Ontario New Directions
Regional capacity to respond to extreme weather:
Synthesis of considerations for agriculture in the context of two Ontario regions

Indicator selection extended beyond agriculture

Final Report
January 25 – March 30, 2016

Submitted by Patricia Larkin

1. Contract Statement of Work

This is the final report for the Ontario New Directions project component to identify a final set of indicators and thresholds for climate change extreme weather impacts and responses (ie., adaptations). During the period, identified tasks and associated deliverables were to:

1. Review and compile data about climate change extreme weather impacts and responses (ie adaptations) according to priorities identified from the overall work objectives
2. Synthesize and analyze findings to identify relevant measures, thresholds, and/or other variables for assessing resilience in agricultural communities. This includes agriculture and was expanded to include such other considerations as health, transportation/infrastructure, socio-economics, etc, as identified by this review
3. Deliver a workshop, including planning and materials
4. Provide a final report and searchable database documenting methods, assumptions, findings and conclusions

The following attachments are integral components of this report:

Excel file: Indicator priorities and considerations (Appendix 1)
PDF: Survey Monkey™ Report (Appendix 2)
Excel file: Indicator workshop assessment searchable database.xlsx (Appendix 3)
PDF: Appendices 4-8, 14-15, and 17
PDFs: Appendix 9-13 – Individual workshop worksheets
PDF: Appendix 16 – Workshop backgrounder on thresholds
PDF: Appendix 18 – Indicator and threshold reference table

2. Background

Climate extremes of particular concern to agriculture and rural areas, potential population health effects of these, potential relevant indicators, and preliminary work on thresholds, were identified in related research in 2015.

The selection of a set of indicators that could be incorporated in Envision modeling in the short, medium and longer term can now be completed. The information and platform will enable users to inform their discussions concerning adaptation needs.

Potential indicators have been considered through an ongoing literature review (attached with updates, Appendix 1), local/regional outreach using a Survey Monkey™ instrument (attached, Appendix 2), input from 2 expert workshops (attached, Appendix 3), and discussion with

members of the interdisciplinary research team. Relevance, data sources, linkages, comparability between regions, timestep requirements, and outstanding questions, among other issues, are now documented.

Previously, indicators related to direct and indirect population health effects of climate change and climate extremes were identified for the general population (Cheng and Berry, 2013; English et al, 2009) as well as those focused on agro-rural systems (National Academy of Sciences, 2014; PHAC, 2006; Zhu, Deng, Switzman & Hazen, 2015). Other OND project work, such as climate extremes of significance to specific crops, is being completed by other team members.

3. Expert outreach

Step 1 – Survey Monkey Instrument

In consultation with the research team, known experts in agriculture, resource management, rural affairs, and health, working in government, non-government, industry organizations, academia, and the volunteer sector, were sent an invitation to complete a Survey Monkey™ questionnaire (Cover letter and distribution list, Appendix 4). The goal was to share a list of potential indicators related to climate extremes for the agricultural sector specifically, and rural communities more generally, thereby initiating engagement with regional experts in order to develop a subset of these for inclusion in Envision modeling. Experts' perspective and insights was sought on how to best characterize issues, in order to identify priority information availability, needs, and gaps.

The survey began with general questions about respondents' field of work, organizational sector, geographic area, and priorities related to extreme weather and environment and health issue areas. The survey then asked for an indication of the relevance of a variety of measures that could be used to track changes and the nature of impacts and interactions between climate change and rural well-being in environmental, agriculture, socio-economic and built systems. Potential indicators were listed within five subsections: Weather, Land, Farms and Production, Transportation and Connectivity, and Demographics. Respondents could also suggest additional indicators they may be familiar with. At the end, the survey provided an opportunity to indicate interest to contribute to the next stage of the work, as well as open questions for further comments.

Respondent's representation

Approximately 80 individuals were sent the explanatory letter and link to the survey instrument; a number of contacts were asked to forward the survey within their network. As such, the response rate cannot be calculated. A total 37 surveys were attempted; 5 were deemed incomplete by Survey Monkey™. For complete details, see the Survey Monkey™ report (PDF attachment, Appendix 2) and excerpted comments (Appendix 5).

