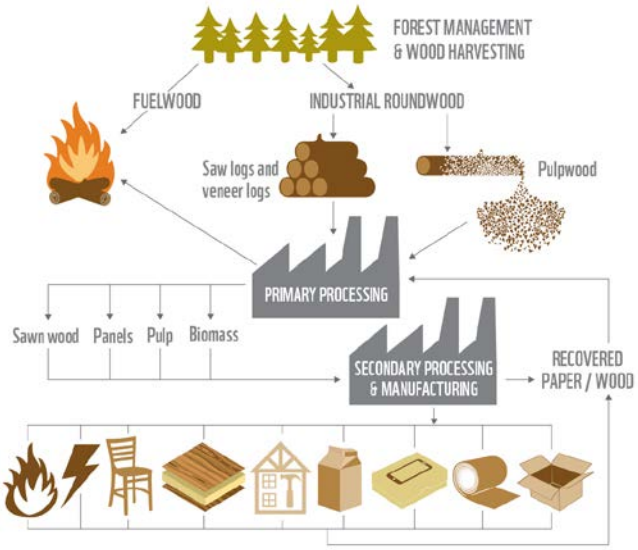

Figure 4: The forest supply chain from forest to end product. From Taylor, 2012

3.1 Supply & Demand

Business supply chains are developed and driven by customer demand. Whilst this is largely true of the commercial forest sector, forestry is unique due to long forest rotations, a slow rate of change in forest composition, and the multiple objectives of natural resource management. Therefore, standard theories of supply and demand don't always apply. Demand for Scottish timber is currently limited to a narrow range of species which produce construction grade material, with the remaining market share provided by imports. If species-diverse forests are required to ensure a resilient forest resource, this creates a challenge for productive growers. New markets and forest products may need to be developed to drive this change and create more diverse forests. Opportunities may be available for businesses and customers able to adjust and become more supply driven.

Scotland's forest resource delivers a wide range of ecosystem services and forest stands are often required to deliver multiple management objectives. Therefore the species composition and quality of forest stands are not always suitable for certain end products. The rate of change to the timber resource is slow, at less than 5% a year, due to both regulations limiting the area which can be felled annually and due to limited harvesting capacity. This slow rate of change places constraints on adaptation actions but also gives the processing sector time to adapt to gradual changes in composition.

4 Risks and Opportunities from Climate Change for Forestry in Scotland

The Evidence Report for the Second Climate Change Risk Assessment (CCRA2 2016) summarises the projected changes in Scotland's climate:

- Increasing year round average temperatures;
- Increase in average winter rainfall;
- Decrease in average summer rainfall;
- Increase in extreme weather events, such as storms and flooding.

The risks arising from these likely changes can be considered as the combination of both the extent of the impact and the probability of occurrence, or likelihood. In this report we consider a wide range of climate change impacts but not the likelihood of each risk, which will vary with time, location and adaptive capacity. Instead this report aims to inform the first stage of risk management, which is to identify potential risks in order that subsequent risk assessment and management may be carried out.

The risks to Scotland's forests from climate change have been previously explored (Nicoll, 2016; Scottish Government, 2014); however, less consideration has been given to projected climate change impacts on infrastructure, businesses and industry across the forestry sector which were identified in the Evidence Report for the second Climate Change Risk Assessment. In Appendix 1 we summarise the significant risks identified in the report and in the recent Agriculture and Forestry Climate Change Report card (Morison & Matthews, 2016) and describe the significance for the forest sector. In the next section we summarise the main impacts at each stage of the forestry supply chain and consider the impacts on other stages of the forest supply chain.

5 Climate Change Impacts

5.1 Primary Climate Change Impacts

Figure 5 summarises the key primary impacts for each stage of the forest supply chain.

