Managing Crop-Soil-Water Interactions on the Canadian Prairies

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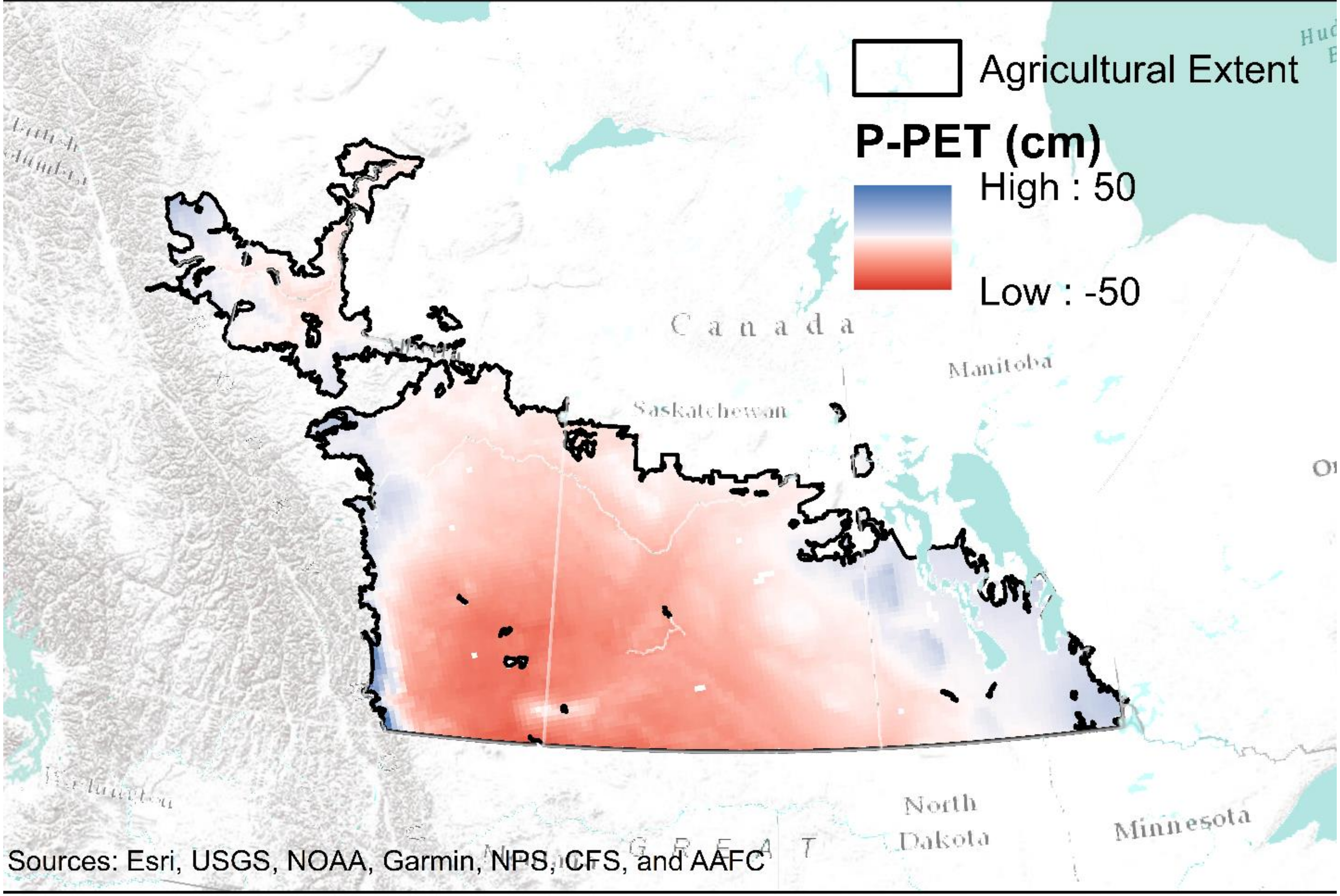
