Hydro-economic modelling

Roy Brouwer, Jorge García, Rute Pinto

Annual meeting of the Integrated Modelling Program for Canada (IMPC)
Saskatoon, 18 July 2018

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Team in Waterloo

- January – February 2018 Hongxiu Liu

- January 1, 2018 – now Rute Pinto

- June 1, 2018 – now Jorge García

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Main objective

- Development of integrated hydro-economic modeling tools to assess the broader direct and indirect economic impacts of water policy

- Great Lakes Basin
- Saskatchewan River Basin with Leila Eamen

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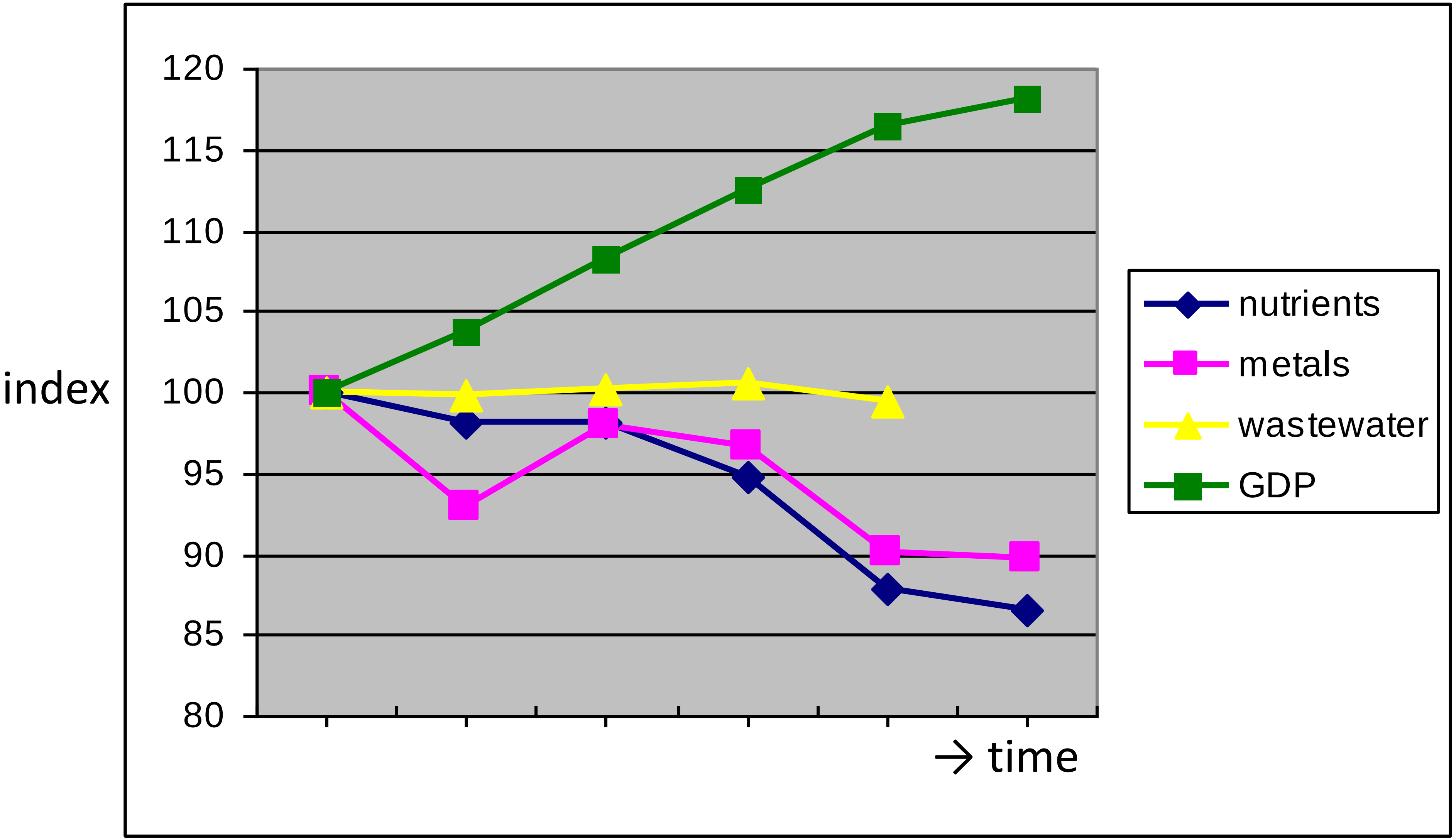
Brouwer, R., Schenau, S. and van der Veeren, R. (2005). Integrated river basin accounting and the European Water Framework Directive. Statistical Journal of the United Nations Economic Commission for Europe, 22(2), 111-131.



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Year 1

- Brouwer, R., Liu, H. and Neverre, N. (2017). A Survey of Hydro-Economic Models in Canada. pp 12.

Model	General Characteristic	Application Area	Target Sector(s)	User(s)
Aquarius	Non-linear programming model (profit maximization)	Alberta's South Saskatchewan River Basin	Municipal, agricultural, and recreational water uses	University of Alberta and the Alberta Research Council
CEEOT	Comprehensive Economic and Environmental OptimizationTool (profit maximization)	3 watersheds in Alberta: Red Deer River, Indianfarm Creek, and Whelp Creek	Agriculture	Alberta Agriculture and Forestry
imWEBs	Economic optimization (cost-effectiveness)	Agricultural watersheds in Ontario, Manitoba, Saskatchewan, and Alberta	Agriculture	Academics
SHE	Partial equilibrium model solved using Stochastic Dual Dynamic Programming	Saguenay river, Quebec	Hydropower, dam building	Hydropower companies
SSRBIEW	Economic input-output model (economic optimization based on maximization of output)	South Saskatchewan River Basin (Alberta and Saskatchewan)	Agriculture, residential, municipal, industrial, and energy water uses	Prairie Adaptation Research Collaborative
SVM	Hydrological simulation model	Lake Ontario-St. Lawrence River and Upper Great Lakes	Recreational boating, commercial navigation, hydropower, municipal and industrial water uses	Various stakeholders and interest groups, government and water utilities
WQVM 1.0	Non-market valuation tool based on benefits transfer function	All water bodies in Canada	Boatable, fishable, swimmable, drinkable water quality	ECCC
WUAM	Computer simulation model (multi-sectoral water supply and demand balance modelling)	South Saskatchewan River Basin (Alberta and Saskatchewan)	Municipal, industrial, power generation, irrigation, livestock and instream water uses	Prairie Adaptation Research Collaborative

