Application of SWAT model to assess hydrological impacts of virtual water export under extreme event conditions in Canada

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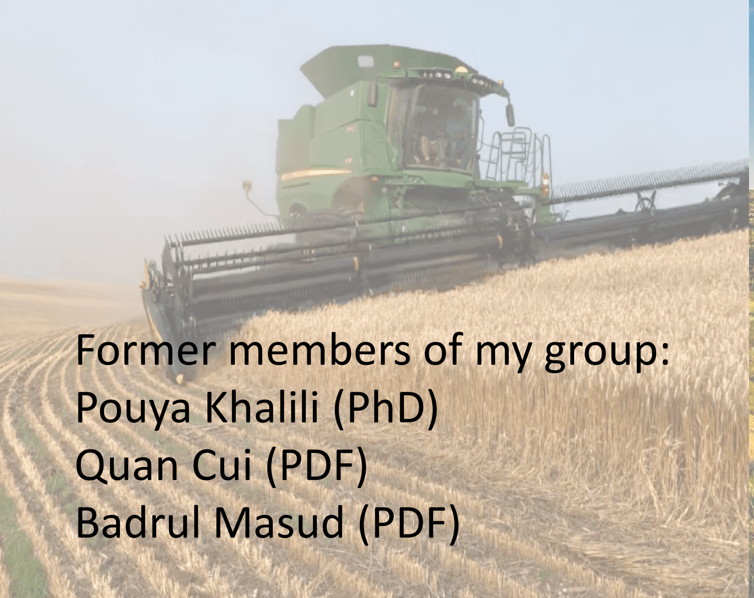
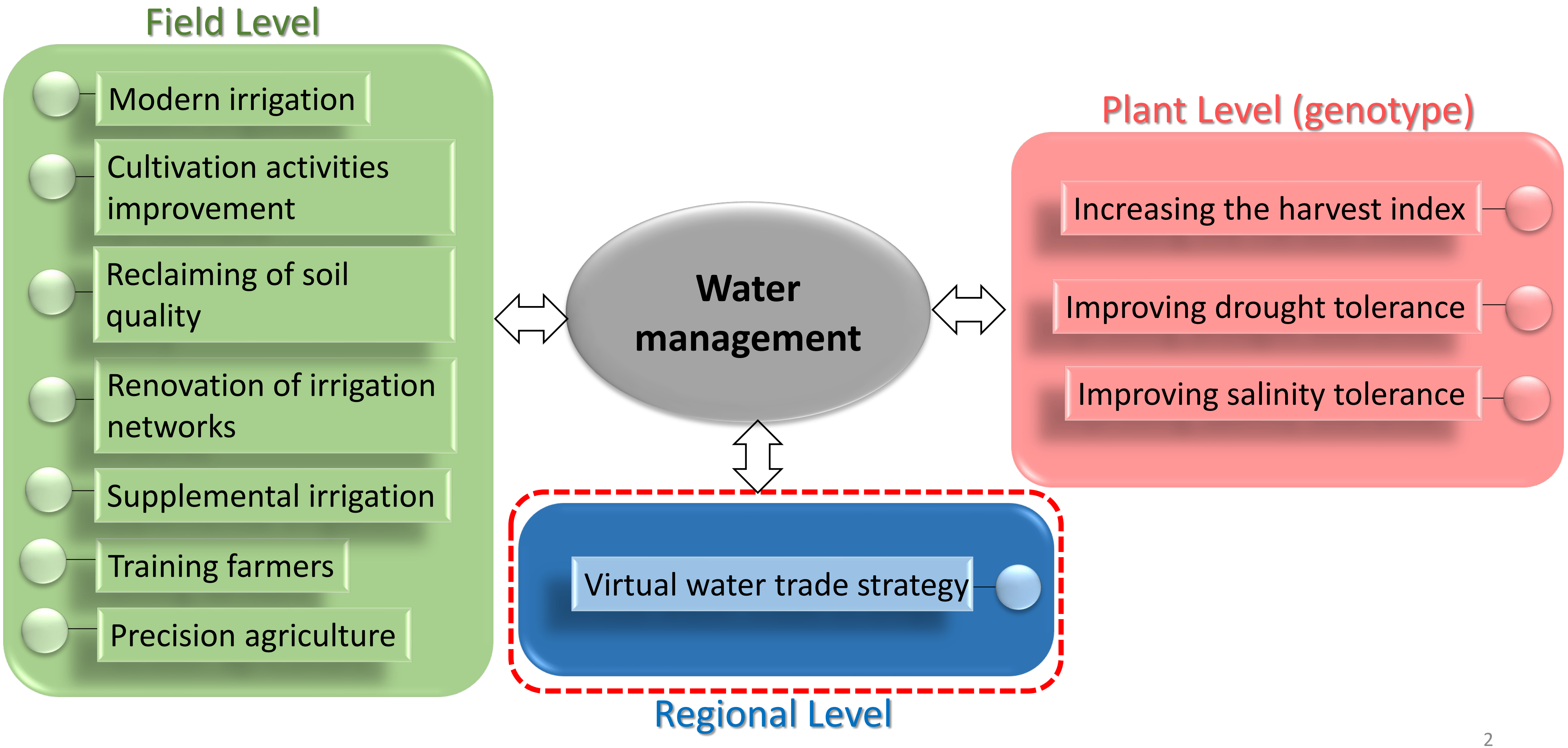


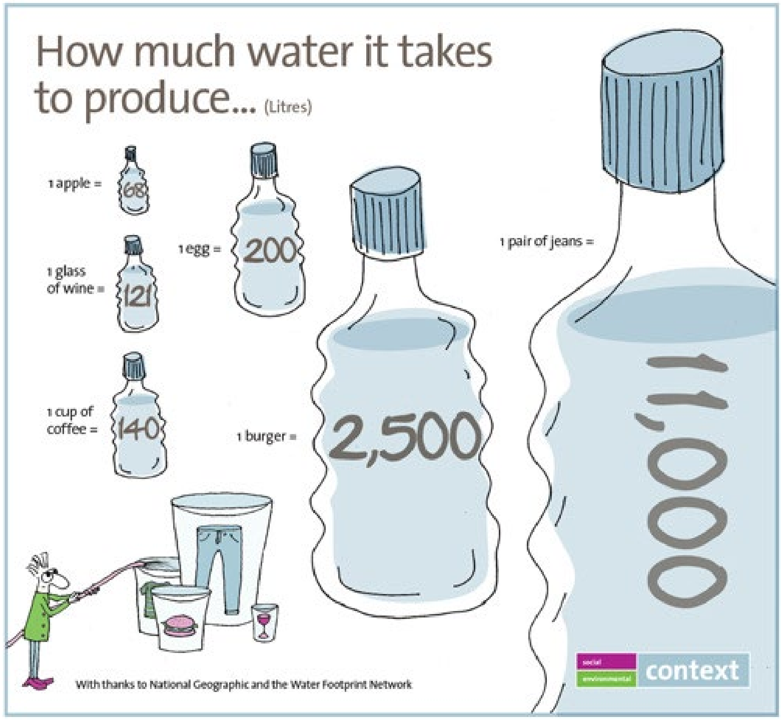
Former members of my group:
Pouya Khalili (PhD)
Quan Cui (PDF)
Badrul Masud (PDF)