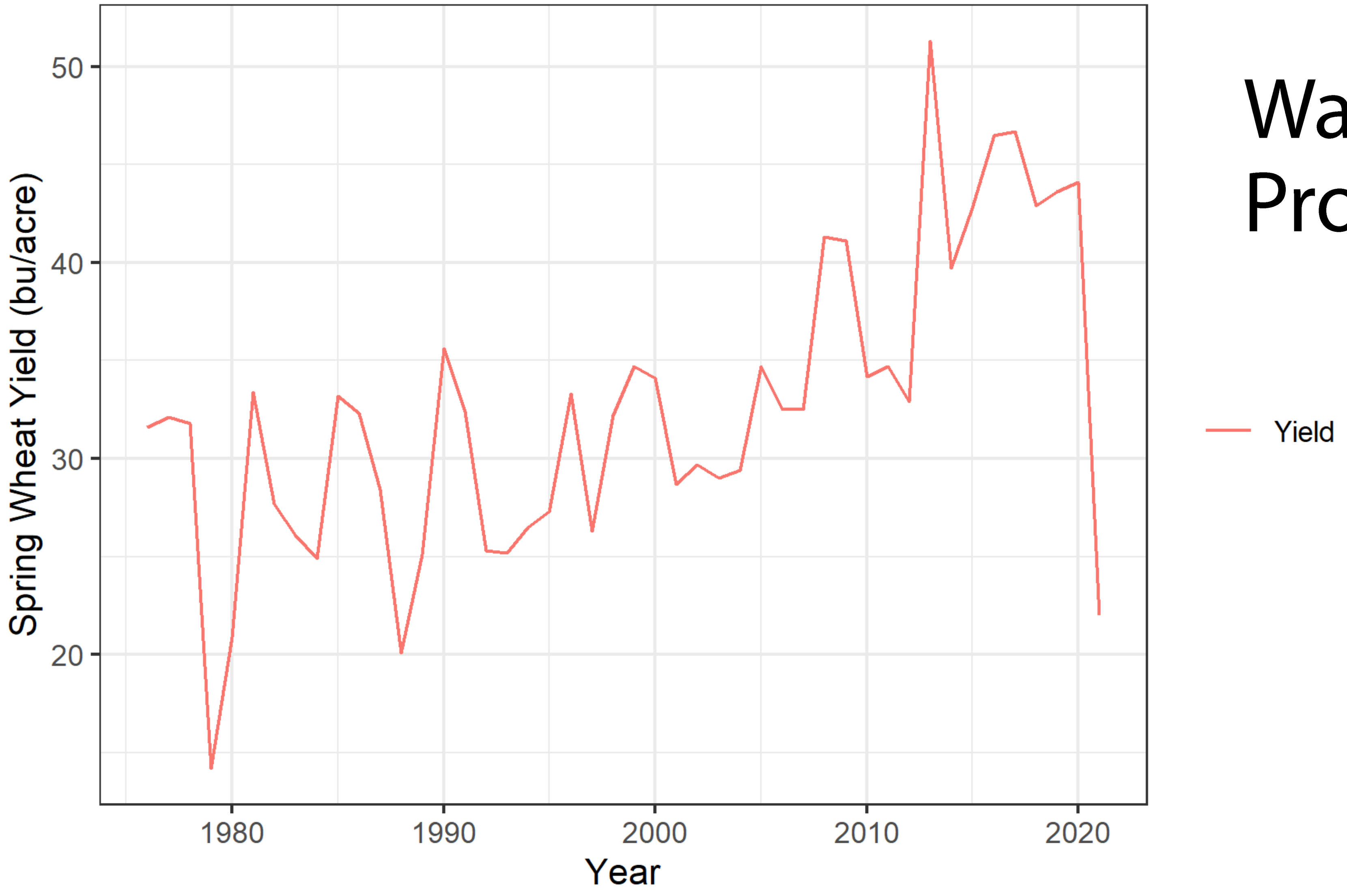
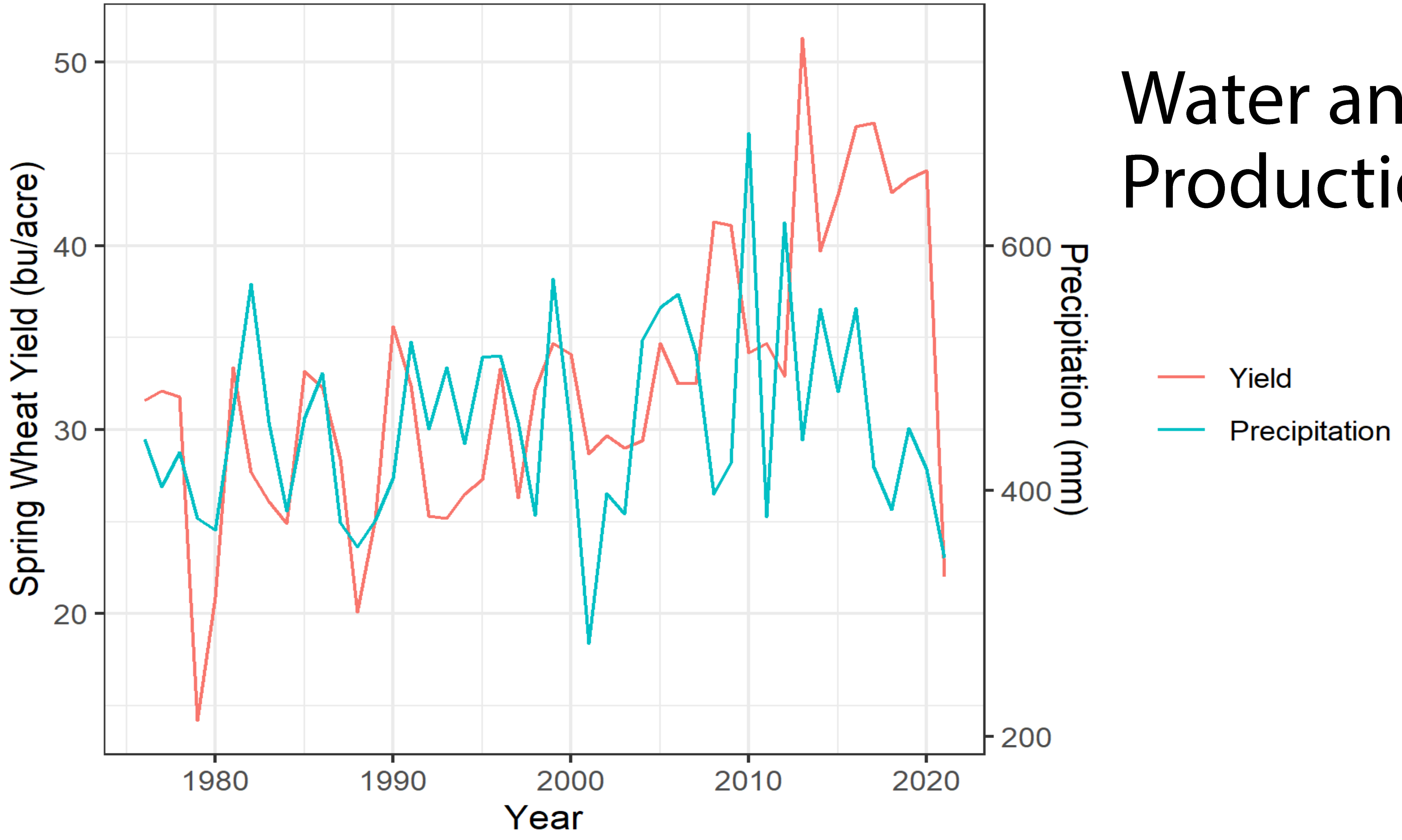


