Ontario Climate and Agriculture Assessment Framework (OCAAF)

Agroclimatic risks and opportunities for two regions and production systems in Ontario

August 23, 2017

Al Douglas (OCIFAR) and Neil Comer (Risk Sciences International)
Outline of the Webinar

- Learn about OCAAF and **hear about the results** of its application to:
  - forage-based beef production in the Clay Belt (timothy)
  - corn in southwestern Ontario (ecodistrict 7E-1)

- Overview of management objectives and thematic policy briefs.

- Q&A
Who we are

**Project Administration**
Al Douglas, OCCiAR
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**Collaborating Specialists**
Dr. Neil Comer, Risk Sciences International
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**Supporters:**
MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS
Ontario
Beef Farmers of Ontario
OFA
LRIC
UNIVERSITY OF TORONTO
UQAT
What is OCAAF?

The Ontario Climate and Agriculture Assessment Framework (OCAAF)

A regional framework to assess baseline and future agroclimatic risks and opportunities

Goals

- To inform policy, program and management choices.
- To help prepare for the impacts of climate change through adaptation.
Objectives

- Build an adaptable, transportable, translatable, and functionally expandable risk-opportunity assessment framework and apply to:
  - Forage production systems in Ontario’s Clay Belt (timothy) (Region 1)
  - Corn production in southwestern Ontario, Eco-district 7-E1 (Region 2)

- Analyze decadal regional climate change risks and opportunities out to 2050.

- Based on the results, adaptation options and policy briefs.
Outputs/Results

► Final Report highlighting entire project – FINAL REPORT

► Documentation of approach, and use of indices – DESIGN DOCUMENT

► Collections of crop-specific agroclimatic risk and opportunity indices.

► Results from index applications: current (baseline) climate, climate change projections, maps, etc.

► Audience = Provincial policy advisors and program managers, extension, ag associations, producers, research.

All project outputs can be accessed here: www.climateontario.ca/p_OCAAF.php
Methods
Phase 1: Development of the Framework

- White Paper
- Scoping/Design Workshop
- Criteria and Indicators
- Design Document
Building on an Existing Tool: Land Suitability Rating System (LSRS)

- Developed by scientists at Agriculture and Agri-food Canada (1995).
- The LSRS assesses the suitability of land for crop production, based on measurable qualities of:
  - Climate
  - Soil
  - Landscape
- It includes a scoring processes for each of these layers and methodologies on how to combine the indices to give an overall rating/score.

RSI is working closely with AAFC scientists to improve the LSRS.

<table>
<thead>
<tr>
<th>CLASS</th>
<th>SCORE</th>
<th>LIMITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80-100</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>60-79</td>
<td>Slight</td>
</tr>
<tr>
<td>3</td>
<td>45-59</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>30-44</td>
<td>Severe</td>
</tr>
<tr>
<td>5</td>
<td>20-29</td>
<td>Very Severe</td>
</tr>
<tr>
<td>6</td>
<td>10-19</td>
<td>Extremely Severe</td>
</tr>
<tr>
<td>7</td>
<td>0-9</td>
<td>Unsuitable</td>
</tr>
</tbody>
</table>

We looked specifically at timothy (*Phleum pretense*). 

Researched and combined:
- Historical spatial climate data
- Historical crop production data from experimental stations
- Information on climate modifiers
- Future climate projections

Results include:
- Projected temperature and precipitation changes at a monthly scale
- Changes to the LSRS scores and suitability for timothy
- Projections of future timothy yield out to 2050
Phase 3: Application to corn in southwestern Ontario

- Ecodistrict 7E-1 and customized OCAAF
- Researched and combined:
  - Historical spatial climate data
  - Historical crop production data
  - Information on climate modifiers
  - Future climate projections
- Results include:
  - Projected temperature and precipitation changes at a monthly scale
  - Changes to the LSRS scores and suitability for corn
  - Projections of future corn yield out to 2050
Phase 4: Adaptation Options and Policy Briefs

For each region, a suite of **adaptation options** were developed.
- Informed by research, BMPs
- Validated through regional advisors and stakeholders

