Past and Future Extreme Climate Events in Canadian Prairies: Integrating Economics and Climate

Suren Kulshreshtha and Elaine Wheaton
University of Saskatchewan
Saskatoon, Canada

Presentation made at the Earth Sciences and Climate Change Conference, San Francisco, July 28 2014

Synopsis

2

- Background
- Extreme Events in the Canadian Prairie Provinces
- Future Climate Change and Extreme Events
- Impacts of Extreme Events on Agriculture
- Impacts of Extreme Events on Other Sectors
- Economic Cost of Extreme Events – Methodological Issues
- Challenges for the Future

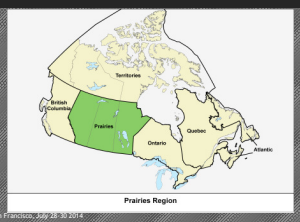
Background

3

- Predictions of climate change for the Canadian prairie region suggest a higher growing season temperature and longer growing season associated with more variable precipitation
- In addition, frequency of some extreme events would also increase
- Canadian Prairie Region is predominantly an agricultural region of Canada
- Increased frequency of extreme events would have a serious impact on the region's economy, and through that on the national economy

Location of Canadian Prairie Provinces

4



Prairies Region

Canadian Prairie Region

5

- Consist of three provinces: Alberta, Saskatchewan, and Manitoba
- Region is the breadbasket of Canada with 81% of all area under crops
- Changes in crop productivity of the region would not only affect field crop producers but also livestock producers and through these impacts, the entire socio-economic fabric of the region
- Though linkages (trade and others), these impacts would permeate to other parts of Canada as well.

Why bother finding out about climate and its extremes?

6

- Signs of a changing climate are clear and having effects
- Temperature extremes are changing, especially in the winter and spring
- Precipitation is highly variable
- Climate has strong effects, especially on year to year changes of agricultural production and water resources
- In the region, droughts are frequent and create large negative impacts

Most Expensive Canadian Natural Disasters (Total Estimated Economic Impact >=$1 billion 2000$)
[Courtsy: Grace Koshida, Environment Canada]

Date of occurrence	Event	Location	Estimated Total Cost (billion 2000$)
2001-2002	Drought	Prairies,Ontario, Nova Scotia, PEI	$5.8
1980	Drought		$5.8
	Freezing rain	Ontario to New Brunswick	$5.4
1988	Drought	Prairies	$4.1
1979	Drought	Prairies	$3.4
1984	Drought	Prairies	$1.9
	Flood	Québec	$1.6
May, 1950	Flood	Manitoba	$1.1
	Hurricane Hazel	Toronto & Southern ON	$1.1
1931-1938	Drought	Prairies	$1.0
1989	Drought	Prairies	$1.0

Climate Resources for Agriculture- New Normal (Beaulieu and Wittrock 2013)

8

- Evidences of climate change are already here.
- Frost free season has lengthened at a rate of about 5d/10y or at least 25d in central agricultural SK since the 1960s
- Crop heat units have increased
- Number of hot days (>35C) has increased from about 1-3d in the 1960s to 2-5d in the 2000s
- Number of cold days (<-40C) has decreased from 1-6d in the 1960s to near zero in the 2000s

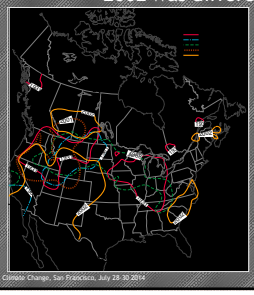
Extreme Events on the Canadian Prairies

10

- Most extreme events on the Canadian Prairies are of two types:
  - Occurrence of dry spells
  - Heavy rainfall / precipitation
- Typically dry spells, alternatively called droughts, also come in different forms
  - In terms of scope, they can be local, regional, or national in nature
  - In terms of periodicity, they can be single period or multi-period droughts
- In the past multi-period droughts have occurred in 1890s, 1910s, 1930s, late 1950s to early 1960s, 1980s, 1999-2005, and 2009-10.

Many droughts but Drought of 2001-2002 was different

11



- 2001 and 2002 drought years appear to be the most extensive of this set of major droughts
- Preferred area for droughts in Canada is the southern prairie provinces
- Northward extension of these recent droughts appears unusual
- 2001-2002 was a major multi-year drought, unlike many others

Excessive Moisture Extremes

12

- Saskatchewan has among the most extreme rainfall events in Canada. For example, the largest eight hour precipitation event in Canada occurred in the Vanguard area of southwestern Saskatchewan on 3 July 2000. Damage included flooded buildings, washed-out roads and rail lines, compromised drinking water supplies, and decreased agricultural production (Hunter *et al.* 2002)
- In 2014, flooding in southeast Saskatchewan and southwest Manitoba has left 1.5 million ha of crop unseeded or drowned