Based on the number of responses, some experts indicated affiliation to more than one field of work and sector. The majority indicated land, water or air resources management (15/44%) with agriculture (12/35%) and health experts (11/32%). Another 8 (21%) indicated "other", with two individuals being retired. Most respondents work in government (23/62%). The next highest was the non-profit sector (5/13%) and Voluntary sector (4/11%).

Of the choices provided for geographic area, 17 (46%) of respondents were located or worked within Eastern Ontario, including the City of Ottawa, with just over half of these within Mississippi-Rideau (7/21%) and Raisin – South Nation Watersheds (1/3%). Thirteen respondents (35%) were from other geographic areas, identified as: National (2); all Ontario (2); South West Ontario (2); Grey Bruce; Bonnechere/Madawaska; Niagara, Guelph; and "all scales". No participant indicated s/he was in the Peel Region.

Respondents were required to specify their County. Twenty-four indicated some portion of eastern Ontario (Ottawa, Lanark, Prescott Russell, Stormont Dundas Glengarry, Frontenac). Two each indicated "Ontario" and "Not applicable", with others indicating Hastings, Elgin, Brant, Wellington Dufferin Guelph, Niagara, Renfrew, Grey Bruce and "Canada".

Respondents' priorities

Of the choices provided, the five most concerning weather priorities were clear: Flooding and erosion, Drought, Heatwave/extreme heat, Ice storm, and Severe thunderstorm. Each had between 48% and 59% responses. The next highest priority was Cold wave (27%). Other choices were: Hurricane/Tornado; Hail storm, and Wildfire.

Of the choices provided, environment and health priorities related to climate extremes were more varied. Those with at least 25% response rate were: Water contamination (65%); Pest and disease epidemic outbreaks (51%); Crop stress (41%); Invasive and weedy species introductions (35%); Food shortage (27%); Drinking water shortage (quantity) (27%); and Human health epidemic/infectious disease (30%). Three respondents added an aspect of natural heritage (biodiversity) as another priority. Other choices were: Populations with chronic disease, Occupational health and safety, Accidental injury/death in general population; Mental health.

Potential indicators – assessment of relevance

Respondents then indicated relevance of potential indicators presented in five sub-groups as listed below. Choices included: Very relevant, Somewhat relevant, Not relevant, and No comment. The latter column was provided because some respondents would not have been familiar with the domain of all potential indicators.

- Weather
    - Late spring frost (date)
    - Heat spell duration index (max number of consecutive days with daily max temperature >5C above normal, by month)
    - Extreme heat (three or more days >32C, by month)
    - Drought severity (changes in annual length, by month)
    - Drought severity (frequency (multi-year trend))
    - Heavy rainfall (consecutive wet days by season)
    - Number of high Cooling Degree Days (CDD) (no. degrees that a day's average temperature is above 18C)
    - Extreme cold
- Land
    - Undisturbed/natural land cover (forest or wetland; percentage or total hectares)
    - Erosion risk (e.g., two year peak flow; land use on clay soils)

    - Watershed buffer zone (percentage shoreline permanently vegetated, e.g., Wetland Buffer Integrity Index)
    - Reforestation/deforestation (percentage of land cover or total hectares)
    - Changes in growing season
    - Deficit/excess of water (e.g., streamflow/discharge rates)
    - Infrastructure in high flood risk zone (e.g., farm use, residential, or institutional;
    - proportion of total)
    - Species range shifts (e.g., hantavirus, invasives)
    - Rural land management and species biodiversity (farm or development; fragmentation index, farm field size)
- Farms and Production
    - Relative shares of small/medium/large farms (percentage of regional income/area by farm type and size)
    - Yearly agricultural output compared to long-term average (bushels/ha or kg/cow)
    - Proportion or hectares of farmland under conservation, perennial crops, winter cover crops, no-till, rotational grazing (shifting management practices in relation to productions)
    - Seeding date (i.e. start of season)
    - Livestock density (animals/ha by type)
    - Infrastructure (e.g., proportion of barns with a/c; proportion of farms with irrigation systems; tile drainage ...)
    - Manure Management strategies (change in prevalence by type)
    - Mix of crop type, perennial vs annual
    - Farmland management and species biodiversity (field size, fragmentation index)
- Transportation and Connectivity
    - Critical infrastructure (roads, power, telephone, wifi network, drinking water, sanitation, etc)
    - Informal networks and community support (e.g., rural cohesiveness, awareness, response planning, access to public health and emergency systems, etc.)
- Demographics
    - Proportion of rural inhabitants relative to total regional population
    - Agricultural producers as proportion of total rural population
    - Share of rural population more vulnerable to climate change (because of age, gender, socio-economic status, health status)
    - Age of farmers

See the Survey Report (PDF attachment) for complete details, including response rates.