Three thematic **policy briefs** to convey how provincial departments can support management of agricultural climate change risks and opportunities.
Stakeholder Consultation

- **Region 1:**
  - Scoping workshop in Guelph (December 2015)
  - Results workshop in New Liskeard (December 2016)

- **Region 2:**
  - Scoping workshop in Guelph (March 2017)
  - Results workshop in Ridgetown (May 2017)
OCAAF Results: FORAGE-BASED BEEF PRODUCTION IN THE GREAT CLAY BELT
1. Current Yield & Land Suitability Rating System (LSRS)
Identify relationships between HISTORICAL climate and timothy yield from available data (we need this for step 2)
(e.g. Temperature, Growing Degree Days, Precipitation, Evaporation)

2. Future Climate
Using the most recent IPCC climate model projections

3. Future Yield
Given climate change – how are yields expected to change?
Spatially – Observed Temperature

1951-1980 Normals Period

Source: ECCC and NRCan CANGRD
Spatially – Observed Temperature

Source: ECCC and NRCan CANGRD
Spatially – Observed Precipitation

1951-1980 Normals Period

Source: ECCC and NRCan CANGRD
Spatially – Observed Precipitation

Source: ECCC and NRCan CANGRD
Timothy (like all C3 grasses), best performs around 20°C and Dry Matter Yield (DMY) can suffer with temperatures over 25°C (Moser et al. 1996)

- Higher GDD5 increases DMY IF moisture and Growing Season Length allows multiple cuts
- Association with DMY and PRECIP-POTENTIAL EVAP is suggested (Bootsma and Boisvert, 1991)
- The minimum GDD5 of about 880 is easily surpassed in the Clay Belt (1 cut)
- 2 cut GDD5 requirement: 1360 and 3 cut requirement: 1840 (Bootsma and Boisvert, 1991)
- Growing Season Length and ‘kind’ is important (Bootsma and Boisvert, 1991)

References:

Our Data:
Kapuskasing Farm Timothy Yield (1984-2000) (Lafreniere)

- Increase in GDD5: Increase in DMY
- Increase in P-PE: Slight Decrease in DMY
Climate Indices Critical to LSRS

- Growing Degree Days
- Crop Heat Units
- Potential Evaporation
- Growing Season Length
- Excess Spring/Fall Moisture

AND allows for customized, crop-specific modifiers

We apply LSRS calculations to the gridded CANGRD climate data (at 10 km resolution) throughout the Clay Belt with GIS.
Authors have indicated limitations for timothy growth and we have selected 2 of these

- Fall Hardening – cold periods in the fall season to strengthen the timothy for winter cold (good)
- Winter Thaw – occurrence of warm periods during the winter season (bad)

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Source</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Hardening</td>
<td>FH-COLD Bélanger 2002</td>
<td>100 Cold Degree Days in Fall</td>
</tr>
<tr>
<td>Winter Thaw</td>
<td>W-THAW Bélanger 2002</td>
<td>Above freezing periods during Winter</td>
</tr>
</tbody>
</table>
We then repeat the calculations at each of the 10km grid points for each decade: 2020s, 2030s, 2040s and 2050s to get new scores.
Future Climate Projections for the Clay Belt
We use the ‘RCP 8.5’ Emission Assumption

- Our current Emission Trajectory
- This is the ‘business as usual’ path
- Even with International Agreement to limit GHGs, warming will continue
The Climate Models & Uncertainty

FUTURE PROJECTION DATA – 40 Models from IPCC AR5 (2013)

Combined to produce ENSEMBLE projection along with the ‘spread’ or uncertainty of these projections

Only possible with the use of many models – NOT just one

What about PROJECTION UNCERTAINTY?

