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HUMAN RESOURCE DEVELOPMENT CENTRE

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REPORT

Topic: "Impact of climate change on forests"

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This document provides an overview of additional reading resources related to the main topics that were covered in the lecture on the "Impacts of climate change on forests".

1) **Climate change, climate reconstruction & prediction**

The Fifth Assessment Report (AR5) compiled by the Intergovernmental Panel on Climate Change (IPCC) and published in 2014 provides a detailed overview of the science behind climate change within a historical context, present climatic and environmental impacts, as well as predicted impacts on future climate based on various scenarios. In this respect, the most relevant sections of the report include the Summary for Policymakers, and chapters 1 and 2. An updated AR6 report is due to be released in 2022. Understanding climatic history during the last millennium is of particular importance and examples of regional (Rydval et al. 2017) and hemispheric (Wilson et al. 2016) temperature reconstructions based on tree ring data provide additional insight into past climatic conditions.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

Rydval, M., Loader, N. J., Gunnarson, B. E., Druckenbrod, D. L., Linderholm, H. W., Moreton, S. G., Wood, C. V. & Wilson, R. (2017). Reconstructing 800 years of summer temperatures in Scotland from tree rings. *Climate Dynamics*, *49*(9), 2951-2974.

Wilson, R., Anchukaitis, K., Briffa, K. R., Büntgen, U., Cook, E., D'arrigo, R., ... & Zorita, E. (2016). Last millennium northern hemisphere summer temperatures from tree rings: Part I: The long term context. *Quaternary Science Reviews*, *134*, 1-18.

2) **Dendrochronology & Dendroclimatology**

Trees rings represent an important proxy archive of the history of tree growth and serve as a record of complex interactions of climatic, ecological and environmental variability and change. By utilizing these properties, dendrochronology offers the possibility to develop absolutely dated timeseries of past growth variability with a broad range of applications. A general basic overview of dendrochronology is available in Thinktrees (2021) and more detailed information is provided in Speer (2010), Schweingruber (2012) and Fritts (2012).

Fritts, H. (2012). *Tree rings and climate*. Elsevier.

Speer, J. H. (2010). *Fundamentals of tree-ring research*. University of Arizona Press.

Schweingruber, F. H. (2012). *Tree rings: basics and applications of dendrochronology*. Springer Science & Business Media.

Thinktrees (2021) Principles of Dendrochronology (URL: https://www.thinktrees.org/wp-content/uploads/2019/07/Principles-of-Dendrochronology.pdf)

3) Interaction of climatic and non-climatic factors in relation to tree growth and forests

a) Treeline environments

Treeline ecotone environments represent the bioclimatic range limits of tree species and various studies have investigated possible treeline shifts in response to increasing temperatures related to climate change. The complicated nature and uncertainties in relation to assessing changes in treeline position are illustrated by examples from Sweden in Moen et al. (2004) and Van Bogaert et al. (2011) along with the potential role of albedo (de Vit et al., 2014). A further example from the Czech mountains is discussed in Kašpar et al. (2017)

de Wit, H. A., Bryn, A., Hofgaard, A., Karstensen, J., Kvalevåg, M. M., & Peters, G. P. (2014). Climate warming feedback from mountain birch forest expansion: reduced albedo dominates carbon uptake. *Global Change Biology*, *20*(7), 2344-2355.

Kašpar, J., Hošek, J., & Treml, V. (2017). How wind affects growth in treeline Picea abies. *Alpine Botany*, *127*(2), 109-120.

Moen, J., Aune, K., Edenius, L., & Angerbjörn, A. (2004). Potential effects of climate change on treeline position in the Swedish mountains. *Ecology and Society*, *9*(1).

Van Bogaert, R., Haneca, K., Hoogesteger, J., Jonasson, C., De Dapper, M., & Callaghan, T. V. (2011). A century of tree line changes in sub-Arctic Sweden shows local and regional variability and only a minor influence of 20th century climate warming. *Journal of Biogeography*, *38*(5), 907-921.

b) Drought and forest fires

As atmospheric circulation patterns change and temperatures increase in response to climate change, the frequency and severity of droughts will likely increase in some regions along with associated impacts of related occurrences such as forest fires. A detailed examination of the recent 2018 (and 2019) European drought was performed in several studies (Buras et al., 2020; Hari et al., 2020; Peters et al., 2020) along with historical drought assessments (Hanel et al., 2018).

Buras, A., Rammig, A., & Zang, C. S. (2020). Quantifying impacts of the 2018 drought on European ecosystems in comparison to 2003. *Biogeosciences*, *17*(6), 1655-1672.

