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Natural hazards in Ontario, Canada: an analysis for resilience building

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Abstract

This study analyses all natural hazards that occurred in Ontario, Canada during the period 1900 - 2013. The focus of this research is on the impact on critical infrastructure and critical facilities during these events. There are a total of 160 events during this period; almost 1.5 events per year. The events are classified into hydrological, meteorological, geological, and biological types. In terms of the frequency of the events, floods were the highest at 56 followed by severe thunder storms at 21, 19 wildfires, 17 tornadoes, 14 winter storms, and less than 10 events each of epidemics, drought, unspecified storms, extreme cold and heat, sinkholes, and hurricanes. Damage to critical infrastructure, both short term and long term included damaged power lines due to flooding and ice storms, highway closures, disruption to the ferry service, and back up of sewer with raw sewage onto the streets. Disruptions occurred in critical facilities, such as fire services, isolation of hospitals, no home delivery of milk, ice, and fuel posing threat to life for vulnerable population. Even though flooding was common to both long and short term impacts, for short term impact, the second highest are severe thunder storms and tornadoes followed by epidemics; whereas for long term impact events, the second highest hazard is wildfire followed by severe thunder storms. Extensive analysis has been carried out to provide better understanding of natural hazards occurrences and their impact for the purpose of building disaster resilience in communities.

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Keywords: Natural hazards, Ontario, Canada, Resilience, Critical infrastructure

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1. Introduction

Natural hazards impact every part of the world in various manner depending on geomorphology and demographics of different locations. Figure 1 shows the study area, the Province of Ontario in Canada. Comprehensive disaster databases that are maintained by Public Safety Canada (PSC 2014) and Environment Canada (2014a, b) have been used in this research. Emergency Management Ontario (EMO) is the provincial public agency responsible for recording disaster events and plan for reducing disaster risk to people, property, and the environment. Extreme weather events of rare likelihood of occurrence, as well as changing climate can also have adverse impact on people's health through direct and indirect effects, including social and economic causes. In recent years, the province is realizing the need for appropriate planning and strategy development to enhance resilience of the population (PHO 2014; City Report 2014; Haines et al 2014). An Emergency Management Forum has been set up by the EMO on which representation from every sector including industry, businesses, higher education, power generation, transportation, City management, and utility companies is assured. The first author of this paper is a member of the forum. The Forum meets every month to discuss recent disasters in the province and future course of action and planning.

Fig. 1. Map of Canada with provinces and territories. The Province of Ontario is shown in green.

2. Data and method

Natural hazards experienced in Ontario, Canada have been examined for the period of 1900 – 2013. Publications by Public Safety Canada (PSC 2014) and Environment Canada (Environment Canada 2014a, b) have been used in this study. Figure 2 shows a distribution of these hazards. An interactive link given in the caption allows an access to detailed information about these hazards. A total of 160 events that occurred in the past 113 years have been classified into four categories, namely, hydrological, meteorological, geological, and biological. Within the hydrological category, floods and droughts are included. Meteorological category includes wildfires, tornadoes, cold events, heat events, winter storms, hurricanes, severe thunderstorms, and other unspecified storms. Geological disasters do not pose significant threat in Ontario – even though they have a fairly likelihood of occurrence in Canada's Quebec province in the east and British Columbia in the west. Biological disasters are generally about epidemics and infestation events. In Ontario, there have been epidemics but no infestation event has been recorded during this period.