The use of many models also allows us to consider uncertainty (through percentiles)

Model Max
75th
Model Mean
25th
Model Min
Temperature - Now

Mean Temperature (°C)

Latitude

Longitude

RS1
Temperature – 2050s

Mean Temperature (°C)

Latitude

Longitude

RSI
Precipitation – 2050s

Total Precipitation (mm)
Implications for Forage in the Clay Belt

“Mostly good news, some bad”
Summary of Outcomes

- Historical Temperature (GDD5) is increasing and continues under CC
- Historical Precipitation is increasing and continues under CC
- Increasing GDD5 means double cutting currently possible will be commonplace, and the GDD5 requirement for triple cutting will be possible by the 2050s
- GSL will increase from near 130 days to near 180 days by the 2050s allowing for the cuts
- LSRS Climate Classification will change from mostly CLASS-5 (very severe limitation) to CLASS-3 (moderate limitation)

Timothy Dry Matter Yield and GDD5 relationship:

<table>
<thead>
<tr>
<th>Currently</th>
<th>2050s</th>
<th>+30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>7100 kg/ha</td>
<td>9260 kg/ha</td>
<td>With NO climate modifiers</td>
</tr>
</tbody>
</table>
The 30% increase shown previously JUST considers the relationship between GDD5 and yield.

We see increasing Winter THAW episodes and decreasing Fall HARDENING episodes under CC.

We do not see P-PE (available moisture) as a limiting factor due to:

1. increasing precipitation (historically and projected)
2. clay soil

So we apply the percent deduction from the LSRS climate calculations to reduce the 30 percent since both of these trends are negative influences phenologically, although certainly not critically so.
Calculated LSRS Scores / CLASS
NO WTHAW / FCOLD MODIFIERS

1981-2010
LSRS

5
Calculated LSRS

NO WTHAW / FCOLD MODIFIERS

36

2050s

LSRS

3

rail
road
Implications for Yield:
GDD5 change

Given our historical relationship between GDD5 and Yield we can see spatially how this changes:

1981-2010 vs. 2050s
Implications for Yield

- With no climate modifiers the DM yield per hectare increases by 30% in the 2050s.
- Including the reduction in Fall Hardening and increase in Winter Thaws going forward, it is envisioned this increase will be reduced minimally to perhaps 25% in the 2050s.
- This difference can be eliminated if triple cutting becomes viable as projected.
Recap:
What can we expect to see by 2050?

- **It will be warmer:**
  - Annual = 2.9°C
  - Winter = 4.7°C
  - Spring = 3.2°C
  - Summer = 3.2°C
  - Autumn = 3.3°C

- **Longer growing season**
  - +43 days

- **Increase in GDD**
  - GDD5: 1413 to 1979
  - GDD10: 710 to 1127

- **More potential evaporation (mm)**
  - 455 to 513 (+13%) May to Sep

- **It will be wetter:**
  - Annual = 9%
  - Winter = 19%
  - Spring = 15%
  - Summer = 1%
  - Autumn = 7%

- **More days over 25°C**
  - 30 to 64

- **More freeze-free days**
  - 110 to 144

- **In-season impacts:**
  - Less fall-hardening
  - More winter-thaw

- **Better land suitability scores**
  - From 5 to 3
OCAAF Results:

CORN PRODUCTION IN SOUTHWESTERN ONTARIO (ECODISTRICT 7E-1)
1. Current Yield & Land Suitability Rating System (LSRS)

Identify relationships between HISTORICAL climate and corn yield from available data (we need this for step 2)

(e.g. Temperature, Crop Heat Units, Precipitation, Evaporation)

2. Future Climate

Using the most recent IPCC climate model projections

3. Future Yield

Given climate change – how are yields expected to change?
Spatially – Observed Temperature

1951-1980 Normals Period

Source: ECCC and NRCan CANGRD
Spatially – Observed Temperature

1981-2010 Normals Period

Source: ECCC and NRCan CANGRD
Spatially – Observed Precipitation

1951-1980 Normals Period

Source: ECCC and NRCan CANGRD
Spatially – Observed Precipitation

1981-2010 Normals Period

Source: ECCC and NRCan CANGRD
- Complex interaction of temperature, precipitation, soil conditions, soil fertility and sunshine.
- Temperature stress and moisture stress (too high or too low) have impacts throughout the season.
- Corn development is driven mostly by temperature (crop heat units, or CHU) (OMAFRA, 2009).
- Various phenological phases of growth have different stressors.
- These phenological phases have some quantified thresholds which we will apply to account for factors beyond simply CHU.