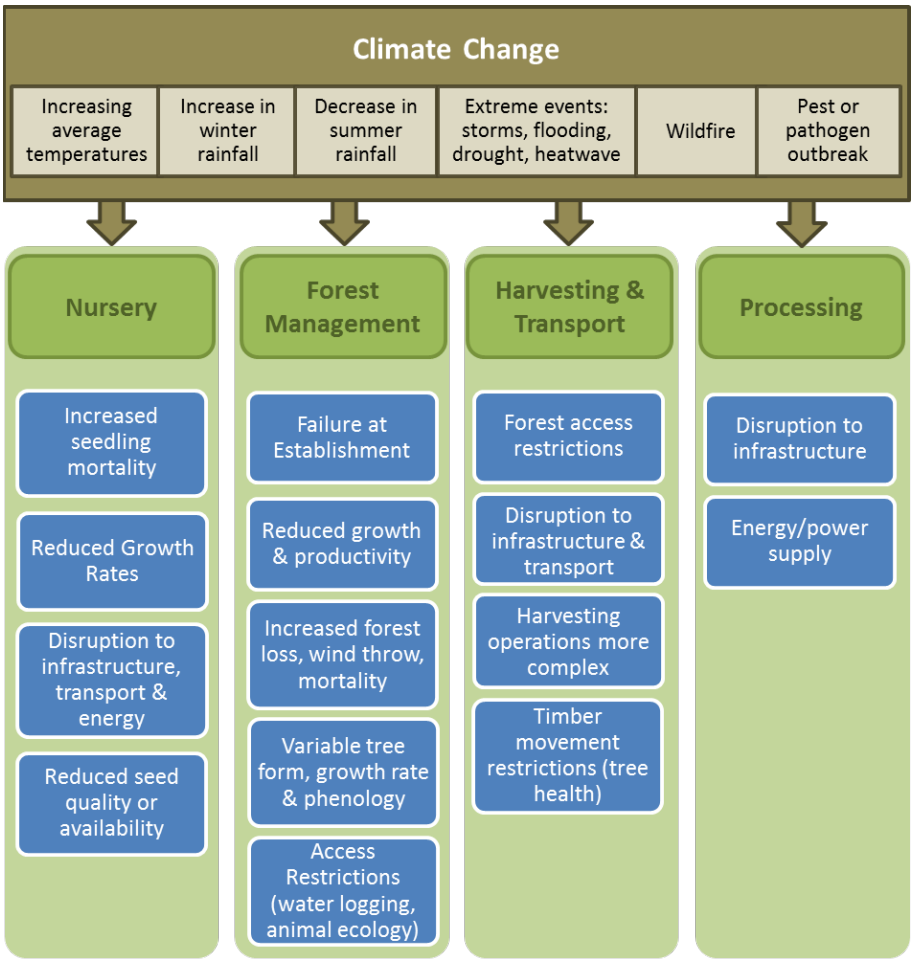

Figure 5: summary of key primary impacts to Scotland's forest supply chain

5.2 Secondary Climate Change Impacts

As described in section 3, climate change can have secondary impacts on a supply chain. Figures 6-9 summarise the key secondary impacts to the stages of Scotland's forest supply chain.

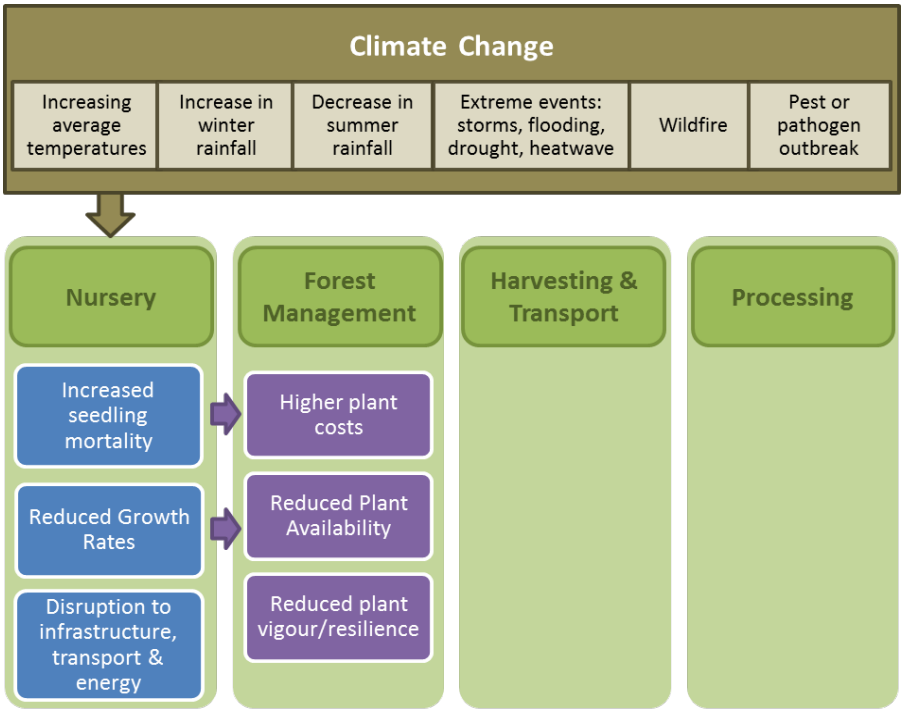

Figure 6: summary of the primary impacts to forest nurseries and subsequent secondary impacts.

