Hi everyone, I am very glad to be here to present the work on forest vulnerability that we are doing in the team of the researcher Isabelle Aubin from the Canadian Forest Service at the Great Lakes forestry Center. Isabelle is a vegetation ecologist that collaborates with many other researchers from the Canadian Forest Service as well as with many universities across Canada. The work I will present today could not have been completed without these collaborators as, you will see through the presentation, evaluating forest vulnerability is at the interface of many fields of expertise, from ecophysiology to genomics to ecology and forestry.
- NOTE: Five slides containing unpublished results have been omitted until we receive their author's approval.
So first of all, Why assess the vulnerability of forests? Well, because climate change is likely to increase the stress on our forests. These stresses are of different natures. On one hand, we expect to see an increase in the frequency, intensity and duration of extreme weather events such as droughts, floods and fires. On the other hand, the average climate and therefore the growing conditions will also be altered.
The impact these stressors will have on the state of our forests will depend largely on their vulnerability. Here, it is important to define what is meant by vulnerability. Throughout this presentation I will detail what approach the team of Isabelle Aubin has undertaken to quantify this vulnerability. This evaluation is made at the species level. So I will also present the vulnerability indicators for the major species present in the great lakes Saint-Lawrence forests and at Petawawa.
Vulnerability is the extent to which a system or component is expected to be adversely affected by climate change. Vulnerability can be assessed at different levels: trees, forests, forest management, forest actors and forest-dependent institutions. Here it is important to clarify that Isabelle's work focuses on the vulnerability of tree species to climate change. This vulnerability is determined by three components: exposure, sensitivity and adaptive capacity. Exposure is the degree of change that a species will experience in the future. Sensitivity is the degree to which an individual of a species will be affected by this change, and adaptive capacity is the ability of the individual or species to acclimatize to changes. Isabelle's work aims to quantify or at least qualify each of these three components of vulnerability, with a particular emphasis on the less studied components, with the aim of improving our predictions regarding future forest scenarios. Today's presentation will detail the progress of Isabelle's work for each of the three components of vulnerability.
First, we will start with exposure
Exposure is the best known component of the vulnerability. That's good because it's the basis for assessing vulnerability. An example here is the work done by Ted Hogg and Dan McKenney to predict changes in the climate humidity index in the future. This index is based on biophysical variables and quantifies the difference between the amount of precipitation and the amount of evapotranspiration at a specific location. With such maps, we can predict the extent of water stress that trees will face in the future. These maps are available on the CFS website.
This concludes our work on tree exposure. I will now present our work on the second aspect of vulnerability, tree species sensitivity.
With the help of several collaborators, in particular Alison Munson from Laval University, Isabelle’s work helped identify the traits and mechanisms underlying sensitivity and evaluate how the available information could be integrated to be comparable between species. In most cases, this work has allowed us to realize that ecological data cannot always be integrated into models. We need to develop conceptual models and do a multidisciplinary review of the literature to aggregate some of the information. This is a colossal work that has been done to lay the foundation for the assessment of species sensitivity.
The next step in assessing species vulnerability is to combine exposure with sensitivity to determine the potential impact on forests that is expected to occur with climate change.
Here, I present the results of a study published last year in the journal Ecosphère. This multi-disciplinary study incorporated climate scenarios, drought impacts, stand composition data and traits from 22 species representing 88% of forest biomass in Canada to provide maps summarizing the potential impact of droughts and the migration of climate niches on forests.
The results are presented according to a color code defined by the intersection of two axes. In x is the amount of biomass in the forests that will be exposed to drought and in y, the average sensitivity of the species making up the forests. So in blue we have the forests highly exposed to drought but composed of species tolerant to drought. In orange, we have species highly sensitive to drought, but that will be less exposed in the future. In purple and pink, we have the worst scenario where a large biomass of trees are exposed and sensitive to drought. In green, it’s the reverse situation where a small biomass is exposed with species of low sensitivity. In beige or pale brown, we have the least concern forests where no biomass will be exposed to drought.

As we can see, the map is highlighting gradually with time.