2024 International SWAT Conference,
July 8-12, 2024
Strasbourg, France

Management of limited water resources



Virtual water



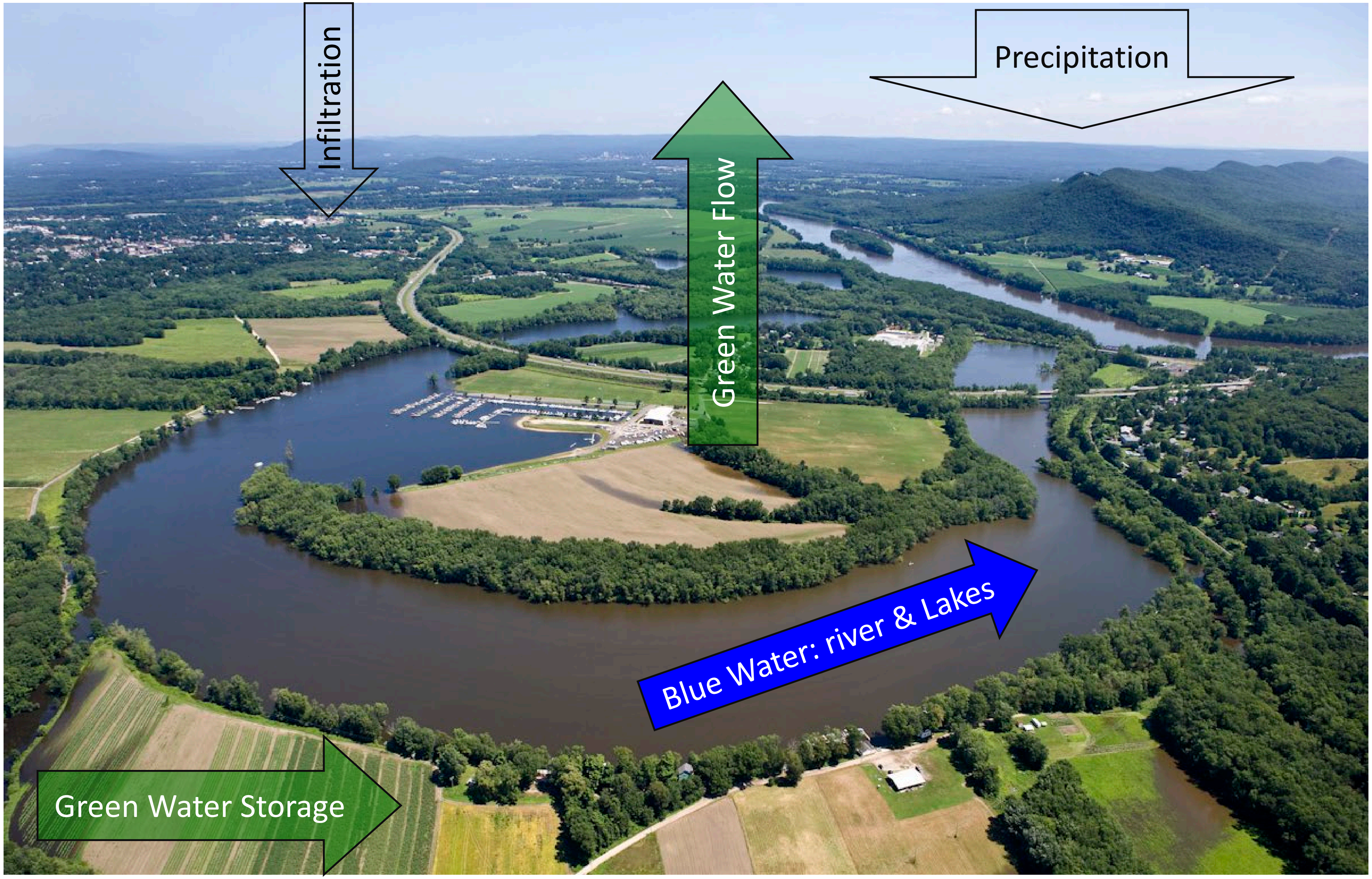
- "**Virtual Water**" is the amount of water used for producing food commodities [Tony Allan, 1993].
- The term **Virtual Water** was originally developed in the context of water-scarce regions (MENA).
- The **Virtual Water Trade Strategy** promotes the import of water-intensive crops and the export of crops with high water-use values.

Virtual water content of commodities (m^3/ton) [Ref: Hoekstra et al., 2012]

Product	USA	China	India	Russia	Indonesia	Australia	Brazil	Japan	Mexico	Italy	Netherlands	World average
Rice (Paddy)	1,275	1,321	2,850	2,401	2,150	1,022	3,082	1,221	2,182	1,679		2,291
Rice (husked)	1,656	1,716	3,702	3,118	2,793	1,327	4,003	1,586	2,834	2,180		2,975
Rice (broken)	1,903	1,972	4,254	3,584	3,209	1,525	4,600	1,822	3,257	2,506		3,419
Wheat	849	690	1,654	2,375		1,588	1,616	734	1,066	2,421	619	1,334
Maize	489	801	1,937	1,397	1,285	744	1,180	1,493	1,744	530	408	909
Soybean	1,869	2,617	4,124	3,933	2,030	2,106	1,076	2,326	3,177	1,506		1,789
Sugarcane	103	117	159		164	141	155	120	171			175
Cotton seed	2,535	1,419	8,264		4,453	1,887	2,777		2,127			3,644
Cotton lint	5,733	3,210	18,694		10,072	4,268	6,281		4,812			8,242
Barley	702	848	1,966	2,359		1,425	1,373	697	2,120	1,822	718	1,388
Sorghum	782	863	4,053						1,212	582		2,853
Coconuts		749	2,255						1,954			2,545
Millet	2,143	1,863	3,269						4,534			4,596
Coffee (roasted)	5,790	7,488	14,500						33,475			20,682
Tea (made)		11,110	7,002									9,205
Beef	**13,193**	**12,560**	**16,482**						**37,762**	**21,167**	**11,681**	**15,497**
Pork	3,946	2,211	4,397						6,559	6,377	3,790	4,856
Goat meat	3,082	3,994	5,187						10,252	4,180	2,791	4,043
Sheep meat	5,977	5,202	6,692						16,878	7,572	5,298	6,143
Chicken meat	2,389	3,652	7,736						5,013	2,198	2,222	3,918
Eggs	1,510	3,550	7,531						4,277	1,389	1,404	3,340
Milk	695	1,000	1,369	1,345	1,143	915	1,001	812	2,382	861	641	990
Milk powder	3,234	4,648	6,368	6,253	5,317	4,255	4,654	3,774	11,077	4,005	2,982	4,602
Cheese	3,457	4,963	6,793	6,671	5,675	4,544	4,969	4,032	11,805	4,278	3,190	4,914
Leather (bovine)	14,190	13,513	17,710	22,575	15,929	18,384	18,222	11,864	40,482	22,724	12,572	16,656