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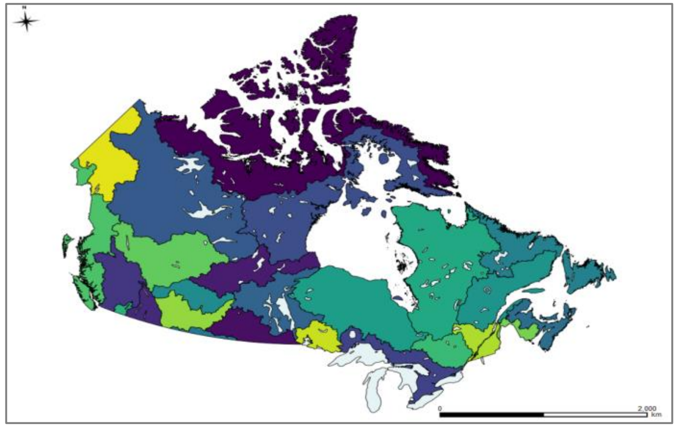
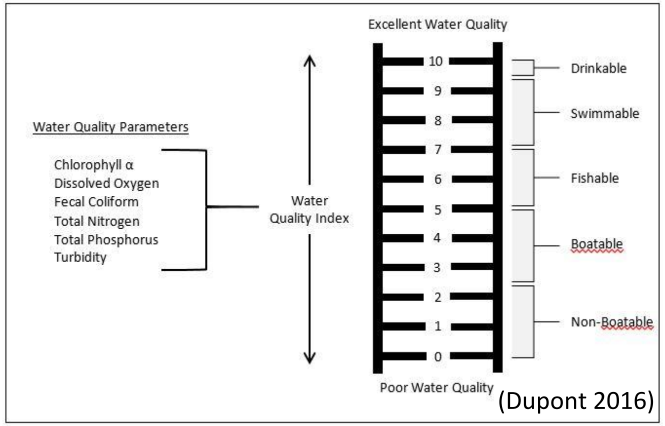
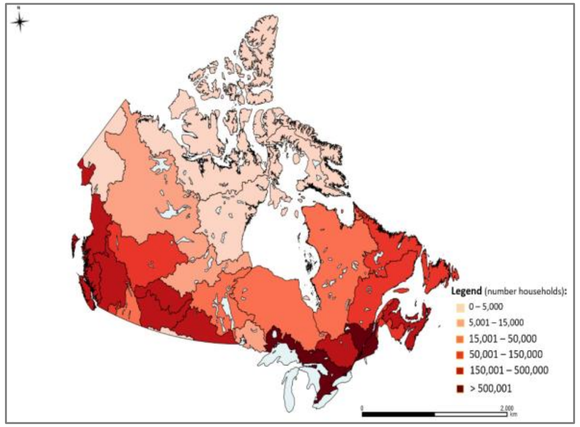
Integrated Modelling Framework

Water Quality Ladder				Water Quality Valuation	
Water Quality parameters		Ecosystem Services		Benefits	
Monitoring →	Thresholds →	WQ Index →	WQ Ladder →	WTP →	TEV





(Dupont 2016)



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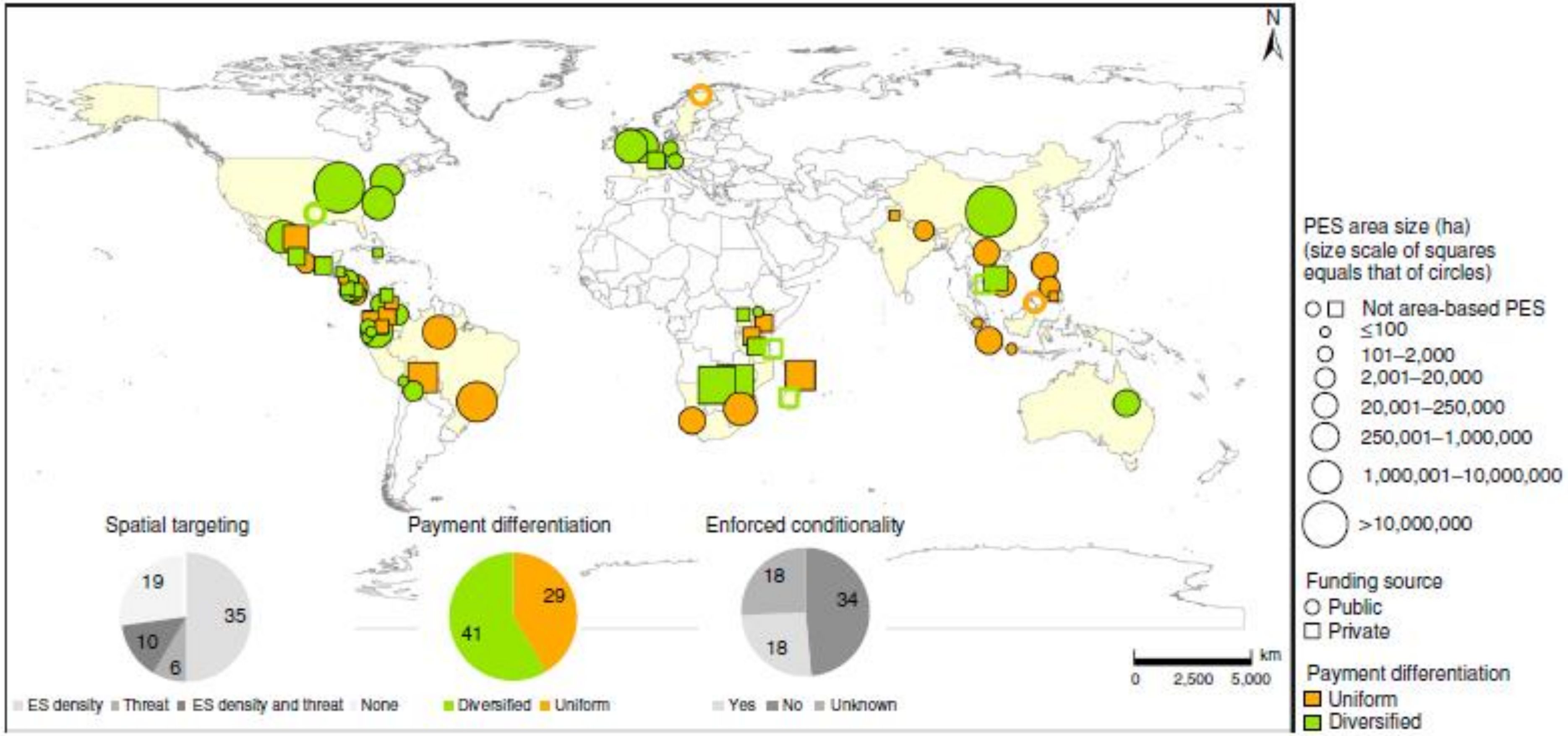
- Wunder, S., Brouwer, R., … , Pinto, R. (2018). From Principles to Practice in Paying for Nature's Services. Nature Sustainability, 1: 145-150.