Our Data:
Corn Yield (Statistics Canada) and Windsor CHU/Yield

Source: Statistics Canada. Table 001-0071- Estimated areas, yield and production of principal field crops by Small Area Data Regions, in metric and imperial units, annual, CANSIM (database).
Increasing CHU is seen historically and will continue going forward.

There are more factors than purely climate (CHU).

A large factor in yield increase is suspected to be the use of different corn varieties which is embedded in the Stats Can yield data.

It can be assumed that yield optimization is the goal of new varieties and this will continue going forward but is incalculable.

Disease/drought tolerant varieties will continue to improve per hectare yield.

We will calculate projected yields based primarily upon increasing CHU with modifying factors for future temperature and precipitation at various phenological phases.
Calculate the Climate Indices Critical to LSRS for Corn

- Growing Degree Days
- Crop Heat Units ✓
- Potential Evaporation ✓
- Growing Season Length ✓
- Excess Spring/Fall Moisture ✓

AND customized, crop-specific modifiers from the literature
Crop Specific Modifiers for Corn: looking to existing literature

Table 4.2: Definitions of crop-specific extreme event indices used in the study.

<table>
<thead>
<tr>
<th>Index name</th>
<th>Definition</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ Poor seeding conditions</td>
<td>Weekly precipitation 30% greater than weekly mean precipitation (between April 23 and May 20)</td>
<td>weeks/year</td>
</tr>
<tr>
<td>✓ Early flooding</td>
<td>Weekly precipitation 30% greater than weekly mean precipitation with 1 to 780 accumulated CHUs</td>
<td>weeks/year</td>
</tr>
<tr>
<td>✗ Pollination drought</td>
<td>CDD &gt;10 with 1,301 to 1,600 accumulated CHUs</td>
<td>annual occurrence (Yes or No)</td>
</tr>
<tr>
<td>✓ R2 (blister) drought</td>
<td>P&lt;45mm with 1,601 to 1,825 accumulated CHUs</td>
<td>annual occurrence (Yes or No)</td>
</tr>
<tr>
<td>✓ R3 (milk) drought</td>
<td>P&lt;45mm with 1,826 to 2,000 accumulated CHUs</td>
<td>annual occurrence (Yes or No)</td>
</tr>
<tr>
<td>✗ Early killing frost</td>
<td>Tmin &lt;=-2°C with 2,165 to 2,475 accumulated CHUs</td>
<td>days/year</td>
</tr>
<tr>
<td>✓ R4 (dough) drought</td>
<td>P&lt;8mm with 2,001 to 2,165 accumulated CHUs</td>
<td>annual occurrence (Yes or No)</td>
</tr>
<tr>
<td>✗ Fall killing frost</td>
<td>Tmin &lt;=-2°C with 2,476 to 2,600 accumulated CHUs</td>
<td>days/year</td>
</tr>
</tbody>
</table>

Source: Zayetsva, A. (2016). Spatio-temporal patterns of extreme weather events and their impacts on corn (Zeamays) and soybeans (Glycine max) in eastern Ontario. Master’s Thesis. Carleton University. Available at: https://curve.carleton.ca/1b2c826c-1648-4174-8fa1-b0c22a7c15b4
We then repeat the calculations at each of the 10km grid points for each decade: 2020s, 2030s, 2040s and 2050s to get new scores.
Future Climate Projections for southwestern Ontario
Temperature - Now

Ecodistrict 7E1 - Climatic data - Annual.Temp.2000s

[RSI logo]
Temperature – 2050s

Near +3°C increase
Precipitation – 2050s

Near +6% increase ANNUALLY
Implications for Corn in Southwestern Ontario

“Large CHU increase and increasing moisture challenges”
Summary of Outcomes

- Historical Temperatures (and CHU) are increasing and continues under CC.
- Historical Precipitation is increasing and continues under CC, but is overcome in summer by increased evaporation → drier summers (evaporation), slightly wetter winter/spring.
- GSL will increase from near 182 days to near 210 days by the 2050s.
- LSRS Climate Classification will change from mostly CLASS-1 (no limitations) to CLASS-2 (slight limitations requiring management due to increased summer moisture deficit).

