



An Overview of Sustainable Forestry in Canada for Architecture and Engineering Students



Main Publication Title:

An Overview of Sustainable Forestry in Canada for Architecture and Engineering Students

Publication Description:

This document is intended to accompany an educational slide deck of the same title available on the [Canadian Wood Council Website](#) and the [Mass Timber Institute Website](#)

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July 29, 2022

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Applicable Canadian Architectural Certification Board (CACB) Learning Objectives

CACB SPC A5: Site Context and Design:

- **The student must demonstrate an ability to analyze and respond to local site characteristics, including urban, non-urban, and regulatory contexts; topography; ecological systems; climate; and building orientation in the development of an architectural design project.**
- This module highlights various ecozones in Canada and illustrates the different tree species that occur in these ecozones. Additionally, the module describes and provides information about how natural elements of the environment affect forests.

CACB SPC B5: Ecological Systems:

- **The student must have an understanding of the broader ecologies that inform the design of buildings and their systems and of the interactions among these ecologies and design decisions.**
- Likely the most relevant application of objectives to this module is the knowledge of ecological systems. This educational module provides sufficient information to inform students of the broad ecology of forests in Canada and their application to building with wood, in addition to the broader interactions of forests with the global climate, and natural disturbance.

CACB SPC C2: Materials:

- **The student must have an understanding of the basic principles used in the appropriate selection and application of architectural materials as it relates to fundamental performance, aesthetics, durability, energy, resources, and environmental impact.**
- This module describes the benefits of building with wood from a conventional and mass timber perspective. It also places wood as a construction material in a larger context from source to implementation in buildings. The module describes the performance, aesthetics, durability, energy use, resource use, and environmental impact of wood to help the student make an informed decision when deciding if wood is an appropriate material to utilize to meet the goals of their project.

CACB SPC D1: Comprehensive Design:

- **The student must demonstrate an ability to produce an architectural design based on a concept, a building program, and a site which broadly integrates contextual factors, structural and environmental systems, building envelopes and assemblies, regulatory requirements, and environmental stewardship.**
- This module will provide students with the background information required to make an educated decision for the use of wood in their designs. It will provide the student with sourcing

information, the sustainability of the Canadian forest industry, and environmental importance of forests to Canada and global climate change mitigation.

CACB SPC E2: Ethical and Legal Responsibilities:

- **The student must have an understanding of the ethical issues involved in the formation of professional judgment; the architect's legal responsibility under the laws, codes, regulations, and contracts common to the practice of architecture; intellectual property rights; and the role of advocacy in relation to environmental, social, and cultural issues.**
- This module describes the environmental benefits of using wood as a building material; it provides students with knowledge on the sustainability of wood in Canada and its social and cultural importance. Students may use this knowledge to make an informed decision on the use of wood as a building material.

Glossary of Terms

Afforestation - The establishment of a tree crop on an area from which it has always, or for very long, been absent. Where such establishment fails and is repeated, the latter may properly be termed reforestation. (Natural Resources Canada, 2020)

Annual allowable cut (AAC) - The amount of timber that is permitted to be cut annually from a particular area. AAC is used as the basis for regulating harvest levels to ensure a sustainable supply of timber. (Natural Resources Canada, 2020)

Artificial regeneration - Renewal of a tree crop by direct seeding or by planting seedlings or cuttings. (Natural Resources Canada, 2020)

Assisted migration – The human intervention to deliberately move species to new, more favourable locations, with the goal of helping them to survive and flourish in a changing climate. (Natural Resources Canada, 2008)

Biodiversity - Species, genetic and ecosystem diversity in an area, sometimes including associated abiotic components such as landscape features, drainage systems, and climate (Swingland, 2013)

Biogenic carbon – Carbon that is contained in biomass. (Biotechnology Industry Organization, n.d.)

Boreal forest - One of three main forest zones in the world (see also tropical forest, temperate forest) located in northern regions and is characterized by the predominance of conifers (such as pine, spruce, larch and fir) and some deciduous (such as poplar and birch). The boreal forest (singular) is a colloquial term often used to refer to the overall forested area within the boreal zone, and sometimes to refer to the boreal zone itself because forests dominate this landscape. Boreal forests (plural) is the preferred term for the forested areas within the boreal zone. (Natural Resources Canada, 2020)

Boreal zone - The broad circumpolar vegetation zone of the high northern latitudes. Although mainly covered with trees, the boreal zone is more than just forest. It contains lakes, rivers and wetlands, as well as naturally treeless terrain such as alpine areas, heathlands in regions where the climate is influenced by the ocean, and grasslands in drier areas. (Natural Resources Canada, 2020)

Carbon sequestration - The uptake and storage of carbon. Trees and plants, for example, absorb carbon dioxide, release the oxygen and store the carbon. Fossil fuels were at one time biomass and continue to store the carbon until burned. (Natural Resources Canada, 2020)

Carbon sink - A carbon reservoir that absorbs and stores carbon from another part of the carbon cycle. A sink stores more carbon than it emits to the atmosphere. This store of carbon can also be termed a reservoir or pool. Although a growing forest can be considered a carbon sink, when the forest stops

growing and its trees die and start decomposing, it becomes a carbon source, because it emits more carbon than it stores. (Natural Resources Canada, 2020)

Clearcut - An area of forest land from which all merchantable trees have recently been harvested. (Natural Resources Canada, 2020)

Clearcutting - A silvicultural method in which most merchantable trees in a stand are harvested simultaneously, producing a fully exposed microclimate for the development of a new age class. (Natural Resources Canada, 2020)

Climate Crisis - Serious problems that are being caused or likely to be caused by changes in the world's weather, in particular the world getting warmer as a result of human activity increasing the level of carbon dioxide in the atmosphere. (Cambridge University Press, 2022a)

Conifer/ softwood - Member of a group of trees commonly called softwoods or gymnosperms. The word gymnosperm, from the Greek gymnos (naked) and sperma (seed), means "naked-seeded." This refers to the fact that conifer seeds are not contained in fruit tissue. The seeds are instead borne on scales, which are grouped together to form cones. Most conifers have persistent foliage consisting of needles or scales. (Natural Resources Canada, 2020)

Cross-laminated timber (CLT) - Large structural panels made of multiple layers of lumber glued together at right angles to each other. Used in walls, floors and roofs; an alternative to concrete and steel systems. (Natural Resources Canada, 2020)

Crown land - Public land that is managed by the federal or provincial/territorial government. (Natural Resources Canada, 2020)

Deciduous - Member of a group of trees commonly called hardwoods or angiosperms. The latter term comes from the Greek "angion (vessel) + "sperma" (seed), denoting the fact that the seed is carried in a fruit. Deciduous trees shed their leaves in autumn. (Natural Resources Canada, 2020)

Deforestation - Permanent removal of forest cover and withdrawal of land from forest use, whether deliberately or circumstantially. (Natural Resources Canada, 2020)

Dimension lumber - Softwood lumber of standardized sizes that is usually 2 inches thick (e.g., 2x4). Used to frame wood buildings like houses. (Natural Resources Canada, 2020)

Embodied carbon - Embodied carbon means all the CO₂ emitted in producing materials. It's estimated from the energy used to extract and transport raw materials as well as emissions from manufacturing processes. (University College London Engineering, n.d.)

Engineered wood products - A composite wood product made from glued fibre, lumber and/or veneer to meet specific design criteria. (Natural Resources Canada, 2020)

Even-aged (forest) - A forest stand or type in which relatively small age differences exist between individual trees (usually 10–20 years). (Natural Resources Canada, 2020)

Forest (Ecology)- Generally, an ecosystem characterized by a more or less dense and extensive tree cover. More particularly, a plant community predominantly of trees and other woody vegetation, growing more or less closely together. (Natural Resources Canada, 2020)

Forest (FAO UN)- Forests are defined by the Food and Agriculture Organization of the United Nations as “land spanning more than 0.5 ha with trees higher than 5 metres and a canopy cover of more than 10% or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.” (Natural Resources Canada, 2020a, p. 17)

Forest conservation – Refers to a range of activities, tools, and approaches to achieve forest health and biodiversity objectives, including in managed forests where harvesting occurs. (Natural Resources Canada, 2021)

Forest management - That branch of forestry concerned with the overall administrative, economic, legal and social aspects and with the essentially scientific and technical aspects, especially silviculture, protection and forest regulation. (Natural Resources Canada, 2020)

Forest management unit - An area of forest land managed as a unit for fiber production and other renewable resources. This unit can be the entire province or territory, a provincial forest management subdivision, an industrial timber limit, etc. (Natural Resources Canada, 2020)

Forest practices - Any activities that enhance or recover forest growth or harvest yield (e.g., site preparation, planting, thinning, fertilizing, harvesting, etc.), and road construction or reconstruction within forest lands. (Natural Resources Canada, 2020)

Forest protection - Refers to the creation of parks and other areas to legally protect them from industrial activity and to help preserve healthy ecosystems. (Natural Resources Canada, 2021)

Forest sector - The forest sector includes governments, conservation and environmental groups, woodlot owners, Aboriginals, urban forestry interests, lumber and pulp and paper producers and value-added industries, forest-reliant communities, the recreation and tourism industries, and other sectors of the economy (including the energy, chemical, and pharmaceutical industries) that derive wealth and well-being from forest resources. (Natural Resources Canada, 2020)

Forestry - Generally, a profession embracing the science, business, and art of creating, conserving, and managing forests and forest lands for the continuing use of their resources, material or other. (Natural Resources Canada, 2020)

Established (regeneration) - A forest regeneration measurement used to assess whether an area has regenerated successfully in Ontario; if it is established, the regenerating trees meet standards (species composition, height, and site occupancy) and are healthy and free from competing vegetation. (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021)

Glue-laminated timber (Glulam) - A structural product made of multiple pieces of lumber glued together in a desired form. Used in non-residential structural applications, often as part of architectural or aesthetic design. (Natural Resources Canada, 2020)

Hardwood- Trees whose leaves are not persistent and fall off at the end of a defined growing season or during a period of temperature or moisture stress. This is the predominant tree type in deciduous forests. Also refers to the wood produced by these trees. (Natural Resources Canada, 2020)

Indigenous Treaty – Indigenous treaties in Canada are constitutionally recognized agreements between the Crown and Indigenous peoples. Most of these agreements describe exchanges where Indigenous nations agree to share some of their interests in their ancestral lands in return for various payments and promises. On a deeper level, treaties are sometimes understood, particularly by Indigenous people, as sacred covenants between nations that establish a relationship between those for whom Canada is an ancient homeland and those whose family roots lie in other countries. Treaties therefore form the constitutional and moral basis of alliance between Indigenous peoples and Canada. (The Canadian Encyclopedia, n.d.)

Inventory (forest) - A survey of a forest area to determine data such as area, condition, timber, volume, and species for a specific purpose, such as planning, purchasing, evaluating, managing or harvesting. (Natural Resources Canada, 2020)

Life cycle assessment (LCA) – A method of assessing the environmental impacts associated with all stages of a products or building’s life cycle, from raw material extraction through to its processing, manufacture, distribution, use, repair, maintenance, and disposal or recycling. For buildings, this is also referred to as Whole-Building Life Cycle Assessment. (Zizzo, 2022)

Mass timber – Mass timber uses state-of-the-art technology to glue, nail, or dowel wood products together in layers. The results are large structural panels, posts, and beams. These exceptionally strong and versatile products are known as mass timber. (naturallywood, n.d.)

Natural/ Ecological Disturbance - An event or force, of nonbiological or biological origin, that brings about mortality to organisms and changes their spatial patterning in the ecosystems they inhabit. (Encyclopaedia Britannica, n.d.)