Payments for Ecosystem Services



Wunder, Brouwer et al. (2018). From Principles to Practice in Paying for Nature's Services. Nature Sustainability, 1: 145-150.

Next steps

- Further explore with Statistics Canada the design of an integrated river basin accounting framework

- Further development of the Water Quality Valuation Model with ECCC

- Review of the potential of water quality trading schemes in N-America (for integration in the hydro-economic model)

Input-Output Model with water constraints

Jorge García, Roy Brouwer, Rute Pinto

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Outline

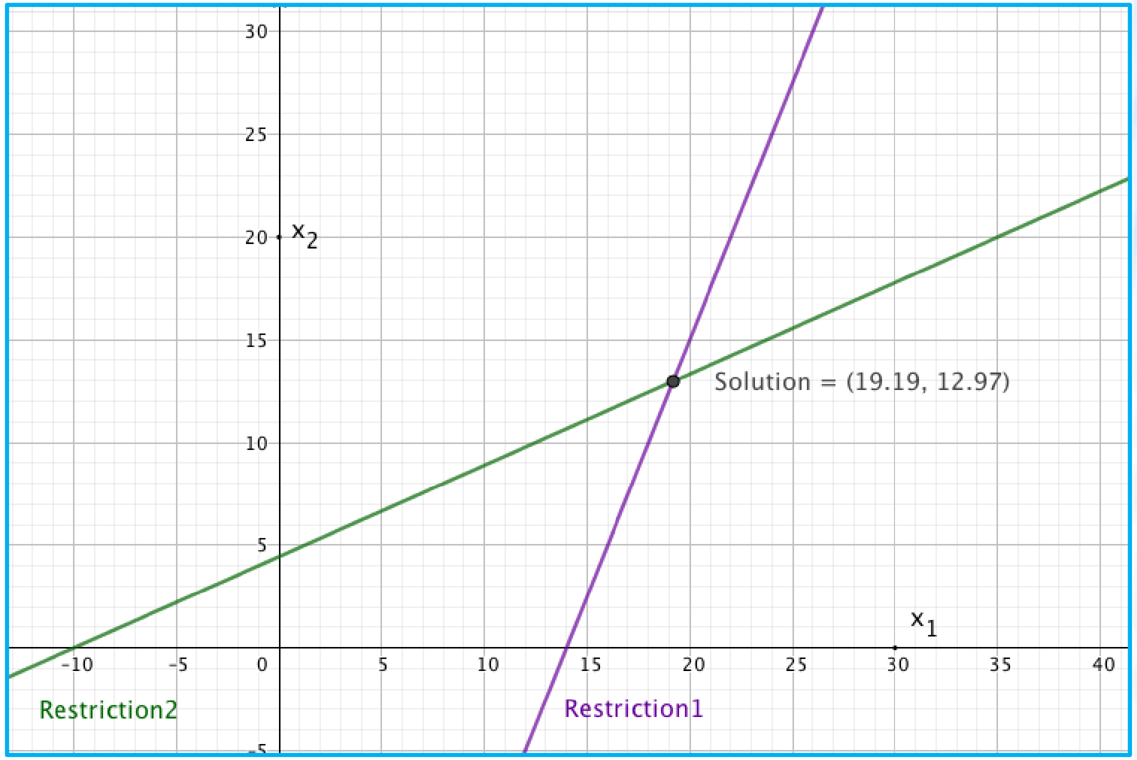
- Input-Output model
- Assumptions
- Data
- Case study: Ontario 2011
- Limitations

Input-Output model

$$\underbrace{\boldsymbol{x}}_{\text{Supply}} = \underbrace{\boldsymbol{Ax} + \boldsymbol{d}}_{\text{Demand}} \qquad \boldsymbol{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}$$

$$(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{x} = \boldsymbol{d}$$

Solution: $\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{d}$



Example of economy with two industries

Assumptions & Scenario

Assumptions

- Final demand fixed.
- Linear relation between output and resource consumption.
- Quality of water not considered.

Scenario

Due to global warming and extreme environmental changes, a decline in industrial water is expected.

