Using geographic information systems to estimate potential pesticide exposure at the population level in Canada

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Outline for today

This presentation will cover:

- About CAREX Canada
- What are pesticides?
- How we are estimating pesticide exposure
- Results: what did we find?
- Challenges and next steps
- Question period

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About CAREX Canada

A multi-institution team of researchers and specialists based at the Faculty of Health Sciences at Simon Fraser University.

The purpose of CAREX Canada is to provide a body of knowledge about Canadians' exposures to known and suspected carcinogens. Prioritizing exposure reduction policies and programs.

About CAREX Canada

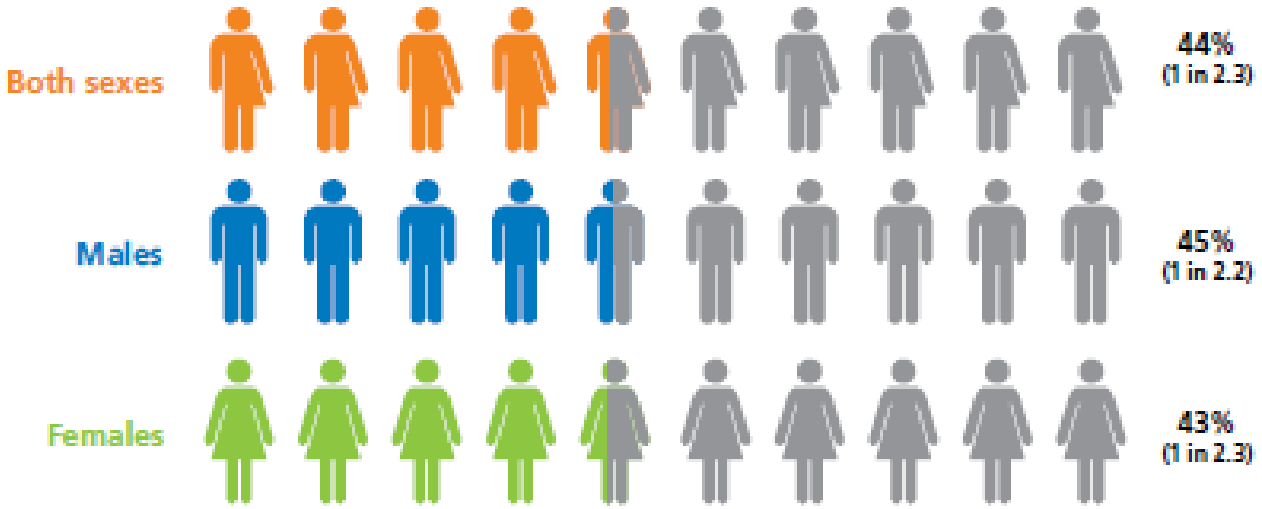
CAREX Canada looks to identify:

- **What** carcinogens are Canadians exposed to, both at work and in the community?
- **Where** in Canada do these exposures occur?
- **How many** people are exposed?
- **How much** are people exposed to?

Vision: To help reduce Canadians' exposures to carcinogens and reduce the risk of cancer

Canadian Cancer Society Statistics

Probability of developing cancer, 2015



Analysis by: Centre for Surveillance and Applied Research, Public Health Agency of Canada
Data sources: Canadian Cancer Registry and National Cancer Incidence Reporting System databases at Statistics Canada

Cancer is the leading cause of death in Canada.

Nearly half of the Canadian population will develop cancer in their lifetime.

About half of all cancers can be prevented through healthy living and policies that protect the health of Canadians.

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What are we talking about today?

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What are pesticides?

Pesticides are commonly used in agricultural to maximize crop productivity, control pests, and improve cosmetic condition (Oerke and Dehne, 2004; Cooper and Dobson, 2007).

Concerns have been increasing due to the extensive application of pesticides in modern agricultural practices (Malone et al., 2004; Lefrancq et al., 2013).

Pesticides

Active ingredients describe the specific chemical used in the pesticides'

- Example: Glyphosate and 2,4-D are active ingredients
- In Canada active ingredients are regulated by the Pest Management Regulatory Agency (PMRA), Health Canada
- 7,500 products registered for use in Canada (~650 active ingredients)

Pesticides and exposure

Pesticide exposure is typically highest in occupational setting (Fenske, 2005)

Exposure to the general population occurs through ingestion of pesticide-treated foods and contact with contaminated air, water and soil (Hildebrandt et al., 2008)

Geographical location also plays an important role, residents near agricultural land can have higher pesticide exposures than those living in non-agricultural areas (Wan, 2015; Ward et al., 2006).