Upon review and analysis, the "very" relevant and "somewhat" relevant indicators were disaggregated from the sectoral approach used in the instrument, and depicted as a logic model illustrating relationships between potential indicators and stated weather (red), and environment and health (purple) priorities (Appendix 6). Very relevant indicators are colour-coded green and somewhat relevant indicators are blue. Linkages between extreme weather and environment and health priorities can be direct or indirect and is not portrayed in the Figure. The relationship of the potential indicator to the sets of priorities can be direct (solid arrow) or indirect (as an

adaptation/intervention) (dashed arrow), each of which can affect population health and wellbeing (on the far right).

Following discussion with the project team, indicators were re-categorized within three groups: climate/climate extremes, vulnerability, and adaptation/intervention (Appendix 7). Team members judged some indicators differently. As suggested by one, "Some interventions could also be seen as adaptations or mitigation measures without specifically being a (concrete) intervention – e.g. a place that already has high (pseudo-) natural cover, as opposed to encouraging land cover conversion, already has value for natural ecosystem processes without it being an "intervention"… although promotion of KEEPING such lands as they are is certainly a management option."

Step 2 – Expert Workshops

Two identical half-day workshops were arranged to further characterize and prioritize the list of potential indicators. Participants were given a choice to contribute in person or via WEBEX connection. Names and representations are provided in Appendix 8.

It was understood that sector participants were starting from a different place in terms of progress within the Envision model and project as a whole.

- Agriculture – validate direction; extend potentials
- Resource managers – update research team with your ongoing work; database/data availability; what like to see
- Public health – newer participants. Provide more information, recommendations for direction in short/medium term; basic database identification what would work best for you; historical and future projections. Project has climate data, can extend with population/infrastructure issues to project futures
- Planners – identify indicators that could be most useful as input to decision making; database

Workshops began with an overview of the Farms to Regions project[1], project extensions through Ontario New Directions (downscaled modeling of climate extremes and broadening of project from agriculture to explicitly include aspects of rural health and wellbeing), and the Envision platform with examples (weather and seeding delays, heat, corn phenological indicators). The rest of the time was devoted to participants addressing worksheets that included the list of surveyed issues and associated indicators from the Survey Monkey, categorized to reflect the IPCC (2007) definition of vulnerability:

> "Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity."

[1] IISD (2015) Mainstreaming Climate Change Integrated Landscape Assessment, Decision-Support Process & Tool Kit: Lessons from Southeastern Ontario. http://www.iisd.org/library/mainstreaming-climate-change-integrated-landscape-assessment-decision-support-process-tool-0

The working session delved into two prongs of vulnerability through five worksheets: 1) exposures (climate/climate extremes), and 2) sensitivity based on system attributes (2a) populations and (2b) infrastructure; as well as (2c) farm and (2d) environmental features. The third prong of vulnerability, adaptive capacity that is supported through the policy or regulatory context, will be addressed later in the OND project.

Participants' sector-based discussions considered issue areas and specific indicators within the five worksheets, but not everyone had time to consider each one (Appendix 9-13). Envision status was provided, with greatest work completed for issues/indicators listed on the climate tab. Additional information was provided at the discussion tables:

- Items suggested by survey comments (Appendix 14)
- Datasets list (Appendix 15)
- Backgrounder on thresholds (Appendix 16)

OND Team members then facilitated and recorded the discussions based on worksheet templates. Workshop input has been collated to populate the searchable database, "Indicator considerations" (Indicator workshop assessment, Excel file attachment, Appendix 3), and include, where possible:

- Units, boundaries or thresholds
- Database source and contact
- Additional questions or needs, including a comment on linkages to other indicators and OND Policy Phase work component
- Other sector impacts
- Recommendation to track
- Comparison across regions
- Timestep and precision requirements
- Any additional comments

Indicator assessment can include a variety of considerations (Appendix 17). Note that additional worksheet columns were not well addressed at the workshops, including detail on indicator reliability and validity (see Workshop worksheet template tab, Excel "Indicator workshop assessment March 30 2016"). This issue is discussed further in Next Steps.