Agricultural Extent
P-PET (cm)
High : 50
Low : -50
Canada
Manitoba
Saskatchewan
North Dakota
Minnesota
Sources: Esri, USGS, NOAA, Garmin, NPS, CFS, and AAFC

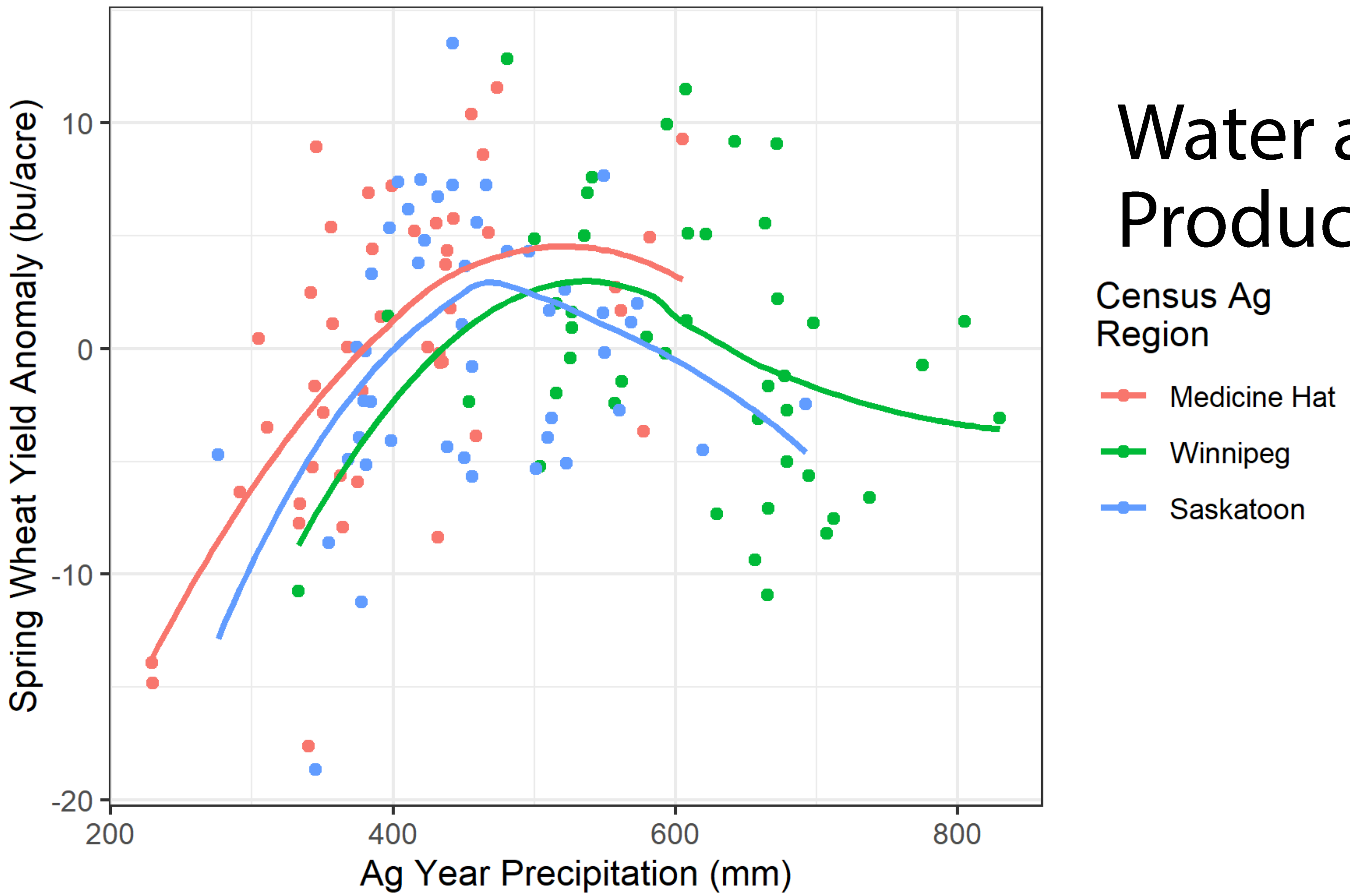
Water and Crop Production



Water and Crop Production



Water and Crop Production



Outline

- How much water do crop use and where does it come from?
- How, and by how much, can we mitigate water related production impacts with management practices?
- What are the ag-water prospects for 2024?