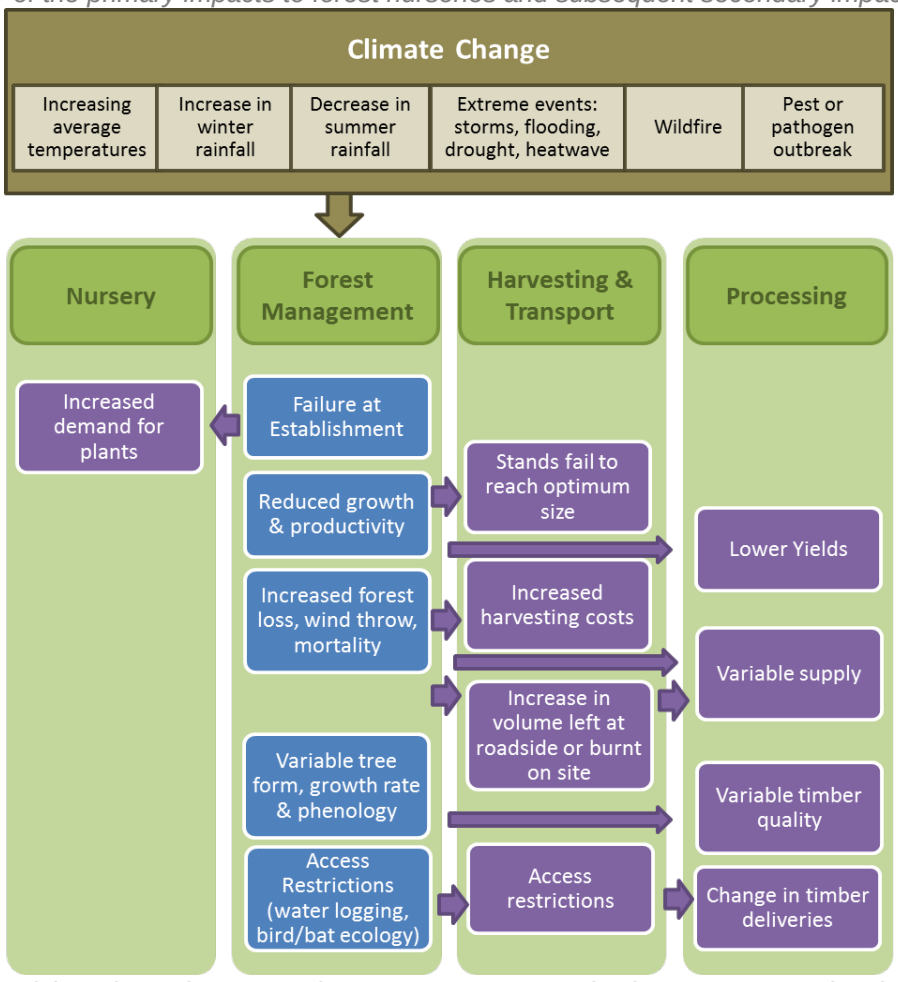

Figure 7: summary of the primary impacts to forest management and subsequent secondary impacts.

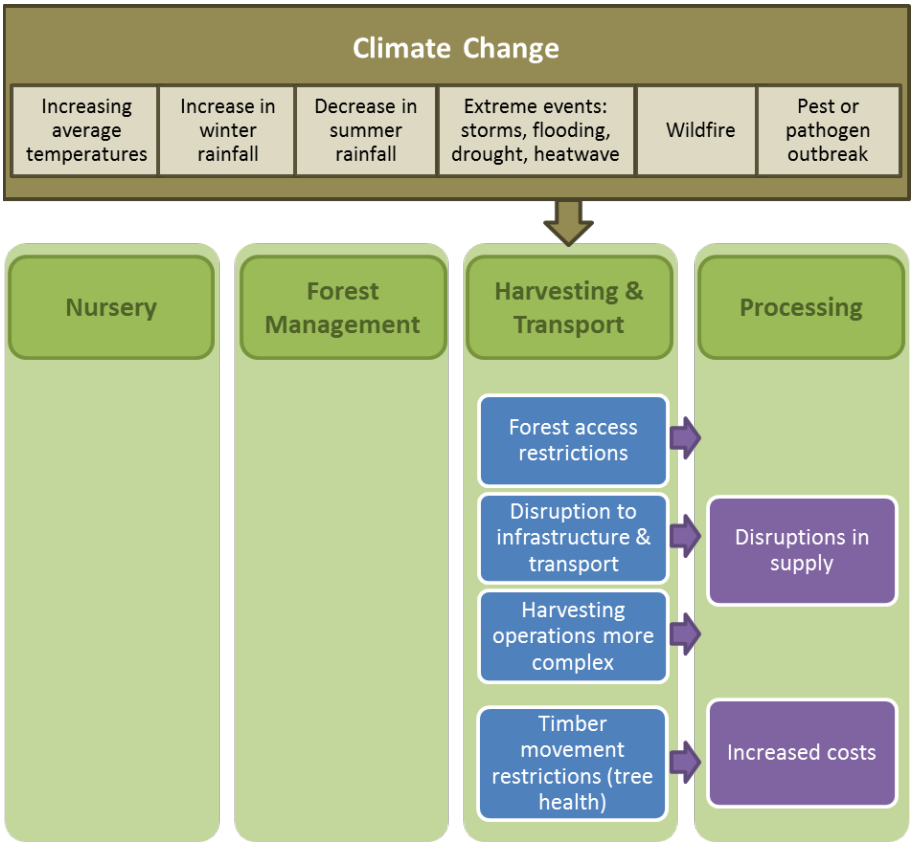

Figure 8: summary of the primary impacts to harvesting and transport and subsequent secondary impacts.

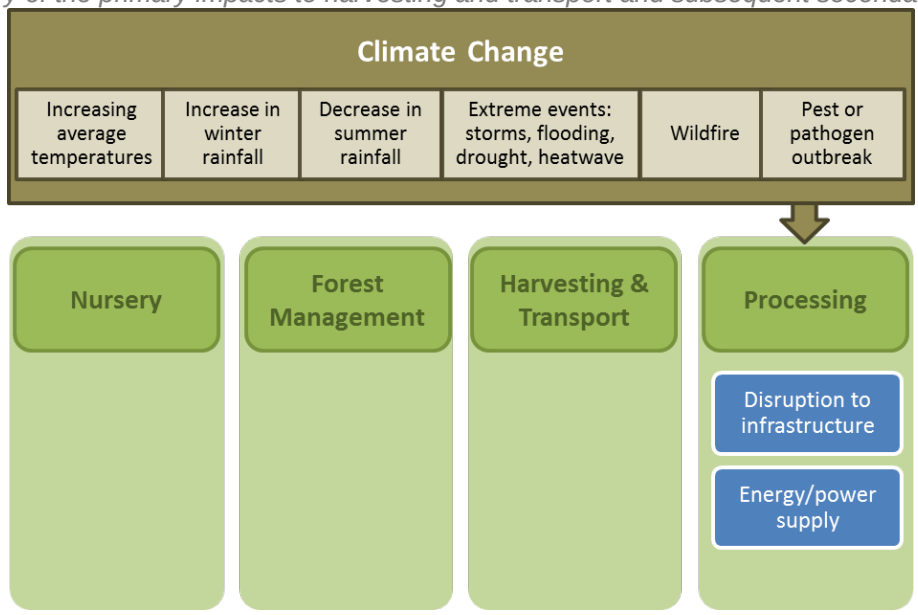

Figure 9: summary of the primary impacts to processing sector and subsequent secondary impacts.