Old growth - A stand of mature or overmature trees relatively uninfluenced by human activity. (Natural Resources Canada, 2020)

Old growth forest - An old growth forest differs significantly from younger stands in structure, ecological function and species composition with respect to canopy closure, age class structure, accumulation of woody debris and the presence of species and functional processes that are representative of the potential natural community. (Natural Resources Canada, 2020)

Pest - Any organism, whether insect, pathogen, mammal, or competing vegetation, capable of causing damage to a forest crop. (Natural Resources Canada, 2020)

Plantation forest - Forest stands established by planting and/or seeding in the process of afforestation or reforestation which are either of introduced species (all planted stands) or intensively managed stands of indigenous species, which meet all the following criteria: on or two species at plantation, even age class, regular spacing. (Natural Resources Canada, 2020)

Primary Forest – Naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. (Mackey et al., 2021)

Regeneration - Renewal of a forest crop by natural, artificial, or vegetative (regrowth) means. Also the new crop so obtained. The new crop is generally less than 1.3 m high. (Natural Resources Canada, 2020)

Shelterwood cutting - Any regeneration cutting in a more or less regular and mature crop, designed to establish a new crop under the protection (overhead or side) of the old, or where the resultant crop will be more or less regular. (Natural Resources Canada, 2020)

Silvicultural system - A process that applies silvicultural practices, including tending (thinning, pruning, etc.), harvesting, and replacement, to a stand in order to produce a crop of timber and other forest products. Note: the system is named by the cutting. (Natural Resources Canada, 2020)

Silviculture - The theory and practice of controlling the establishment, composition, growth, and quality of forest stands to achieve the objectives of management. (Natural Resources Canada, 2020)

Softwood/ conifer - Member of a group of trees commonly called softwoods or gymnosperms. The word gymnosperm, from the Greek gymnos (naked) and sperma (seed), means "naked-seeded." This refers to the fact that conifer seeds are not contained in fruit tissue. The seeds are instead borne on scales, which are grouped together to form cones. Most conifers have persistent foliage consisting of needles or scales. (Natural Resources Canada, 2020)

Stand - A community of trees possessing sufficient uniformity in composition, age, arrangement, or condition to be distinguishable from the forest or other growth on adjoining areas, thus forming a silvicultural or management entity. (Natural Resources Canada, 2020)

Structural panel - A wide, flat material used as a load-bearing component in wooden construction (such as floors, wall sheathing, roof sheathing) or to make concrete forms. (Natural Resources Canada, 2020)

Succession - The gradual supplanting of one community of plants by another, the sequence of communities being termed a sere and each stage seral. (Natural Resources Canada, 2020)

Sustainable forest management (SFM) - Management that maintains and enhances the long-term health of forest ecosystems for the benefit of all living things while providing environmental, economic, social and cultural opportunities for present and future generations. (Natural Resources Canada, 2020)

Sustainable forestry - Management of forested area in order to provide wood products in perpetuity, soil and watershed integrity, persistence of most native species and maintenance of highly sensitive species or suitable conditions. (Natural Resources Canada, 2020)

Temperate forest - One of three main forest zones in the world (see also boreal forest, tropical forest). The woodland of rather mild climatic areas; composed mainly of deciduous trees. (Natural Resources Canada, 2020)

Thinning - A partial cutting or spacing operation made in an immature forest stand to accelerate the growth of the remaining trees. (Natural Resources Canada, 2020)

Timber - A general term for forest crops and stands, and sometimes for any lesser aggregation of such trees. (Natural Resources Canada, 2020)

Traditional Ecological Knowledge - Traditional Ecological Knowledge, also called by other names including Indigenous Knowledge or Native Science, (hereafter, TEK) refers to the evolving knowledge acquired by indigenous and local peoples over hundreds or thousands of years through direct contact with the environment. This knowledge is specific to a location and includes the relationships between plants, animals, natural phenomena, landscapes and timing of events that are used for lifeways, including but not limited to hunting, fishing, trapping, agriculture, and forestry. (U.S. Fish & Wildlife Service, Rinkevich, S., Greenwood, K., & Leonetti, C., 2011)

Wilderness – An area of land that has not been used to grow crops or had towns and roads built on it, especially because it is difficult to live in as a result of its extremely cold or hot weather or bad earth. (Cambridge University Press, 2022b)

Glossary References:

Biotechnology Industry Organization (BIO). (n.d.). *Principles for the Accounting of Biogenic Carbon in Product Carbon Footprint (PCF) Standards*. www.bio.org

Cambridge University Press. (2022a). CLIMATE CRISIS | meaning in the Cambridge English Dictionary. In *The Cambridge Dictionary*. <https://dictionary.cambridge.org/dictionary/english/climate-crisis>

Cambridge University Press. (2022). WILDERNESS | meaning in the Cambridge English Dictionary. In *The Cambridge Dictionary*. <https://dictionary.cambridge.org/dictionary/english/wilderness>

Encyclopaedia Britannica. (n.d.). *ecological disturbance*. Retrieved May 3, 2022, from <https://www.britannica.com/science/ecological-disturbance>

Mackey, B., Skinner, E., & Norman, P. (2021). *A REVIEW OF DEFINITIONS, DATA, AND METHODS FOR COUNTRY-LEVEL ASSESSMENT AND REPORTING OF PRIMARY FOREST A Discussion Paper for the Food and Agriculture Organisation of the United Nations March 2021*. www.griffith.edu.au/research/climate-action

Ministry of Northern Development, Mines, Natural Resources and Forestry. (2021). *State of Ontario's Natural Resources - Forest 2021*. Government of Ontario. <https://www.ontario.ca/page/state-ontarios-natural-resources-forest-2021>.

Natural Resources Canada. (2008). *Adapting Sustainable Forest Management to Climate Change: A review of assisted tree migration and its potential role in adapting sustainable forest management to climate change*.

Natural Resources Canada. (2020). *Forestry glossary*. Natural Resources Canada. <https://cfs.NaturalResourcesCanada.gc.ca/terms#wb-auto-4>

Natural Resources Canada. (2020a). *The State of Canada's Forests: Annual Report 2020*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40219>

Natural Resources Canada. (2021). *Conservation and protection of Canada's forests*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/conservation-and-protection-canadas-forests/17501>.

naturallywood. (n.d.). *Mass timber and taller wood construction*. Retrieved April 17, 2022, from <https://www.naturallywood.com/topics/mass-timber/>

Swingland, I. R. (2013). Biodiversity, Definition of. In *Encyclopedia of Biodiversity: Second Edition* (pp. 399–410). Elsevier Inc. <https://doi.org/10.1016/B978-0-12-384719-5.00009-5>

The Cambridge English Dictionary. (n.d.). Cambridge Dictionary. Retrieved April 17, 2022, from <https://dictionary.cambridge.org/dictionary/english/climate-crisis>

The Canadian Encyclopedia. (n.d.). *Treaties with Indigenous Peoples in Canada*. 2022. Retrieved May 3, 2022, from <https://www.thecanadianencyclopedia.ca/en/article/aboriginal-treaties>

U.S. Fish & Wildlife Service, Rinkevich, S., Greenwood, K., & Leonetti, C. (2011). *Traditional Ecological Knowledge for Application by Service Scientists*. <http://www.esa.org/tek/>

University College London. (n.d.). *Embodied Carbon: Factsheet*. Retrieved April 17, 2022, from <https://www.ucl.ac.uk/engineering-exchange/sites/engineering-exchange/files/fact-sheet-embodied-carbon-social-housing.pdf>

Zizzo, R. (2022). Calculating Embodied Carbon in the Built Environment through Life Cycle Assessment (LCA). www.mantledev.com

Sample Questions

1. What are the implications of public ownership of forest lands in Canada?
2. What are the socioeconomic benefits of the forest industry to Canadian society?
3. What are the benefits and limitations of sustainable forest management certification?
4. Describe the controversy about clearcutting. What are the multiple perspectives involved?
5. Compare the perspectives of different stakeholders (government, industry, environmental groups, First Nations) on the efficacy of existing SFM systems in Canada.
6. Describe the threats Canada's forests face and corresponding potential solutions.
7. Is the government and forest industry doing enough to include Indigenous rights and participation within forest management in Canada?
8. What more could the government and forest industry do to increase Indigenous participation in forest management in Canada?
9. What are some opportunities and barriers for Canada's mass timber sector?
10. How does the current climate crisis impact the forests' ability to capture and sequester carbon? Is this set to improve or get worse into the future?
11. What impact does forest loss have on biodiversity? What are the mechanisms at play?
12. Why are woodland caribou important when thinking of forest conservation?
13. Examine and explain the reasons behind tensions among different stakeholders on the topic of old growth forests.
14. Canada is one of the largest global producers of various wood products. What are the benefits and potential drawbacks of this?

Lecture Notes

Slide 2: Canada: A Forest Country

- Canada's forests cover 38% of the country (Natural Resources Canada, 2020, p. 17).
- Canada has 9% of the world's forests (Natural Resources Canada, 2020, p. 17).
 - o Canada forest cover sits 3rd behind Russia and Brazil.
 - o The majority of Canada's forests (77%) are found in the boreal zone while 37% are found in temperate forests (Natural Resources Canada, 2020, p. 17).
 - o Forest area in Canada is stable; since 1990, less than 0.5% of Canada's forests have been deforested or afforested (Natural Resources Canada, 2020, p. 20).
- Forests are home to the majority of Canada's Indigenous peoples (over 1.1 million or 70% according to the 2016 census) (Natural Resources Canada, 2020, p. 47).
- Canada's forests provide vast environmental, social, and economic benefits.
 - o Benefits magnified for rural Canada; many rural and remote communities depend on forestry for jobs and income (Natural Resources Canada, 2020, p. 47).
 - o Benefits include ecosystem services such as flood control, enhanced water and air quality, biodiversity, and soil preservation (Natural Resources Canada, 2020, p. 43).
 - o Forests are critical to the Earth's carbon cycle due to their capacity to sequester large amounts of carbon (Natural Resources Canada, 2020, p. 43).
 - o Forests provide a wide range of wood and other forest products, and social and cultural benefits such as hiking and camping, and hunting and trapping (which are important traditions for many Indigenous communities) (Natural Resources Canada, 2020, p. 43).

Slide 2 References:

Natural Resources Canada. (2020). *The State of Canada's Forests: Annual Report 2020*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40219>

Slide 3: Which Trees are in Canada's Forests?

- Approximately 180 tree species in Canada's forests (Natural Resources Canada, 2021):
 - o 35 tree species are commercially valuable.
 - o None of these is a species at risk.
- 75% of Canada's forests are in the boreal zone:
 - o Forest regions (such as the boreal forest) are areas that have similar dominant tree species; the dominant tree species in the boreal forest include black spruce, white spruce, jack pine, balsam fir, and tamarack (Natural Resources Canada, 2022).

- o The boreal zone circles the Northern Hemisphere and forms a ring around the North Pole; globally, it covers 1.9 billion hectares, which amounts to 14% of the Earth’s land and 33% of Earth’s forested area (Natural Resources Canada, 2020).
- Tree Canada is an exceptionally good resource for identifying the common tree species in Canada (Tree Canada, n.d.).

Slide 3 References:

Natural Resources Canada. (2020). *8 facts about Canada’s boreal forest*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/boreal-forest/8-facts-about-canadas-boreal-forest/17394>.

Natural Resources Canada. (2021). *Forest Maps*. Natural Resources Canada. <https://www.nrcan.gc.ca/maps-tools-and-publications/maps/forest-maps/16874>.

Natural Resources Canada. (2022). *Forest classification*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/measuring-and-reporting/forest-classification/13179>.

Tree Canada. (n.d.). *Trees of Canada – Tree Canada*. Trees of Canada. Retrieved May 10, 2022, from <https://treecanada.ca/resources/trees-of-canada/>

Slide 4 and 5: Canada’s Forest Products

- Canada is a global forest product manufacturing leader and the fourth largest forest product exporter in the world by value as of 2019 (behind China, the United States, and Germany) (Natural Resources Canada, 2020, p. 53).
 - o Of Canada’s total exports, forest products make up 7% with the three largest export destinations being the United States, China, and Japan.
- **Softwood lumber** is timber that is harvested from coniferous trees, which are trees that have cones and needle-like leaves (Natural Resources Canada, 2019).
 - o This lumber is then sawed into a variety of forest products such as dimensional lumber, appearance-grade lumber, and softwood boards.
 - o Dimensional softwood lumber products are mostly used for the framing in residential buildings; therefore, their demand and pricing are closely related to housing construction in the US, which is where 75% of Canada’s softwood lumber goes.
- **Wood pulp** is a wood fibre that has been mechanically or chemically reduced to pulp (Natural Resources Canada, 2019).
 - o Wood pulp is used as an intermediate product that is then used to produce paper products, packaging, and is also used as a food additive and in clothing.