Maximized Storm Rainfall in SE SK (For perspective, mean annual precipitation is about 350 to 450 mm) (Wheaton et al 2013)

13

Amount (mm)	Duration (h)	Area
556	24	Point estimate
395	24	Basin estimate
449	72	Basin estimate
508	6	10 sq mi
660	24	10 sq mi
736	72	10 sq mi
488	NA	Basin average+snow

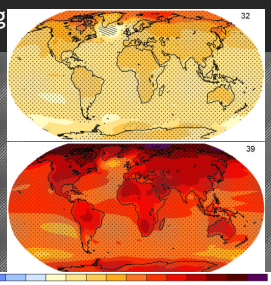
Projected warming

14

Difference between 1986-2005 and 2081-2100

RCP2.6

RCP8.5



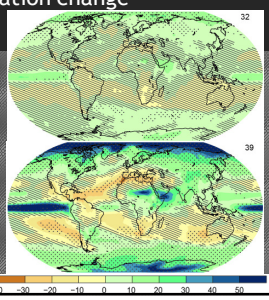
Projected precipitation change

15

Difference between 1986-2005 and 2081-2100

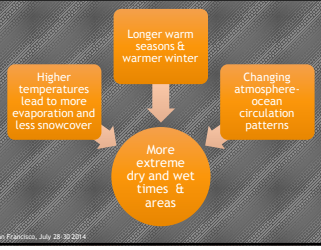
RCP2.6

RCP8.5



Dry Times become Drier & Wet Times become Wetter (Wheaton et al 2013)

16



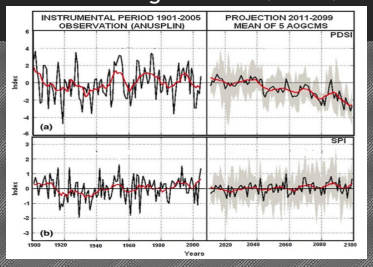
Probable Future Droughts (Wheaton et al 2013)

17

- Increased **intensity** of dryness, driven by increased evaporation potential with higher temperatures and longer warm seasons. Drying likely **overwhelms** projected increases in precipitation
- Droughts of 6-10 months and **longer** increase frequency by about 4 events (2050s)
- **Frequency** of long duration droughts of five years and longer more than doubles towards 2100 AD, and
- Frequency of **decade-long** droughts and longer triples towards 2100.

Past and Future Area- Averaged Summer Drought Indices (Bonsal et al 2012)

18



Future Probable Extreme Precipitation Scenarios (Wheaton et al 2013)

19

- **Number** of 1:20y potential maximum precipitation event **doubles** towards 2100
- Rainfall amount of extreme maximum events **increases** by 5% to 20% (2050s)
- **Many** wet periods similar to those of the 1970s occur towards 2050s, and
- Expect surprises as **new combinations** of climate characteristics emerge
- This is a research gap that requires much more understanding.

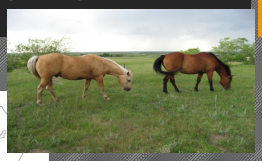
Impacts of Extreme Events on Agriculture

20

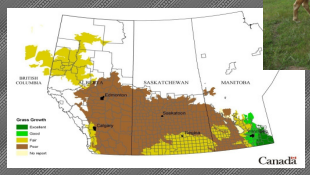
- Both dry and wet events would have devastating impacts on agriculture
- Droughts result in reduced soil moisture, crop losses, soil compaction, herd reduction, cost of feed, forage losses, among others
- Excessive rainfall and flooding result in large damages for agriculture and communities, including: delayed spring planting, crop losses (both quality and quantity), soil compaction (with use of equipment on land), runoff and soil erosion, reduced access to land, and harvest constraints.
- Social impacts of droughts and floods include changes in quality of life, damage to infrastructure, tourism and recreation and uncertainty of public policies

Grasslands Suffer during Droughts

21



Grass Growth on Pastures for 6 June 2002

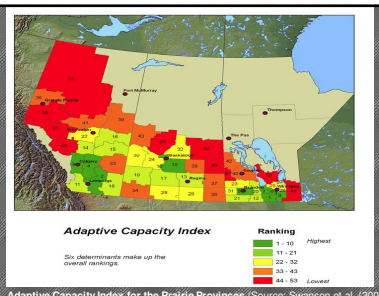


Adapting to these changes and Adaptation Capacity

22

- Adaptation is key to reducing the negative impacts of climate change including extreme events
- Prairie farmers are highly adaptable folks. Undertaking off-farm jobs in periods of lower farm income and rising input cost, is an excellent example
- In response to 2001-2002 droughts, Wheaton et al (2007) mentioned most used types of adaptation were those for crops and livestock, followed by water and economics, then community support and technologies
- Institutions assist producers to make adaptations to droughts
- However, adaptive capacity is unevenly distributed

23



Adaptive Capacity Index for the Prairie Provinces (Source: Swanson et al. (2007)