4. Summary of Findings

Outreach sessions were aimed at characterizing risks and expanding these beyond agriculture to include health, environment, and infrastructure. Indeed the 30-odd "indicators" assessed in the Survey Monkey instrument ballooned to approximately 70 rows within issue areas on the workshop worksheets[2] (Appendices 9-13). Experts also added more.

Comments on workshop process

- Separation of climate indices and impact indices in order to improve the target user's understanding of the project's outputs.
- Definition of climate extremes

[2] The list in the survey monkey may have had an "issue area" assessed for relevance, with several individual indicators of potential interest. The workshop teased these out.

    - moderate extreme – shifts in timing and frequency; another way to look at seasonality
    - major events
- More sense to focus on what information we DO have
- Combine infrastructure sensitivities list – general rural and farm

Review and recommendations on list of indicators to carry forward
The final tally of specific indicators under issue areas within the categories is: climate-related (40); populations (25); rural and farm infrastructure (24); farm system attributes (17); and environmental system attributes (13). The final set of indicators chosen for future projections in the Envision model is to be identified. Selection criteria could include:

- Indicators underway in Envision for agriculture and extend to other sectors
- Variety - at least 2 indicators from each of climate, populations, infrastructure, farm and environmental system attributes
- Indicators actively tracked by one or more sectors
- Indicators with suitable and accessible database (more work needs to be done to confirm)
- Student research
    - Anna Zaytseva – completion of analysis of significance of trends in extremes especially related to crops
    - Tonia Tanner – fragmentation index
    - Cameron Samson – hydrologic parameter to be determined

While a detailed review of the findings has not been completed, a potential list of indicators for team consideration in the short term could begin with:

Climate (4)

- Start of season – of importance to all sectors
- Heat/Warm spell duration, includes heat degree days
- Cold
- Precipitation - consecutive wet days by season – link with Excess water (streamflow, discharge)

Populations (2)

- Basic socio-demographics – rural population, age, income, family status
- Health status – trends in chronic or other disease

Infrastructure (3)

- Flood risk zone
- Indicator related to drinking water system type
- Tile drain network

Farm system (5)

- Agricultural output
- Conservation practices
- Crop type
- Nutrient management

- Pest prevalence

Environmental system (2)

- Fragmentation index
- Dominant and proportion change of various land cover – wetland, woodlot/forest, undisturbed, agriculture

Experts also identified indicators that are important, but hard to measure (ie., may not be measured due to high uncertainty but are key to adaptive planning); as well as others that important but data is currently unavailable (a data gap) (Column J, Excel database). These findings are also useful as an outcome to the OND project.

5. Peel Region

While this project is well established in Eastern Ontario region, activities are underway to replicate the approach in Southern Ontario. Edmundo Fausto, staff member at Toronto Region Conservation Authority and Ontario Climate Consortium Secretariat, was able to participate by WEBEX during one of the workshops. Melanie Williams, Planner for Peel Region, would have liked to participate in a workshop but had a conflicting schedule both days.

Dr. Harvey Hill, AAFC, Saskatoon, is also familiar with the Peel project and may be working similarly for that region. Land & Infrastructure Resiliency Assessment (LIRA) - http://www.crhnet.ca/sites/default/files/library/TS02-01_Kaytor_etal.pdf

Work underway in Peel Region includes

a) Agricultural adaptation

An agricultural adaptation pilot project has been underway in the Region of Peel, working with grains and oilseed producers, including assessment of different cropping options and best management practices. At the outset this project did not include relationships between adaptation and population health although team members recognized the potential consequences of decreased crop yield on income, mental health and food supply (Harris Switzman, Climate Adaptation, Toronto Region Conservation Authority, personal communication).