Pesticides and health

Pesticide exposure may relate to:

- Certain cancer outcomes (IARC, 2017a; Kim et al., 2017)
- Reproductive health issues (Newbold, 2008; Shirangi et al., 2011)
- Adverse birth outcomes (Roberts and Karr, 2012)
- Neurological concerns (Kamel et al., 2007)
- Other more general health problems (Roberts and Karr, 2012; Gilden et al., 2010)

Pesticides and health for children

Exposure to organophosphate (OP) pesticides among children may relate to increases in oxidative stress, which can contribute to the development of chronic diseases (Sapbamrer et al., 2020)

Proximity to agricultural lands may be associated with pesticide exposure and potential health risks for children (Ding et al., 2012; Munoz-Quezada et al., 2012; Sapbamrer et al., 2020).

Pesticides and cancer

- Based on evaluations made by the **International Agency for Research on Cancer (IARC)**

International Agency for Research on Cancer

World Health Organization

- Pesticides are typically classified as, **Group 2A** *Probable*, or **Group 2B** *Possible Carcinogens or not classified*.

Why these three pesticides?
IARC Classification

Pesticide	Type	IARC Classification	Evidence
Glyphosate	Herbicide	Group 2A	Human: Limited (NHL) Animal: Sufficient
2,4-D	Herbicide	Group 2B	Human: Inadequate Animal: Limited Mechanistic: Strong
Chlorothalonil	Fungicide	Group 2B	Animal: Strong

(IARC Monographs Vol 73, 112, 113; PMRA 2017)

Pesticides and cancer

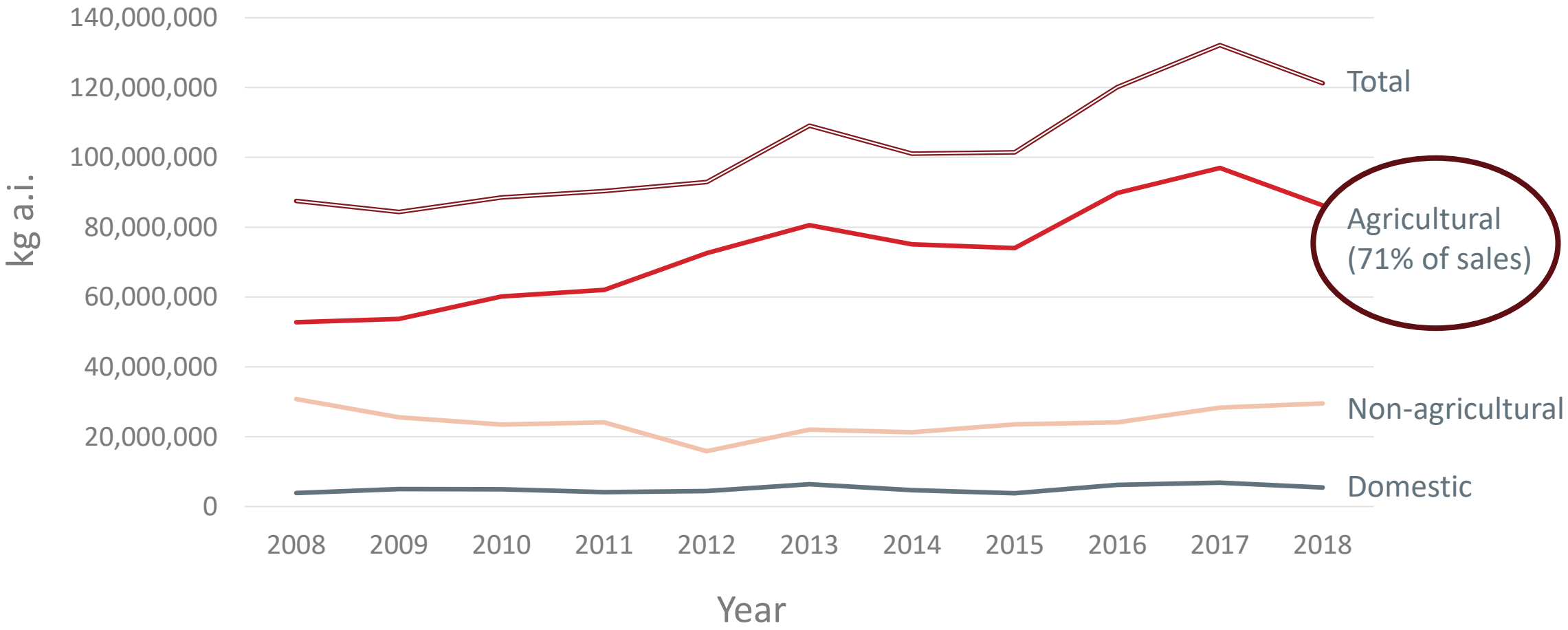
- Research from the Agricultural Health Study, reported no statistically significant link between occupational glyphosate exposure and cancer, but an increased risk of acute myeloid leukemia for high exposure (Andreotti et al., 2018)
- A meta-analysis from the United States, Canada, Sweden and France reported a link between glyphosate and risk of non-Hodgkin lymphoma (NHL) (Zhang et al., 2019)
- Recent studies have provided mixed results related to pesticide exposure and cancer risk
- A common finding is that those with much higher exposure levels may be related to a potential cancer risk (Smith et al., 2017; Parrron et al., 2014)

Purpose and objective

Purpose: to generate national population-level potential exposure estimates in Canada based on agricultural usage for three commonly applied pesticides

Objective: to use a geographic information systems (GIS)-based approach to estimate exposure to three pesticides (2,4-dichlorophenoxyacetic acid (2,4-D), glyphosate and chlorothalonil)

Why focus on agricultural usage?