And eventually, by the end of the century the boreal shield in western Canada in the prairies region have the most exposed and sensitive forests with pink and orange colors. Next, In British Columbia, large tracks of forests are in blue, which means that they are exposed to drought but with tolerant species. And we have a lot of orange in Quebec and New Brunswick which are forests with less biomass exposed, but highly sensitive species.
The team of Isabelle also has made the same exercise, but with the migration of climatic niche. So here in the x axis we have the distance to the suitable habitat, which is based only on climatic niche. So it is the distance where the current climatic conditions will be find in the future. In y, we have the migration capacity of the species with green indicating a good migration capacity and orange a poor migration capacity. For example, birch as an excellent migration capacity because it produce a lot seeds that disperse far by wind. On the contrary, beech has a lower migration capacity because it produces fewer large seeds with lower dispersal capacity.
So here, as we move in time, the maps colors mainly in blue
Indicating that the current climatic conditions will be find way up north for most species, but those species have generally a good dispersal capacity having seeds that disperse by wind for example. In the west we see a big stripe of pink. This is because the climate of alpine ecosystems will be find way up north in the future and the species present have a poor migration capacity.
A tool is currently online that allows forest managers to visualize the potential impact of climate change and drought on a national and regional scale. Also Isabelle confirmed to me that she could share some datasets as needed. Just contact her if you are interested.
An finally, I used these tools to get a closer look at the maps for the area surrounding PRF. As we can see, by the end of the century, the forest here will be less vulnerable than in the hotspot I presented with the Canadian map. However, Laura has also computed these potential impacts for the PRF specifically and we will see this afternoon in the presentation of Mike that it is really a patchy mosaic of forest vulnerability.
Next, I want to talk about the third component of vulnerability, the adaptive capacity. This is the project that I am leading in the team of Isabelle Aubin.
First of all, I have to define what I intend by adaptive capacity. It is a term that can be applied to different contexts. It can cover the capacity of tree species to adapt through plasticity or evolution, it can also cover the capacity of forests and ecosystems to adapt or that of forest communities or organizations to adapt in the face of climate change. Here, I focus only the first context. That of tree species to adapt to the new growing conditions.
So I developed a conceptual diagram with the help of Isabelle and Laura. This diagram covers 4 axes of adaptation, first, that of individual trees through their phenotypic plasticity, this is their capacity to modulate their traits to remain fitted to the environment. For us, the best example of plasticity is our tanning in response to more exposure to sun. The second axis is the level of genetic diversity in a tree population that will determine the diversity responses to change, but also provides the material for species evolution. Next we have the level of genetic exchanges within a population which represents the number of occasions for a species to evolve, and finally the possibility of genetic exchange beyond populations such as that between populations, sub-species or between species through hybridization.
The goal here is to quantify adaptive capacity along each of these axes in order to see what species have more potential to adapt to the new conditions and which would require special attention. For example, here red maple has a large capacity of genetic exchange between populations. White pine is not particularly good or bad, but as we can see red pine as the lowest adaptive potential due to its low genetic diversity and potential for genetic exchange. In addition for some species we don’t have the data required to evaluate their plasticity, such as for red pine.
So as we can see, there remains a lot of uncertainties in vulnerability assessment.
These uncertainties led me to think that different management intensities could be provide different advantages in the face of climate change. On one hand, we don’t really know what nature is capable of and thus there is room for « no action » combined with monitoring to assess the performance of natural processes of adaptation. On the contrary, the full control option in high-yield plantation might also offer interesting opportunities to grow trees in a reduced time frame to limit the duration a stand is exposed to climate change. This high-yield option may also benefit from new possibilities for genetic improvement and provenance selection. In between natural and high-yield option management will be based on our best-knowledge of the functioning of forest ecosystems and climate change. With increasing forest vulnerability we may begin to incorporate éléments of adaptation silviculture into each management options up to a point where we may ourself adapt to the potential loss of forest ecosystems. This is not a prescription portfolio of options, but my point with it is to present the full scope of possibilities for the forests of the future. This project is currently under review in the journal BioScience.
So to summarize the information, we often consider the portfolio of options where we promote forest resistance, resilience or transition in the face of climate change.
And I only want to point out that there are more options such as the no action natural or the super intensive and controlled environment of high-yield plantations.
This ends my presentation I thank you very much for your attention and I also like to thank all the collaborators in the different projects.