6 Adaptation Actions

Actions may be taken at each stage of the supply chain to reduce risks from climate change and also to take advantage of any opportunities presented. These may have direct or indirect impacts on other stages of the supply chain.

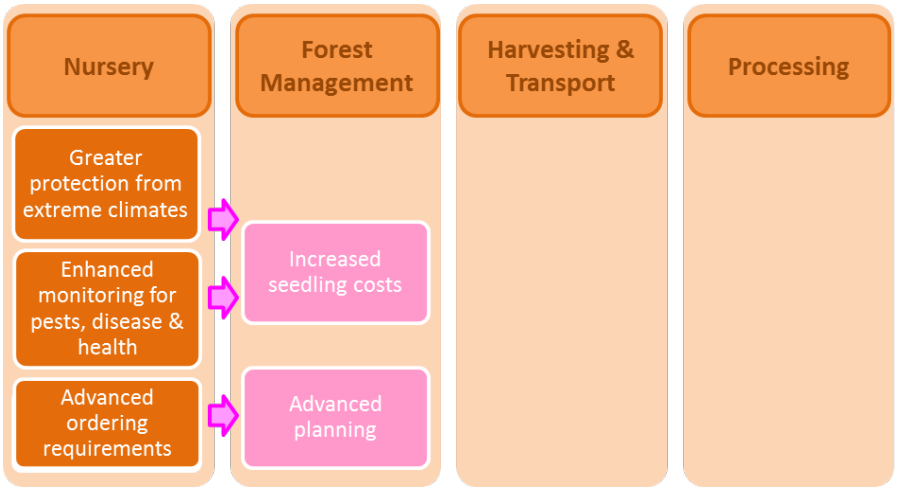

Figure 10: summary of nursery stage adaptation actions and subsequent tertiary impacts

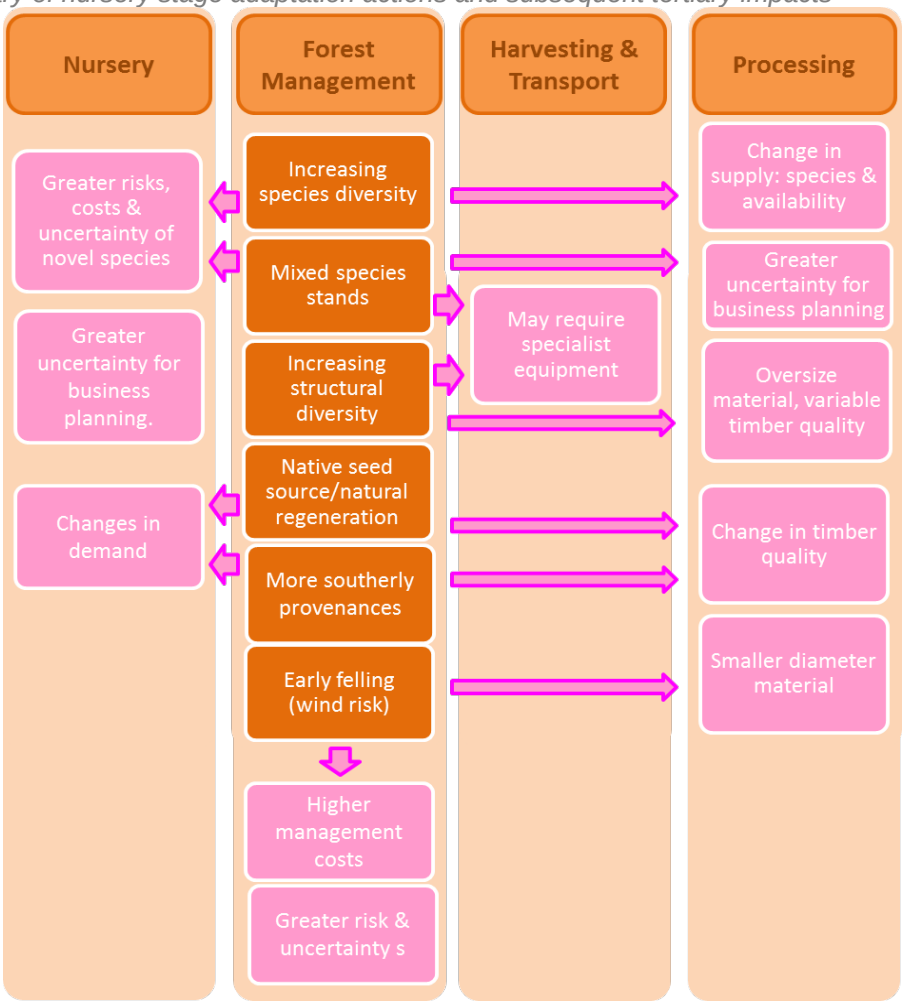

Figure 11: summary of forest management stage adaptation actions and subsequent tertiary impacts

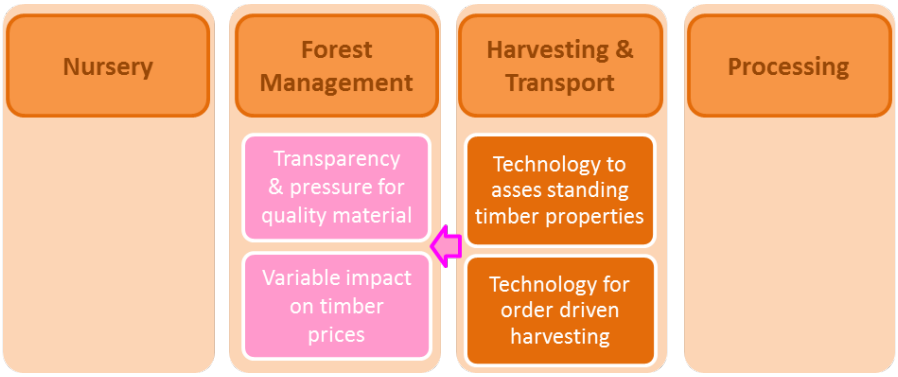

Figure 12: summary of harvesting & transport stage adaptation actions and subsequent tertiary impacts