- o The most common wood pulp product produced in Canada is northern bleached softwood kraft pulp (NBSK), which is used to make printing and writing paper, and tissue.
- **Newsprint** is a pulp product made of thermomechanical pulp (Natural Resources Canada, 2019).
 - o It is used to make newspapers, magazines, and similar products.
 - o The market for newsprint has declined with the rise of digital media and is expected to continue declining.
- **Printing and writing paper** is another pulp product that is higher quality than newsprint and is used for a variety of office papers such as for printers, envelopes, forms, and paper pads (Natural Resources Canada, 2019).
 - o Similar to the market decline for newsprint, the same is expected for printing and writing paper as the world becomes more digital.
- **Structural wood panels** include oriented strand board (OSB) and plywood (Natural Resources Canada, 2019).
 - o OSB is made from strands of wood cut from small logs and is used mostly for load-bearing purposes in residential buildings, wall sheathing, flooring, roofing, and to make furniture.
 - o Plywood is made of several thin layers of wood that are glued together and is mostly used to make walls, floors, roof sheathing since it provides strength, stiffness, and stability.

Slide 4 and 5 References:

Natural Resources Canada. (2019). *Forest fact book 2018-2019*. Canadian Forest Service. <https://cfs.nrcan.gc.ca/publications?id=39505>.

Natural Resources Canada. (2020). *The State of Canada's Forests: Annual Report 2020*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40219>.

Slide 6: Canada's Forest Sector is Important for the Economy

- In 2020, 184,510 people were employed by the forest sector in Canada (Natural Resources Canada, 2021, p. 44).
 - o This includes 12,000 Indigenous people (6.5% of Canada's forestry workforce) (Natural Resources Canada, 2021, p. 46).
 - o Although the COVID-19 pandemic and issues such as forest fires, pests, and trade disputes are expected to impact demand for forest products for several years. There are many opportunities for the forestry sector to continue to be a major employer for many communities across Canada, particularly remote and rural communities where few other industries operate (Natural Resources Canada, 2021, p. 44).

- In 2018, the forest sector generated \$1.9 billion in revenue for provincial and territorial governments (Natural Resources Canada, 2020, p. 49).
- In 2020, the forest sector contributed \$25.2 billion (1.2%) to Canada's nominal GDP (Natural Resources Canada, 2021, p. 50).
 - o This is a 4% increase from 2019, while the overall economy contracted by 5.6% during this period (Natural Resources Canada, 2021, p. 50).
 - o Canada's forestry sector's real GDP declined by 1.6% while the total economy's real GDP declined by 5.2% (Natural Resources Canada, 2021, p. 50).
 - o The forest sector benefitted from higher lumber and panel prices, but the pandemic caused an overall decline in real terms due to a slowdown in some operations (Natural Resources Canada, 2021, p. 50).
- In 2019, Canada's forest product exports were valued at \$33 billion (4th largest in the world behind China, the US, and Germany) (Natural Resources Canada, 2020, p. 49-50).
 - o Canada is a global leader in forest product production and over two thirds of these products are exported.
 - o The United States is Canada's largest trading partner and accounted for 68% of Canada's forest product exports in 2019.

Slide 6 References:

Natural Resources Canada. (2020). *The State of Canada's Forests: Annual Report 2020*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40219>.

Natural Resources Canada. (2021). *The State of Canada's Forests: Annual Report 2021*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/state-canadas-forests-report/16496>.

Slide 7: Forest Harvesting

- In 2019, approximately 757,000 hectares of forest were harvested - this is *less than 0.5%* of Canada's forests annually (Natural Resources Canada, 2021, p. 29).
 - o The area harvested each year is significantly less than the areas impacted by insects and forest fires each year (Natural Resources Canada, 2021, p. 29).
 - o The area harvested each year depends on multiple factors such as the demand for Canadian forest products, and forest management decisions in response to pests and forest fires (Natural Resources Canada, 2021, p. 29)
- Harvesting of crown forests is regulated to ensure a sustainable supply of timber (Natural Resources Canada, 2021, p. 29).

Slide 7 References:

Natural Resources Canada. (2021). *The State of Canada's Forests: Annual Report 2021*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/state-canadas-forests-report/16496>.

Slide 8: No Forest Harvesting is Allowed Without Regeneration

Regeneration

- Forest regeneration is the act of growing back the forest after harvesting and is required on all public lands in Canada (Natural Resources Canada, 2020, p. 25).
 - The type of forest regeneration method; artificial or natural regeneration, depends on the forest type, silviculture system, and required composition of the new forest (Natural Resources Canada, 2020, p. 25).
 - Forest regeneration ensures that harvested areas regenerate into forests and continue to provide timber, ecosystem services, and social benefits such as recreation (Natural Resources Canada, 2020, p. 25).
- In 2019, approximately 547 million seedlings were planted on 397,000 hectares of provincial forest land in Canada and 8,600 hectares of forest were established by seeding (Natural Resources Canada, 2021, p. 30).
 - The area regenerated each year is strongly related to the recent area harvested, which is impacted by market factors but is always bound by sustainable forest management laws and regulations (Natural Resources Canada, 2021, p. 30).

Slide 8 References:

Natural Resources Canada. (2020). *The State of Canada's Forests: Annual Report 2020*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40219>.

Natural Resources Canada. (2021). *The State of Canada's Forests: Annual Report 2021*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/state-canadas-forests-report/16496>.

Slide 9: Is Forest Regeneration Successful?

- Independent forest audits occur every 10-12 years for each forest management unit in Ontario. The auditing period differs by province. (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2022; Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021a)
 - o During these audits, auditors assess sustainable forest management, which includes forest regeneration.
 - o An independent auditor assesses the performance of the sustainable forest license holder and the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry in meeting their forest management responsibilities.
 - o Action plans are developed after the audits are done to address the findings made by the auditor.
 - o Independent forest audit reports are publicly accessible and can be viewed here: <https://www.ontario.ca/page/independent-forest-audits>.
 - o Examples of third-party independent auditors in Ontario are KBM Resources Group (<https://kbm.ca/>), Arbex Forest Resource Consultants Ltd. (<http://arbex.ca/>), and ArborVitae Environmental Services Ltd. (<http://www.avesltd.ca/>).
- From 1999 to 2019, the average compliance rate was 94% (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021b).
- It can take 15 or more years for harvested areas to be established (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021b).
- In Ontario, forest managers conduct surveys to assess forest regeneration; successful regeneration is classified as "established", which means that the regenerating trees meet standards (species composition, height, and site occupancy) and are healthy and free from competing vegetation (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021b).

Slide 9 References:

Ministry of Northern Development, Mines, Natural Resources and Forestry. (2021a). *Forest monitoring*. Government of Ontario. <https://www.ontario.ca/page/forest-monitoring>.

Ministry of Northern Development, Mines, Natural Resources and Forestry. (2021b). *State of Ontario's Natural Resources - Forest 2021*. Government of Ontario. <https://www.ontario.ca/page/state-ontarios-natural-resources-forest-2021>.

Ministry of Northern Development, Mines, Natural Resources and Forestry. (2022). *Independent forest audits*. Government of Ontario. <https://www.ontario.ca/page/independent-forest-audits>.

Slide 10: Ownership of Canada's Forests

- **90% of Canada's forests are publicly owned and managed for the public by provincial and territorial governments** (Natural Resources Canada, 2020).
 - Of the forests owned by the government, provinces and territories are responsible for developing and enforcing laws and regulations, setting up timber supply agreements with forestry companies which outline all responsibilities, monitoring forestry activities to ensure compliance with laws and regulations, and collecting royalties.
- **4% of Canada's forests are publicly owned and managed for the public by the federal government** (Natural Resources Canada, 2020).
 - These forests are mostly in national parks, on the Department of National Defence lands, and on reserve lands owned or controlled by Indigenous peoples.
 - There are many federal departments responsible for managing this land and they include Aboriginal Affairs and Northern Development Canada, Department of National Defence, Natural Resources Canada, and Parks Canada.
- Most harvesting in public forests in Canada is done by private forestry companies (Natural Resources Canada, 2020).
 - These companies have an agreement with the provincial or territorial government to supply timber and must comply with laws and regulations.
- **6% of Canada's forests are privately owned** (Natural Resources Canada, 2020).
 - These are mostly large forests owned by forestry companies in New Brunswick, Nova Scotia, Ontario, Quebec, and British Columbia.
 - This category also includes small family-owned forests.
 - Although privately-owned forests constitute a very small proportion of Canada's forests, they contribute substantially to the timber harvested; 10% of all timber harvested in Canada comes from privately owned forests.

Slide 10 References:

Natural Resources Canada. (2020). *Forest land ownership*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/forest-land-ownership/17495>.

Slide 11: Provincial Forest Laws

- Section 92A in the 1982 amendments to the Constitution Act, 1867 gives provinces and territories the power to manage their own forests (Natural Resources Canada, 2017).
- Provinces and territories develop and enforce laws, regulations, and policies related to forests, which ensure that (Natural Resources Canada, 2020):
 - Indigenous interests are considered
 - Wildlife habitat is protected
 - Timber harvesting is regulated
 - Forest regeneration occurs
- Monitoring and enforcement are crucial and include (Natural Resources Canada, 2020):
 - Reporting from forestry companies
 - Audits
 - Investigations of infractions
- Canada has many laws and regulations so that forestry operations only occur in approved areas where there has been adequate and long-term planning (Natural Resources Canada, 2021).

Slide 11 References:

Natural Resources Canada. (2017). *Roles and Responsibilities of Governments in Natural Resources*.

Natural Resources Canada. <https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/earth-sciences-resources/earth-sciences-federal-programs/roles-responsibilities-governments-natural-resources/8882>.

Natural Resources Canada. (2020). *Canada's forest laws*. Natural Resources Canada.

<https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/canadas-forest-laws/17497>.

Natural Resources Canada. (2021). *Legality and sustainability*. Natural Resources Canada.

<https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/canadas-forest-laws/legality-and-sustainability/13303>.

Slide 12: Federal Forest Laws

- Section 91 of the Constitution Act, 1867 gives the federal government the power to manage their forest lands (Natural Resources Canada, 2017).
- Federal laws that apply to these forests include the Indian Act, First Nations Land Management Act, and National Parks Act (Natural Resources Canada, 2020).

- Federal laws and agreements that apply to all forests in Canada include (Natural Resources Canada, 2020):
 - o Laws such as the Species at Risk Act, Fisheries Act, Migratory Birds Convention Act, and Plant Protection Act
 - o International agreements such as the Convention on Biological Diversity and the Convention on International Trade in Endangered Species of Wild Fauna and Flora

Slide 12 References:

Natural Resources Canada. (2017). *Roles and Responsibilities of Governments in Natural Resources*.

Natural Resources Canada. <https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/earth-sciences-resources/earth-sciences-federal-programs/roles-responsibilities-governments-natural-resources/8882>.

Natural Resources Canada. (2020). *Canada's forest laws*. Natural Resources Canada.

<https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/canadas-forest-laws/17497>.

Slide 13: Old Growth Forests

- What is an old growth forest? While there is no one definition of what an old growth forest is as they are very complex and diverse, they are generally known to contain old trees that exist in landscapes relatively undisturbed by humans (USDA – Pacific Northwest Research Station, 2003).
- Old growth forests can differ in age, structure, and disturbance history. They generally have a high amount of diversity both horizontally, and vertically (USDA – Pacific Northwest Research Station, 2003).
- Old growth forests are ecologically important because they hold a tremendous amount of biodiversity, especially those in British Columbia (Moffatt, 2021a).
- There are over 11.1 million ha of old growth forests in British Columbia. In B.C., some of the interior forests are considered to be old growth if the trees they contain are more than 140 years old. (Government of the Province of British Columbia, n.d.).
- The province of British Columbia has committed a new integrated management approach for old growth forests, taking into consideration economic, environmental, and Indigenous reconciliation interests. The goal is to complete this contentious process in 2023 (Government of the Province of British Columbia, n.d.).
- Despite this new approach to old growth management, activists such as Greenpeace maintain that the old growth forests in B.C. are being cut down at an alarming rate (Moffatt, 2021b).