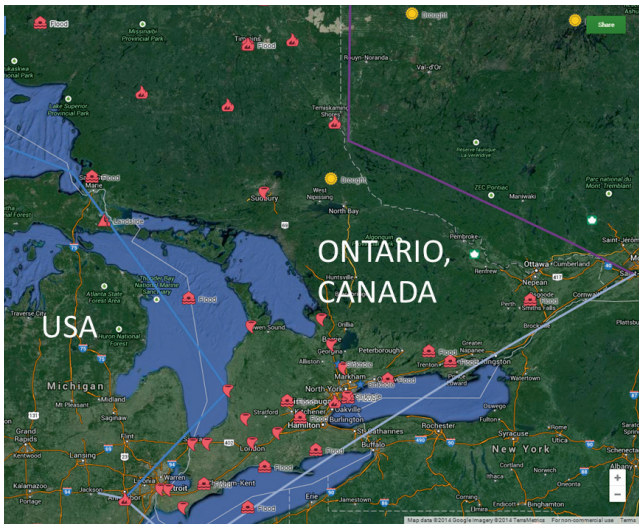

Fig. 2. : Distribution of most common natural hazards (shown in red) in Ontario. An interactive map is available at https://mapsengine.google.com/map/u/0/edit?mid=zkey8iIPyBZM.kyZci0tyUBwM

The distribution of all hazards clearly shows (Fig. 3) that floods top the list with 56 events, followed by severe thunder storms at 21, wildfires at 19, 17 tornadoes, 14 winter storms, and others, less than 10 occurrences.

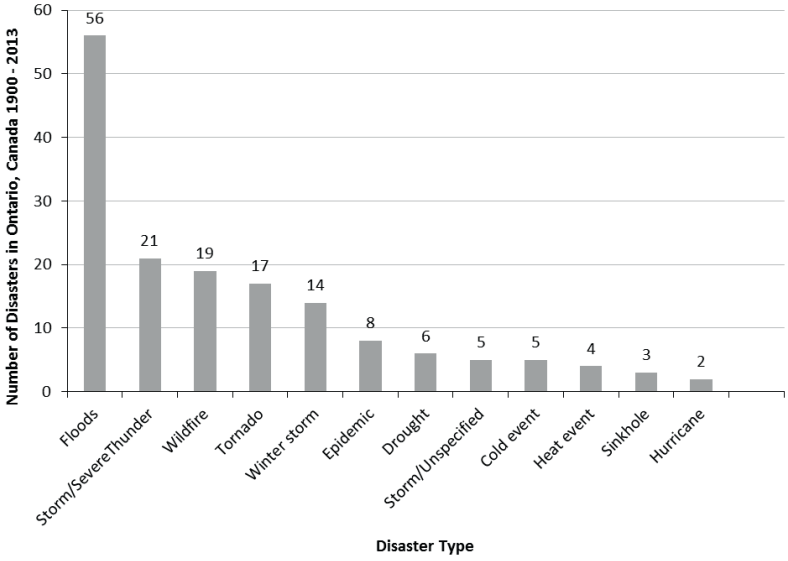

Fig. 3. Disaster types and numbers in Ontario during 1900 – 2013.

3. Analysis

Natural disasters of Ontario, Canada over past 113 years have been studied for the analysis. Geological disasters, such as tsunamis, earthquakes, and volcanoes are not common in Ontario. A total of 160 events were recorded, averaging at about 1.4 disasters per year. Short and long term impacts of these events have been examined – with a particular attention to critical infrastructure and critical facilities. Disruptions in services and businesses cost the

province, insurance industry, and businesses a fortune as well as a risk of going out of business for private sector (Dolce 2014; The Star 2014: Nirupama et al 2014). Adverse impacts of disasters during the study period include, reduced productivity, inability to provide essential services (water, electricity, gas etc.), loss of income for many, highway closures, damaged powerlines to flooding and ice storms, and backup of sewers with raw sewage spilling into the streets (Armenakis and Nirupama 2013; Nirupama and Armenakis 2013; D'Andrea 2010; GOC 2012).