Trends in pesticides sales in Canada (kg of active ingredients), 2008-2018

(PMRA, 2020)

Why these three pesticides?
Sales data

Based on the 2016 Pest Control Sales Report:
Glyphosate is the most commonly sold herbicide in Canada
2,4-D is the second most common
Chlorothalonil is the second most common fungicide sold in Canada

These three are also classified as 2A or 2B by IARC

The most commonly sold fungicide in Canada is mancozeb but had not been evaluated by IARC for carcinogenicity, so potential cancer risks are unknown (PMRA, 2016)

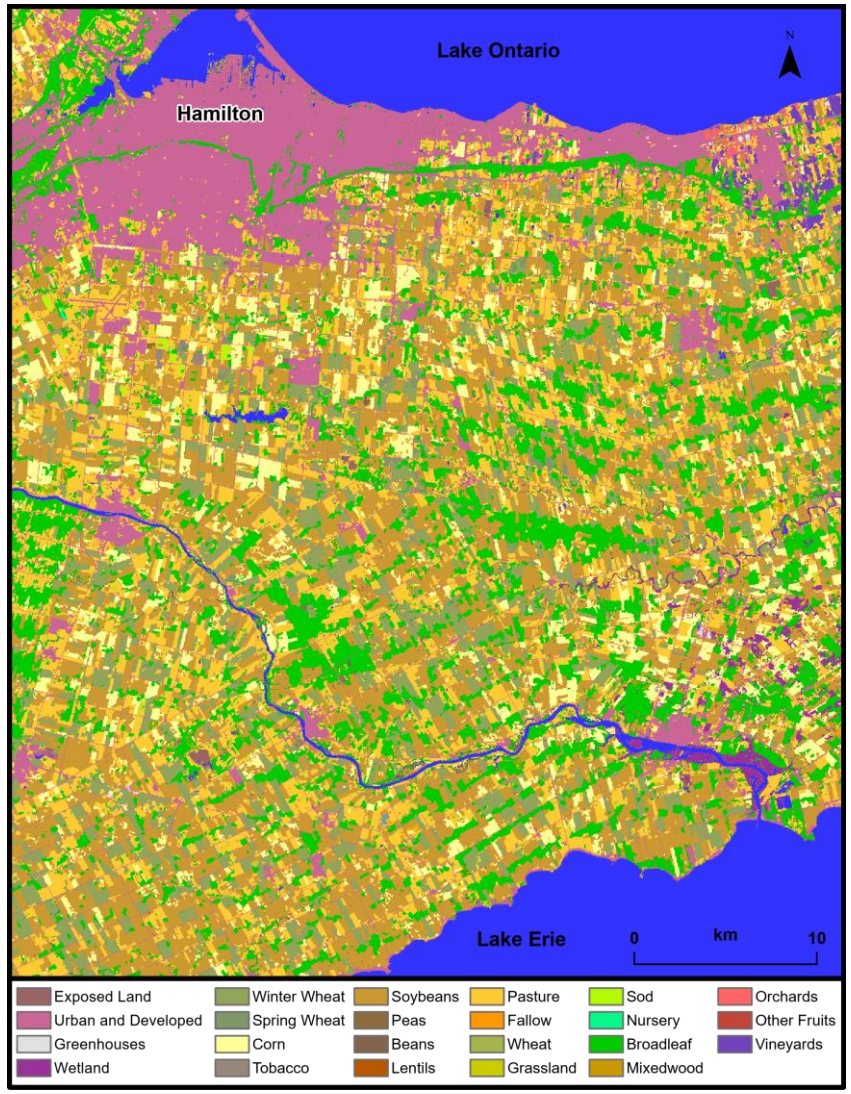
Data sources

Three main publicly available data sources:

- Type of crops being grown in Canada
- Crop specific pesticide application rates
- Population data on the number of people

Data sources: Crop type

- **Crop type**: Agriculture and Agri-Food Canada's Annual Crop Inventory (ACI) for 2016. Raster surfaces compiled with a spatial resolution of 30 m
- The average accuracy in 2016 was 89%, verified through provincial insurance companies and ministries