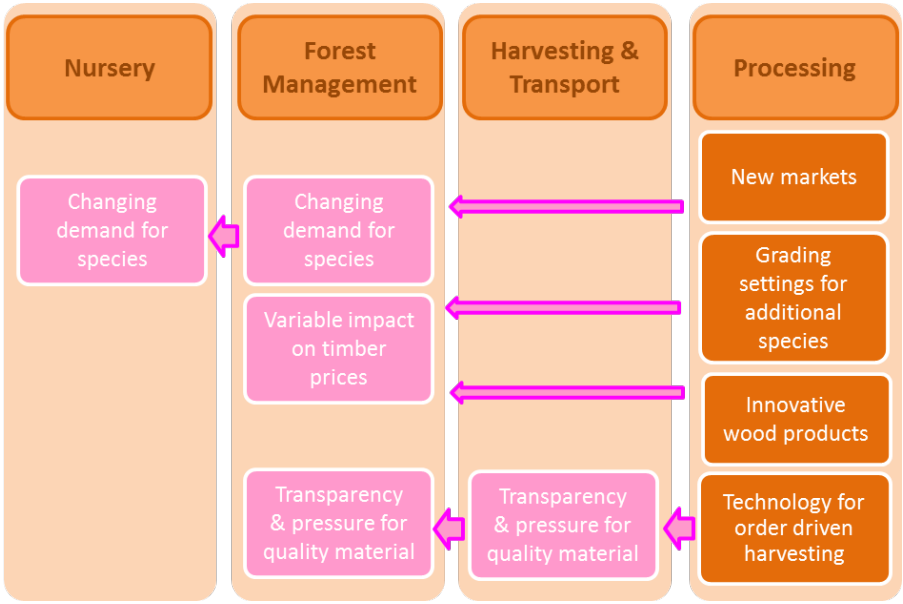

Figure 13: summary processing stage adaptation actions and subsequent tertiary impacts

7 External drivers of change

Climate change is projected to have impacts on a wide range of sectors. The forest sector has many dependencies with other sectors, such as agriculture, construction and energy. Climate change impacts, changes in policy, and adaptation actions taken by these sectors may impact the forest sector.

Climate change will also impact Scotland's political and socio-economic futures, which will impact production and customer demand. Scenarios such as those contained in the UK National Ecosystem Services Assessment (2014) can assist in exploration of potential future scenarios.

Global markets will also be disrupted by an increased risk of extreme weather events around the world and longer term changing climates. This may cause disruption to UK businesses through international supply chains, distribution networks and global markets. Scotland's forest sector has European and global dependencies. Timber prices are dependent on global markets, which will affect supply and demand and impact the forest supply chain. Demand for Scottish timber could increase with an increase in timber construction and preference for locally grown timber. Likewise, there may be a preference for British grown seedlings over imports for tree health concerns. Timber availability will be impacted by both international and domestic climate impacts. Having international supply chains with overseas markets may increase the resilience of companies to domestic risks.

The impacts of climate change on other sectors and on political and socio-economic futures are included for awareness rather than assessment at this stage due to high levels of complexity and uncertainty. Figure 14 illustrates the patterns of primary and secondary impacts on a supply chain and the end customers, as brought about by climate change impacts on other sectors and on political and socio-economic futures. Continued monitoring, high level assessment, communication and contingency planning are necessary to manage significant risks.

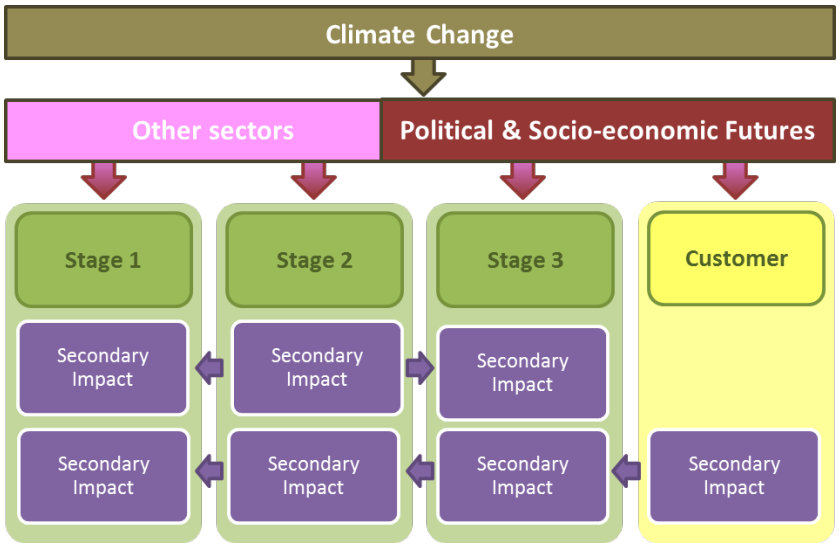

Figure 14: Climate change may also impact other sectors and political and socio-economic futures, which may in turn impact a supply chain

8 Barriers to Adaptation

Bottlenecks in the supply chain may reduce the rate or the ability of the whole chain to adapt. The following barriers are included as examples, but will require further exploration:

Nursery

- Limited seed source availability;
- Time delay for sourcing novel species and learning how to germinate and grow them;
- Higher business risk and cost for nurseries to grow novel species;
- Time lag to respond to demand created by an extreme event.