Ag-Water Balance

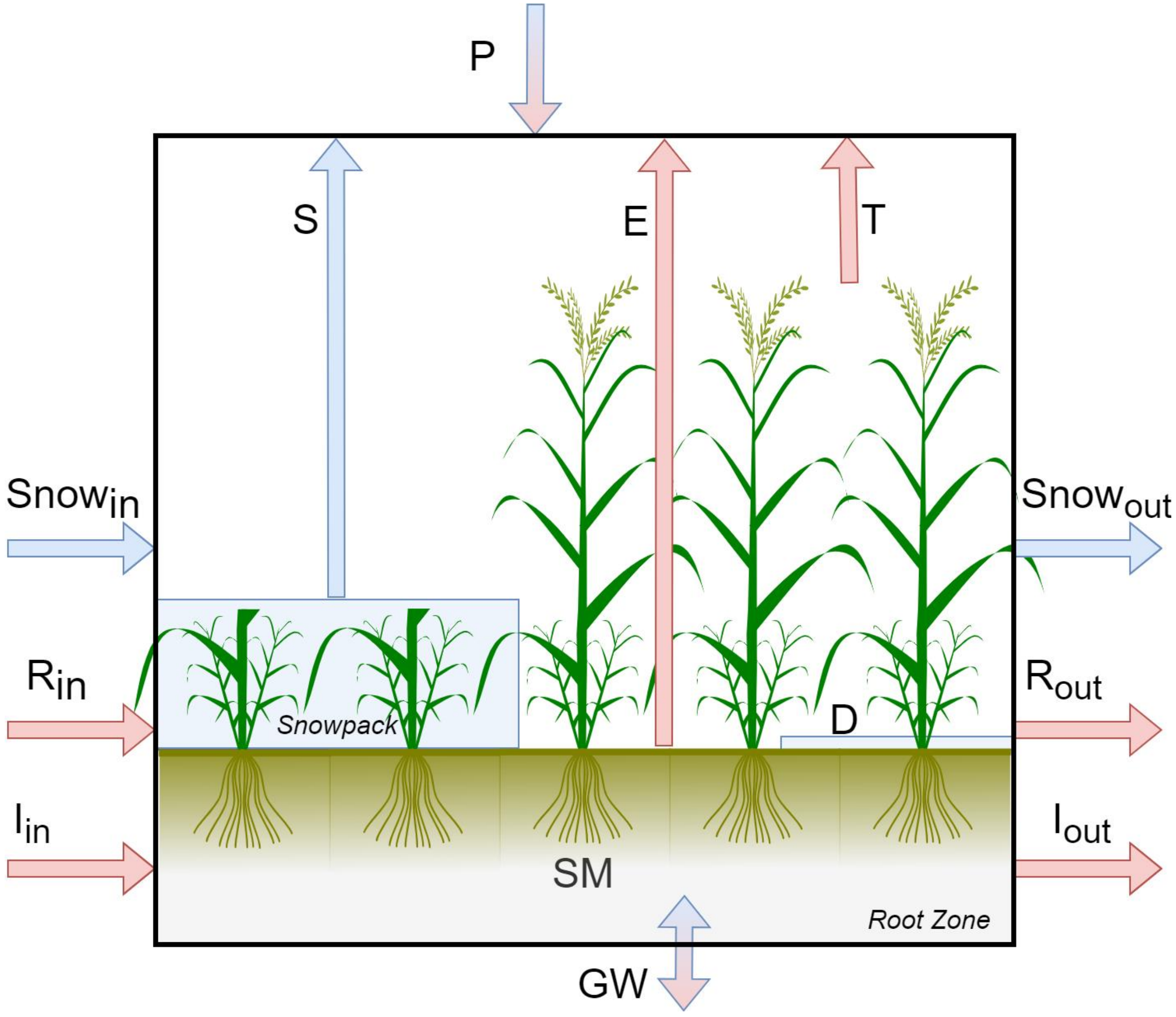
- Winter and summer hydrology are not isolated
- Winter water balance

$$P + \Delta S = S + \nabla \text{Snow}$$

- Summer Water balance

$$P + \Delta S = E + T + R$$

P=Precipitation
ΔS= Change in soil moisture
S=Sublimation
∇Snow=net snow movement
E=Evaporation
T=Transpiration
R=Runoff