Total water supply decrease of

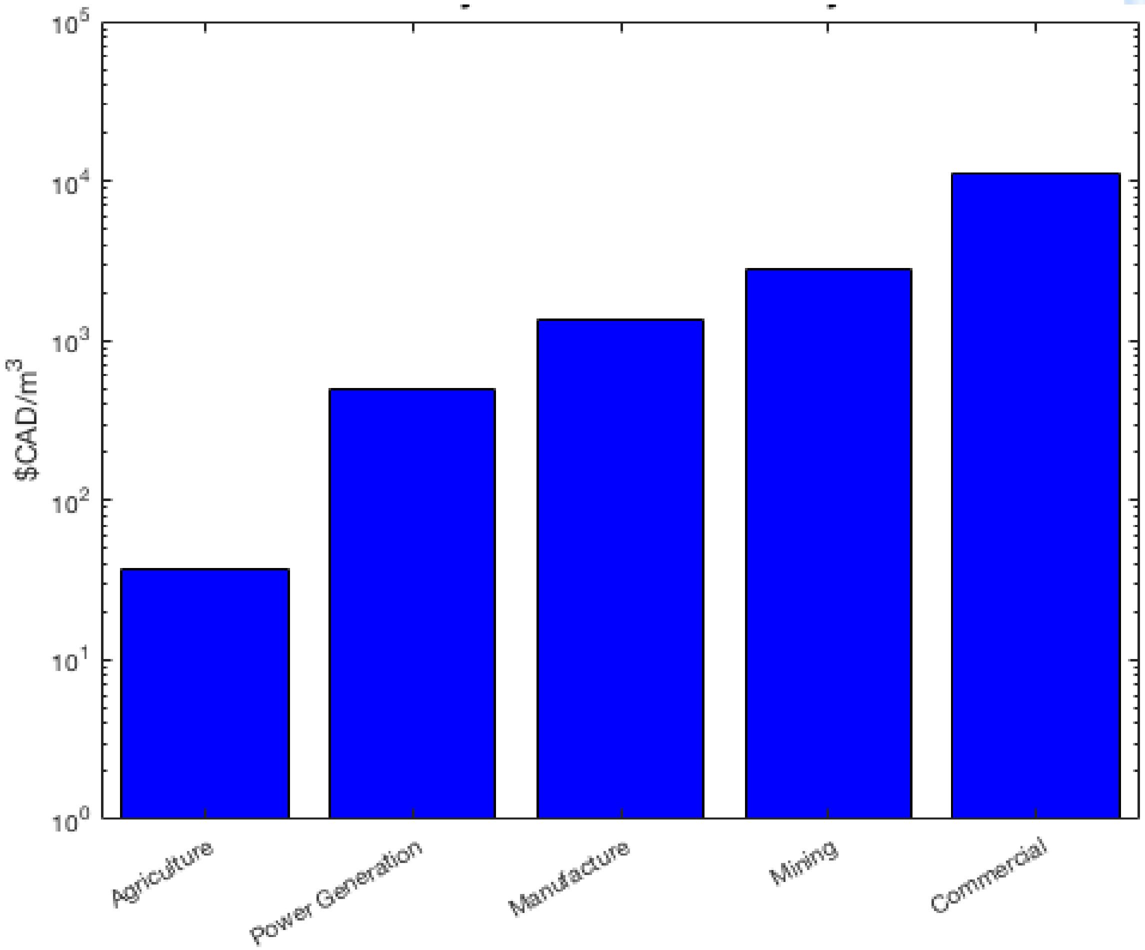
- 10%
- 20%
- 30%

Baseline: water consumption of 2011.

Data

- Ontario 2011
- Industries: 32
- Water data: Statistics Canada[1,2,3], Environment and Climate Change Canada[4], & own estimation.

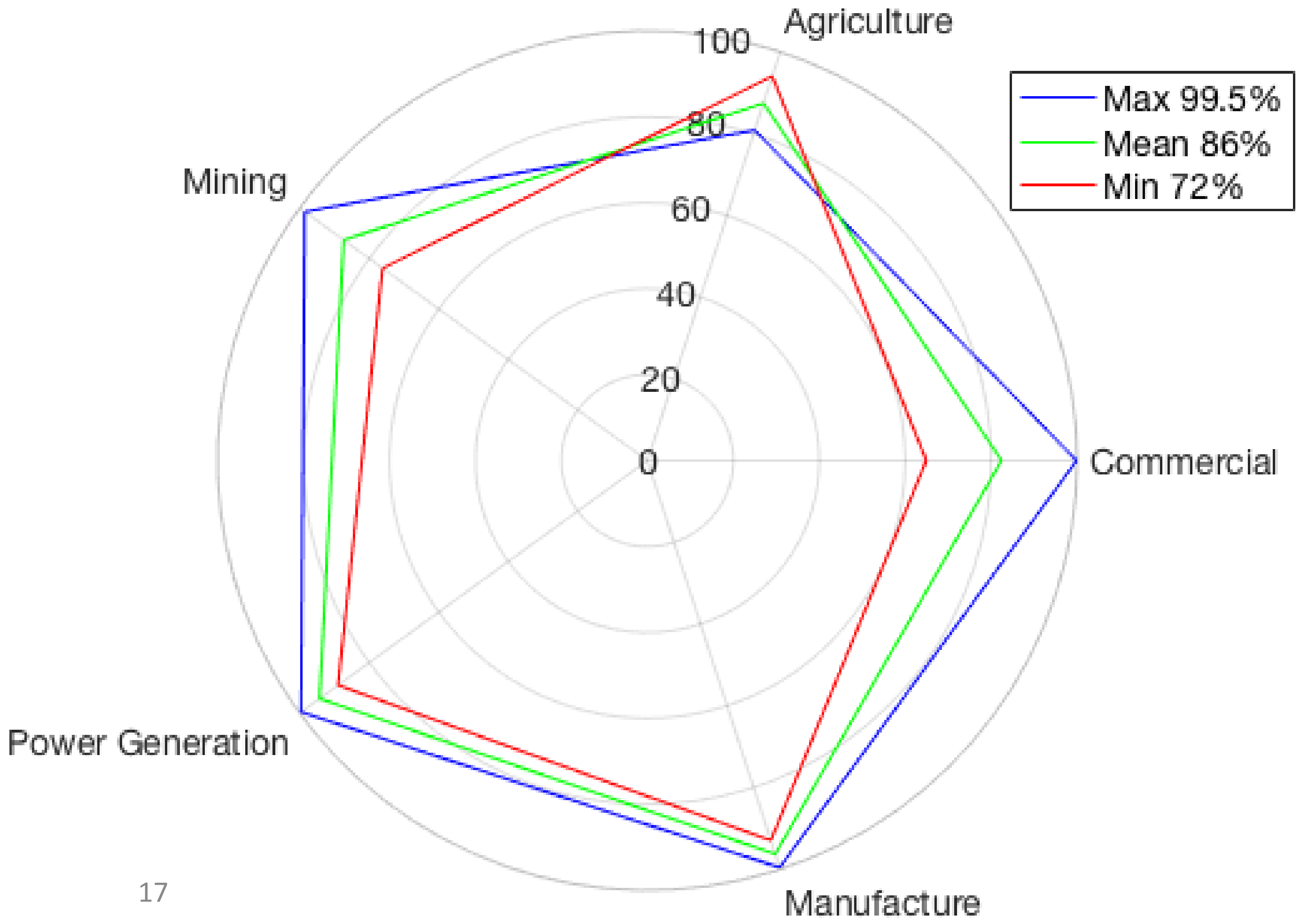
Productivity of consumed water [$/m³]