Management

- Knowledge limitations for novel species and mixtures (including their susceptibility to pest and diseases, yield projections, invasiveness, specific management requirements and performance under different management scenarios);
- High risk associated with species change.

Harvesting and Transport

- Felling capacity (equipment available, forest road building rates).

Processing

- Saw mill processing capacity;
- Grading settings only available for a limited number of species;
  Limited customer demand for novel species

9 Conclusions

This report has explored the primary impacts of climate change at each stage of Scotland's forest supply chain, and has provided a framework to identify potential secondary and tertiary impacts on other stages of the supply chain. Each stage of Scotland's forest supply chain is likely to be directly affected by climate change in the form of **primary** impacts. Increased average temperatures, more extreme rainfall patterns in winter and summer, extreme events such as floods, catastrophic storms, and drought, pest and pathogen outbreaks, and wildfires, all have the ability to impair operations within each step of Scotland's forest supply chain. Increased mortality and reduced growth at nursery and forest levels; costly and difficult operations at the establishment, management, harvesting, and transport stages; and disruption to infrastructure, are just some of the examples of primary climate change impacts on Scotland's forest supply chain.

Secondary climate change impacts are due to the interdependence between the stages of Scotland's forest supply chain, and represent the consequences that primary impacts on one stage have on other stages. For instance, reduced availability of nursery material would impact plants costs and resilience at the forest management level. Reduced forest growth, larger forest losses, and lower quality trees would impact the volume, quality, and costs of harvesting and processing operations. Similarly, climate change impacts on the harvesting and transport stage would reduce availability and increase costs at the processing stage.

Adaptation actions are required for each stage of the supply chain, but their implementation at each stage is likely to cause **tertiary** impacts on the other stages. These impacts are most likely to put pressure on all the stages, and result in increases of uncertainty and costs across the entire supply chain. For instance, forest stands with more complex structures and species mixtures would require that nurseries modify their operations and species portfolios. Similarly, different equipment might be

required for harvesting different species, and the processing sector might need to modify their infrastructure and/or operations to comply with different species, timber sizes and volumes.

Further discussion with experts within the forestry sector at each stage of the supply chain is recommended to identify additional risks. As part of this discussion, the following topics should be explored in detail:

- Primary climate change impacts at each stage of the supply chain
- Potential secondary impacts
- Adaptation options for each stage of the supply chain and potential impacts for other stages
- Barriers to adaptation at each stage. Barriers affecting the entire supply chain
- External drivers of change, i.e. impacts on other sectors, political and socio-economic futures

Identifying these risks will allow subsequent risk assessment and risk reduction (adaptation) actions to be put in place. It is worth emphasising that there are themes which extend across the entirety of the supply chain, such as species diversification, which will require communication between all stages to identify solutions.

Conversely, barriers to adaptation at each stage of the supply chain have the potential to inhibit adaptation of the wider supply chain, and thereby reduce overall resilience.

Input from experts at all levels, practitioners, researchers and policy leads, from both the public and private sector will be necessary to fully address these questions and build a resilient forest supply chain, and consequently a resilient, adapted, and sustainable forest sector.

10 References

Brown, I., Thompson, D., Bardgett, R., Berry, P., Crute, I., Morison, J., Morecroft, M., Pinnegar, J., Reeder, T., and Topp, K. (2016) *UK Climate Change Risk Assessment Evidence Report:* Chapter 3, Natural Environment and Natural Assets. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

CJC consulting (2015) *The economic contribution of the forestry sector in Scotland* http://scotland.forestry.gov.uk/images/corporate/pdf/economic-contribution-forestry-2015.pdf

Dawson, R.J., Thompson, D., Johns, D., Gosling, S., Chapman, L., Darch, G., Watson, G., Powrie, W., Bell, S., Paulson, K., Hughes, P., and Wood, R. (2016) *UK Climate Change Risk Assessment Evidence Report*: Chapter 4, Infrastructure. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

Forestry Commission (2017) The United Kingdom Forestry Standard (UKFS) Forestry Commission, Edinburgh www.forestry.gov.uk/theukforestrystandard

Morison, J.I.L. and Matthews, R.B. (eds.) (2016) Agriculture and Forestry Climate Change Impacts Summary Report. Living with Environmental Change. www.nerc.ac.uk/research/partnerships/ride/lwec/report-cards/agriculture

Nicoll, B. (2016) Risks for woodlands, forest management and forestry production in the UK from climate change www.nerc.ac.uk/research/partnerships/ride/lwec/report-cards/agriculture-source08

Scottish Government (2014) Climate Ready Scotland: Scottish Climate change Adaptation Programme www.gov.scot/Resource/0045/00451392.pdf

Surminski, S., Style, D., Di Mauro, M., Townsend, A., Baglee, A., Cameron, C., Connell, R., Deyes, K., Haworth, A., Ingirige, B., Muir-Wood, R., Proverbs, D., Watkiss, P., and Sze Goh, L. (2016). *UK Climate Change Risk Assessment Evidence Report*: Chapter 6, Business and Industry. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

Taylor, R. (Ed) 2012 Chapter 4: Forests and Wood Products in *Living Forests Report* WWF, Switzerland wwf.panda.org/livingforests