Based upon detailed impacts collected from various sources (PSC 2014; Environment Canada 2014a, b; Nirupama and Armenakis 2014; The Star 2014a, b; National Post 2014; Armenakis and Nirupama 2014; CBC 2014; Global News 2013; Toronto Star 2013; Kimbell 2013) of all of the events analyzed in this study, short term and long term impacts of the disasters are illustrated in Figure 4. To discuss a few outstanding examples, the 1995 snowstorm that hit southern Ontario caused closing of the Peace Bridge between Ontario and New York, and Muskoka, Ontario airport and weather office were evacuated. The 2013 ice storm in Toronto left over a million people without power for few days, and some for over a week. This particular event left a long term impact on the province. In the same year, unprecedented flooding due to excessive single-day rain broke the previous record of flooding caused by Hurricane Hazel in 1954. In July 1936, Ontario hit 42.2 °C killing 1,180 people. In January 1953, a freighter sank in high winds in Lake Superior causing 17 deaths. In December 1944, a blizzard and accompanying strong winds caused closure of factories that were producing war ammunitions for a few days. In June 1999, a portion of TransCanada highway was washed out in heavy rains. In the early 20^{th} century, a number of devastating wildfires destroyed significant and healthy forest areas. In 1963 and 1973 severe heat and drought stress resulted in low crop yields in Ontario, drastically cutting soybean and corn production and potato and apple production respectively – obviously long term impacts. A Northern Ontario community, Winisk had such severe flooding that it had to be evacuated by air, abandoned, and a new town site was developed upstream of Winisk River. A number of other First Nations communities in Northern Ontario have had disasters due to flooding, water contamination, landslides, and wildfires leaving widespread devastation and long term disruptions in the region.

Decadal and seasonal analysis of hazards presents important and valuable insights, as shown in Figure 5. The decade of 1990-2000 was particularly severe with 34 disasters recorded in Ontario. The decade prior to that (1980-1990) experienced a total of 26 events. Seasonally speaking, the month of January experienced maximum number (a total of 28) of disasters in Ontario (Fig. 6). The month of May had 21 events, and April is next with 20 events. This pattern explains the nature of weather pattern in Ontario. In the month of January, cold weather systems can persist for weeks on end causing winter storms, freezing rain, ice pallets, and high winds, as well as floods in other areas where snow fall is followed by a sudden warm spell. Other causes for flooding include, ice blockages and debris damming the river and freeze and thaw cycles raising water levels. Around April and May, a combination of spring thaw and precipitation led to widespread flooding, tornadoes, and storms. Specifically noteworthy event was in Kashechewan and Fort Albany First Nation communities due to a warm air assault on a heavy snowpack. Lightening caused wildfires around May in 2010, however, in 1998-2000, and 2007, record dryness causing burnt grass, cracked soil, curled up leaves, shriveled corn cobs, and dying trees led to severe wildfires. The months of June and July have seen a mix of wildfires, tornadoes, flooding, and sinkhole events. Some years have been particularly wet, for example, in 2002 the Capital city of Canada, Ottawa (Ontario) had dangerous water levels in the Rideau Canal. In 2013 a cloudburst dumped about 126 mm of rain (Nirupama and Armenakis 2014) in Toronto.

August weather patterns can be complex with combinations of large low pressure centre to the northwest of the Great Lakes and a strong stationary high pressure system in the East. This system rotates in opposite directions, generating a large surface pressure gradient that is capable of maintaining winds from the southwest for more than two weeks. Snow cover on the ground adds to the complexity of the situation that allows the air to keep its heat. At times, a persistent west to east jet stream further north than usual keeps cold Arctic winds confined to the upper regions of Canada, enabling warm air to surge northward unhindered (Environment Canada 2014a).