CORN YIELD PROJECTIONS DRIVEN BY CHU alone will INCREASE

Current Average Corn Grain Yield
~8,000 kg/ha

2050s
~11,300 kg/ha

+41% With NO climate modifiers
Calculated LSRS Scores / CLASS

Ecodistrict 7E1 - LSRS Climatic Factors - ClimateRating_2000s

CLASS 1

1981-2010

LSRS
Calculated LSRS

2050s

CLASS 2

LSRS
### Deduction Factors – details

<table>
<thead>
<tr>
<th></th>
<th>1981-2010 Baseline</th>
<th>2050s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Deficit</td>
<td>P-PE (May 1 - August 31)</td>
<td>-164.5</td>
</tr>
<tr>
<td>Excess Spring Moisture Ded.</td>
<td>PPE in May</td>
<td>-0.3</td>
</tr>
<tr>
<td>Excess Fall Moisture Ded.</td>
<td>PPE in Sep</td>
<td>-3.6</td>
</tr>
</tbody>
</table>

### Modifiers

<table>
<thead>
<tr>
<th>Modifier</th>
<th>1981-2010 Baseline</th>
<th>2050s</th>
</tr>
</thead>
<tbody>
<tr>
<td>poor_seeding (no. weeks /4)</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Early Flooding (weeks per year)</td>
<td>6</td>
<td>5.9</td>
</tr>
<tr>
<td>drought-r2 (frequency in 30 years)</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>drought-r3 (frequency in 30 years)</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>drought-r4 (frequency in 30 years)</td>
<td>28</td>
<td>26</td>
</tr>
</tbody>
</table>

*Not much change in modifiers, due to small change in precipitation.*

*Largest Factor:*
Implications for Yield based on CHU

- We use our historical relationship between CHU and Yield
- We use the assumption this will hold and the major influence on yield will be CHU
- We will assume continued development of corn varieties and their optimization for future climate
Implications for Yield

If the area under corn is the same as 2011: production increases from 199K tonnes to 282K tonnes per year in 2050s.
Recap:
What can we expect to see by 2050?

- It will be warmer:
  - Annual = 3.3°C
  - Winter = 3.6°C
  - Spring = 2.8°C
  - Summer = 3.2°C
  - Autumn = 3.1°C

- It will be wetter:
  - Annual = 6%
  - Winter = 13%
  - Spring = 13%
  - Summer = same
  - Autumn = 3%

- Longer growing season
  - +28 days

- Increase in CHU
  - 3943 to 4923 (+25%)

- More days over 25°C
  - 84 to 121

- More freeze-free days
  - 249 to 291

- More potential evaporation (mm)
  - 552 to 640 (+16%) May to Sep

- In-season impacts:
  - More CHU and yield potential
  - Same summer precip but...
  - Higher evaporation & moisture stress

- Decreased LSRS (Land Suitability Rating System) Score
  - From 1 to 2
Adaptation Options and Policy Briefs
Five Main Management Objective Categories

1) Expand forage-based beef production in the Clay Belt – 4 specific measures
2) Ensure proper management of water at the farm-level – 3 specific measures
3) Ensure proper management of land at the farm-level – 3 specific measures
4) Support agricultural research + dissemination of information – 3 specific measures
5) Farmers are implementing adaptive measures to account for the impacts of climate change – 2 specific measures

15 Adaptation Options in Total
Four Main Management Objective Categories

1) Encourage water management practices that mitigate the impacts of climate change – 5 specific measures

2) Improve soil management practices and build soil health – 2 specific measures

3) Support agriculture research, innovation and knowledge exchange – 2 specific measures

4) Encourage the implementation of adaptive measures – 3 specific measures

12 Adaptation Options in Total
The project team developed 3 thematic policy briefs that stem from the results of OCAAF’s two applications. They focus on:

- Grappling with Climate Change Impacts by Strengthening Agricultural Extension in Ontario
- Managing Water for Agriculture under Ontario’s Changing Climate
- Enabling Transformation of Two Farming Systems in Ontario’s Changing Climate

**Target audience** = provincial government policy- and decision-makers (e.g. OMAFRA, OMNRF, MOECC)
Thank you! Questions?

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