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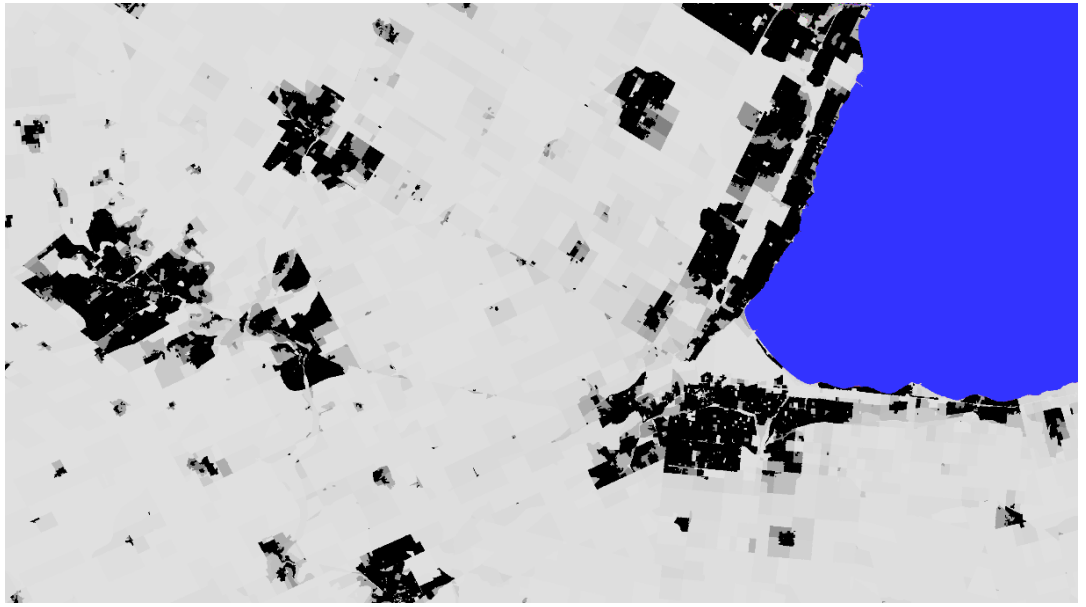
Data sources: Application rates

- **Application rates**: US Department of Agriculture, Chemical Use Program and Ontario's Ministry of Agricultural, Food & Rural Affairs

- These sources provide information on the yearly average rate of pesticides applied to particular crops (kg)

Data sources: Population

- **Population data**: obtained from the 2016 Canadian Census of Population
- Determine the geographic distribution of people by census subdivision (CSD)



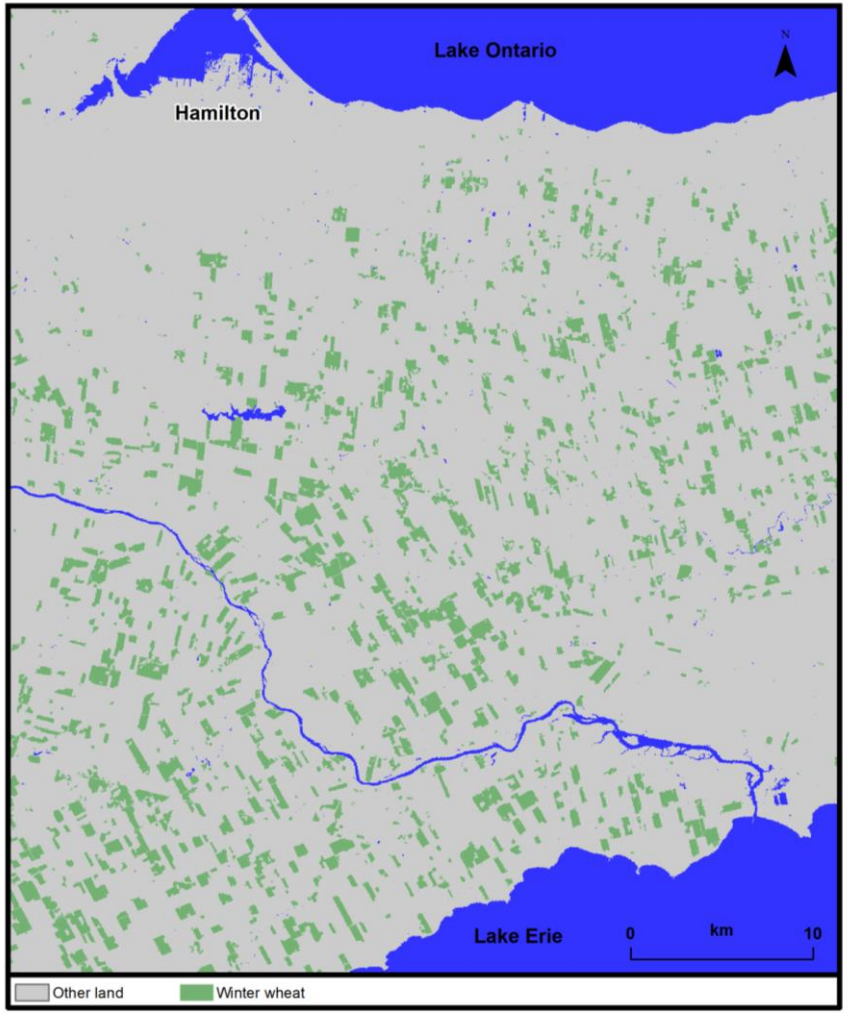
Data analysis: Approach

Following previous GIS based methods applied (Allpress et al., 2008; Brody et al., 2001; Wan, 2015)

- Isolate crops to determine total area within each CSD for each crop
- Crop specific average pesticide application rates were multiplied by crop area
- Crop specific values were summed to provide a total potential exposure by CSD

$$x = \sum_{a} C * P$$

x = total potential pesticide applied for each CSD.
$\sum_a$ = Sum of all crops.
C = Total area of each crop in km.^{2}
P = amount of pesticides applied in KG for each crop.