- Indigenous leaders in B.C. have requested that the government put a halt on old growth logging (Moffatt, 2021b).
- Fairy Creek in B.C. is an area of contention as activists are blockading access to the last remaining 5000 or so acres of old growth forest from the logging company Teal Jones (CBC, 2022).
- Old growth protection protests have historic roots going back to the Clayoquot protests which took place in the 1980s and earlier. The current protests are still ongoing tensions from these original protests many decades ago. There are mixed feelings from Indigenous communities who feel they have the right to manage these lands as they see fit. In the past few years, over 1100 people have been arrested against the blockade injunction at Fairy Creek (Hayward, 2021).
- It is not just B.C. forests that are under threat, the boreal is also under threat from logging (Lewis C., Jordan A., 2021).

Slide 13 References:

CBC. (2022). *Court reinstates injunction against Fairy Creek logging protesters* / CBC News. CBC . <https://www.cbc.ca/news/canada/british-columbia/injunction-reinstated-against-fairy-creek-protesters-1.6328496>

Government of the Province of British Columbia. (n.d.). *Old Growth Forests*. Retrieved April 3, 2022, from <https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/old-growth-forests>

Hayward, J. (2021). Second judge to consider stay application in Fairy Creek logging protest case – Victoria News. *Victoria News*. <https://www.vicnews.com/news/second-judge-to-consider-stay-application-of-old-growth-logging-protesters-in-b-c/>

Moffatt, S. (2021a). *How old-growth forests keep falling on B.C. Premier John Horgan's watch*. Greenpeace Canada. <https://www.greenpeace.org/canada/en/story/47756/how-old-growth-forests-keep-falling-on-b-c-premier-john-horgans-watch/>

Moffatt, S. (2021b). *Saving Fairy Creek and Why Ancient Forests are Worth More Standing* - Greenpeace Canada. Greenpeace Canada. <https://www.greenpeace.org/canada/en/story/47068/saving-fairy-creek-and-why-ancient-forests-are-worth-more-standing/>

R. T., Lewis, C., & Jordan, A. (2021). *By a Thousand Cuts: How Powerful Companies' Wood Sourcing is Degrading Canada's Boreal Forest*. www.suerossi.com

USDA - Pacific Northwest Research Station. (2003). New Findings About Old-Growth Forests. *Science Update*, 4. <http://www.fs.fed.us/pnw>

Slide 14: Protecting Biodiversity

- Biodiversity loss is consequential and predicted to worsen in the future (Cardinale et al., 2012).
- Protecting plant and forest biodiversity contributes to climate crisis solutions (Langford et al., 2022).
- Forest fragmentation refers to a loss of forest and the division of the remaining forest into smaller blocks (Riitters, 2007).
- Forest fragmentation occurs when forest habitat is destroyed, leaving smaller isolated patches of forests behind, that are no longer connected as they used to be.
- Forest fragmentation is detrimental because it results from habitat destruction, dividing habitat into smaller fragments that are isolated between a matrix of human influences land (Haddad et al., 2015).
 - The same article maintains that scientists generally agree that fragmentation is detrimental to biodiversity. There is however, still uncertainty in terms of the extent of impact varying levels of fragmentation can have on biodiversity.
- WCS Canada (President and Senior Scientist, Dr. Justina Ray) works to save wildlife in Canada through science, conservation, action, and inspiration (WCS Canada, n.d.)
- The government of Canada has recognized the threat that some forestry practices have on woodland caribou habitat, and is attempting to restore their habitat in the boreal forest (Natural Resources Canada, 2021a)
- Canada is a signatory to the High Ambition Coalition for Nature and People, which is committed to a global goal of protecting at least 30% of the world's lands and oceans by 2030 (Environment and Climate Change Canada, 2020; High Ambition Coalition for Nature and People, n.d.)
 - Canada has almost 24 million hectares of protected forests (mostly in national and provincial parks); this is almost 7% of Canada's total forest area and does not include many millions of additional hectares that are in remote, inaccessible areas (Natural Resources Canada, 2021b)

Slide 14 References:

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., MacE, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. In *Nature* (Vol. 486, Issue 7401, pp. 59–67). Nature Publishing Group. <https://doi.org/10.1038/nature11148>

Environment and Climate Change Canada. (2020). *Canada joins the High Ambition Coalition for Nature and People*. Government of Canada. <https://www.canada.ca/en/environment-climate-change/news/2020/09/canada-joins-the-high-ambition-coalition-for-nature-and-people.html>.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., Collins, C. D., Cook, W. M., Damschen, E. I., Ewers, R. M., Foster, B. L., Jenkins, C. N., King, A. J., Laurance, W. F., Levey, D. J., Margules, C. R., ... Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, 1(2).

<https://doi.org/10.1126/sciadv.1500052>

High Ambition Coalition for Nature and People. (n.d.). *Home*. High Ambition Coalition for Nature and People. <https://www.hacfornatureandpeople.org/home>.

Langsdorf, S., Löschke, S., Möller, V., & Okem, A. (2022). *Climate Change 2022 Impacts, Adaptation and Vulnerability Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. www.ipcc.ch

Natural Resources Canada. (2021a). *Woodland caribou – boreal population*. Government of Canada. <https://www.NaturalResourcesCanada.gc.ca/our-natural-resources/forests/sustainable-forest-management/conservation-and-protection-canadas-forests/woodland-caribou-boreal-population/13201>

Natural Resources Canada. (2021b). *Conservation and protection of Canada's forests*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/conservation-and-protection-canadas-forests/17501>.

Riitters, Kurt H. 2007. Forest Fragmentation. Pages 9-15 In: Forest health monitoring: 2005 national technical report. General Technical Report SRS-104. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

WCS Canada. (n.d.). *Staff*. Retrieved April 4, 2022, from <https://www.wcscanada.org/Staff-all/ProjectId/631.aspx>

Slide 15: Forest Management Planning is Required by Law in Canada

- One of the main tools used to ensure forest sustainability in Canada (Natural Resources Canada, 2020).
 - o Each forestry company is required by law to create a forest management plan, and have it approved by the government before they can begin harvesting.
 - o Forest management planning involves work schedules, 5-20-year approval periods, and is based on long-term plans.
 - o A forest management plan usually covers a period of several years; in Ontario it covers a 10-year period (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021).

- A forest management plan (Natural Resources Canada, 2020):
 - o Provides an assessment of the current state of the forest (inventory), which includes information on the size, number, and species of trees in the forest,
 - o Sets out the management objectives, which must show a commitment to balancing social, environmental, and economic values,

- o Identifies protected areas with non-timber values such as: wildlife habitat, recreation, tourism,
- o Describes the harvesting, regeneration, and other activities to be carried out:
 - Other activities include providing access to timber through the construction of roads and bridges and maintenance to ensure the forest is productive.
 - To guide activities such as roadbuilding and timber harvesting, more detailed plans are also written along with annual operating plans that detail where and when harvesting and regeneration activities will occur.
- There is long-term monitoring of forestry practices to ensure plan adherence (Natural Resources Canada, 2020).
 - o This involves tracking timber that is harvested, ensuring companies meet forest regeneration standards, conducting audits to determine plan adherence and assessing the effectiveness of forest management activities.
 - o Governments also review each forestry company's plans after a certain period of time based on the province.
 - o Forestry companies must submit regular reports on their activities and update their plans in response to changing conditions and objectives; there are penalties such as warnings, fines, and suspension of timber harvesting rights if forestry companies do not comply with forest management plans.
- No plans are approved without public participation (Natural Resources Canada, 2020).
 - o Forest management plans include involvement from Indigenous communities, the public, and stakeholders at many stages.
 - o In many provinces, such as Ontario and British Columbia, forest management plans must be made available to the public for review.
 - Ontario's forest management plans are available here: https://nrip.mnr.gov.on.ca/s/fmp-online?language=en_US.
- Forest science is the foundation of forest management planning (Natural Resources Canada, 2020).
 - o Provincial and territorial governments use the best available science to support forest management planning requirements, practices, and policies.
 - o Research is constantly occurring in Canada's forests to inform sustainable forest management practices.
 - o The Canadian Forest Service, a science-based policy organization that is part of the federal government, provides science and policy expertise on forestry issues; topics under study include climate change, forest fires, and forest pests and diseases (Canadian Forest Service, 2020).

Slide 15 References:

Canadian Forest Service. (2020). *Canadian Forest Service research projects*. Government of Canada. <https://cfs.nrcan.gc.ca/projects>.

Ministry of Northern Development, Mines, Natural Resources and Forestry. (2021). *Forest management planning*. Government of Ontario. <https://www.ontario.ca/page/forest-management-planning>.

Natural Resources Canada. (2020). Forest management planning. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/forestmanagement-planning/17493>.

Slide 16: Silvicultural Systems

- Silviculture (from the Latin *silvi*, which means ‘forest’) is the art and science of growing trees (Ministry of Natural Resources, 2013).
 - o It involves “controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society such as wildlife habitat, timber, water resources, restoration, and recreation on a sustainable basis” (U.S. Forest Service, n.d.).
- A silvicultural system refers to a planned program of treatments that is designed to achieve specific stand structural objectives (Ministry of Forests, 2003).
 - o Treatments include specific harvesting methods, regeneration techniques, and stand tending methods such as thinning.
- The silvicultural systems typically used in Canada are:
 - o **Single tree selection**, which involves the removal of single trees to create small openings that promote the growth and establishment of shade tolerant tree species such as sugar maple (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021).
 - o **Group selection**, which involves the removal of small groups of trees to create openings that promote uneven-aged or multi-cohort stands as the groups of trees are replaced.
 - Group selection can increase tree species diversity as it promotes the regeneration of shade-intolerant species due to the larger canopy gaps along with the regeneration of shade-tolerant species.
 - Group selection may also have other ecological benefits such as the creation of wildlife habitat and increased levels of biodiversity.
 - o **Shelterwood**, which involves the removal of trees in a series of cuts in order to achieve a new stand under the shelter of the remaining trees (Beadle & Sands, 2004).
 - In this system, the remaining trees provide the seed source for the new trees.

- The shelterwood system is suitable for trees that have intermediate shade tolerance (mid-tolerant) (Algonquin Forestry Authority, 2022).
 - This system mimics natural disturbances such as fire, insect outbreaks, and wind storms; in Ontario, the shelterwood system is used to regenerate white pine (Ministry of Natural Resources, 2013).
 - White pine has intermediate shade tolerance and is adapted to a fire regime consisting of surface fires every 20-40 years and stand-replacing fires every 150-300 years.
 - Since Canada does not have a natural fire regime anymore due to fire suppression, the shelterwood system emulates this natural fire regime and allows for the growth and establishment of white pine.
- o **Clearcut**, which involves the removal of the entire stand over a short period of time to create an exposed microenvironment for the establishment of a new even-aged stand (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021).
 - Regeneration then occurs naturally as seedlings and saplings grow or through the planting of new trees.
 - Clearcutting is considered by many to be environmentally harmful, but there are circumstances in which this system is the most suitable.
 - In many natural forests, large levels of tree loss arise from natural disturbance (usually through fire) and are critical for forest regeneration and replacement; clearcutting emulates this kind of natural disturbance and provides opportunities for new trees, particularly those requiring lots of sun, to grow (Ministry of Natural Resources, 2013).
 - Clearcutting is mainly used in stands with tree species that are adapted to regenerating after large natural disturbances such as fires; these species include jack pine, black spruce, poplar, and white birch (Ministry of Natural Resources, 2013).
 - Clearcutting also provides wildlife habitat for species that prefer young forests such as moose (Ministry of Natural Resources, 2013).
- Silvicultural system selection depends on the condition of the forest stand such as the species' shade tolerance, natural disturbance regime, moisture needs, and the desired future state of the forest (Ministry of Natural Resources, 2013).
- Silvicultural research by Natural Resources Canada and its partners is underway to identify strategies to lower production costs, increase the volume and quality of timber, while ensuring forest sustainability (Natural Resources Canada, 2020).
- Data on the area harvested in Canada by silvicultural system is available in the National Forestry Database (Canadian Council of Forest Ministers, 2022).