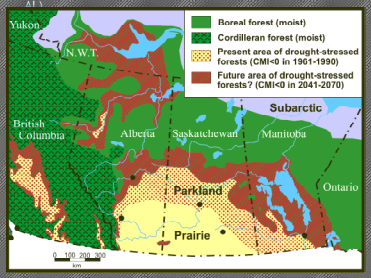
Impacts of Extreme Events on Non-agricultural sectors

24

- Drought stressed forests -- Forests are vulnerable to droughts
- Agricultural based manufacturing - high cost of importing inputs
- Transportation infrastructure in the northern regions of the Prairie Provinces would be affected
- Health of individuals - emergence of new diseases, increased stress, also heat stress, for e.g.

DROUGHT-STRESSED FORESTS (HOGG ET AL.)

25



Impacts on Transportation Sector

26

- Increased frequency of intense rains would affect erosion of roads, bridges, culverts, and railways
- Higher frequency of heat waves would result in degradation of railways and asphalt-based roads
- Northern winter roads could only be used for a shorter period
- Reduced snow clearing expenditures in more years
- Post of Churchill ice-free season will increase, but to expand capacity requires large investments

Future Possible Droughts and Floods?

27

- Chances of multi-year droughts increase
- Increases in severity and area
- Droughts overwhelm the increases in average precipitation
- Expect surprises, such as switches to extreme rainfalls
- Extreme rainfall events will increase

True Economic Cost of Extreme Events

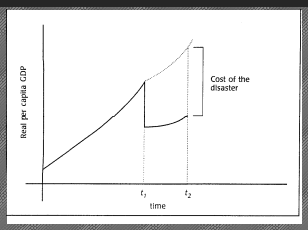
28

- Typical practice is to take drought / floods one year at a time
- This lead to serious underestimation
- Reasons include:
  - Even a single year drought can have impacts on the future productivity of the economy
  - True cost of the drought combines current as well future impacts

Cost of a Disaster – Total vs. Single Period

(Dore and Etkins, 2000)

29



A Comprehensive Assessment of Economic Cost of Extreme Events

30

- All assessments should be done from both local and national accounting stances
- From economic theory point of view, the ideal manner in which we could estimate the economic costs to the society of an extreme event (or for that matter, any disaster) is to equate it to:
  - DISTORTIONS CREATED BY THE EXTREME EVENT TO THE NORMAL DEVELOPMENT AND EXPANSION OF THE ECONOMY

Sources of Distortion should include

31

- Direct loss of value added due to the extreme event in various sectors of the economy
- Loss of human capital (Loss of human lives and associated human capital)
- Indirect economic losses / costs
- Loss of capital destroyed by the event (To include man-made private capital, such as buildings, machinery, and man-made social capital, such roads, bridges)
- Fiscal costs of the government, including effects of changes in fiscal measures (Additional taxes needed)
- Distributional issues of impacts
- Value of lost ecological goods and services – Non-Market Goods
- Economic losses resulting from social impacts of the event
- Cost of adaptation measures (including possible migration)

Sources of Distortion should include (2)

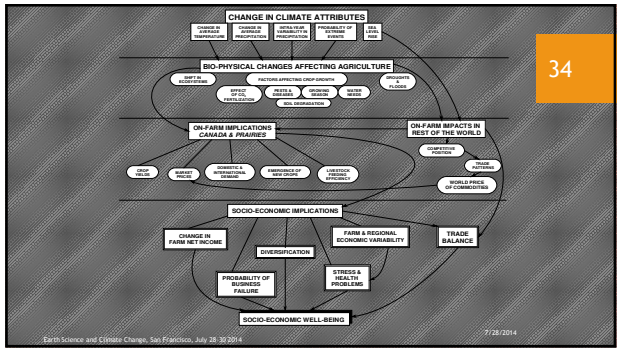
32

- According to the Millennium Ecosystem Assessment of the United Nations, "Humans are totally dependent on the nature"
- Nature provides us with four types of services: Provisioning Services, Cultural Services, Supporting Services, and others.
- Since these services enhance individual's well-being, they place a value on them, called Ecological Goods and Services
- Any reduction in these services reduces social welfare and therefore, need to be accounted for.
- Loss of human capital – Loss of lives plus effect of stress
- Long-term cost of adaptation (including migration)

Future Research Needs

33

- Need for an integrated assessment of climate change impacts
- Need to estimate the true social cost of extreme events to include not just the direct costs and benefits but all social and fiscal costs



34

Concluding Remarks -- Future Expected Agroclimates

35



- Accelerated changes in above conditions, e.g. longer growing seasons, milder winters, decreased snow cover, increased heat waves
- Past droughts may seem mild compared with future droughts
- Increased potential for major rainstorms and floods
- More switches of dry/wet and hot/cold
- Expect the unexpected with unstable climates