1. Provincial Symmetric Input-Output Table – Small Aggregation- Ontario, 2011, Table 15-211-XCE
2. Industrial Water use 2011, Table 16-401-X
3. Total number of jobs, S-level, Table: 36-10-0306-01
4. Canadian Environmental Sustainability Indicators: water withdrawal and consumption by sector, 2016

Case study: Ontario 2011

10 % Water decrease

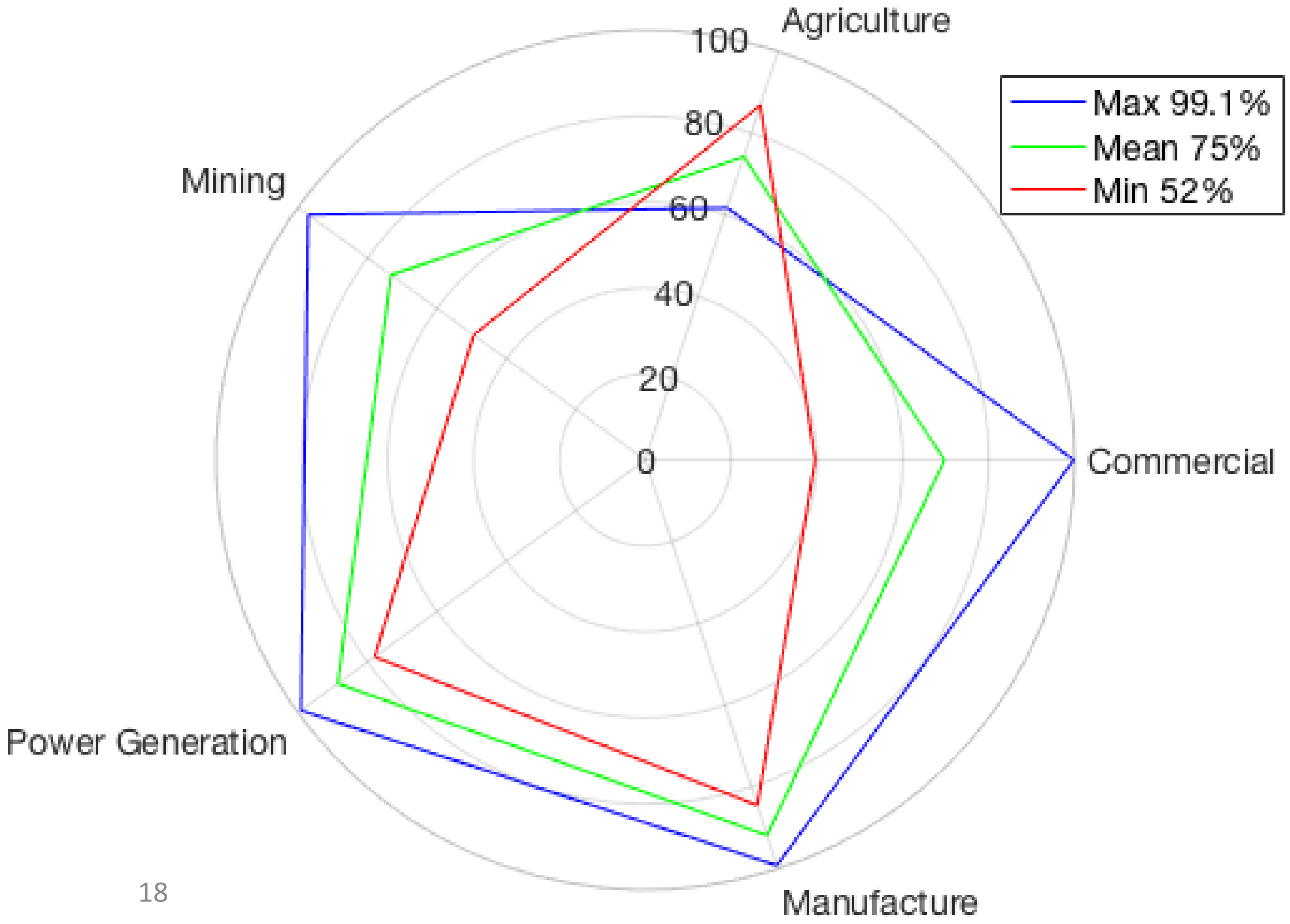


Range ΔGDP: 0.5-27.5% decrease

ΔGDP%/Δwater%			
Sector	Max	Mean	Min
Agriculture	1.9	1.2	0.59
Commercial	0.01	1.7	3.5
Manufacture	0.04	0.37	0.7
Mining	0.14	1.2	2.4
Power Generation	0.04	0.6	1.1
Total GDP	0.04	1.4	2.7

