Since we have different backgrounds, I have first provided a brief explanation of ecosystem stresses. I then discuss climate effects on forests where I outline climate data availability and possible general questions to focus on climate effects on forests with some suggested climate metrics. The possible next steps for tasks are outlined. For your interest, I’ve also given you some other sources of climate information but do not suggest that we use those sources because they are either climate projections or do not cover the time period we need. I welcome any suggested revisions to our path forward as this document is a straw dog which can be torn apart if you don’t think it will work :)

**Background: Ecosystem Stresses**

Ecosystem pressures or stressors can be characterized along the continuum of stress to disturbance. Five modifying factors can be used to categorize the stress-disturbance continuum of spatial and temporal scales (see Table 2 below). These modifiers are key factors that determine the level of impact of a stressor on a species, population or individual biota. The characteristics of the stressor needs to be considered when assessing its impact on the overall health of the forest across the region from impacts observed in local plot sites or individual trees. Natural habitats typically experience the same stressors repeatedly over time such that species have evolved to adapt to these predictable stressors. Biota may become adversely affected when they encounter stresses and/or disturbances that the species has not been commonly exposed to so has not been able to adapt to.

Table 2. Stress-Disturbance Continuum

|  |  |  |
| --- | --- | --- |
| **Modifier** | **Stress** | **Disturbance** |
| Duration | Long-term | Short-term |
| Magnitude | Large area | Small area |
| Severity | Low (Chronic, sub-lethal) | High (Acute, Lethal) |
| Timing | On-going to Seasonal | Specific Events |
| Periodicity | Regularly Repeating | Regular to Irregular |

Forest stresses have been categorized into inciting, predisposing or contributing factors. Inciting factors are intense stresses, usually of short duration, which can cause severe injury. Examples of inciting factors include defoliating insects, such as forest tent caterpillar, severe drought, flooding, frost, weather extremes, and acute fumigations of phytotoxic air pollutants. Inciting factors may kill trees outright. Predisposing factors tend to be long-term or endemic (i.e., occur naturally in local area). Examples include subtle climate stress (e.g., drought or spring heat waves), nutrient deficient soil, aluminum toxicity to fine tree roots, tree genetics, advanced tree age, and chronic pollution levels. These factors impose a permanent stress on the forest ecosystem, resulting in reduced tree vigour that in turn renders the tree more susceptible to damage from other agents. Predisposing factors rarely directly result in tree mortality but are significant links in the decline cycle. Cumulative effects are influenced by how multiple stresses act sequentially, concurrently, synergistically, antagonistically, or cumulatively on a forest stand. Contributing factors can also be long-term in nature or endemic to the forest ecosystem. These include bark beetles, canker fungi, root and wood rot fungi and viruses. Contributing factors find it easier to infect and may even act more aggressively in trees that have been weakened by predisposing or inciting factors. The contributing agents may eventually kill trees that are in a weakened condition. Usually, healthy trees that have not been adversely stressed by the various predisposing and inciting factors can resist infection or even recovering from contributing stresses. Atmospheric pollutants, such as acidic precipitation and ozone, are hypothesized to act as either predisposing or contributing factors leading to tree decline. Air pollution is a long-term chronic stress such that signal is hard to detect given other annual stresses that vary across the years and swamp the air pollution effects.

**Climate Effects on Forests**

Climate data are available either for individual sites or interpolated average conditions across regions. The two types of data have different advantages and disadvantages. Environment and Climate Change Canada (ECCC <https://climate.weather.gc.ca/index_e.html>) is the best open source although their interfaces are not great and need to download site by site for some climate data (time consuming). Several interpolated model have been developed to grid ON into various regions and give average regional climate conditions. McKenny et al 2006 regional 1901-2000 monthly climate normals for regions was used in the gridded ON Climate Model 2005 that I have obtained.

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I would love to download climate data and compare all 111 OFBN plots but that would be too much work for our available time. I suggest that we focus on the 14 plots where we’ve been monitoring forest understory climate and precipitation in nearby open areas. As mentioned, we cannot use the OFBN met data because it is not open source data although I do plan to post on Open Data Portal in the future after finish data processing and QA/QC.

There are hundreds of research papers that demonstrate that climate conditions over the long-term and annual differences affect forest health. Temperature and moisture are the most important climate factors influencing forest health. Extreme events will be the biggie affecting forest health because of

Increases in Intensity, Duration and Frequency

Irregular Timing and

Less Periodicity (more variable and less predictable)

Possible questions for our dashboard are:

1. How have climate conditions changed over the 32-year data record in the 14 OFBN sites?
2. Do climate conditions differ among the 14 OFBN sites?
3. Do climate condition changes over the years differ among the 14 OFBN sites.