Slide 16 References:

Algonquin Forestry Authority. (2022). *Silvicultural Systems: Even-Aged — Shelterwood*. Algonquin Forestry Authority. <https://algonquinforestry.on.ca/policy-planning-sustainable-forest-management-policy/silvicultural-systems-even-aged-shelterwood/>.

Beadle, C., & Sands, R. (2004). Tree Physiology: Physiology and silviculture. *Encyclopedia of Forest Sciences*, 1568–1577. <https://doi.org/10.1016/b0-12-145160-7/00097-1>.

Canadian Council of Forest Ministers. (2022). *Harvest | National Forestry Database*. National Forestry Database. <http://nfdp.ccfm.org/en/data/harvest.php>

Ministry of Forests. (2003). *Silvicultural Systems Handbook for British Columbia*. Government of British Columbia. <http://www.for.gov.bc.ca/HFP/Pubssilvsystems.htm>.

Ministry of Natural Resources. (2013). *Emulating natural disturbances: clearcut silviculture in Ontario*. Government of Ontario. <https://dr6j45jk9xcmk.cloudfront.net/documents/3123/stdprod-110056.pdf>.

Ministry of Northern Development, Mines, Natural Resources and Forestry. (2021). *Forest Management Guide to Silviculture in the Great Lakes-St. Lawrence and Boreal Forests of Ontario*. Government of Ontario. <https://www.ontario.ca/page/forest-management-guide-silviculture-great-lakes-st-lawrence-and-boreal-forests-ontario>.

Natural Resources Canada. (2020). *Silvicultural research*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/industry-and-trade/forest-industry-tools-research/silvicultural-research/13341>

U.S. Forest Service. (n.d.). *Silviculture*. U.S. Forest Service. <https://www.fs.fed.us/forestmanagement/vegetation-management/silviculture/index.shtml>.

Slide 17: Causes of Deforestation

- Deforestation refers to the permanent removal of forested land to other uses such as agriculture or urban sprawl (Government of Canada, 2020).
- Timber harvesting and natural disturbances such as forest fires, which lead to forest cover change, are not considered deforestation since the area is replanted or regenerates naturally, which renews the forest.
- Canada has a very low deforestation rate at less than 0.5% each year between 1990 to 2018 (Natural Resources Canada, 2020, p. 20).
 - o The large increases in deforestation during the years 1993 and 2006 were caused by the flooding of forests during the development of hydroelectric reservoirs (Natural Resources Canada, 2020, p. 20).

- The industries that cause the most deforestation in Canada are the mining, oil, and gas, and agriculture industries (Natural Resources Canada, 2020, p. 20).
- Canada has the National Deforestation Monitoring System (NDMS), which is one of the world's most sophisticated systems to track land use changes from forest to other land uses such as agriculture or urban development (Dyk et al., 2015).
- The extent of Canada's deforestation has been challenged by environmental groups.
 - o A notable example is a study done by the Wildlands League; a Canadian not-for-profit charity dedicated to nature conservation:
 - This study argues that deforestation in Canada is higher than reported due to "logging scars," which refer to the loss of productive forest from clearcutting forests in Ontario (Wildlands League, 2020).

Slide 17 References:

Dyk, A., Leckie, D. G., Tinis, S., & Ortlepp, S. M. (2015). *Canada's National Deforestation Monitoring System: System Description*. National Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=36042>.

Government of Canada. (2020). *Deforestation*. Government of Canada. <https://www.canada.ca/en/services/environment/natural-resources/forests/deforestation.html>.

Natural Resources Canada. (2020). *The State of Canada's Forests: Annual Report 2020*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40219>.

Wildlands League. (2020). *Logging Scars Report*. Logging Scars: Wildlands League. <https://loggingscars.ca/report/>.

Slide 18: What is Forest Certification?

- Forest certification, which is performed by third-party independent auditors, is the public's source of info to assess the sustainability of forestry operations (Natural Resources Canada, 2021a).
 - o Forest certification is in addition to the laws and regulations surrounding forest management in Canada and provide additional assurance that a forest company is operating sustainably (Natural Resources Canada, 2021a).
 - o Forest certification emerged in the 1990s and was adopted quickly across Canada (Natural Resources Canada, 2021a).
 - o Forest certification allows consumers to consider this in their purchasing decisions and forestry companies can use it to show their commitment to sustainability (Natural Resources Canada, 2021a).

- o Forest certification can also help improve forestry practices globally as consumer demand for certified wood increases (Natural Resources Canada, 2021a).
- o Some of the assurances that forest certification provides are sustainable harvesting plans, wildlife habitat protection, soil quality maintenance, and ensuring that no illegal logging is occurring (Forest Products Association of Canada, 2020).
- In 2020, more than 75% of Canada’s managed forests were certified (Natural Resources Canada, 2021a).
 - o Globally, this represents 36% of all certified forests; this means that Canada has the largest area of independently certified forests of any nation (Natural Resources Canada, 2021a).
- Some environmental advocates call for improvements to forest certification:
 - o Greenpeace, an independent global campaigning network dedicated to environmental protection, published a report called “Destruction: Certified”, which evaluates the effectiveness of numerous certification programs and describes the limitations of forest certification (Greenpeace International, 2021).
 - o A coalition of Canada environmental groups (Ecojustice, Stand.earth, and the Ancient Forest Alliance) have filed an investigation request into the Canadian Standards Association for false sustainable labelling of wood from British Columbia (Baker, 2021).

Slide 18 References:

Baker, R. (2021, July 21). Green coalition challenges certification claims that Canada’s forestry products are sustainable. *Canada’s National Observer*. <https://www.nationalobserver.com/2021/07/21/news/green-coalition-challenges-certification-claims-canadas-forestry-products>.

Forest Products Association of Canada. (2020). *Forest certification in Canada: The Programs, Similarities & Achievements*. FPAC. <https://www.fpac.ca/reports/forest-certification-in-canada-the-programs-similarities-achievements>.

Greenpeace International. (2021). *Destruction: Certified*. Greenpeace. https://www.greenpeace.org/static/planet4-international-stateless/2021/04/b1e486be-greenpeace-international-report-destruction-certified_finaloptimised.pdf.

Natural Resources Canada. (2021a). *Forest certification in Canada*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/forest-certification-canada/17474>.

Slide 19: Canada's Certification Systems

- The two largest forest certification systems in Canada are:
 - **Forest Stewardship Council (FSC)**
 - Initially supported by environmental organizations
 - **Sustainable Forestry Initiative (SFI)**
 - Developed by the forest industry
- The standards used to evaluate forest operations for sustainability are constantly updated to reflect current knowledge and concerns about sustainable forest management (Forest Products Association of Canada, 2020).
- The Woodworkers Alliance for Rainforest Protection, a coalition of woodworkers, wood importers, and ecologists advocating for the end of tropical deforestation and illegal logging, developed the idea of forest certification in the early 1990s (Rotherham, 2016).
 - After environmental organizations like the World Wildlife Fund (WWF) began advocating for forest certification, the Forest Stewardship Council (FSC) was established (Rotherham, 2016).
 - Forest managers have adopted FSC certification in response to market pressures; a core group of environmental non-profit organizations have encouraged consumers to only purchase and use FSC-certified products (Rotherham, 2016).
- FSC was established in 1993 and is globally popular (Forest Stewardship Council, n.d.).
 - It is considered the most robust forest certification system by many environmental organizations such as the World Wildlife Fund and Greenpeace, who helped establish it (Rotherham, 2016).
 - It is also considered the most prescriptive and comprehensive forest certification system in Canada (Forest Stewardship Council, n.d.).
- SFI was established in 1993 by the forest industry (American Forest and Paper Association) as a less prescriptive alternative to FSC (Sustainable Forestry Initiative, n.d.).
 - Currently, SFI is independently managed and has more rigorous standards than when it was established (Sustainable Forestry Initiative, n.d.).
 - SFI only operates in North America.
- FSC International is one of two international forest certification programs; the other is the Programme for the Endorsement of Forest Certification (PEFC).
 - The common objective of both (FSC and PEFC) is to improve forest management and provide assurance to the public and customers that forest products come from sustainably managed forests and not from illegal operations (Natural Resources Canada, 2021).
- Another forest certification system that is used in Canada, but to a much smaller degree, is the Canadian Standards Association (CSA) (Natural Resources Canada, 2021).

- o It accounts for 7% of certified forests in Canada and its standards are heavily dependent on local conditions (Forest Products Association of Canada, n.d.; Canadian Sustainable Forest Management, n.d.).
 - o The first CSA sustainable forest management standard was published in 1996, with new editions published in 2002, 2008, and 2016.
- Although all forest certification programs have similar goals related to sustainable forestry, they differ in their comprehensiveness and prescriptiveness (Gutierrez Garzon et al., 2020).

Slide 19 References:

Canadian Sustainable Forest Management. (n.d.). *Forests Certified to CSA: your assurance of Canada's highest standard*. Canadian Standards Association. <https://www.csasfmforests.ca/default.htm>.

Forest Products Association of Canada. (2020). *Forest certification in Canada: The Programs, Similarities & Achievements*. FPAC. <https://www.fpac.ca/reports/forest-certification-in-canada-the-programs-similarities-achievements>.

Forest Products Association of Canada. (n.d.). *Canadian Statistics*. Certification Canada. <https://certificationcanada.org/en/statistics/canadian-statistics/>.

Forest Stewardship Council. (n.d.). *Home page*. Forest Stewardship Council. <https://ca.fsc.org/ca-en>.

Gutierrez Garzon, A. R., Bettinger, P., Siry, J., Abrams, J., Cieszewski, C., Boston, K., Mei, B., Zengin, H., & Yeşil, A. (2020). A comparative analysis of five forest certification programs. *Forests*, *11*, 863, 1-12. doi:10.3390/f11080863.

Natural Resources Canada. (2021). *Forest certification in Canada*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/forest-certification-canada/17474>.

Rotherham, T. (2016). Forest Management Certification in Canada and around the world. *The Forestry Chronicle*, *92*(02), 142–146. <https://doi.org/10.5558/tfc2016-031>

Sustainable Forestry Initiative. (n.d.). *Home page*. Sustainable Forestry Initiative. <https://forests.org/>.

Slide 20: Natural Disturbance is in the Life Cycle of Forests

- Disturbance, such as forest fires, insect outbreaks, and disease have regenerated forests for thousands of years, and are part of the natural forest cycle (Natural Resources Canada, 2022).
 - o Disturbance removes old and unhealthy trees, helps cycle nutrients, and creates dead wood, which becomes food and habitat for plants and animals, and helps new trees to grow (Natural Resources Canada, 2022).

- Fire, insect outbreaks, and other natural disturbances have a much larger impact on forests than harvesting does.
 - In 2020, approximately 19 million hectares were impacted by fire, insects, and disease; this is almost 25 times the area harvested by the forest sector (Forest Products Association of Canada, 2021).

- The boreal forest requires natural disturbances such as forest fires, and insect and disease outbreaks (Natural Resources Canada, 2010).
 - Disturbance often occurs on a larger scale there compared to other forests in Canada such as temperate forests (Natural Resources Canada, 2022).
 - Large insect outbreaks and diseases help to renew the forest by killing sick and ageing trees; this reduces competition among trees and can help make forests more productive (Natural Resources Canada, 2022).
 - Fires release valuable nutrients stored in the leaf layer on the forest floor and open the canopy to allow sunlight to enter, which helps new trees grow.
 - Fire also allows fire-adapted tree species such as jack pine and lodgepole pine to regenerate by opening their cones and releasing their seeds; these tree species have serotinous cones which are covered in resin and require high temperatures to melt them and allow the cones to open and release the seeds (Natural Resources Canada, 2022).