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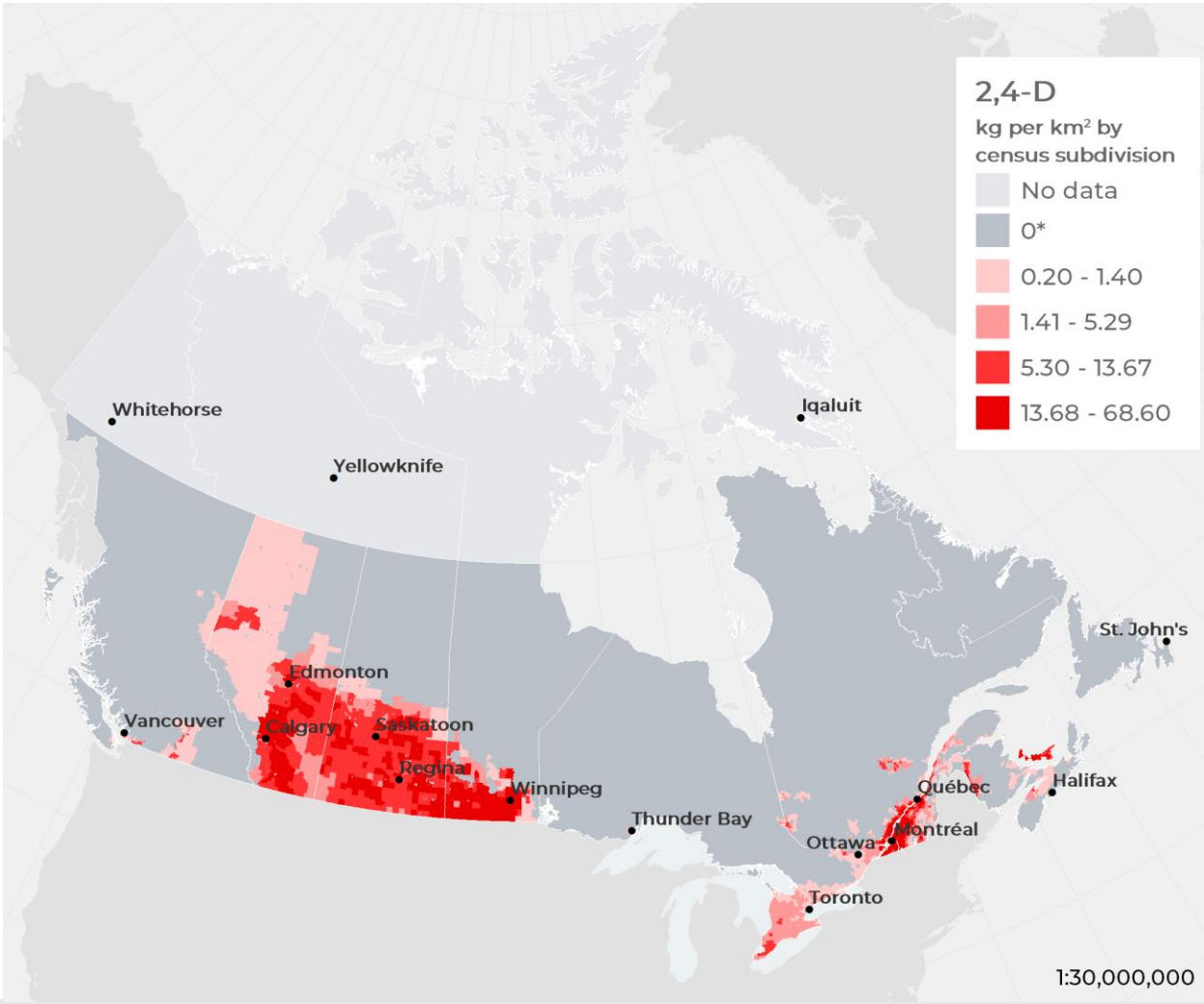
Data analysis: Approach

- Total amount of pesticide applied within each CSD was divided by the total acreage
- Reported as kg of pesticides per sq/km of agricultural land
- For example, if 14 kg of glyphosate were applied to crops in a CSD with a total area of 10 km^2, 1.4 kg/km^2
- The estimated application rate was used as a proxy for potential exposure
- Population exposure compiled by quartile to estimate the number of people exposed by province