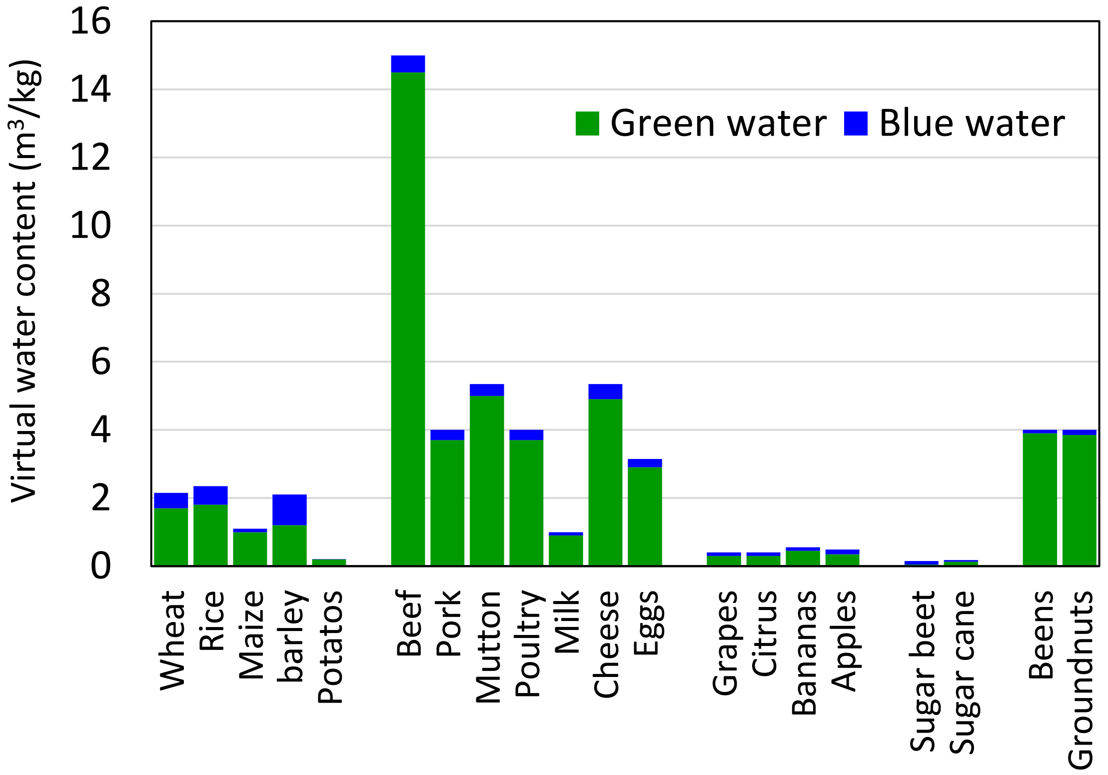
Blue and green water resources

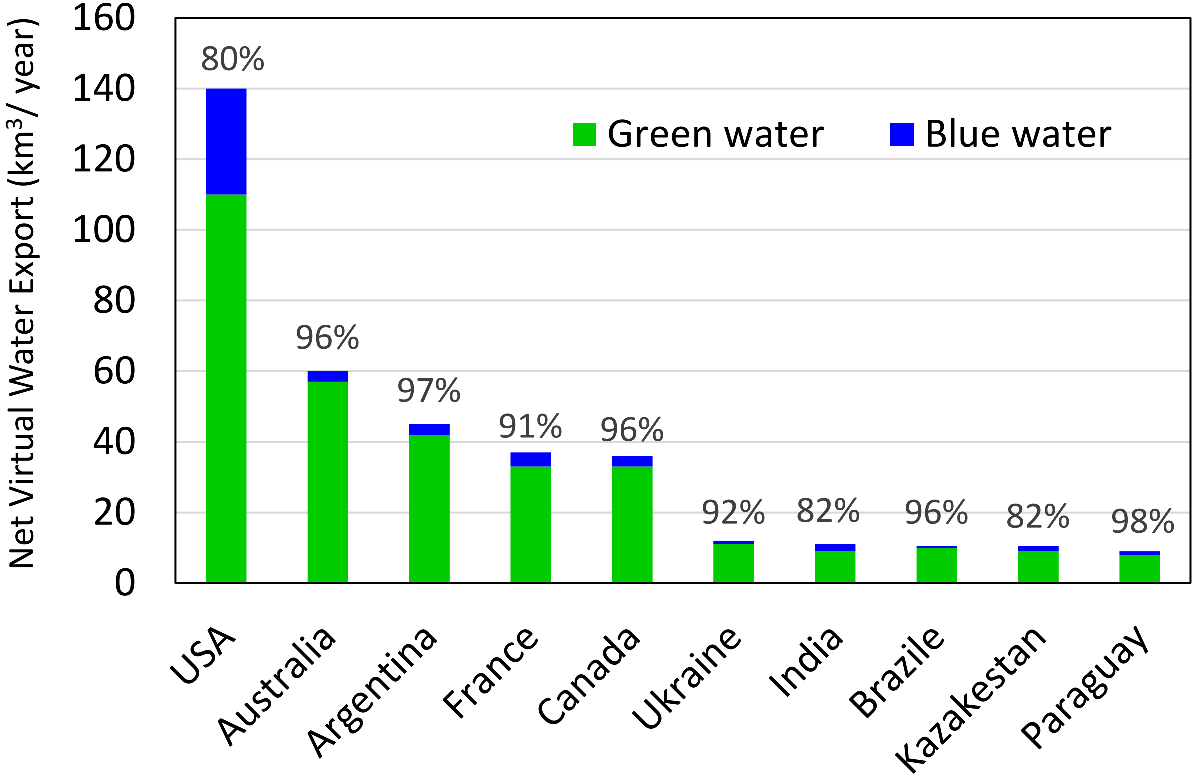
[Falkenmark and Rockstrom, 2006]



Virtual water content and the net VW export

[Hoekstra and Mekonnen, 2012; Graham et al., 2020]