- Disturbance gives way to succession, which shapes landscapes by producing a variety of forest types with trees of different ages and species; this contributes to biodiversity (Natural Resources Canada, 2020a, p. 31).

- Research is ongoing to better understand how Canada’s forests respond to disturbance and how to use this information to improve forest management practices to maintain healthy forests (Natural Resources Canada, 2020b).

Slide 20 References:

Forest Products Association of Canada. (2021). *Fire, Pests & Disease*. Forestry for the future. <https://www.forestryforthefuture.ca/topics/fire-pest-disease>.

Natural Resources Canada. (2010, November 25). *Natural Disturbances in Canada's Boreal Forest* [Video]. Youtube. <https://www.youtube.com/watch?v=bH1yAOhlmnE>.

Natural Resources Canada. (2020a). *The State of Canada’s Forests: Annual Report 2020*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40219>.

Natural Resources Canada. (2020b). *Forest management and natural disturbances research*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/wildland-fires-insects-disturbances/forest-management-and-natural-disturbances-research/13187>.

Natural Resources Canada. (2022). *Why forests need fires, insects and diseases*. Natural Resources Canada. <https://www.nrcan.gc.ca/our-natural-resources/forests/wildland-fires-insects-disturbances/why-forests-need-fires-insects-and-diseases/13081>.

Slide 21: The Climate Crisis is Increasing the Frequency and Intensity of Natural Disturbance

- Fires, insect outbreaks, and disease are becoming more frequent and severe due to climate change (Natural Resources Canada, 2020a).
 - Studies show that fire activity is increasing in Canada's forests (Flannigan et al., 2015; Kelly et al., 2013).
- This puts communities and forests at risk and releases large amounts of CO₂ into the atmosphere.
 - Large wildfires such as the one in Fort McMurray, AB in 2016 and Parry Sound, ON in 2018 led to large community evacuations and damage to property (Snowdon, 2017; Roy, 2018).
- Forest management practices to help forests adapt to climate change are being explored (Natural Resources Canada, 2020b; Natural Resources Canada, 2021).
 - For instance, the sector is exploring the use of assisted tree migration, which involves the human-assisted movement of trees to areas that are more climatically suitable (Natural Resources Canada, 2020c).

Slide 21 References:

Flannigan, M. D., Wotton, B. M., Marshall, G. A., de Groot, W. J., Johnston, J., Jurko, N., & Cantin, A. S. (2015). Fuel moisture sensitivity to temperature and precipitation: Climate change implications. *Climatic Change*, 134(1-2), 59–71. <https://doi.org/10.1007/s10584-015-1521-0>

Kelly, R., Chipman, M. L., Higuera, P. E., Stefanova, I., Brubaker, L. B., & Hu, F. S. (2013). Recent burning of boreal forests exceeds fire regime limits of the past 10,000 years. *Proceedings of the National Academy of Sciences*, 110(32), 13055–13060. <https://doi.org/10.1073/pnas.1305069110>

Natural Resources Canada. (2020a). *Impacts*. Natural Resources Canada. <https://www.nrcan.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/climate-change-impacts-forests/impacts/13095>.

Natural Resources Canada. (2020b). *Adaptation*. Natural Resources Canada. <https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/adaptation/13099>.

Natural Resources Canada. (2020c). *Assisted migration*. Natural Resources Canada. <https://www.nrcan.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/climate-change-impacts-forests/adaptation/assisted-migration/13121>.

Natural Resources Canada. (2021). *Forest Change adaptation tools*. Natural Resources Canada. <https://www.nrcan.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/climate-change-impacts-forests/forest-change-adaptation-tools/17770>.

Roy, G. (2018, August 6). Forest fires like ones in Ontario can take long-term environmental toll, experts say. *Global News*. <https://globalnews.ca/news/4372835/forest-fires-environmental-impact/>.

Snowdon, W. (2017, January 17). Fort McMurray wildfire costs to reach almost \$9B, new report says. *CBC*. <https://www.cbc.ca/news/canada/edmonton/fort-mcmurray-wildfire-costs-to-reach-almost-9b-new-report-says-1.3939953>.

Slide 22: Forests Capture and Store Carbon

- Carbon Storage and sequestration of forests:
 - Forests help maintain the earth's carbon balance through carbon fluxes. This is the exchange of carbon from tree biomass (leaves, wood) and soils to and from the atmosphere. This is especially important in the current climate crisis as atmospheric carbon dioxide is known as a contributor to global warming cascading to adverse climatic events.
 - Carbon sequestration is known as the process by which atmospheric carbon dioxide is consumed through photosynthesis by plants, and used to create biomass such as leaves, wood, roots, and soils (United States Department of Agriculture (USDA) Forest Service, n.d.).
 - Forests have absorbed 25% of the carbon emitted by human activities in the past four decades (Natural Resources Canada, 2022).
 - A broad overview of forest carbon sequestration is described by Kananaskis (2017). The report states that Canada's boreal forests and peatlands store large amounts of carbon. The report also maintains that peatland contains a large amount of carbon, however the carbon flux in the peatlands has been historically low as this carbon is in a sense, locked into the ground (Kananaskis, 2017).
 - The boreal and temperate forests in Canada are some of the world's most important carbon sinks. Scientists are calling on Trudeau to protect these important resources (Labbe, 2022).

- The role of soils in carbon storage:
 - Soil also holds a significant amount of carbon in Canada (Saxifrage, 2022)
 - Hudson and James Bay lowlands are important carbon storage areas due to their carbon dense peatlands (Martin, 2022).

Slide 22 References:

Kananaskis, A. (2017). *Forest Carbon sequestration and avoided emissions*. www.ivey.org

Labbe, S. (2022). *90 scientists call on Trudeau to protect forests ahead of climate plan - Victoria Times Colonist*. Times Colonist. <https://www.timescolonist.com/local-news/logging-threatens-critical-lifeline-to-fend-off-climate-crisis-scientists-warn-trudeau-5192011>

Martin, C. (2022). *Digging into soil carbon: How the ground under our feet can help fight climate change*. World Wildlife Fund. <https://wwf.ca/stories/what-is-soil-carbon-climate-change/>

Natural Resources Canada. (2022.). *Forest carbon*. Retrieved March 31, 2022, from <https://www.NaturalResourcesCanada.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/climate-change-impacts-forests/forest-carbon/13085>

Saxifrage, B. (n.d.). *How B.C.'s forests became a carbon-spewing liability | Canada's National Observer: News & Analysis*. Retrieved March 31, 2022, from <https://www.nationalobserver.com/2022/03/04/analysis/how-bcs-forest-became-carbon-spewing-liability>

United States Department of Agriculture (USDA) Forest Service. (n.d.). *Carbon Sequestration*. Retrieved April 3, 2022, from <https://www.fs.fed.us/ecosystemservices/carbon.shtml>

Slide 23: Factors Impacting Forest Carbon Storage:

- Climate change is resulting in more intense and frequent wildfires, droughts and insect infestations (Kananaskis, 2017., Walker et al., 2019)
- As a result, some forests in British Columbia that have been carbon sinks in the past, are now transitioning to becoming carbon sources (Saxifrage, 2022).
- Canada has an obligation under the United National Framework Convention on Climate Change (<https://unfccc.int/>) to monitor and report the GHG emissions and changes in the carbon stock of its forests (Natural Resources Canada, 2022d).

Monitoring Carbon fluxes:

- The Canadian Forest Service (CFS) uses the National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) to monitor carbon.
- This reporting occurs annually.
- Within this, the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) is used.
- This model estimates that Canada's managed forests have been a sink for the past 70 years (Kananaskis, 2017).

- One report points out the loopholes behind the carbon accounting present in Canada’s logging industry (Skene et al., 2021).
 - Background information for this report can be found in the report (Bramley et al., 2021).

Factors impacting carbon storage:

- There are many factors impacting the levels of carbon stored in forests including:
 - Growth, decomposition, disturbances (fire, and insects), harvesting and land-use changes.
 - There has already been an increase in fire severity and pest infestations such as the Mountain Pine Beetle in British Columbia and Alberta. This leads to forests acting more as carbon sources rather than sinks as high levels of pest infestation causes high tree mortality, and decreases overall forest health.
 - While it is known that young trees sequester more carbon than old trees, it is relatively well understood that converting old-growth forests (topic covered in slide 13) to young forests does not decrease atmospheric carbon dioxide (Harmon et al., 1990., Kananaskis, 2017).

The potential of carbon sequestration by forests:

- Tree planting in understocked areas has the potential to increase carbon sequestration capacity of forests in the United States (Domke et al., 2020). In addition, tree planting in previously forested sites has the greatest potential to mitigate emissions compared to afforestation (Waring et al., 2020).
- One study found that natural forests store more carbon than plantation forests, because of an increased complexity and storage of carbon in the soil and forest floor. The same study by Waring et al (2020) also found that the planting location matters as well as the type of species planted, and the fate of the wood that is produced from these forests (Waring et al., 2020).
- Carbon capture can be enhanced through forest management. For example: removing dying and diseased trees can enhance carbon uptake by growing trees.

Slide 23 References:

Bramley, M. J., Advisor, S., & Canada, N. (2021). *Canada’s Approach to Forest Carbon Quantification and Accounting: Key Concerns*.

Harmon, M. E., Ferrell, W. K., & Franklin, J. F. (1990). Effects on Carbon Storage of Conversion of Old-Growth Forests to Young Forests. In *New Series* (Vol. 9, Issue 4943).

Kananaskis, A. (2017). *Forest Carbon sequestration and avoided emissions*. www.ivey.org

Natural Resources Canada. (2022d.). *Forest carbon*. Retrieved March 31, 2022, from <https://www.NaturalResourcesCanada.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/climate-change-impacts-forests/forest-carbon/13085>

Saxifrage, B. (n.d.). *How B.C.'s forests became a carbon-spewing liability* | *Canada's National Observer: News & Analysis*. Retrieved March 31, 2022, from <https://www.nationalobserver.com/2022/03/04/analysis/how-bcs-forest-became-carbon-spewing-liability>

Skene, J., Polanyi, M., Pruess, E., Weingart, T., Ng, J., Walsh, K., Spacher, A., Vinyard, S., Lewis, C., Jordan, A., Barratt-Brown, L., Axelrod, J., Stashwick, S., Boan, J., Connolly, M., Sumner, J., Hesselink, T., & Desmarais, M.-È. (2021). *Missing the Forest: How Carbon Loopholes for Logging Hinder Canada's Climate Leadership*. www.suerossi.com

Walker, X. J., Baltzer, J. L., Cumming, S. G., Day, N. J., Ebert, C., Goetz, S., Johnstone, J. F., Potter, S., Rogers, B. M., Schuur, E. A. G., Turetsky, M. R., & Mack, M. C. (2019). Increasing wildfires threaten historic carbon sink of boreal forest soils. *Nature*, 572(7770), 520–523. <https://doi.org/10.1038/s41586-019-1474-y>

Waring, B., Neumann, M., Prentice, I. C., Adams, M., Smith, P., & Siegert, M. (2020). Forests and Decarbonization – Roles of Natural and Planted Forests. *Frontiers in Forests and Global Change*, 3. <https://doi.org/10.3389/ffgc.2020.00058>

Slide 24: Indigenous Participation in Forestry:

Overview of Indigenous Participation in Forestry:

- There is a long history and progress to be made on the topic of truth and reconciliation with respect to Indigenous communities in Canada, including within the forest industry.
- One study found an underrepresentation of diverse groups (including Indigenous communities) on community forest boards, and forest-sector advisory committees (Egunyu et al., 2020).
- More information about Indigenous Peoples' rights in Canada can be found in Henderson & Bell (2020) (Henderson & Bell, 2020).
- The unique ecological knowledge of Indigenous Peoples is recognized. Traditional Ecological Knowledge can be defined as “the culturally and spiritually based way in which Indigenous people relate to their ecosystem” (Natural Resources Canada, 1999).
- Parks Canada recognizes the importance of Indigenous knowledge and has engaged in many partnerships with Indigenous communities (Parks Canada, n.d.).
- As the first stewards of the forest in Canada, Indigenous communities have extensive knowledge and experience when it comes to forest management. Many industry leaders and conservation authorities recognize the role of Indigenous communities in moving towards a more sustainable future. Organizations such as the Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), Natural Resources Canada (NRCAN), Forest Products Association of Canada (FPAC), Canadian Council of Forest Ministers (CCFM), and the Ontario Professional Foresters Association (OPFA), recognize the need to respect Indigenous communities in forestry in terms of their knowledge and best practices, and also in sharing economic benefits that come from forest management (CCFM, 2022; Forest Products Association of Canada, 2021; Forest

Stewardship Council, n.d.; Natural Resources Canada, n.d.; Ontario Professional Foresters Association, 2018; Parks Canada, n.d.; Sustainable Forestry Initiative (SFI), n.d.).