UK National Ecosystem Services Assessment (2014) UK National Ecosystem Services Assessment Follow On: Synthesis of Key Findings http://uknea.unep-wcmc.org/resources/tabid/82/default.aspx

Wieland, A. & Wallenburg, C.M. (2013): The influence of relational competencies on supply chain resilience: a relational view. International Journal of Physical Distribution & Logistics Management. Vol. 43, No. 4, pp. 300-320. www.ilnet.tu-berlin.de/fileadmin/fg175/Downloads/resilience-relational-view.pdf

Appendix 1. Summary of Climate Change Impacts on Scotland's Forestry Sector

The risks to Scotland's forests from climate change have been previously explored (Nicoll, 2016; Scottish Government, 2014); however, less consideration has been given to projected climate change impacts on infrastructure, businesses and industry across the forestry sector. The Evidence Report for the Second Climate Change Risk Assessment identifies a wide range of climate risks to the UK. In Table 1 we summarise the significant risks identified in the report for Natural Environment (Brown *et al.*, 2016), Infrastructure (Dawson *et al.,* 2016) and Business & Industry (Surminski *et al.,* 2016) alongside the recent Agriculture and Forestry Climate Change Report Card (Morison & Matthews, 2016). Below we describe the significance of these impacts for the forest sector.

Table 1. Summary of Key Climate Change Impacts

Natural Environment & Natural Assets	Infrastructure	Business and Industry
Increased risk from pests and diseases	Storm damage to pylons, data cables and power lines from wind and lightning	Risks to business from reduced access to capital
Increased wind damage from exceptional storms	Risk to power generation and water supply from low or high river flows	Risks and opportunities for business from changes in demand for goods and services
Increased growth rates and productivity where water availability is not limiting	Loss of power affecting digital and tele-communication networks	Risks to business from disruption to supply chains and distribution networks
Decreased growth rates and productivity in drier areas	Landslides and storm damage causing road and rail closures	Changes to policy and regulation
Increased risk from droughts	Flood damage to roads, bridges and drains	
Increased risk from water logging	Flooding of substations disrupting power supply	
Increased risk of wild fires	Damage to ports from rising sea levels, storm surges and coastal erosion	
	Change in rainfall distribution changing demand on water supplies	
	Increased risk from heatwaves disrupting transport and power	

10.1 Natural Environment and Natural Assets

Storms

Storm damage may result in a loss of timber, damage to standing trees, high costs of clean-up, disruption to markets and timber processing, as well as subsequent damage from insects, pests and

fire. Timber quality may also be affected due to an increase in stem defects and changes to integral wood properties such as reaction wood.

Productivity

Increases in growth rate in areas that are currently cooler and wetter due to lengthened and warmer growing seasons. Faster growth rates could reduce timber quality in some species or genotypes, and potentially result in nutrient imbalances in extreme cases.

Decreased growth rates in areas that are currently dry, or on shallow or free draining soils. Growth rates may also be reduced through pest and disease outbreaks.

Changes in climate may affect seed production or quality and the frequency of mast years. There may be increased failure at establishment and increased beat up demands as a result of drought, storm damage, water logging or flooding, unsuitable climate conditions, competition from invasive non-native species and increased browsing pressure.

Drought

An increase in the frequency or severity of drought would reduce growth rates in drought years. Severe drought stress would increase tree mortality and forest die back. Exact effects will depend on location, degree of drought, and species sensitivity. Timber quality may be reduced as a result of drought crack. Drought may cause damage to establishing young trees; both planted and naturally regenerated, and could disrupt management activities such as planting.

Increased CO_2 levels

Increased atmospheric CO_2 concentrations in the future may increase growth rates, especially in young trees, although long term impacts and effects on mature trees are unclear. Effects are species dependent and constrained by nutrient and moisture availability. Increased CO_2 also reduces tree water loss and could reduce growth rate reductions from drought.

Species suitability

Changing species suitability could shift the natural distribution of species, moving species north or to higher altitudes. A natural shift is unlikely to be seen widely in Scotland as many tree line forests are managed.

Waterlogging and flooding

Increased winter rainfall on clay or peat soils can lead to water logging, reducing growth rates, increase mortality, reduced stability to wind, and reduced access for machinery affecting thinning and harvesting. Flooding could result in damage to forest infrastructure.

Changes to phenology (growth patterns and timing)

Warmer conditions will result in early onset of bud burst and growth, which can result in longer growing seasons but can also increase the risk of frost damage. Longer autumn periods before leaf fall may result in longer growing seasons. In some species this may result in increased lammas growth, resulting in increased knots in timber which would reduce timber quality. Longer growing seasons could also impact wood properties, such as by altering earlywood and latewood ratios. Warmer autumns could reduce the hardening of buds and plant material for some species, increasing risk of damage to nursery material and standing trees over winter. For some species there may be reduced natural chilling due to milder winters, counteracting the effect of warmer springs that are driving earlier bud-break, and similar effects could alter natural regeneration. For some species, artificial seed chilling may be required to ensure dormancy is broken which may require modified nursery practices

Changes in the ecology of protected animals and insects, such as ground nesting birds, birds of prey, dormice, butterflies, beetles or bats could alter restrictions on access for forest operations.

Pests and diseases

The risks from pests and diseases are likely to increase, resulting in decreased growth and increased mortality. New tree pests or pathogens may be introduced to the UK and the introduction of new tree species and increased planting of novel species could both create new host-vector combinations. Statutory Plant Health Notice and felling to reduce spread also result in impacts such as reduced yield and transport restrictions. It is difficult to identify which impacts are directly a result of climate change but increased stress from climate change can increase the vulnerability to pests and disease damage, and could create new niches and opportunities for the spread of both new and existing pests and pathogens.