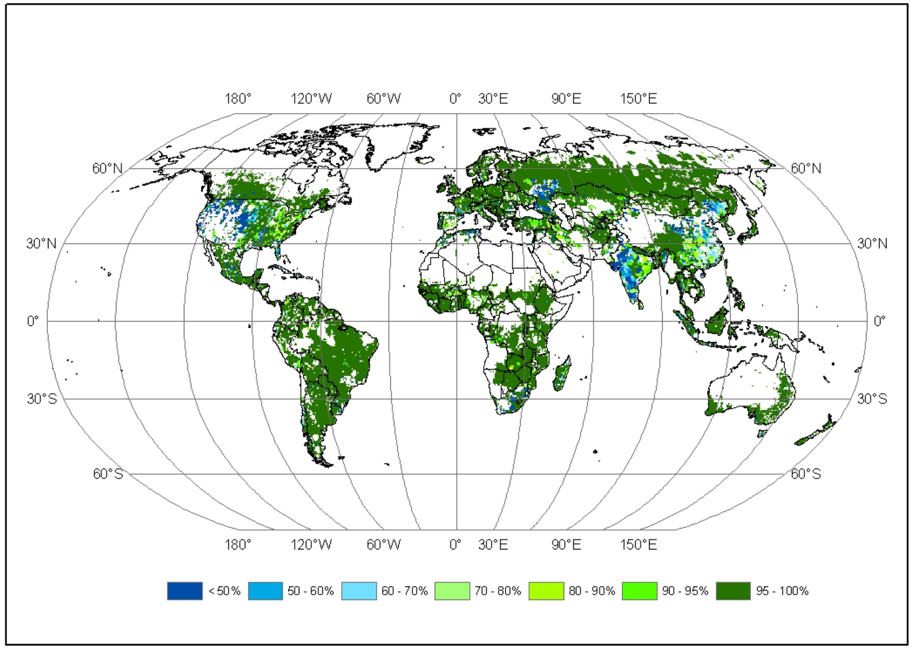


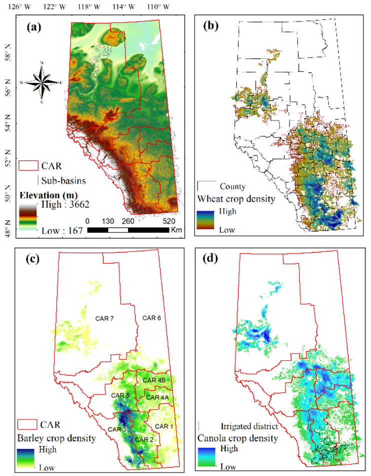


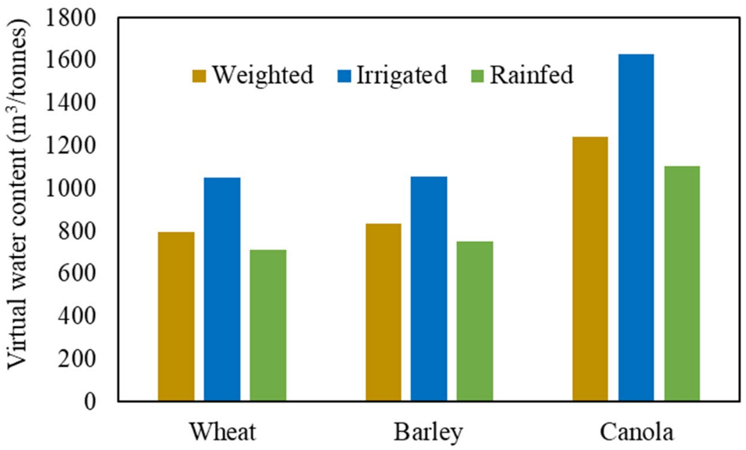
- If most crop production relies on green water, why is blue water scarcity a concern in many countries worldwide?

1. Water challenges are local

[Ref: Hoekstra et al., 2012; 2019]

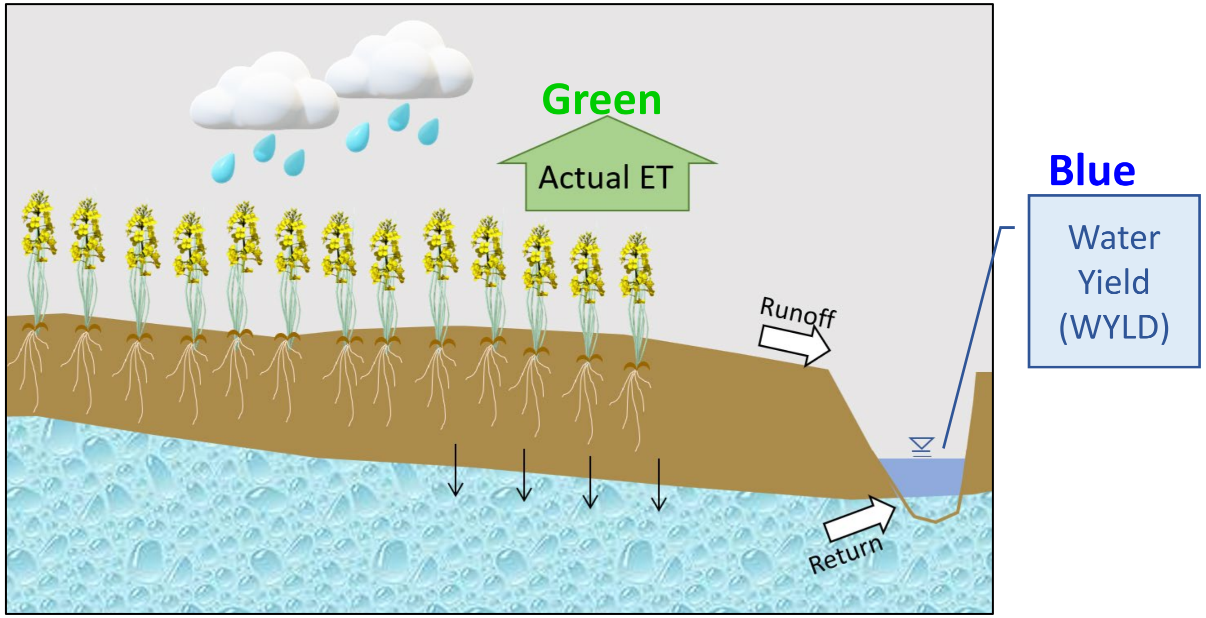


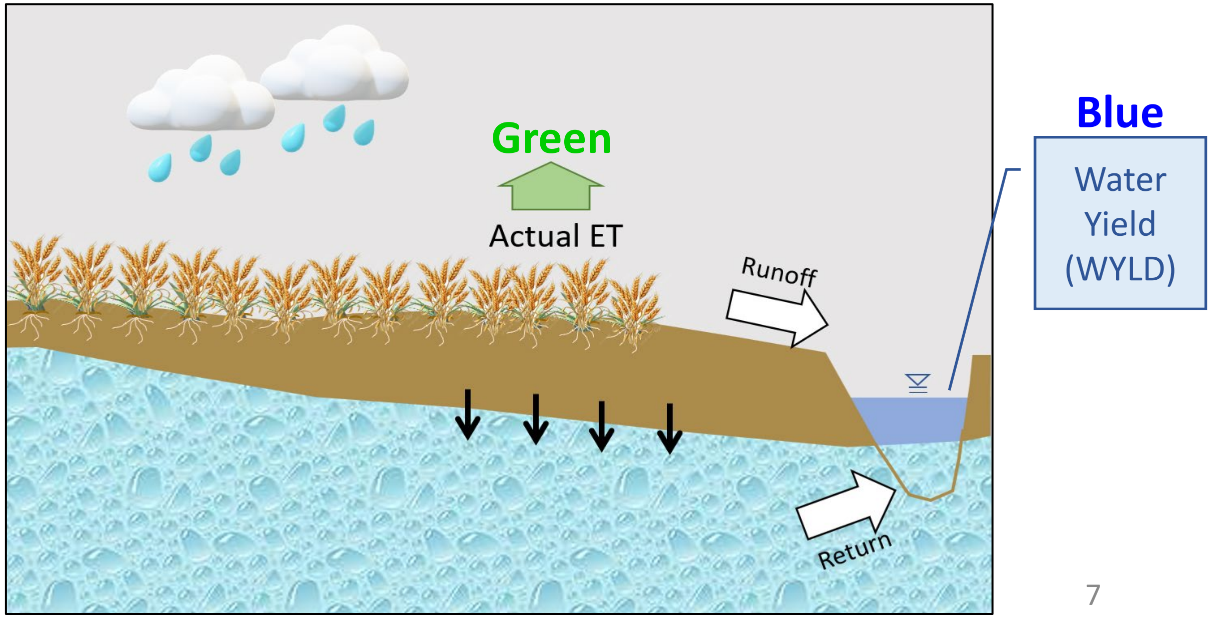




[Ref: Masud et al., 2019]