- More than 70% of Indigenous people's live near forests (Canadian Council of Forest Ministers (CCFM), 2022).
- The history of Indigenous people is closely tied in with the forest.
- It is also important to note that Indigenous peoples are not simply stakeholders of forest management, but they hold important rights in terms of forest land that is stated in the Canadian constitution (National Aboriginal Forest Association, 2020)
- Ontario for example has been committed to increasing the inclusion of Indigenous communities in forest management planning. The Forest Management Planning Manual (FMPM) allows First Nation and Metis communities some flexibility in terms of how they can be involved in developing a forest management plan. This is done in consultation with the Ministry of Natural Resources. (Ministry of Natural Resources, 2017)
- The Government of Canada provides funding opportunities for Indigenous Communities in Forestry through their Indigenous Forestry Initiative (Natural Resources Canada, 2022).
- Indigenous communities in Canada have a sacred relationship with Woodland Caribou (Smith, 2015).

Relevant Indigenous Communities

- Some current partnerships that involve Indigenous communities include:
- British Columbia Community Forest Association comprises 100 Indigenous communities (British Columbia Community Forest Association, n.d.)
- Whitefeather Forest Initiative operating under a forest tenure (Whitefeather Forest Management Corporation, n.d.)
- A full list can be found in the NAFA report (National Aboriginal Forest Association, 2020).
- As a result of extensive industrial activity occurring in the Grassy Narrows First Nations territory, the community has banned logging in certain areas (Prokopchuk, 2018).

Other Indigenous Resources:

1. The Government of Canada's Principles respecting their relationship with Indigenous peoples (Department of Justice Canada, 2018).
2. Publication describing the Indian Act and Aboriginal Governance in Canada (Coates, 2008).
3. More information about Traditional Ecological Knowledge and its application towards scientific research (U.S. Fish & Wildlife Service et al., 2011).

4. More information about Truth and Reconciliation in Canada (Crown-Indigenous Relations and Northern Affairs Canada, 2021).
5. A description of the political, cultural, environmental, and economic implications of forest use in Canada among Aboriginal people (Tindall et al., 2013).
6. Information regarding Aboriginal Forestry issues in Canada (NAFA, n.d.).

Slide 24 References:

Canadian Council of Forest Ministers (CCFM). (2022). *Indigenous Peoples and forests*. <https://www.ccfm.org/canadians-and-communities/indigenous-peoples-and-forests/>

Canadian Journal of Forest Research, 50(11), 1152–1159. <https://doi.org/10.1139/cjfr-2020-0026>

Coates, K. (2008). *The Indian Act and the Future of Aboriginal Governance in Canada*. http://laws.justice.gc.ca/en/showdoc/cs/I-5/bo-ga:s_5/en#anchorbo-ga:s_5.

Crown-Indigenous Relations and Northern Affairs Canada. (2021). *Truth and Reconciliation Commission of Canada*. <https://www.rcaanc-cirnac.gc.ca/eng/1450124405592/1529106060525>

Department of Justice Canada. (2018). *Principles respecting the Government of Canada's relationship with Indigenous peoples*. <https://www.justice.gc.ca/eng/csj-sjc/principles-principes.html>

Egunyu, F., Reed, M. G., Sinclair, A. J., Parkins, J. R., & Robson, J. P. (2020). Public engagement in forest governance in Canada: Whose values are being represented anyway?

Forest Products Association of Canada (FPAC). (2021). *Indigenous Partnerships | Forestry For The Future*. <https://www.forestryforthefuture.ca/topics/indigenous-partnerships>

Forest Stewardship Council. (n.d.). *Home Page | Forest Stewardship Council*. Retrieved July 28, 2022, from <https://fsc.org/en>

Henderson, Wi. B., & Bell, C. (2020). *Rights of Indigenous Peoples in Canada*. The Canadian Encyclopedia. <https://www.thecanadianencyclopedia.ca/en/article/aboriginal-rights>

Ministry of Natural Resources and Forestry. (2017). *Forest Management Planning Manual*. www.serviceontario.ca/publications

NAFA. (n.d.). *The Resource Centre for Aboriginal Forestry Issues in Canada*. Retrieved May 9, 2022, from http://nafaforestry.org/forest_home/about.html

National Aboriginal Forest Association. (2020). *Fifth Report on Indigenous-Held Forest Tenures in Canada 2020*.

Natural Resources Canada. (1999). *Traditional Ecological Knowledge within the Government of Canada's First Nation Forestry Program*. <https://cfs.NaturalResourcesCanada.gc.ca/pubwarehouse/pdfs/10458.pdf>

Natural Resources Canada. (2022). *Indigenous Forestry Initiative*. Retrieved April 3, 2022, from <https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/forest-sector-funding-programs/indigenous-forestry-initiative/13125>

Ontario Professional Foresters Association. (2018, March). Indigenous Peoples, Lands, and Resources. *The Professional Forester - Issue 229*, 20–20. www.opfa.ca

Parks Canada. (n.d.). *Indigenous leadership in conservation - Science and Conservation*. Retrieved April 3, 2022, from <https://www.pc.gc.ca/en/nature/science/autochtones-indigenous>

Prokopchuk, Ma. (2018). *Grassy Narrows declares logging ban in its territory ahead of forest management planning*. CBC News. <https://www.cbc.ca/news/canada/thunder-bay/grassy-narrows-logging-ban-1.4856870>

Smith, P. (2015). A Reflection on First Nations in their Boreal Homelands in Ontario: Between a Rock and a Caribou. *Conservation and Society*, 13(1), 23–38. <https://doi.org/10.4103/0972-4923.161214>

Sustainable Forestry Initiative (SFI). (n.d.). *Indigenous Relations*. Retrieved April 3, 2022, from <https://forests.org/indigenous/>

Tindall, D. B., Trospen, L. R., & Perreault, P. (2013). *Aboriginal Peoples and Forest Lands in Canada* (L. R. Trospen, D. B. Tindall, & P. Perreault, Eds.). UBC Press.

U.S. Fish & Wildlife Service, Rinkevich, S., Greenwood, K., & Leonetti, C. (2011). *Traditional Ecological Knowledge for Application by Service Scientists*. <http://www.esa.org/tek/>

Slide 25: Indigenous Communities and Forests:

- Indigenous communities have been managing Canadian forests and some forests in the United States for generations through dynamics such as cultural burning (Manke, 2022., Schelenz, 2022).
- A description of the Indian Act in Canada and the future of Aboriginal governance in Canada can be found in Coates (2008) (Coates, 2008).
- Keith Thor Carlson is an ethnohistorian focusing on Indigenous history in Western Canada and Northwestern United States. These resources can be found here (Carlson, n.d.).
- The Pikangikum First Nation who steward the Whitefeather Forest reached an agreement with the Ontario Ministry of Natural Resources to create a management plan that reflects their values (MNDMNRF, 2021., Pikangikum First Nation, 2006).
- There is sometimes contention between the self-governance rights of Indigenous communities and the objectives of environmental organizations and NGO's (Bullock et al., 2020).
- One example of an Indigenous led forestry company is Wincrief Forestry Products (Wincrief Forest Products, n.d.).

- Indigenous Communities have historically used fire as a forest management practice (Wheelock, 2022).

Other References:

1. Links to Aboriginal forestry in Canada (Canadian Forests, 2022).
2. Centre for Indigenous Environmental Resources (CIER, n.d.).
3. Indigenous held forest tenures in Canada (National Aboriginal Forest Association, 2020).
4. Grassy Narrows logging ban (Prokopchuk, 2018).
5. The British Columbia Community Forest Association provides resources to aid community forestry within Indigenous Communities (British Columbia Community Forest Association, n.d.).
6. Whitefeather forest management initiative website (Whitefeather Forest management Corporation, n.d.).
7. Dr. Carlson is the Research Chair in Indigenous Community-Engaged History at the University of Saskatchewan. There are some excerpts of his work included in publications (Carlson, n.d.).

Slide 25 References:

British Columbia Community Forest Association –. (n.d.). *Local Forests, Local People, Local Decisions*. Retrieved April 3, 2022, from <https://bccfa.ca/>

Bullock, R., Zurba, M., Reed, M. G., & McCarthy, D. (2020). Strategic Options for More Effective Indigenous Participation in Collaborative Environmental Governance. *Journal of Planning Education and Research*. <https://doi.org/10.1177/0739456X20920913>

Canadian Forests. (2022). *Aboriginal Forestry in Canada*. <https://www.canadian-forests.com/aboriginal-forestry.html>

Carlson, K. (n.d.). *Chapter by Dr. Carlson included in other scholarly works*. Retrieved May 9, 2022, from <https://artsandscience.usask.ca/keithcarlson/chapters.php>

Carlson, K. (n.d.). *Keith Thor Carlson Publications*. Retrieved April 6, 2022, from <https://artsandscience.usask.ca/keithcarlson/chapters.php>

CIER. (n.d.). *Centre for Indigenous Environmental Resources*. Retrieved April 3, 2022, from <https://yourcier.org/>

Coates, K. (2008). *The Indian Act and the Future of Aboriginal Governance in Canada*. http://laws.justice.gc.ca/en/showdoc/cs/I-5/bo-ga:s_5/en#anchorbo-ga:s_5.

Manke, K. (2013). *How Indigenous burning shaped the Klamath's forests for a millennia* | *Berkeley News*. Berkeley News. <https://news.berkeley.edu/2022/03/14/how-indigenous-burning-shaped-the-klamaths-forests-for-a-millennia/>

Ministry of Northern Development, M. N. R. and F. (2021). *Sustainable Forest Licence for the Whitefeather Forest*. Ontario, Ca. <https://www.ontario.ca/page/sustainable-forest-licence-whitefeather-forest>

National Aboriginal Forest Association. (2020). *Fifth Report on Indigenous-Held Forest Tenures in Canada 2020*.