Results: 2,4-D

- 2,4-D exposure is much higher in areas where cereal crops, potatoes, and fruit are more commonly grown due to the higher application rates
- The prairie provinces (Alberta, Saskatchewan, Manitoba), Prince Edward Island, and Southern Quebec all had higher potential exposure than other provinces



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Results: 2,4-D

Potential population exposure by province, 2016

Exposure quartile (kg/km²)	0*	Lowest (0.2 - 1.40)	1.41-5.29	5.30-13.67	Highest (13.67-68.60)	Total population
AB	245,200	189,300	2,816,300	550,600	265,800	4,067,200
BC	2,832,100	1,149,300	232,000	418,400	16,400	4,648,100
MB	96,800	23,400	69,900	817,500	270,600	1,278,400
NB	617,900	77,500	18,200	15,000	18,500	747,100
NL	519,700	-	-	-	-	519,700
NS	726,600	139,800	45,300	11,900	-	923,600
ON	4,608,800	5,877,800	2,809,100	152,800	-	13,448,500
PEI	1,700	2,200	42,800	26,600	69,700	142,900
QC	2,773,700	1,078,200	1,130,300	1,811,300	1,370,900	8,164,400
SK	77,100	92,400	444,700	417,300	66,800	1,098,400
Canada	12,499,600	8,629,900	7,608,700	4,221,300	2,078,600	35,038,100

- Over 2 million people in Canada live in areas with the highest quartile
- This amounts to about 6% of the Canadian population
- PEI has the highest proportion of it's population exposed in the highest quartile
- Quebec had the largest number of people exposed in the highest quartile

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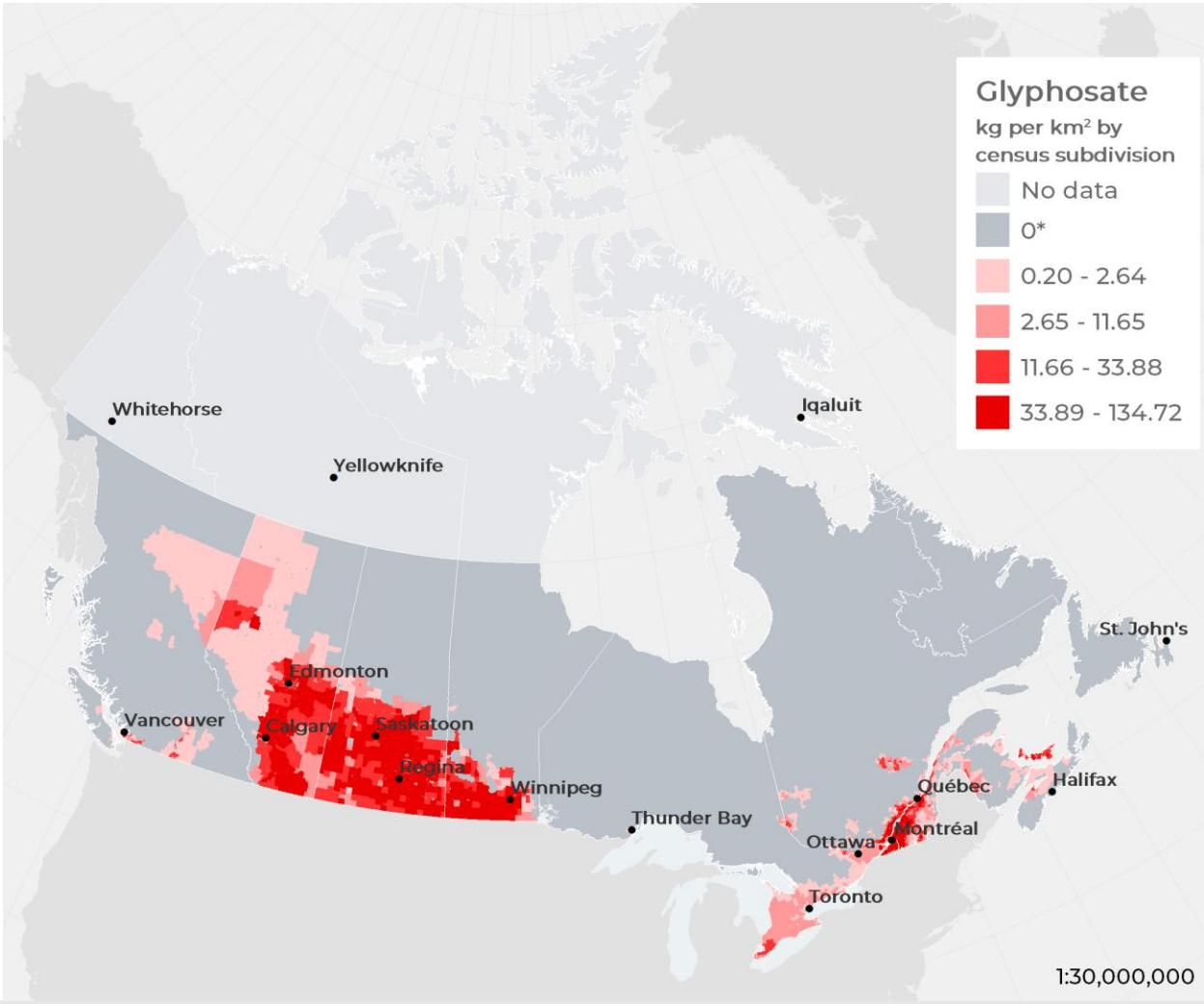
Results: Glyphosate