Hanel, M., Rakovec, O., Markonis, Y., Máca, P., Samaniego, L., Kyselý, J., & Kumar, R. (2018). Revisiting the recent European droughts from a long-term perspective. *Scientific reports*, *8*(1), 1-11.

Hari, V., Rakovec, O., Markonis, Y., Hanel, M., & Kumar, R. (2020). Increased future occurrences of the exceptional 2018–2019 Central European drought under global warming. *Scientific reports*, *10*(1), 1-10.

Peters, W., Bastos, A., Ciais, P., & Vermeulen, A. (2020). A historical, geographical and ecological perspective on the 2018 European summer drought.

c) Prehistoric forests in Scotland

An assessment of paleoenvironmental records detailed in Tipping et al. (2008) reveals how climate change and human impact shaped and affected prehistoric Scots pine tree growth in Scotland.

Tipping, R., Ashmore, P., Davies, A. L., Haggart, B. A., Moir, A., Newton, A., ... & Tisdall, E. (2008). Prehistoric Pinus woodland dynamics in an upland landscape in northern Scotland: the roles of climate change and human impact. *Vegetation history and archaeobotany*, *17*(3), 251-267.

d) Forest fragmentation and positive feedbacks (Amazon rainforest example)

Deforestation and forest fragmentation represents a significant factor in weakening forest resilience to environmental change and habitat loss. In the context of the Amazon rainforest, forest fragmentation and the potential acceleration of forest decline due to positive feedbacks is discussed in Laurence and Williamson (2001) and the possibility of future climate change induced dieback is addressed in Malhi et al. (2009).

Laurance, W. F., & Williamson, G. B. (2001). Positive feedbacks among forest fragmentation, drought, and climate change in the Amazon. *Conservation biology*, *15*(6), 1529-1535.

Malhi, Y., Aragão, L. E., Galbraith, D., Huntingford, C., Fisher, R., Zelazowski, P., ... & Meir, P. (2009). Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. *Proceedings of the National Academy of Sciences*, *106*(49), 20610-20615.

e) Divergence

Divergence has recently been identified as a phenomenon, which complicates uniformitarian assumptions, and involves the decrease in sensitivity or decoupling of tree growth from climatic drivers in some areas where tree growth was previously more sensitive to climatic variability in the past. This phenomenon is discussed in an overview by D'Arrigo et al. (2008).

D'Arrigo, R., Wilson, R., Liepert, B., & Cherubini, P. (2008). On the 'divergence problem'in northern forests: a review of the tree-ring evidence and possible causes. *Global and planetary change*, *60*(3-4), 289-305.

f) Disturbance

Natural and anthropogenic sources of disturbance represent an additional important factor, which affects tree growth. The role disturbance history plays in impacting tree growth patterns is explored for example in studies from the Carpathian Mountains (Schurman et al., 2018) and Scotland (Rydval et al., 2016).

Rydval, M., Druckenbrod, D., Anchukaitis, K. J., & Wilson, R. (2016). Detection and removal of disturbance trends in tree-ring series for dendroclimatology. *Canadian Journal of Forest Research*, *46*(3), 387-401.

Schurman, J. S., Trotsiuk, V., Bače, R., Čada, V., Fraver, S., Janda, P., ... & Svoboda, M. (2018). Large-scale disturbance legacies and the climate sensitivity of primary Picea abies forests. *Global change biology*, *24*(5), 2169-2181.

4) Forest health, productivity & management implications of climate change

Climate change has had and is expected to continue to have significant implications for the health and productivity of forests, as well as major consequences for forest management and long-term planning. A general account of some of the expected impacts of climate change on forestry is detailed in Kirilenko and Sedjo (2007) and additional examples of ongoing and expected climate change impacts on forests in Scotland along with probable implications and scenarios for forest management are provided in Forestry Commission Scotland (2008), Ray et al. (2008) and Ray et al. (2019).

Kirilenko, A. P., & Sedjo, R. A. (2007). Climate change impacts on forestry. *Proceedings of the National Academy of Sciences*, *104*(50), 19697-19702.

Forestry Commission Scotland 2008 - Impacts of climate change on forests and forestry in Scotland (URL: https://www.forestresearch.gov.uk/documents/940/scottish_climate_change_final_report.pdf)

Ray, D., Wainhouse, D., Webber, J., & Gardiner, B. (2008). Impacts of climate change on forests and forestry in Scotland. *Forest Research Report, Forestry Commission: Scotland, UK*.

Ray, D., Petr, M., Mullett, M., Bathgate, S., Marchi, M., & Beauchamp, K. (2019). A simulation-based approach to assess forest policy options under biotic and abiotic climate change impacts: A case study on Scotland's National Forest Estate. Forest Policy and Economics, 103, 17-27.