b) 2012: Assessing Public Health Vulnerability to Climate Change in the Region of Peel

Identified potential public health issues included Extreme temperatures, Air quality, Extreme weather and natural disasters/hazards, Food-borne and water-borne illness, Vector-borne disease. Populations identified who may be most at risk based on Demographics (age, education, SES), Behaviour (i.e., air quality and outdoor exercise), Housing, Access to services. Project has examined past trends, examined the current adaptive capacity - Current programs, Regulations

The Ontario Climate Consortium has some related activities - http://climateontario.org/wp/adaptation-and-mitigation/

Planning and Support

- The Peel Climate Risk Analysis Framework Tool – P-CRAFT
  - *Incomplete - More information not currently available*
- A Climate Change Risk Assessment and Adaptation Strategy for York Region, Ontario
  - *Incomplete - More information not currently available*

- 2013 Climate and Extreme Weather Resilience in Peel
  - Workshop agendas and presentations: http://climateontario.org/wp/climate-and-extreme-weather-resilience-in-peel/
- Enhancing Resilience to Severe Weather and Climate Change: Assessing Risks and Opportunities for Key Elements of Ontario's Transmission Grid
  - http://climateontario.org/wp/enhancing-resilience-to-severe-weather-and-climate-change-assessing-risks-and-opportunities-for-key-elements-of-ontarios-electrical-transmission-grid/

Research Support

- Study of Climate Change, Extreme Weather Events & Management Activities on Canadian Forests - http://climateontario.org/wp/wp-content/uploads/2014/03/ORCCC_Report_TurkeyPoint_2reducedsize.pdf
  - Incorporated plant and soil nitrogen cycling algorithms, including biological fixation and soil mineralization, nitrification and denitrification in the Canadian Terrestrial Ecosystem Model (CTEM v1, Arora & Boer, 2005) which is coupled it to the Canada Land Surface Scheme (CLASS; Verseghy, 2000). The carbon and nitrogen coupled CLASS-CTEM+N model (Huang et al., 2011) includes most of the terrestrial ecosystem processes including photosynthesis, plant and soil respiration, plant phenology, allocation, biomass turnover, litterfall, mortality, fire and competition between plant functional types. This model helps to simulate N constraints on carbon cycling and to evaluate the impact of climate change and nitrogen feedbacks on vegetation ecosystems. Implementation of improved CLASS-CTEM+N in the 2nd generation Canadian Earth System Model (CanESM) would provide an assessment tool to generate robust scenarios of future climate for policy development.
- Changing Wind Regimes in Ontario - http://climateontario.org/wp/wp-content/uploads/2014/03/ORCCC_WindReport-2.pdf
  - The North American Regional Reanalysis (NARR) data set contains all the atmospheric information used to generate weather forecasts for North Amer¬ica at three hour intervals since 1979. It is part of the global NCEP data base but at a finer grid resolution of 32 km. It is the same data set used to validate climate change models for their ability to replicate present day climate. The domain for this project includes wind information at approximately 4000 grid locations which provides extremely fine geographical detail compared to the current monitoring network, particularly in the North, where weather stations are separated by hundreds of kilometers. Surface (10m) wind speeds are grouped into monthly and seasonal 31 year averages to demonstrate how wind speed typically varies over a year at all locations
- Economic Impact of Climate Change on Vulnerable Communities - http://climateontario.org/wp/wp-content/uploads/2014/03/ORCCC_Report_IBC-Rev21.pdf
  - Suggested constructing scenarios that can bracket the range of risks and quantify the likely consequences and costs a local community would experience given its economic situation, the size of its population and exposure to particular climatic and weather related events.\
  - Develop vulnerability curves to estimate expected losses of assets at risk
  - practical and useful methodologies for estimating the expected economic losses of inaction in the face of climate change and uncertainty.

- Work based on a comprehensive survey of economic modelling approaches; recommended use of a general equilibrium approach embedded in a simple input-output model with a local impact module be utilized for the second phase of the project. It will capture the indirect and induced impacts in a straightforward manner without having to use extremely complex approaches, such as Computable General Equilibrium (CGE) modelling, that are likely to be difficult to implement in view of their modelling and data demands particularly at the community level.