- Glyphosate exposure is much higher in areas where crops such as canola, wheat, corn and soybeans were more commonly grown

- The prairie provinces (Alberta, Saskatchewan, Manitoba), along with parts of Southern Quebec all have higher potential exposure to glyphosate



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Results: Glyphosate

Potential population exposure by province, 2016

Exposure quartile (kg/km²)	0*	Lowest (0.20 - 2.64)	2.65 - 11.65	11.66 - 33.88	Highest (33.89 - 134.72)	Total population
AB	194,900	179,900	2,452,600	904,100	335,800	4,067,200
BC	2,270,300	795,600	1,038,600	542,700	800	4,648,100
MB	92,900	16,800	75,200	831,600	261,900	1,278,400
NB	518,900	171,400	37,700	17,500	1,500	747,100
NL	517,600	2,100	-	-	-	519,700
NS	708,900	157,500	45,300	11,900	-	923,600
ON	4,516,900	4,260,000	4,531,300	140,200	-	13,448,500
PEI	1,700	2,800	44,800	73,500	20,100	142,900
QC	960,500	2,851,100	1,210,400	1,830,200	1,312,100	8,164,400
SK	60,600	45,800	154,600	705,200	132,100	1,098,400
Canada	9,843,200	8,483,100	9,590,600	5,057,000	2,064,200	35,038,100

- Also over 2 million people, live in areas with the highest quartile of glyphosate exposure
- Manitoba and Saskatchewan had the highest percentage of their population (85% and 76%) living in areas with above median exposure, but most were not in the highest quartile
- Quebec again has the highest number of residents in the highest exposure

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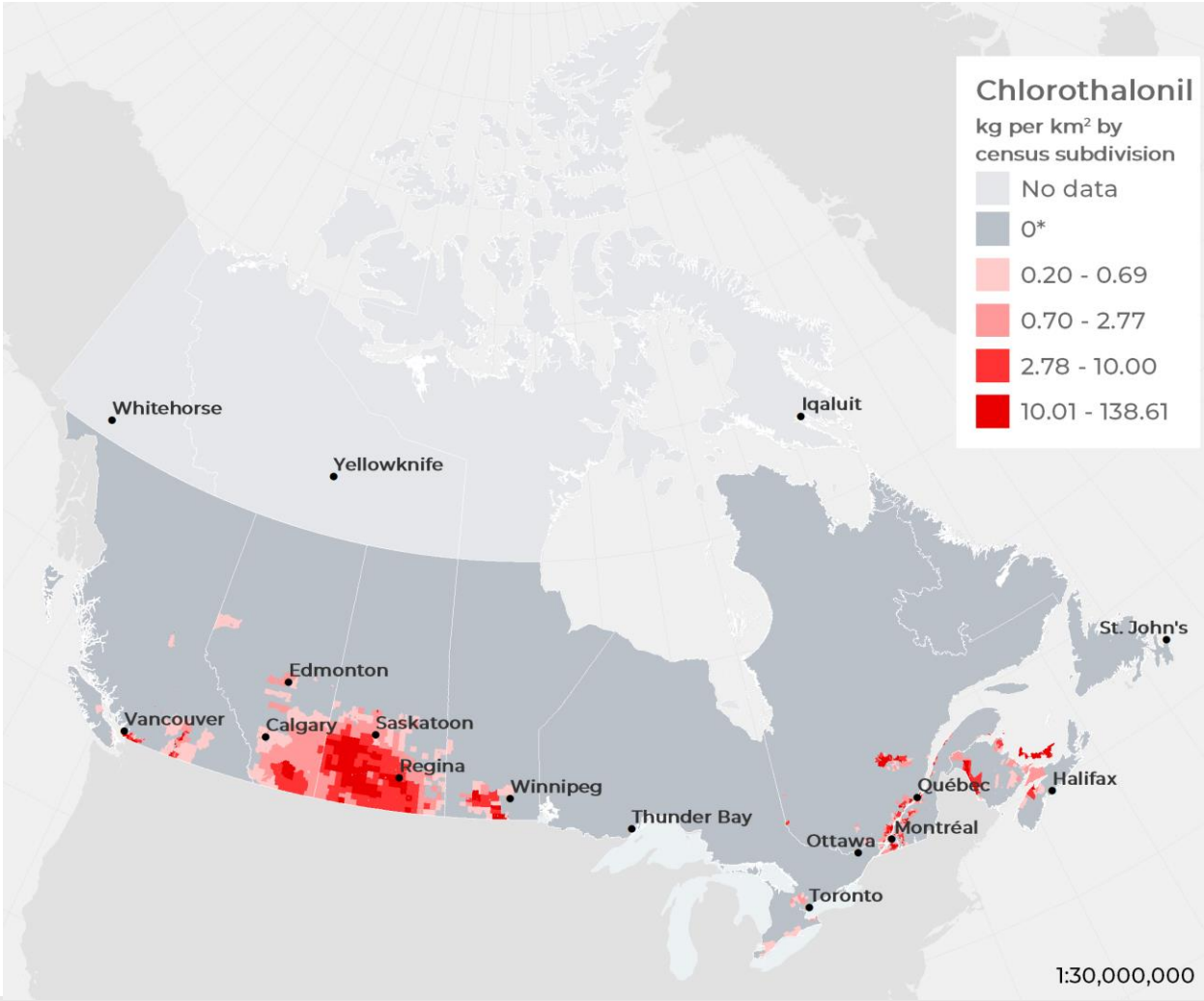
Results: Chlorothalonil