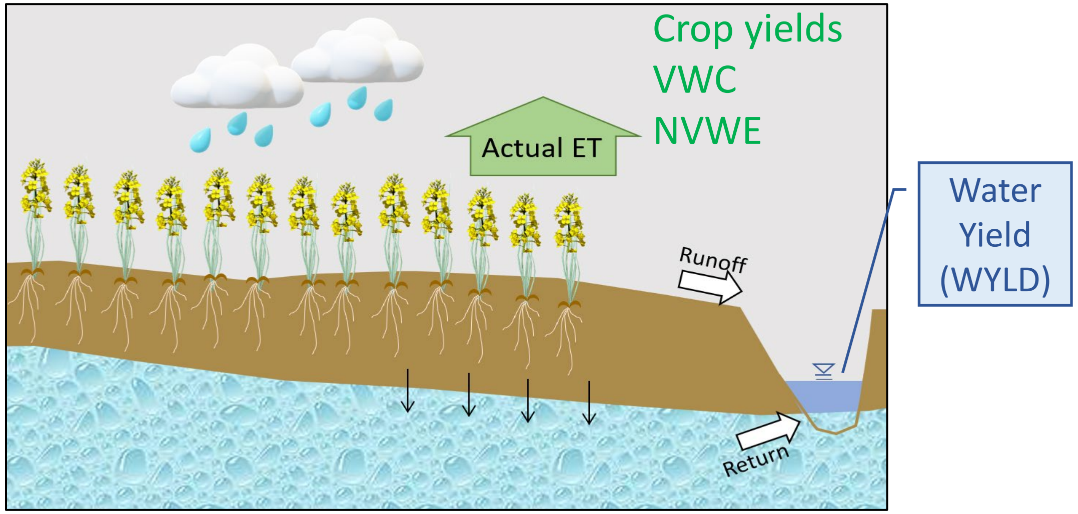
2. Blue and green water resources are interlinked

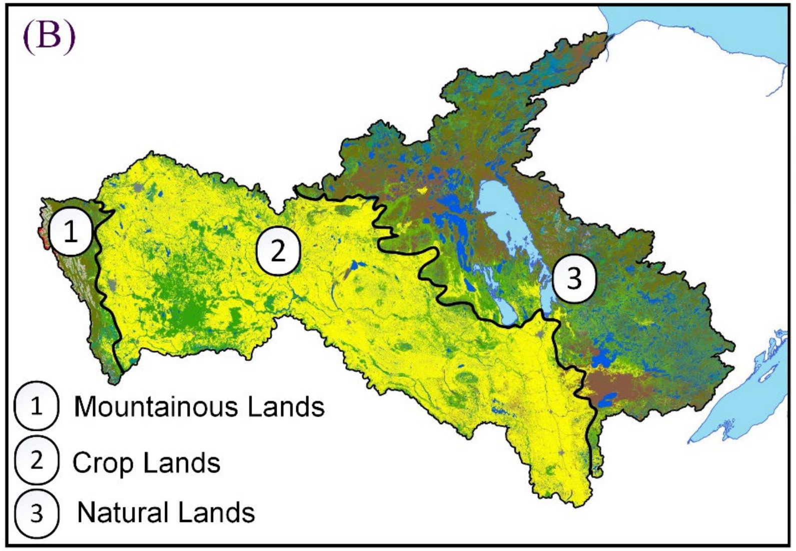


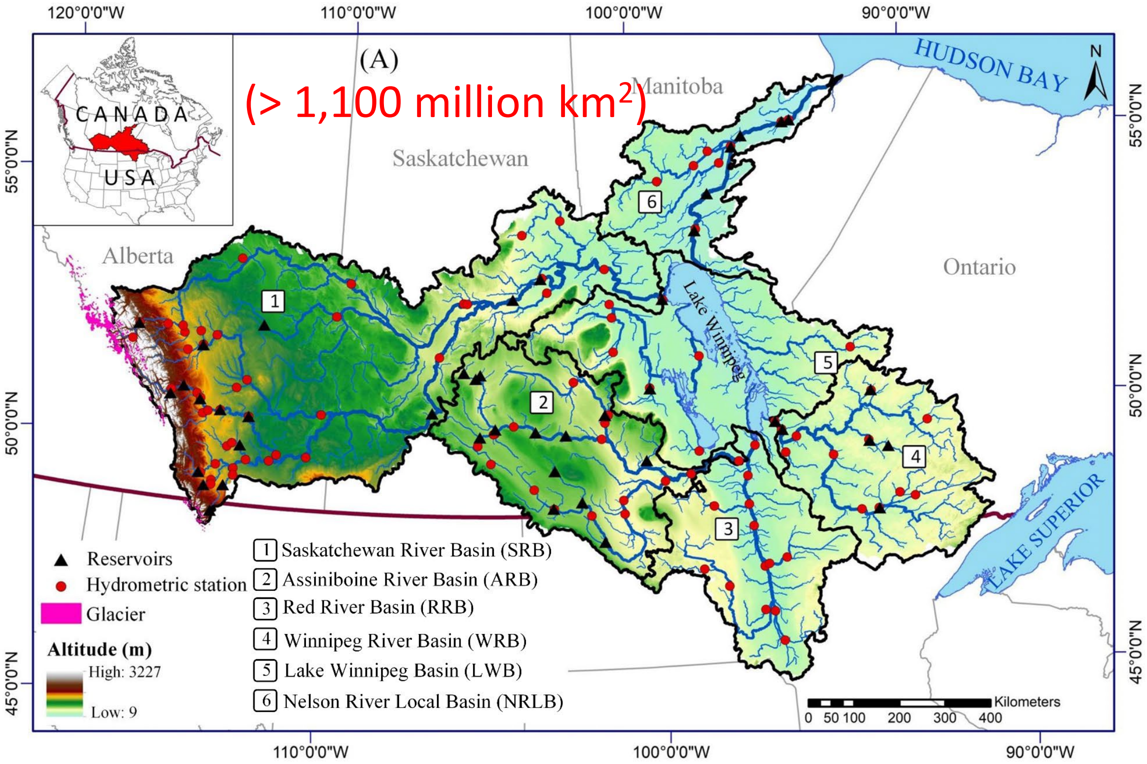


Objectives:

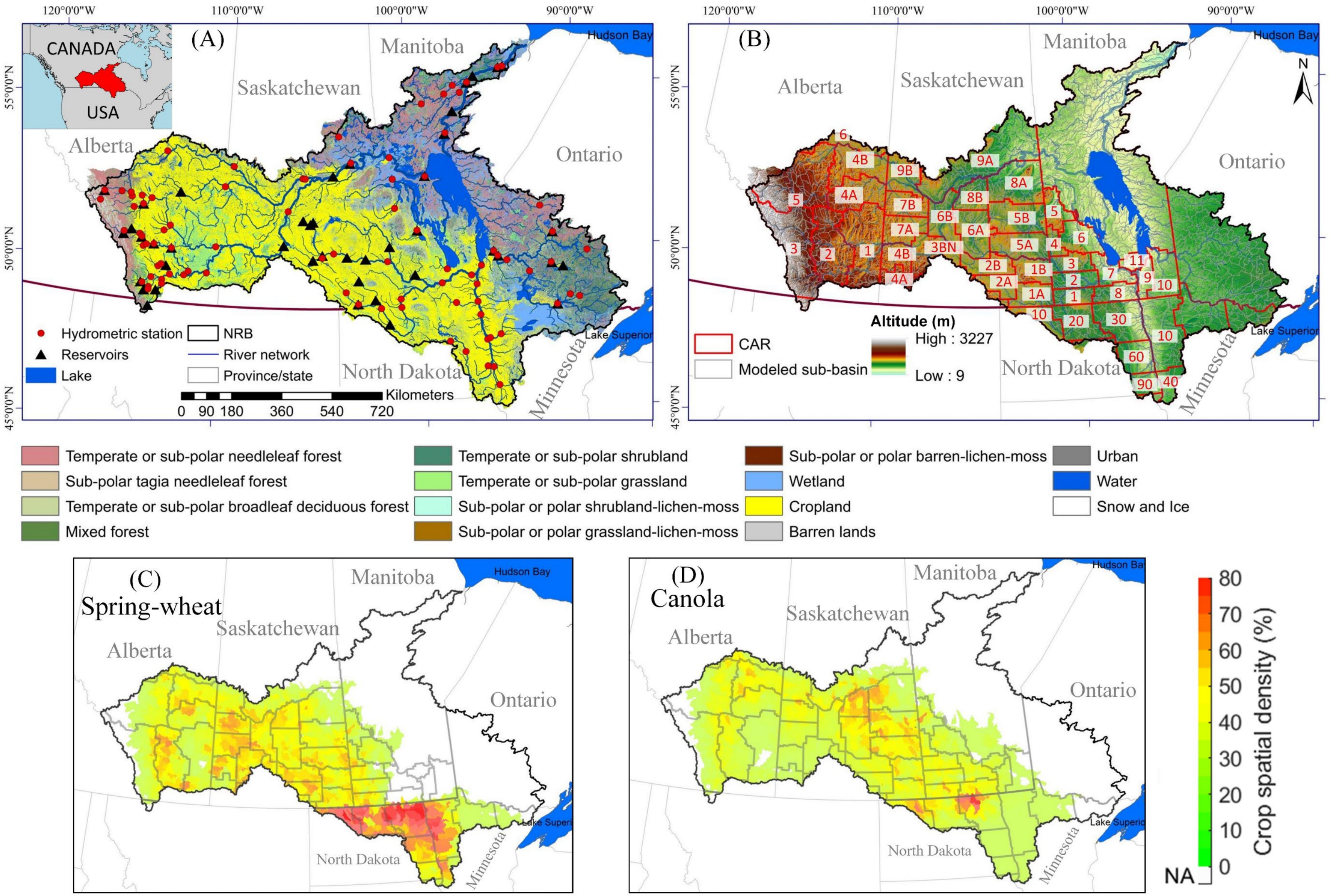
- Relationships between Hydrological WYLD, crop Y, VWC, NVWE
- Droughts and post-droughts
- Past and future





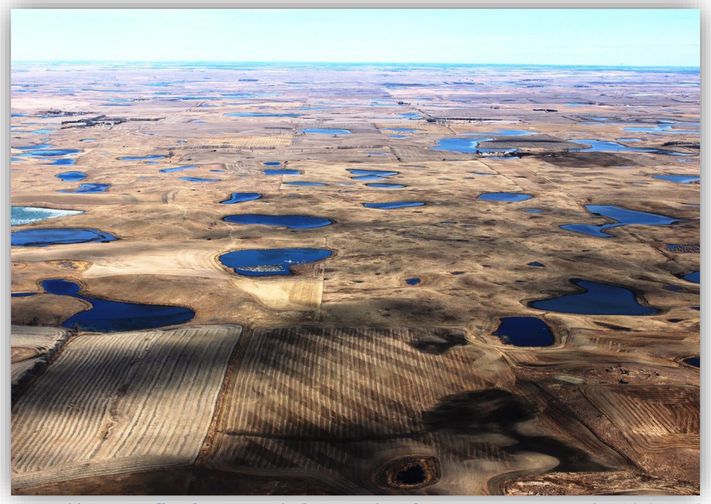


Agro-hydrological model: Soil and Water Assessment Tool



Calibration-validation:

- 1982-2016
- 86 Streamflow (44 dams)
- Wheat, Barley, Canola yields



https://www.flickr.com/photos/usfwsmtnprairie/16826406199

[Ref: Khalili et al., **2023**. Journal of Hydrology]
[Ref: Khalili et al., **2024**. Journal of Hydrology]

Post-processing of model outputs:

Understanding the impacts of drought and post-drought conditions

Step 1

SPEI
Agricultural drought

Step 2

LMD
Longest and the Most Severe Drought

Step 3

Historical
1982-2016

Future
2070-2099

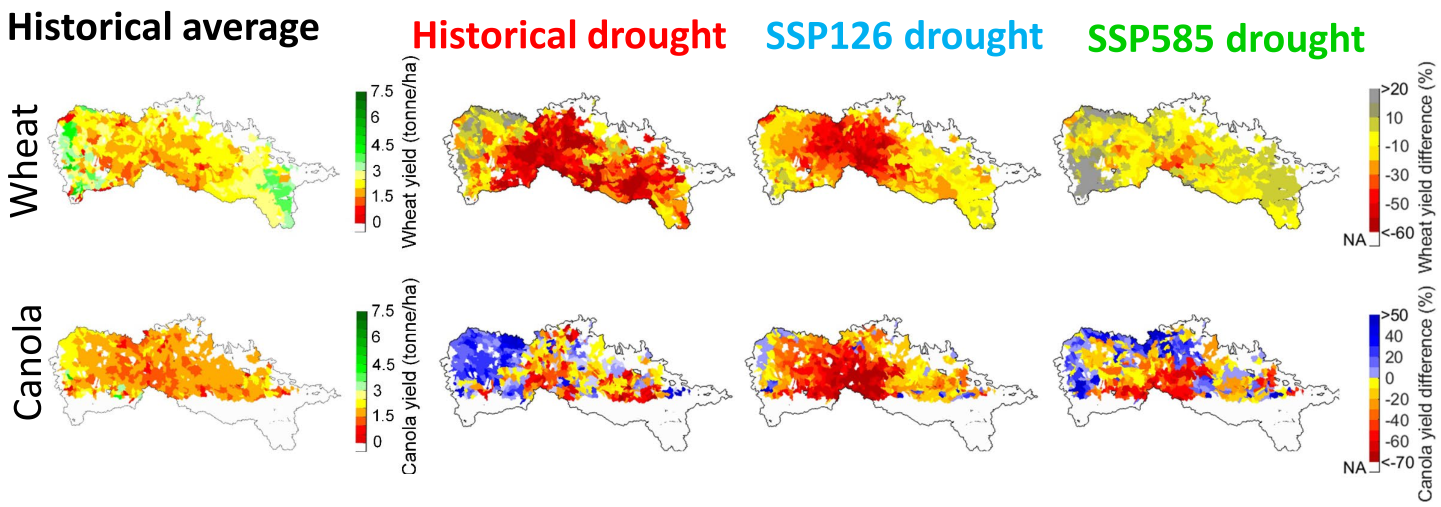
Step 4

6 GCM- CMIP6
Downscaled

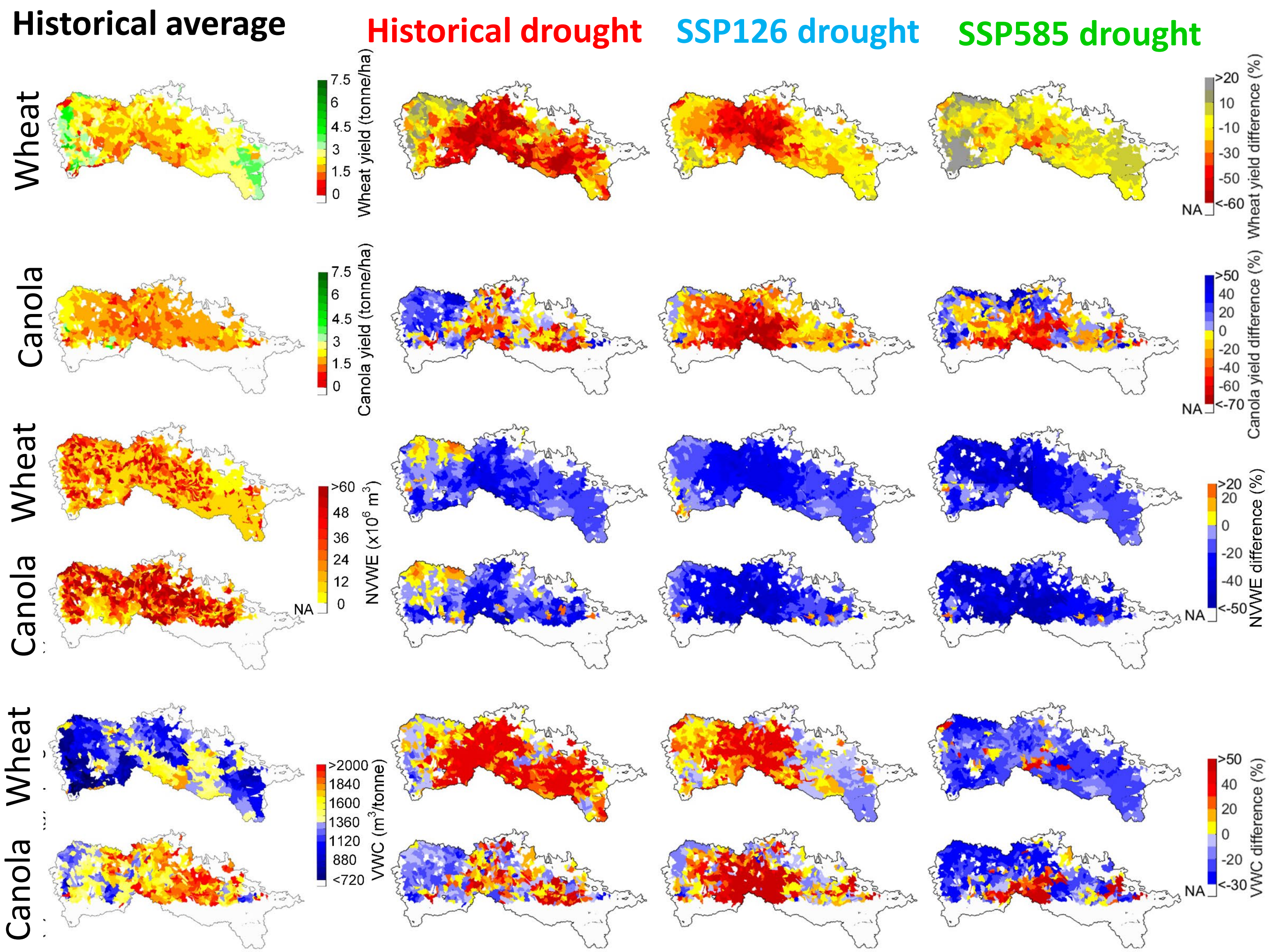
SSP126
SSP585

Step 5

Crop yields
VWC
NVWE
Hydrologic WYLD



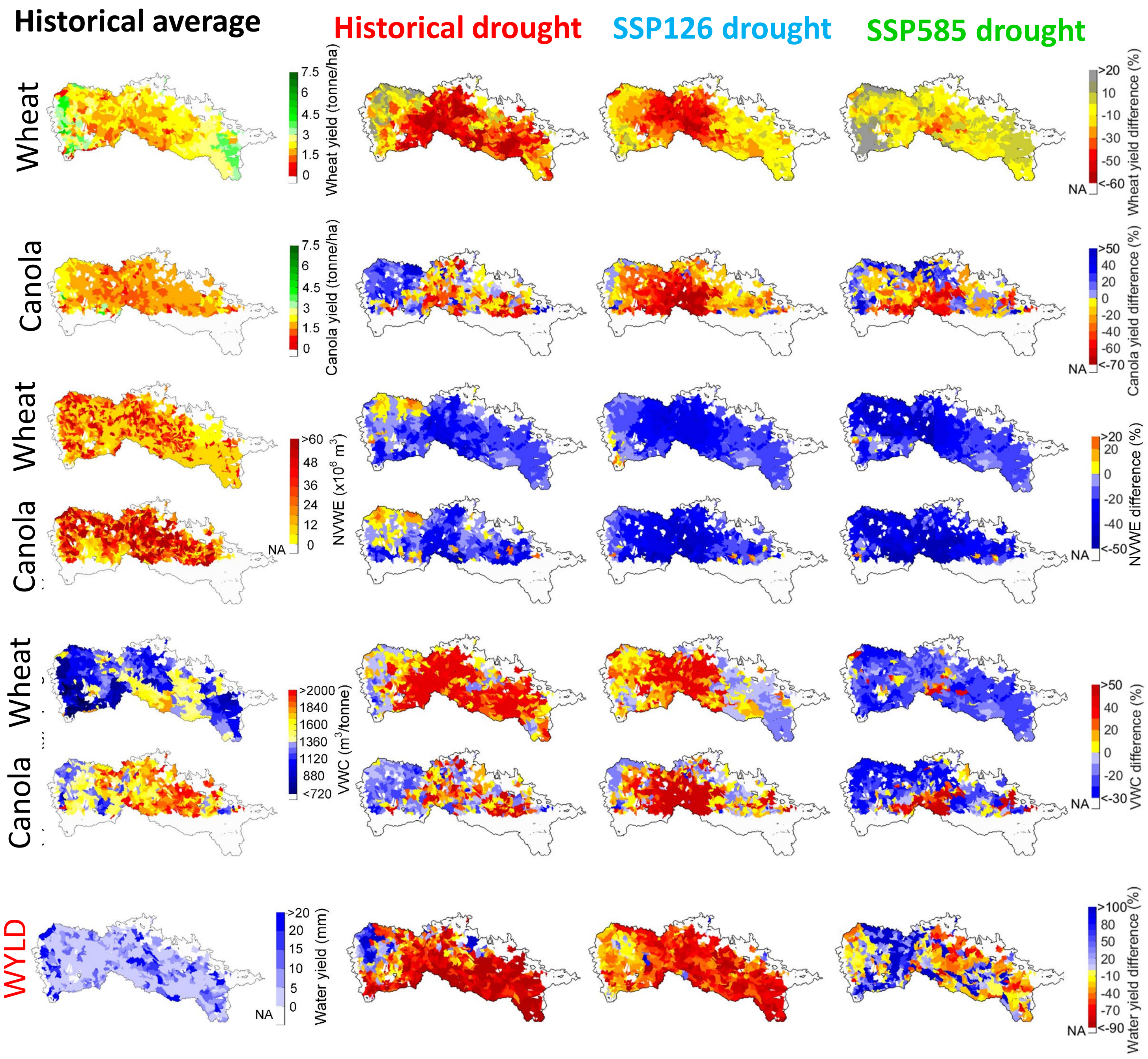
Reduced crop Y, more in SK than AB



Reduced crop Y, more in SK than AB

Reduced NVWE associated with reduced crop Y

Increased VWC, ET demand
SSP585: reduced VWC, CO2 effects



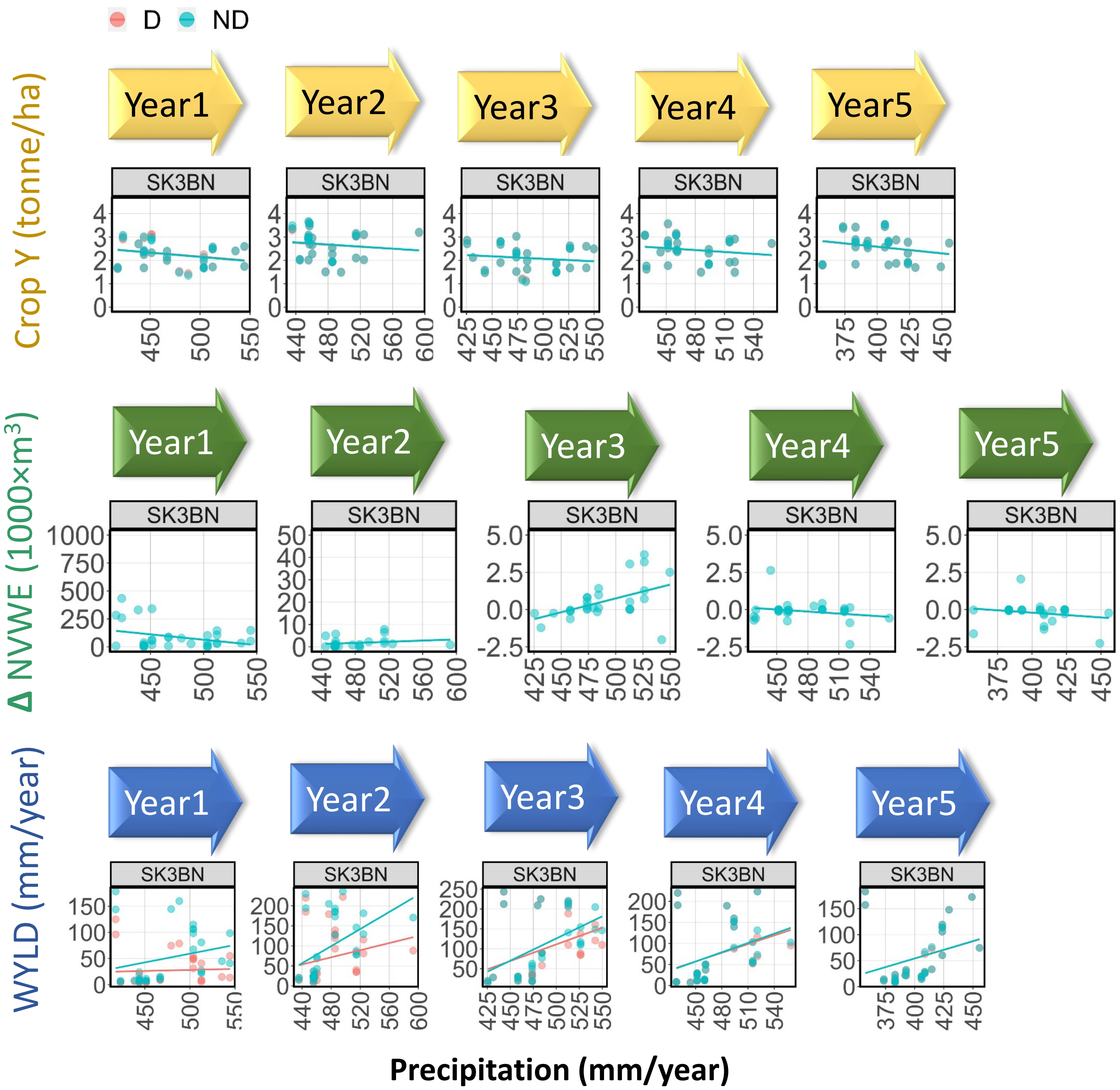
Reduced crop Y, more in SK than AB

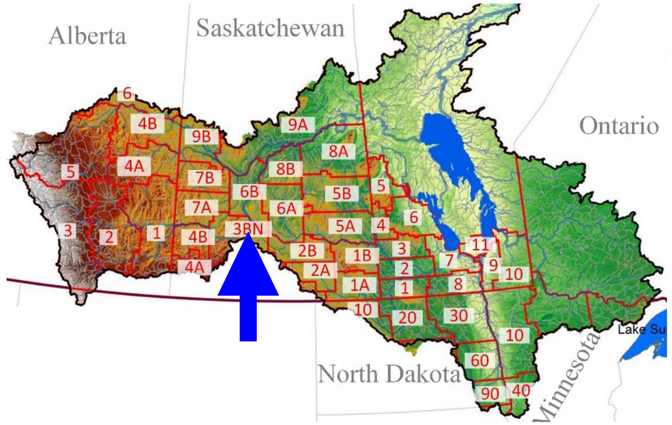
Reduced NVWE associated with reduced crop Y

Increased VWC, ET demand
SSP585: reduced VWC, CO2 effects

Significant reduction in WYLD

Post-drought results





Slow recovery of WYLD

[Ref: Khalili et al., **2024**. Journal of Hydrology]

Conclusion

- Significant reduction of Y, NVWE, and WYLD under drought conditions with potentially a more severe decrease under future droughts than in the past.
- A slight decrease or no change in Y and NVWE during post-drought years.
- Cost of a substantial decline in WYLD during post-drought years.
- Due to variation in crop VWC (e.g., wheat and Canola), a cropping pattern adjustment may help alleviate WYLD reduction and regional crop production under future droughts.

Poster # 9: snow drought- groundwater drought propagation
The afternoon during the poster session

References

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For more details, please refer to: Watershed Science and Modelling Laboratory, University of Alberta, Canada

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