Case study: Ontario 2011

20 % Water decrease

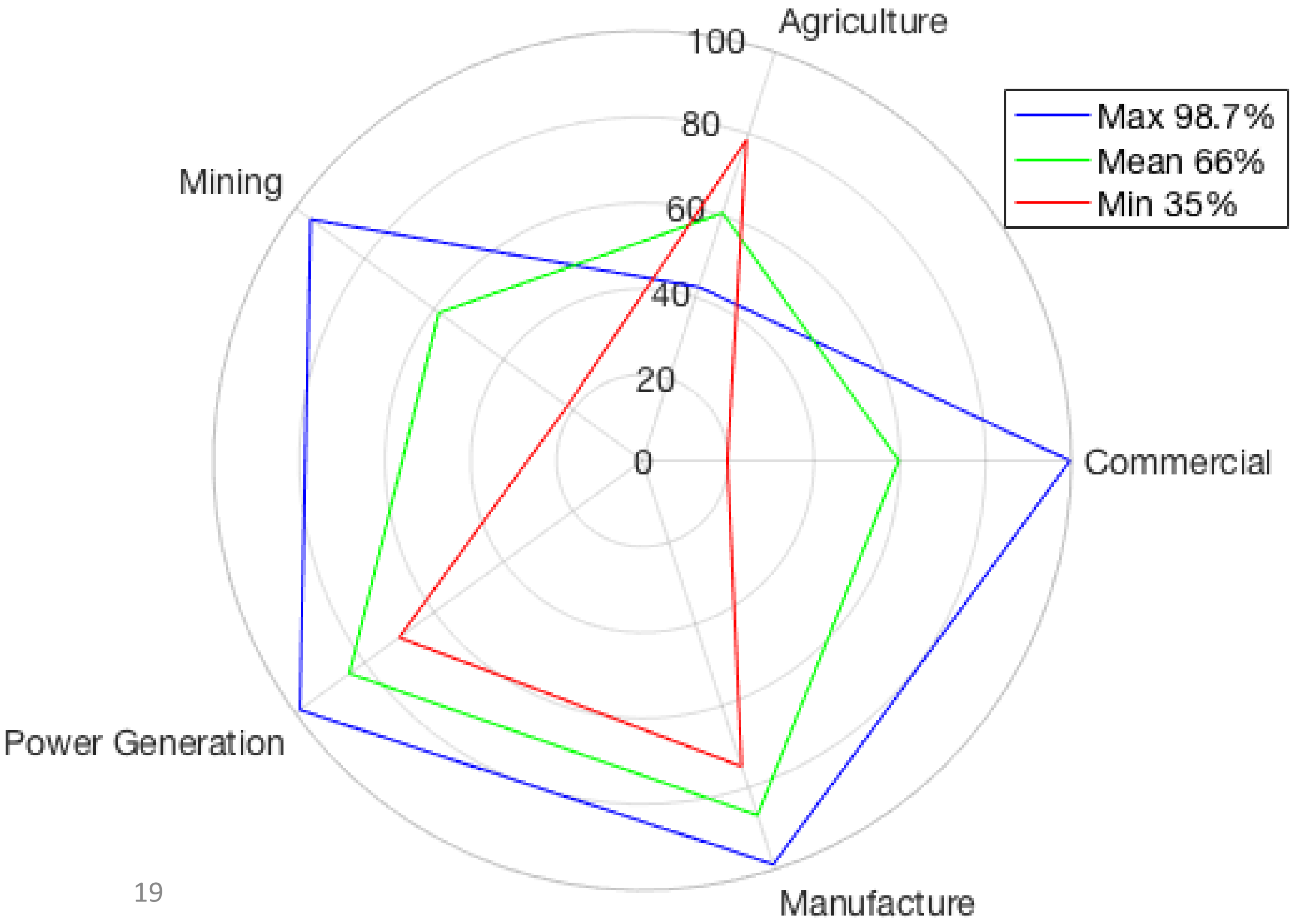


Range ΔGDP: 0.8-48% decrease

ΔGDP%/Δwater%			
Sector	Max	Mean	Min
Agriculture	1.9	1.3	0.6
Commercial	0.01	1.5	3
Manufacture	0.04	0.4	0.8
Mining	0.15	1.3	2.5
Power Generation	0.04	0.6	1.1
Total GDP	0.04	1.2	2.4

Case study: Ontario 2011

30 % Water decrease



Range ΔGDP: 1.3-65% decrease

ΔGDP%/Δwater%			
Sector	Max	Mean	Min
Agriculture	1.9	1.3	0.7
Commercial	0.01	1.3	2.6
Manufacture	0.04	0.4	0.8
Mining	0.14	1.4	2.6
Power Generation	0.04	0.5	1
Total GDP	0.04	1.1	2.2