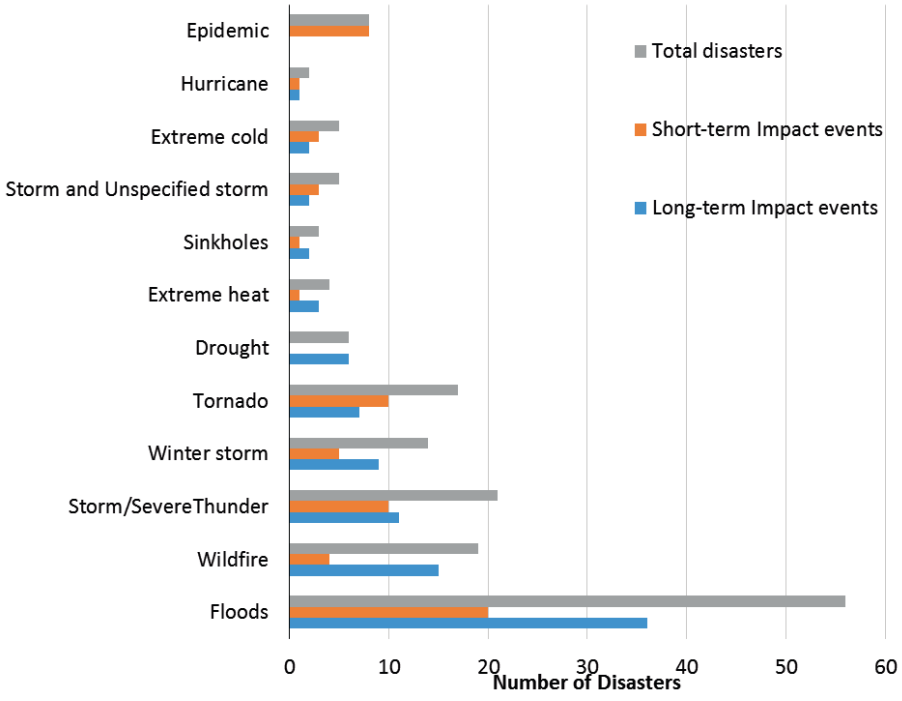

Fig. 4. Number of natural disaster events with their long and short term impacts.

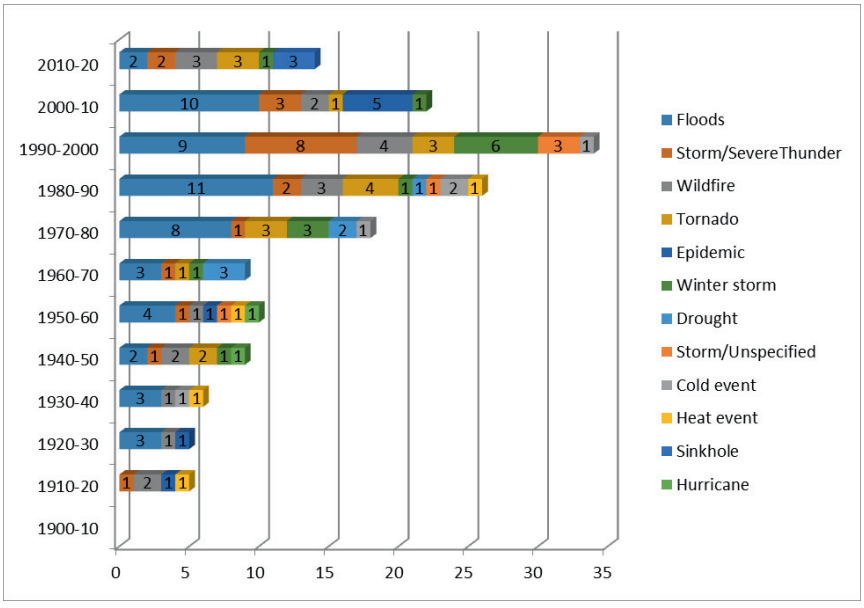

Fig. 5. Decadal distribution of disasters in Ontario during 1900-2013. Numbers shown in each bar represent the total number of each disaster type falling within the decade.