- Chlorothalonil exposure is much higher in areas where root crops such as potatoes along with fruits were more commonly grown
- Southern British Columbia, Prince Edward Island, Southern Quebec, and parts of the Saskatchewan all have higher potential exposure to chlorothalonil than other areas of the country



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Results: Chlorothalonil

Potential population exposure by province, 2016

Exposure quartile (kg/km²)	0*	Lowest (< 0.70)	0.70 - 2.78	2.78 - 10.00	Highest (10.00 - 138.61)	Total population
AB	3,390,900	376,700	166,200	124,600	8,800	4,067,200
BC	2,317,300	314,600	545,400	283,700	1,187,100	4,648,100
MB	1,142,900	64,400	14,200	36,600	20,200	1,278,400
NB	590,800	56,100	31,700	36,500	32,100	747,100
NL	505,500	14,200	-	-	-	519,700
NS	793,600	41,200	50,900	25,900	11,900	923,600
ON	12,800,800	488,200	159,500	-	-	13,448,500
PEI	4,800	36,100	1,900	10,600	89,500	142,900
QC	5,926,000	454,400	1,176,600	410,700	196,600	8,164,400
SK	384,300	292,900	113,800	266,200	41,200	1,098,400
Canada	27,856,900	2,138,900	2,260,200	1,194,800	1,587,400	35,038,100

- Over 1.5 million people (5% of the population) in Canada live in areas with the highest quartile
- British Columbia had the highest number of people living in the top quartile for potential exposure (1.19 million people)
- Prince Edward Island had the highest percentage of their population living in areas with above average exposure (63%)

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Discussion

- People living near agricultural lands had a higher predicted potential exposure
- The total number of people potentially exposed in PEI is low, but the proportion of their population exposed is quite high
- This likely relates to the number of potato and grain farms in PEI

Discussion

- Over 1.1 million people were in the highest exposure quartile for chlorothalonil in BC
- May relate to the abundance of fruit farms and development patters of higher population density in the Fraser Valley and Okanagan regions

Discussion

- A similar pattern was observed in Southern Quebec for 2,4-D and glyphosate
- Over 1.3 million people were in the highest exposure category in Quebec, which accounts for 16% of their population
- Likely relates to higher population densities near agricultural lands

Discussion – Estimating exposure

- Pesticide exposure estimates are a methodological issue for epidemiological studies examining pesticides and health (Carles et al., 2018)
- There really is a lack of data on potential exposures (Shirangi et al., 2011; Parrron et al., 2014)
- Exposure data typically comes from self report, examining concentrations in water/soil/air or biomonitoring in urine (Aulagnier et al., 2008; Aylward et al., 2013; Morgan et al., 2014)
- While effective these methods can be invasive and expensive, they are also difficult to translate from individual to population level

Discussion - Contributions

- GIS has been used to obtain a better understanding of how agricultural activity may relate to environmental pesticide exposure (Wan, 2015; VoPham et al., 2015; Allpress et al., 2008)
- This study added to the previous work and shows that estimates of pesticide exposure from agricultural may vary based on where you live

Some limitations

- This is only measuring application rates, actual exposure is not known
- Actual usage is not known as well, some farms may use more or less than average
- Methods focus on potential exposure in the environment but these estimates do not account for dietary ingestion
- The number of people potentially exposed may be over or under-estimated due to the actual location of the residence and the time of day that the pesticides were applied

Conclusion

- Estimates potential exposure to pesticides in agricultural areas
- Adds to the growing body of literature on using GIS for pesticide exposure estimates
- While we focused on national and provincial scales, more fine tuned analysis could be completed
- While pesticide application rates do not translate directly to exposure, it does provide population level estimates to identify areas of concern

Acknowledgements

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Research team

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Any questions

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