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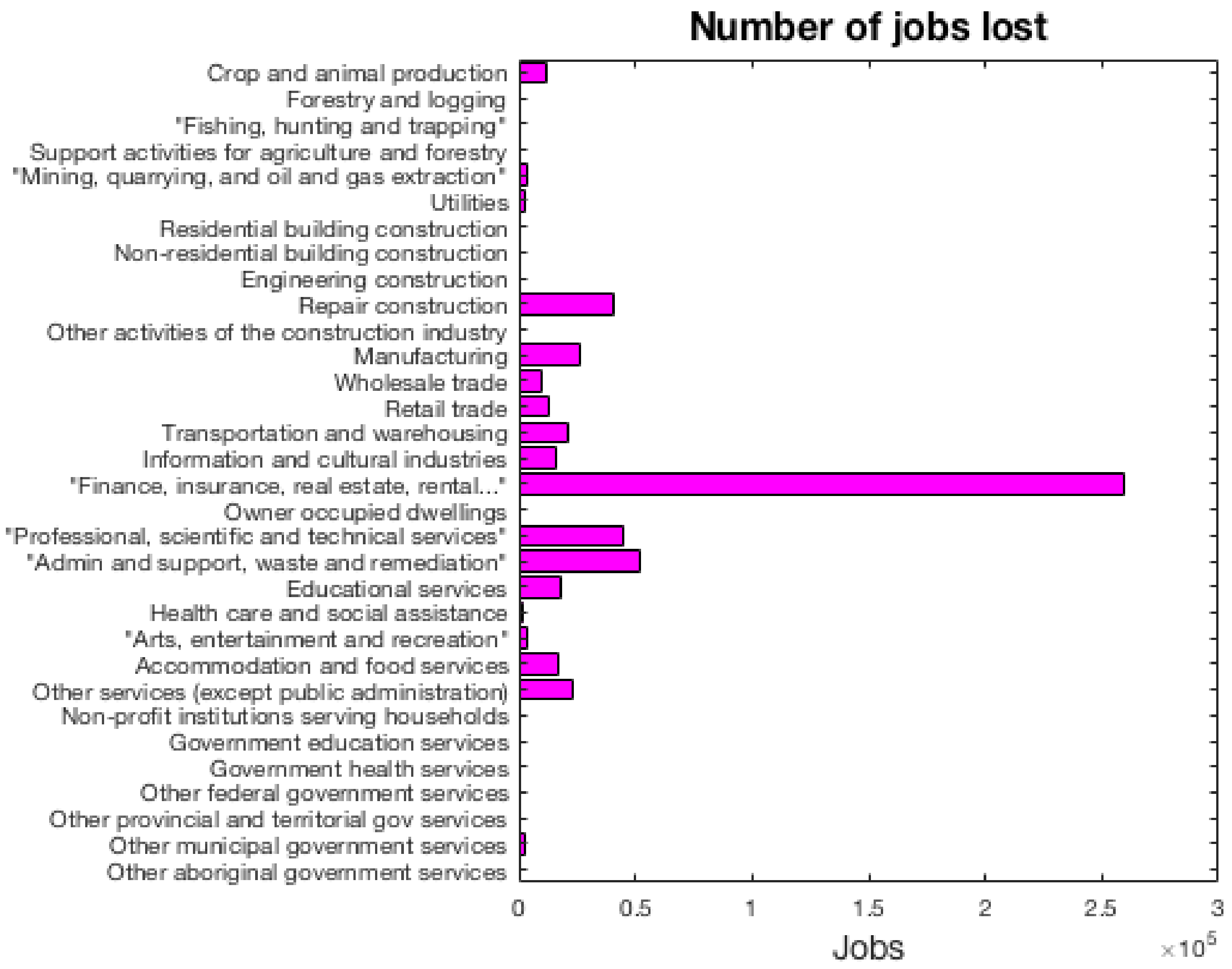
Case study: Ontario 2011



10 % Water decrease

Assuming mean solution:

Total jobs lost: 568,860

Percentage job decrease: 8.2%

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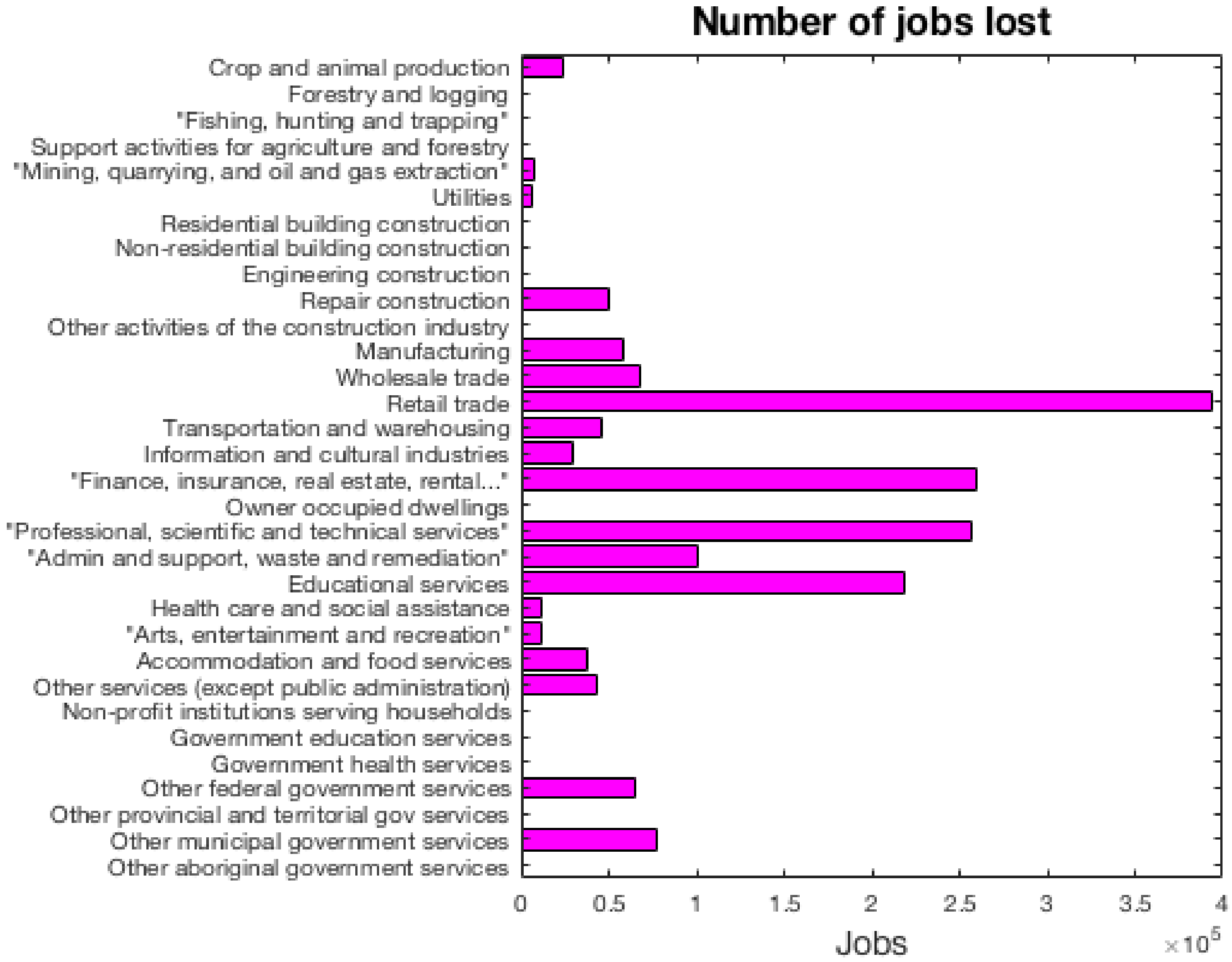
Case study: Ontario 2011