The use of climate anomalies would remove the effect of the site-specific climate differences i.e., take the measured climate metric for the site and subtract the average found for the site. Environment and Climate Change Canada (ECCC)’s 1981-2010 Climate normals for the site would be used as the averages.

1. Are the annual plot Decline Index (DI) means influenced by the climate conditions found in the plot?

Use the standardized DIZ values.

Vast numbers of climate metrics are used to describe climate conditions. To simplify, I suggest we focus on the following climate metrics that have been shown to influence hardwood forest canopy health. This list is already getting possibly too long! Some of these metrics involve time lag effects. I did statistical analyses that showed time lag effects influence annual and spatial DI patterns (see my summary document on temporal and spatial decline patterns).

Highest priority as the following five metrics have been shown to influence hardwood crown health in Vermont.

1. April minimum temperatures
2. Preceding August minimum temperature
3. Preceding October minimum temperature
4. No. of January days w/Tmax > 2 SD
5. No. of preceding August days w/Tmax > 2 SD

(see ):

Second but still high priority are the following climate metrics that have been shown to be related to growth and DI in OFBN plots but have some statistical methodological issues.

1. Maximum temperature in the spring (Mar, Apr, May), summer (June, Jul, Aug) , fall (Sep, Oct, Nov) or winter (Dec Jan Feb) (current year or 1-year lag i.e. from previous year)
2. Minimum temperature in summer
3. Maximum temperature Winter (1 year lag)
4. Total rain in spring or winter (Previous 1-year lag).
5. Winter total precipitation (current and previous year’s snowfall 1-year lag)

(see)

The timing of extremes influences the severity of impacts.

1. # of spring heat wave events (temperature > 32o C for 5 consecutive days)

(see )

We already have a lot of metrics but what is missing from research is the sequential timing and synergistic effects of multiple climate events. Most forest ecologists recognize this as an important driver affecting forest health but I have never seen a paper that tackles these cumulative climate stress effects. We could be on cutting edge if we tackle this. Possible cumulative stress combinations could be:

1. Dry and hot events followed by extreme cold events; events could be seasonal climate conditions or short-term weather events within a season.
2. Other Extreme event combinations (see lists of standardized extreme definitions)

 

**Tasks Required**

1. Prepare draft story line so we focus our efforts. Story line may change as we get findings or if we run into issues.
2. Identify which Environment and Climate Change (ECCC) weather stations are most suitable to represent climate conditions in the 14 OFBN plots that have I’ve inserted a pdf of the closest Environment Canada station to the 14 plots where we’ve been monitoring forest understory climate and precipitation in nearby open areas. Plot 2017.xlsx contain the plot locations and I have shape files if you would like. ECCC stations are located in open areas that meet standardized conditions and represent regional conditions, but they will differ from forest microclimate monitoring in the plot. Verify that selected ECCC site has similar elevation, land cover, etc. I attached the xlsx of weather stations shown on the map and have the have the shape files if you want. I didn’t create this map so I am not sure whether complete list. Thus, I’ve also attached the Weather station catalogue that is used internally and doesn’t convert well from text file. I used to work for EC and my hubby still does and is a climate expert. Sites vary in their data record.



1. Download climate data for the most suitable Environment and Climate Change (ECCC) weather station to the 14 OFBN plots where we have conducted forest microclimate monitoring.
2. Extract relevant climate metrics form these downloaded data. This extraction will require programming or some data processing to derive our climate metrics from the downloaded raw climate data.
3. Extract relevant climate normal data from the subset of ON sites that have generated 1981-2010 climate normals to calculate climate anomalies. The climate normals pdf makes it sound fantastic but I can give insight to data issues and limitations. See below for the list of Ontario climate normal stations. I had previously started to download the ON Climate normal data for each station but will need to send separately as huge file. I may not be able to email as large file. I have had account problems getting the Microsoft Cloud to sync for me.



1. Calculate climate anomalies for each relevant climate metric for each site. Programming or data processing will be required to derive these climate anomalies.
2. Generate graphics that address the four questions for each climate metric.
3. Prepare story line with text and graphics and build story line dashboard

**Other Climate Data or Information Availability**

I’ve done a comprehensive search and the ON Open Data Portal has the following two sources of climate data. Our Ministry has helped fund the ON Climate Data Portal which has future climate projections (<https://data.ontario.ca/dataset/climate-data-high-resolution-projections>). MNRF hired a contractor to create a climate database of key climate metrics in Ontario but only goes up to 2005 so does not cover our range of years (<https://data.ontario.ca/dataset/in-filled-climate-data>).

Other open climate sources are:

Climate Change Canada Climate Data

<https://www.canada.ca/en/environment-climate-change/services/climate-change/canadian-centre-climate-services/display-download.html>

Climate Data Canada <https://climatedata.ca/>

<https://climateatlas.ca/>