Invasive species

Invasive species affect natural regeneration and tree growth by competing for space, light, water and nutrient resources. Milder winters may result in increased growing conditions for invasive species. Changing conditions may result in existing species or newly introduced species becoming invasive.

Wildfire

Wildfires result in extensive damage to the natural environment, businesses and infrastructure. There is likely to be a loss of habitats, including forest habitats, and damage to ecosystem service provision such as carbon storage, biodiversity, water quality, employment and timber production. There will also be disruption to local populations, damage to property and infrastructure. Wildfires result in potential health impacts from air and water pollution and there is the potential for loss of life. Forest fires will impact forest business sites due to the proximity of many forest offices to forests. Both wild fires and fire risks warnings result in the closure of public access land and have economic impacts on recreation and tourism businesses.

10.2 Infrastructure

Infrastructure encompasses energy, transport, water, waste and communication, which provide services such as: lighting, heating, transport (road, rail, air, sea), sanitation, digital infrastructure and telecommunications. Climate change is projected to increase the frequency and severity of risks to these services, although the nature of the risk will vary with location. Disruption to these services will impact the forest sector.

Damage to coastal infrastructure and ports could limit the import and export of a range of forest products, such as timber, wood chip, pulp or paper.

Road and rail closures could restrict the movement of nursery material, timber, vehicles and forest machinery disrupting forest and processing operations. Transport disruption can also impact staffing levels and reduce productivity.

Forest infrastructure such as roads, bridges and culverts may be damaged by flooding, wind, heatwaves and landslides.

Disruption to power supplies would disrupt operations at each stage of the forest supply chain, perhaps affecting the processing sector more severely.

Disruption to communication networks would negatively impact business operations and productivity at each stage of the supply chain.

Staff worker health, safety and productivity could be negatively impacted by an increase in the frequency or severity of extreme weather events, such as storms, heavy rain, flooding or heatwaves.

Any water-intensive stages or processes could be impacted by reduced water availability.

Risk to other sectors from forestry

- Damage to power lines and disruption to electricity supply from falling trees
- Disruption to transport networks through blocked roads or rail lines from tree failures
- Landslides blocking road or rail networks
- Forest run off impacting water quality

These latter risks have the potential to cost businesses and the wider forest sector financially as well as damaging its reputation. Additional regulations could be introduced to manage these risks if the sector is not seen to be taking sufficient action.

10.3 Business and Industry

Climate change poses risks and creates opportunities for business activities in the UK. Several of the main climate impacts overlap with those described for infrastructure and therefore only additional impacts are included.

Access to capital

Climate change may restrict the access of UK business to capital, investment or insurance. The supply of capital by UK banks and private investors is vulnerable to climate change. The physical risks of climate change may also disrupt insurance arrangements. Access to finance may be restricted for businesses across the forest sector, as may the ability of businesses and forests owners to arrange insurance. Access to funding to finance adaptation may also be limited. The inclusion of forest ownership in investment portfolios may increase or decrease depending on the relative risk to forests and other sectors.

Demand for goods and services

Climate change adaptation is expected to change the demand for some products and services, therefore there is an opportunity for businesses which address impacts early and anticipate future change, but also a risk that demand for some products may decrease. Demand for timber and wood fuel products may change in response to climate change.

Supply chains and distribution networks

The increased risk of extreme weather events around the world may cause disruption to UK businesses through their international supply chains, distribution networks and global markets. However, relationships with overseas markets may increase the resilience of companies to domestic risks. Timber availability and timber prices will be impacted by both international and domestic climate impacts.

Policy and regulation

The UK Government has a role in enabling, facilitating and supporting private sector adaptation through policies, regulation and other supportive measures such as information sharing and raising awareness. Changes to regulations or other government intervention made necessary by climate change also pose an indirect risk to businesses.

References

Brown, I., Thompson, D., Bardgett, R., Berry, P., Crute, I., Morison, J., Morecroft, M., Pinnegar, J., Reeder, T., and Topp, K. (2016) *UK Climate Change Risk Assessment Evidence Report:* Chapter 3, Natural Environment and Natural Assets. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

Dawson, R.J., Thompson, D., Johns, D., Gosling, S., Chapman, L., Darch, G., Watson, G., Powrie, W., Bell, S., Paulson, K., Hughes, P., and Wood, R. (2016) *UK Climate Change Risk Assessment Evidence Report*: Chapter 4, Infrastructure. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

Morison, J.I.L. and Matthews, R.B. (eds.) (2016) Agriculture and Forestry Climate Change Impacts Summary Report. Living with Environmental Change. www.nerc.ac.uk/research/partnerships/ride/lwec/report-cards/agriculture

Nicoll, B. (2016) Risks for woodlands, forest management and forestry production in the UK from climate change www.nerc.ac.uk/research/partnerships/ride/lwec/report-cards/agriculture-source08

Scottish Government (2014) Climate Ready Scotland: Scottish Climate change Adaptation Programme www.gov.scot/Resource/0045/00451392.pdf

Surminski, S., Style, D., Di Mauro, M., Townsend, A., Baglee, A., Cameron, C., Connell, R., Deyes, K., Haworth, A., Ingirige, B., Muir-Wood, R., Proverbs, D., Watkiss, P., and Sze Goh, L. (2016). *UK Climate Change Risk Assessment Evidence Report*: Chapter 6, Business and Industry. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.