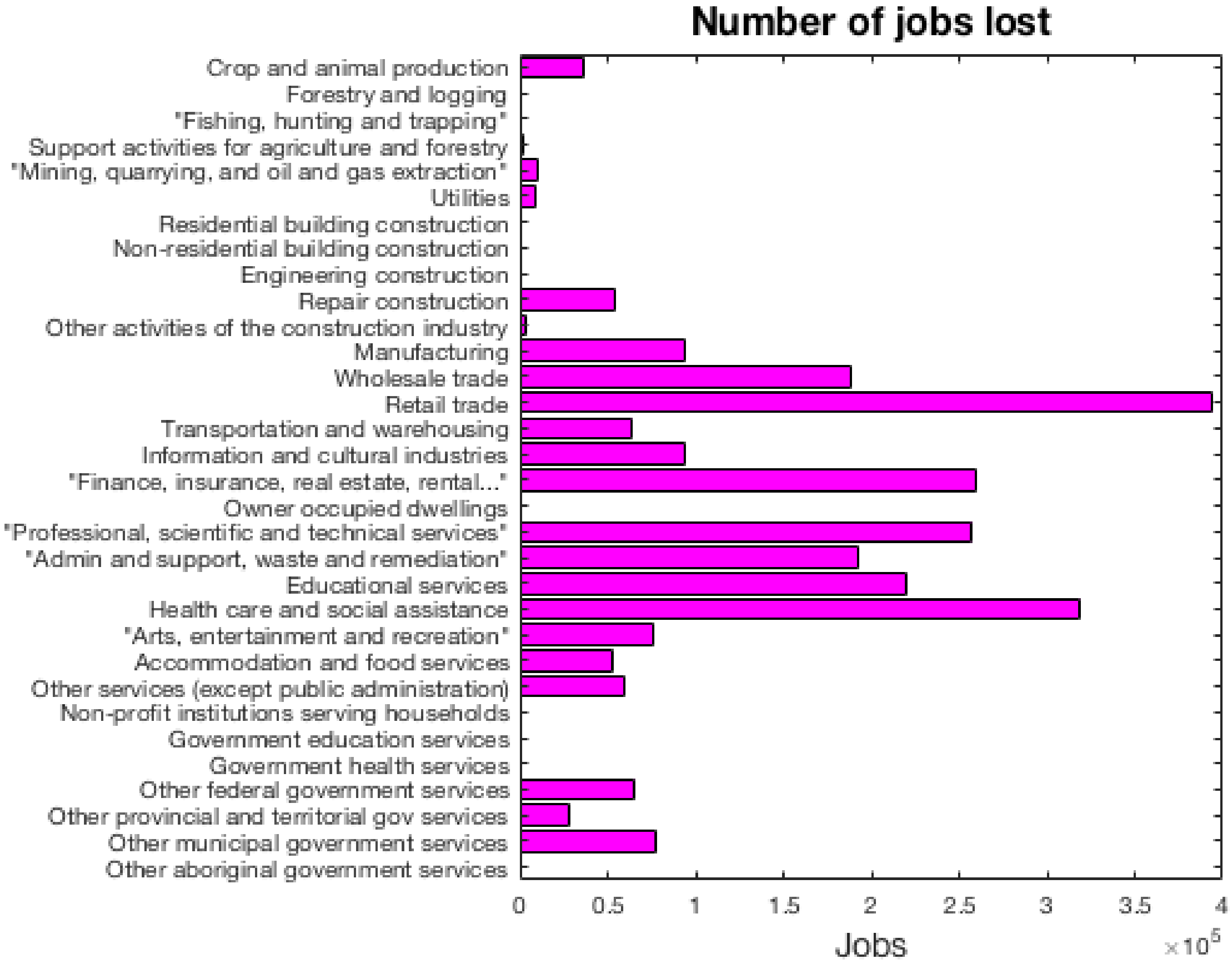
20 % Water decrease

Assuming mean solution:

Total jobs lost: 1,769,200

Percentage job decrease: 25%

Case study: Ontario 2011



30 % Water decrease

Assuming mean solution:

Total jobs lost: 2,554,700

Percentage job decrease: 37%

Limitations and next steps

- Model does not capture dynamics
- Limitations in data aggregation lead to proportionality assumptions

- Further linking of water quantity and quality data to economic activities (e.g. P-emission levels of economic activities)
- Up and down-scaling procedures to develop an I-O model for the GL basin

Thank you!