- Water and Climate - http://climateontario.org/wp/water-and-climate/

Key contacts
Edmundo Fausto, Project Manager, Ontario Climate Consortium Secretariat and TRCA - *efausto@trca.on.ca*
Melanie Williams, Principal Planner, Research & Analysis, Integrated Planning Division - *melanie.williams@peelregion.ca;*
Mark Pajot, Climate Change Specialist, Integrated Planning Division - overseeing the entire climate change strategy at the moment - *mark.pajot@peelregion.ca*

6. Next steps

The immediate goal is for the Project Team to complete indicator selection, confirm database sources, and plan for inclusions within the Envision platform. This process could delve deeper into indicator selection criteria, including an assessment of reliability and validity which was not well addressed in the outreach reported here. Furthermore, a list of indicators that are important, but hard to measure, as well as those with a data gap, are identified in the Excel database in a number of instances and these could be compiled in a word-document format for reporting and future discussions.

With respect to indicators going forward, an indicator and threshold table prepared for this project at an earlier phase is re-attached as a reference document (Appendix 18). Sources and thresholds input within Envision will be peer reviewed in order to be sure the study is accurately portraying threshold information and timestep requirements. This will be completed prior to implementation.

The research team also intends to maintain dialogue with engaged experts, including notification when the Carleton University portal is operational. This will provide documents and links that may be of interest to practitioners but may be outside the scope of the OND project at this point in time.

In terms of geographical area, Eastern Ontario is active, with a project goal to transfer and replicate the model to Southern Ontario in the future. Communication is being maintained with Peel Region contacts.

Lastly, the project will include analysis and discussion of the policy context in which decisions are made. The chosen indicators and scenario analysis will support decision makers during their climate change adaptation discussions and interventions that may unfold in order for wide ranging sectors to reduce circumstances related to vulnerability and/or enhance population resilience.

Respectfully submitted,

Patricia Larkin
March 30, 2016

References

Cheng, J.J., and Berry, P. (2013). Development of key indicators to quantify the health impacts of climate change on Canadians, and Online Supplemental Materials. International Journal of Public Health 58: 765-775. DOI 10.1007/s00038-013-0499-5

Cheng, J.J., and Berry, P. (2013). Online Supplemental Materials - Development of key indicators to quantify the health impacts of climate change on Canadians. International Journal of Public Health 58: 765-775. DOI 10.1007/s00038-013-0499-5

English, P.B., Sinclair, A.H., Ross, Z., Anderson,H., Boothe, V., Davis, C., Ebi, K., Kagey, B., Kristen Malecki, K., Shultz, R., & Simms, E. (2009). Environmental health indicators of climate change for the United States: Findings from the state environmental health indicator collaborative. Environmental Health Perspectives 117:1673–1681. doi:10.1289/ehp.0900708 available via http://dx.doi.org/ [Online 18 May 2009]

IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. M. Parry, O. Canziani, J. Palutikof, P. van der Linden & C. Hanson (Eds.), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 987). Cambridge, UK: Cambridge University Press.

National Academy of Sciences. (2014). A framework for assessing effects of food system. Appendix B: Selected Metrics, Methodologies, Data, and Models. Available at http://www.nap.edu/catalog.php?record_id=18846

Public Health Agency of Canada. (2006). How healthy are rural Canadians: An assessment of their health status and health determinants. Retrieved from https://secure.cihi.ca/free_products/rural_canadians_2006_report_e.pdf

Swanson, D. A., Hiley, J. C., Venema, H. D., & Grosshans, R. (2007). Indicators of adaptive capacity to climate change for agriculture in the Prairie Region of Canada. Winnipeg, MB: IISD.

Wall, E., & Marzall, K. (2006). Adaptive capacity for climate change in Canadian rural communities. Local Environment, 11(4), 373-397. doi: 10.1080=13549830600785506

Zhu, H., Deng, Z., Switzman, H., & Hazen, S. (2015). Identification and Validation of Extreme Weather Indicators for Agricultural Production and Rural Resilience in Ontario Project Final Report prepared for Agriculture and Agri-Food Canada (pp. 49).