Pikangikum First Nation. (2006). *Keeping the Land*. www.whitefeatherforest.com

Prokopchuk, Ma. (2018). Grassy Narrows declares logging ban in its territory ahead of forest management planning. CBC News. <https://www.cbc.ca/news/canada/thunder-bay/grassy-narrows-logging-ban-1.4856870>

Schelenz, R. (2022). *How the Indigenous practice of “good fire” can help our forests thrive*. Phys.Org. <https://phys.org/news/2022-04-indigenous-good-forests.html>

Wheelock, J. (2022). *How the Indigenous practice of “good fire” can help our forests thrive Once outlawed, cultural burns can save our forests from uncontrollable wildfire*. <https://www.youtube.com/watch?v=i6kKwsA1B3U>

Whitefeather Forest Management Corporation. (n.d.). Whitefeather Forest Initiative. Retrieved April 3, 2022, from <https://www.whitefeatherforest.ca/>

Wincrief Forestry Products. (n.d.). *Wincrief Forestry Products L.P.* Retrieved April 6, 2022, from <https://www.facebook.com/Wincrief/>

Slide 26: New Directions for Sustainable Forest Products

Benefits of Building with Wood

- Renewable and abundant (Forest Products Laboratory, 2021)
- Low embodied carbon and energy (Forest Products Laboratory, 2021):
 - Decarbonizing the buildings and construction centre is key to reduce emissions and meet climate targets (Global Alliance for Buildings and Construction, International Energy Agency and the United Nations Environment Programme, 2019).
 - As climate change is increasingly recognized as a significant threat, cities such as Toronto are pursuing ambitious climate strategies (City of Toronto, 2021); these strategies include examining the benefits of using low-carbon construction materials such as wood.
- Visually appealing and enhanced wellbeing:

- o The variety of grain patterns and colours of wood, along with the ability to enhance it using stains, varnishes, and other finishes makes it a visually appealing building material (Forest Products Laboratory, 2021).
- o Being surrounded by natural elements like wood can provide wellness benefits such as stress reduction (Augustin & Fell, 2015).
- Strong, durable, and resilient:
 - o Wood has a high strength to weight ratio and is highly durable (Forest Products Laboratory, 2021).
- Faster to build and often cost-effective:
 - o Wood buildings can be prefabricated (components are built off-site in factories and assembled on-site) which can save time and money, but more research and development and support for the prefabrication industry is needed (Forestry Innovation Investment, n.d.; Kuan & Kaustinen, 2016).
- Biodegradable and recyclable:
 - o A study on the feasibility of recycling and reusing building materials such as wood from single-family homes in Metro Vancouver explores the opportunities and challenges of doing so (Forrest, 2021).
 - o There is potential for wood to be a highly sustainable building material, but issues related to its reuse and recyclability need to be addressed (Kaye, 2012).
- FPInnovations is a group that specializes in “the creation of solutions that accelerate the growth of the Canadian forest sector” (FPInnovations, n.d.).

Slide 26 References:

Augustin, S. & Fell, D. (2015). *Wood as a Restorative Material in Healthcare Environments*. FPInnovations. https://www.glass.org/sites/default/files/2020-09/wood_as_a_restorative_material.pdf.

City of Toronto. (2021). *TransformTO Net Zero Strategy: A climate action pathway to 2030 and beyond*. <https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/>.

Forest Products Laboratory. (2021). *Wood handbook – wood as an engineered material*. United States Department of Agriculture Forest Service. https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr282/fpl_gtr282.pdf.

Forestry Innovation Investment. (n.d.). *Prefabricated wood building systems*. NaturallyWood. <https://www.naturallywood.com/topics/prefabrication/>.

Forrest, J. (2021). *The feasibility of recycling and reusing building materials found in single-family homes built after 1970 in Metro Vancouver*. University of British Columbia.

https://sustain.ubc.ca/sites/default/files/2021-010_Feasibility%20of%20recycling%20and%20reusing_Forrest.pdf .

FPInnovations. (n.d.). *Home - FPInnovations*. Retrieved July 28, 2022, from <https://web.fpinnovations.ca/>

Global Alliance for Buildings and Construction, International Energy Agency and the United Nations Environment Programme. (2019). *2019 global status report for buildings and construction: Towards a zero-emission, efficient and resilient buildings and construction sector*.

<https://www.worldgbc.org/sites/default/files/2019%20Global%20Status%20Report%20for%20Buildings%20and%20Construction.pdf>.

Kaye, L. (2012, July 24). Recycled wood: the truly green key to a sustainable built environment. *The Guardian*. <https://www.theguardian.com/sustainable-business/recycled-wood-green-sustainable-built-environment>.

Kuan, S. & Kaustinen, M. (2016). *What is holding back the expanded use of prefabricated wood building systems?* FP Innovations. <https://library.fpinnovations.ca/en/permalink/fpipub5807>.

Slide 27: Life-Cycle Assessment (LCA) Comparing Wood, Concrete, and Steel

- Life Cycle Assessment is a method to assess the total energy inputs for a product from creation (cradle) to disposal (grave). (Glover et al., 2002).
- One literature and meta-analysis article concluded that by substituting conventional building materials like steel and concrete with mass timber reduced construction phase emissions by 69% on average (Himes & Busby., 2020).
- The building sector accounts for a large portion of greenhouse gas emissions globally. In 2008, this figure was 12% in Canada, but this figure does not reflect other processes involved in construction, like transportation and manufacturing. Examining embodied carbon includes all processes involved in creating greenhouse gas emissions when constructing buildings (Toronto & Dulmage., 2018).
- The study by Pajchrowski et al., (2014), is an example of the life cycle assessment of buildings (Pajchrowski et al., 2014).
- International Institute for Sustainable Development published a report outlining some limitations of LCA studies. While they are the best tool that is currently available to assess the environmental impact of certain processes, there should be awareness about its limitations (Stiebert et al., 2019).
- Some key findings of this report include:
 - Regional variability can affect life cycle emissions. Examples of these variabilities include differences among how countries produce steel and concrete. For example, Canada's steel furnaces use recycled steel and renewable electricity and are therefore considered more efficient than steel mills using coal.
 - Depending on how wood is sourced, the related GHG emissions can vary.

- If construction materials are implemented efficiently, and plan for a long life, GHG impacts based on material choice are negligible. With this, there is no one size fits all approach, and material should be chosen on a case-by-case basis.
- Accounting for the embodied carbon of wood is complex as it is a biogenic carbon cycle.
- Ryan Zizzo, who is a professional engineer, and an Instructor at the Toronto Metropolitan University (formerly Ryerson University) is a contributor to the field of embodied carbon (Mantle Developments, n.d.)
- Another study found that the location of wood suppliers with reference to cross laminated timber manufacturing facilities affects the overall environmental impacts of mass timber (Chen, 2019).
- Kelly Alvarez Doran is an Adjunct Professor at the Daniels faculty of Architecture, Landscape, and Design at the University of Toronto. He also leads MASS Design Group's London studio and is a subject matter expert in sustainability and regenerative design (University of Toronto John H. Daniels Faculty of Architecture, L. and D., n.d.).
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Slide 27 References:

Chen, C. X., Pierobon, F., & Ganguly, I. (2019). Life Cycle Assessment (LCA) of Cross-Laminated Timber (CLT) produced in Western Washington: The role of logistics and wood species mix. *Sustainability (Switzerland)*, 11(5). <https://doi.org/10.3390/su11051278>

Glover, J., White, D. O., & Langrish, T. A. G. (2002). Wood versus Concrete and Steel in House Construction. *Journal of Forestry*.

Himes, A., & Busby, G. (2020). Wood buildings as a climate solution. *Developments in the Built Environment*, 4. <https://doi.org/10.1016/j.dibe.2020.100030>

Mantle Developments - Net-zero Carbon & Climate-resilient Developments. (n.d.). Retrieved July 28, 2022, from <https://mantledev.com/>

Stiebert, S., Echeverria, D., Gass, P., & Kitson, L. (2019). *Emission Omissions: Carbon accounting gaps in the built environment IISD REPORT*. www.iisd.org

Toronto, O., & Dulmage, S. (2018). *EMBODIED CARON WHITE PAPER EXECUTIVE SUMMARY*.

University of Toronto John H. Daniels Faculty of Architecture, L. and D. (n.d.). *Kelly Alvarez Doran*. Daniels. Retrieved May 15, 2022, from <https://www.daniels.utoronto.ca/people/adjunct-faculty/kelly-alvarez-doran>

Slide 28: Potential for Mass Timber

- Mass timber is an engineered wood structural building material used for mid-rise and large-scale infrastructure (buildings and bridges) (Advanced Research Systems, n.d.; Anderson, Dawson, & Muszynski, 2021; Canadian Wood Council, 2022; Kesik & Martin, 2021; Mass Timber Institute, n.d.a.; Think Wood, 2022).
 - o Mass timber uses multiple solid wood panels that are nailed and glued together to create “massive” pieces such as panels and beams to create this large-scale infrastructure (Natural Resources Canada, 2021, p. 9).
 - o Dr. Ted Kesik (Professor of Building Science) is currently involved in the design of low-carbon buildings (Ted Kesik | Daniels, n.d.).

- Mass timber is a renewable building material with numerous environmental, social, and economic benefits (John H. Daniels Faculty of Architecture, Landscape, and Design, 2021).
 - o It is able to store large amounts of carbon (Churkina et al., 2020).
 - o Studies have shown that mass timber is fire resistant, has a high load bearing capacity, and is lightweight (Natural Resources Canada, 2021, p. 8).

- Canada could become a global leader in mass timber given its supply of wood from sustainably managed forests (Natural Resources Canada, 2021, p. 19).
 - o The impacts of using mass timber on climate and forests is being examined (Pasternack et al., 2022).

- The State of Mass Timber in Canada (2021) identifies mass timber companies (Element5, n.d.; Nordic Structures, 2022; StructureCraft, n.d.; Structurlam Mass Timber Corporation, 2022) and manufacturing facilities (Natural Resources Canada, 2021, p. 18) in Canada.

- There are opportunities for collaboration among architects, engineers, researchers, and other skilled professionals in the mass timber sector in Canada (Mass Timber Institute, n.d.b.)

- Woodworks is a Canadian Wood Council program that is intended to promote the use of wood in non-residential, mid-rise, and tall building markets in Canada (Woodworks, n.d.).

Slide 28 References:

Advanced Research in Timber Systems | Engineering at Alberta. (n.d.). Retrieved July 28, 2022, from <https://www.ualberta.ca/engineering/research/groups/timber-systems/index.html>

Anderson, R., Dawson, E., & Muszynski, L. (2021). *2021 International Mass Timber Report*. Forest Business Network. <https://www.masstimberreport.com/>.

Canadian Wood Council. (2022). *Mass Timber*. Canadian Wood Council. <https://cwc.ca/en/how-to-build-with-wood/wood-products/mass-timber/>.

Churkina, G., Organschi, A., Reyer, C. P., Ruff, A., Vinke, K., Liu, Z., Reck, B. K., Graedel, T. E., & Schellnhuber, H. J. (2020). Buildings as a global carbon sink. *Nature Sustainability*, 3(4), 269–276. <https://doi.org/10.1038/s41893-019-0462-4>.

Element5. (n.d.). *Element5: Modern Timber Buildings*. Element Five. <https://elementfive.co/>.

Kesik, T., & Martin, R. (2021). *Mass Timber Building Science Primer*. Mass Timber Institute, University of Toronto, Canada. <https://academic.daniels.utoronto.ca/masstimberinstitute/building-science-primer/>.

Mass Timber Institute. (n.d.a). *All About Mass Timber*. University of Toronto John H. Daniels Faculty of Architecture, Landscape, and Design. <https://academic.daniels.utoronto.ca/masstimberinstitute/about-mass-timber/>.

Mass Timber Institute. (n.d.b). *Contacts and Connections*. University of Toronto John H. Daniels Faculty of Architecture, Landscape, and Design. <https://academic.daniels.utoronto.ca/masstimberinstitute/contacts-connections/>.

Natural Resources Canada. (2021). *The State of Mass Timber in Canada*. Natural Resources Canada. <https://cfs.nrcan.gc.ca/publications?id=40364>.

Nordic Structures. (2022). *Nordic structures, leader in sustainable wood solutions*. Nordic. <https://www.nordic.ca/en/home>.

Pasternack, R., Wishnie, M., Clarke, C., Wang, Y., Belair, E., Marshall, S., Gu, H., Nepal, P., Dolezal, F., Lomax, G., Johnston, C., Felmer, G., Morales-Vera, R., Puettmann, M., & Van den Huevel, R. (2022). What is the impact of mass timber utilization on climate and forests? *Sustainability*, 14(2), 758. <https://doi.org/10.3390/su14020758>.

StructureCraft. (n.d.). *Structural Engineering + Timber Construction*. StructureCraft. <https://structurecraft.com/>.

Structurlam Mass Timber Corporation. (2022). *Opening a world of possibilities through mass timber*. Structurlam. <https://www.structurlam.com/>.

Ted Kesik | Daniels. (n.d.). Retrieved July 29, 2022, from <https://www.daniels.utoronto.ca/people/core-faculty/ted-kesik>

Think Wood. (2022). *Create a mass-timber-piece*. Think Wood. <https://www.thinkwood.com/mass-timber>.

Woodworks. (n.d.). *Wood-Works – Program of the Canadian Wood Council*. Retrieved July 28, 2022, from <https://wood-works.ca/>