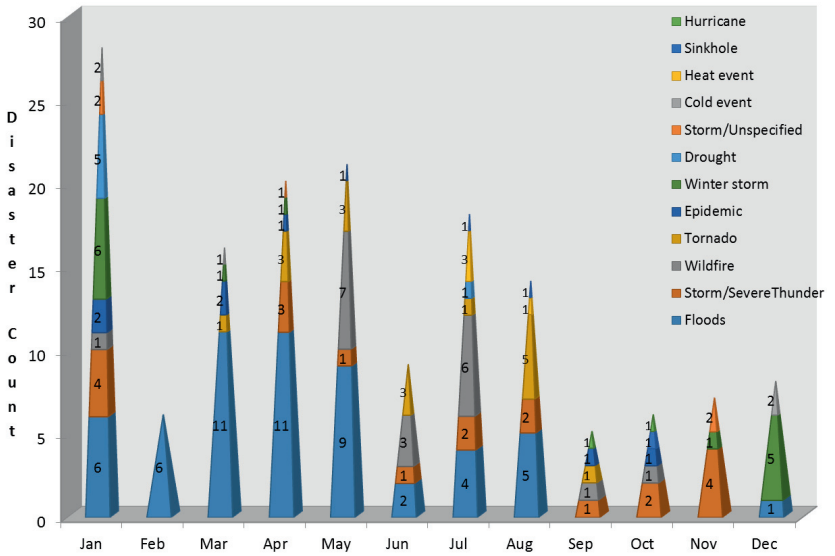

Fig. 6. Seasonal trends by monthly distribution of disasters in Ontario during 1900-2013. Numbers shown within each bar represent total number of each disaster type within the month.

Recent disasters in Toronto left long term impacts in the region. The ice storm in December 2013 and flooding in July 2013 have reignited the debate on disaster resilience (Armenakis and Nirupama 2014; Coulson 2014). During the ice storm, widespread failure of powerlines was caused by the weight of ice accumulation on them as well as falling tree branches, disrupting essential services (hospitals, electricity, and water) in the city.

Economic cost of all the disasters analyzed in this study has not been discussed due to discrepancies in numbers reported by various sources and unreliability of adjustment for inflation. However, according to the number of fatalities and people affected in these disasters, epidemic stands out with most affected persons (Spanish influenza of 1918), followed by winter storm and floods (Table 1).

Table 1: Number of fatalities and people affected in all the disasters analyzed in this study.

	Floods	**Severe Thunder Storms**	**Wildfire**	**Tornado**	**Epidemic**	**Winter storm**	**Drought**	**Storm/ Unspecified**	**Cold event**	**Heat event**	**Sink hole**	**Hurricane**
Fatalities	9	390	366	55	50979	84	0	17	15	1195	0	81
Affected	318166	12	40050	970	2020469	8619513	0	0	200	189	0	7472

4. Concluding remarks

The Province of Ontario in Canada is prone to a number of hydrological, meteorological, and biological disasters. Most frequent events include, flooding, wildfires, severe storms, and winter storms. Provincial authorities (Young 2013; TRC 2009; Nirupama and Etkin 2012) are engaged in taking stock of their understanding of potential hazards and their possible impacts in the region. Flooding (riverine and from cloudburst), being the most frequent disaster, the province must consider mitigation measures to protect critical infrastructure and critical facilities in order to enhance people's resilience and reduce damage in the future. Some of the feasible measures include, landuse planning and restricted development in floodplains (need to update zoning), addressing sedimentation concern in major rivers and creeks and widening of the channels or dredging of river beds to enhance their carrying capacity, and mid-size dykes where possible. In addition, to reduce damage from urban flooding, municipalities can consider having dry ponds in every subdivision, similar to current regulations regarding having parks in every

neighborhood. These dry ponds will allow the excessive rainwater to get collected in them when necessary. Also, improving drainage systems in each of the watersheds in the province and removal of snow blockage from drainages will reduce infrastructural vulnerabilities. Thunderstorms and tornadoes, being next most frequent events, should also be given priority in disaster mitigation planning to address specific impacts caused by them. It must be acknowledged here that the province is efficient in responding to wildfires and measures are being taken to encourage people from building properties in urban-forest interface.

To address short and long term impacts of winter storms, building underground powerlines (like gas lines) may be considered. It an expensive mitigation alternative by some experts, but it will resolve devastating consequence of ice accumulation and tree branches snapping on them. Structural modifications and regulations can be introduced to reduce property damage from ice storms in light of the fact that a standard house roof in Ontario is designed to hold only up to 2 feet of snow, more than that will cause the roof to collapse. Additionally, tall trees can be imposed restricted use in heavily populated residential areas. The Emergency Management Ontario maintains a State-of-the-Art Emergency Operation Centre to respond to disasters (Thomson et al 2014). It is our intent that this study will provide valuable insight into past 113 years of disasters to alleviate future impacts from disasters.

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