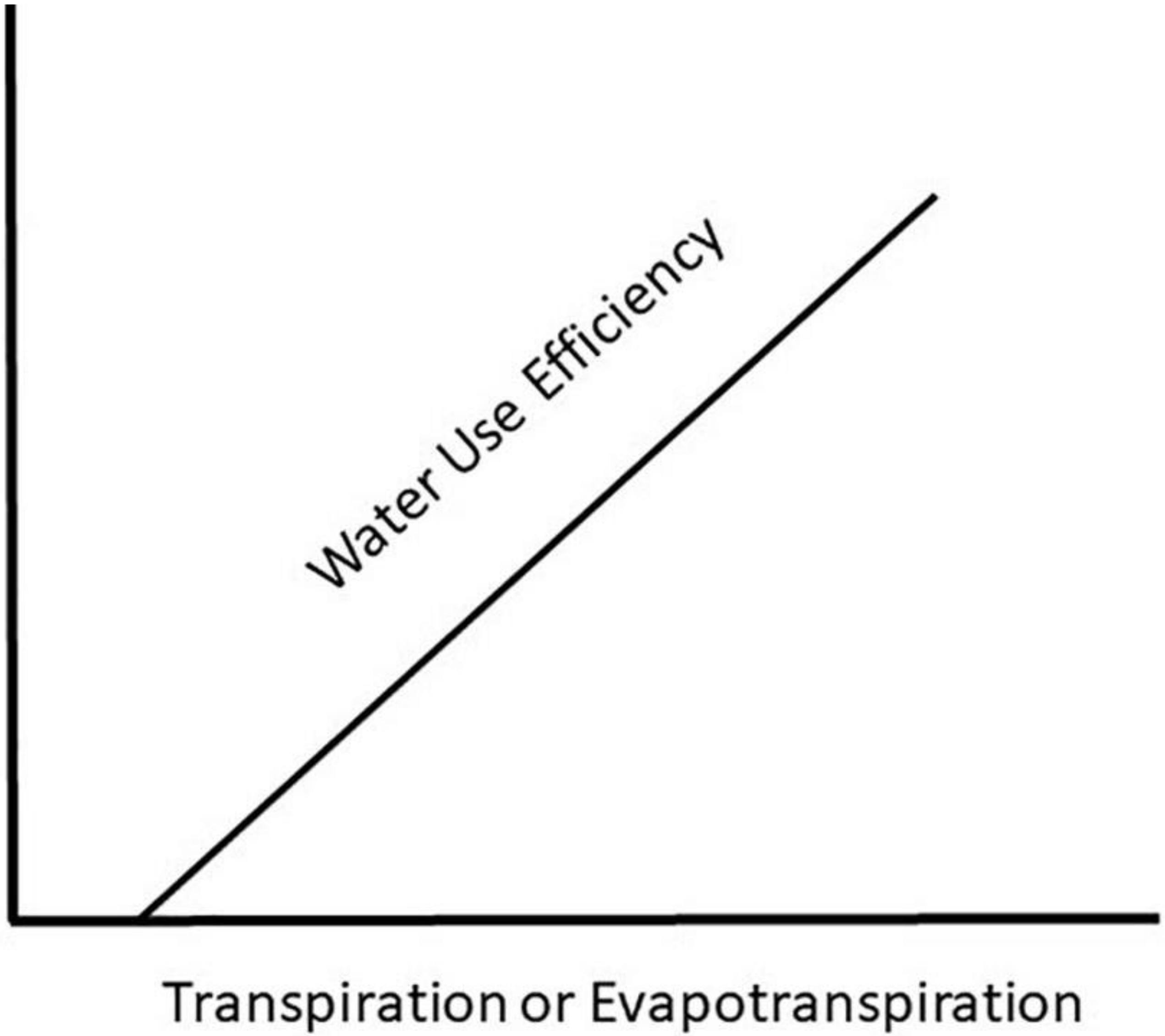
Water Use Efficiency

Relates crop production to water use

$$WUE = \frac{crop\ production}{crop\ water\ use}$$

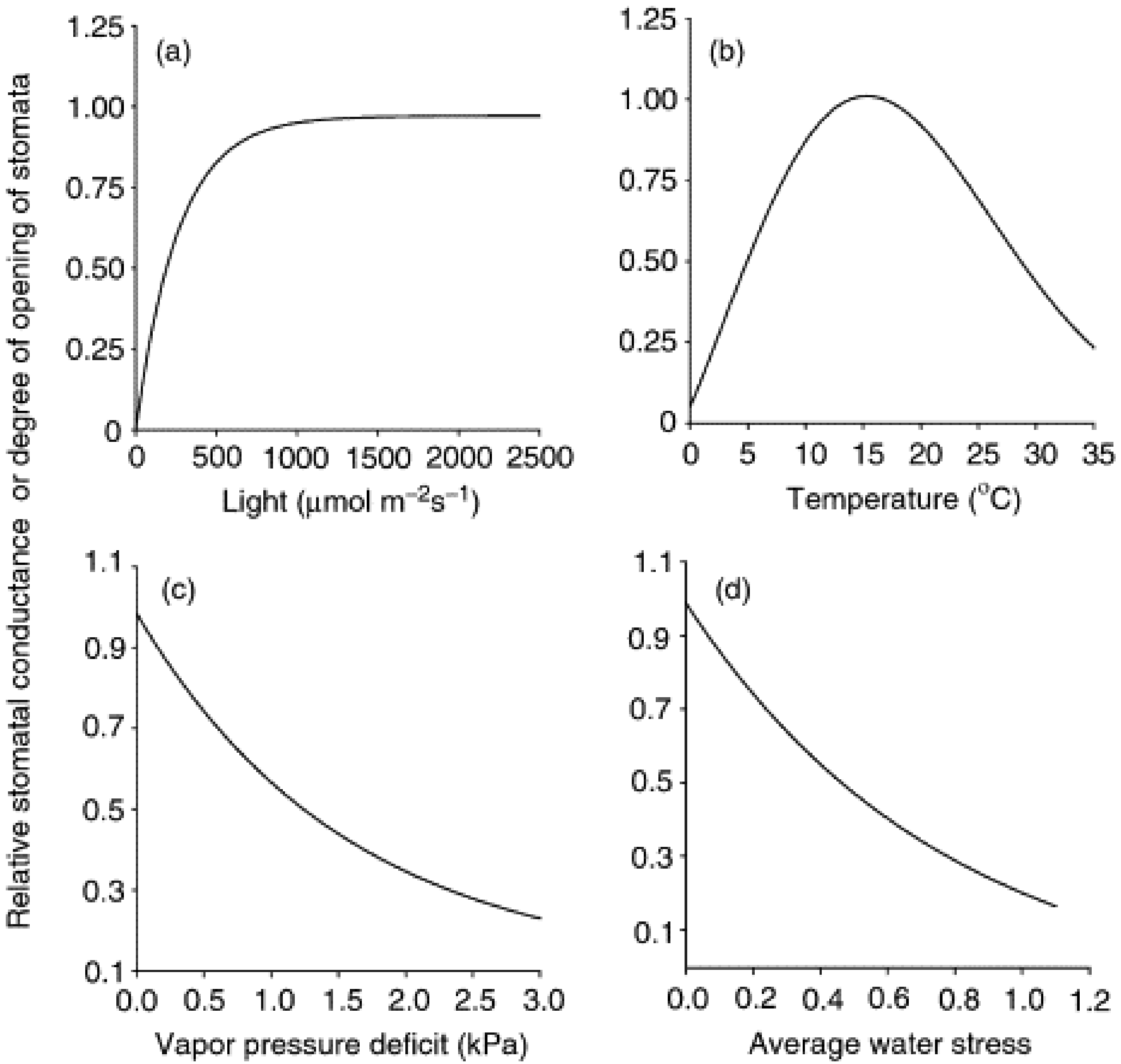
Value to compare:

- Crop type/Cultivars
- Environmental response
- Agricultural management practices
- Climatic differences



Environmental Factors vs WUE

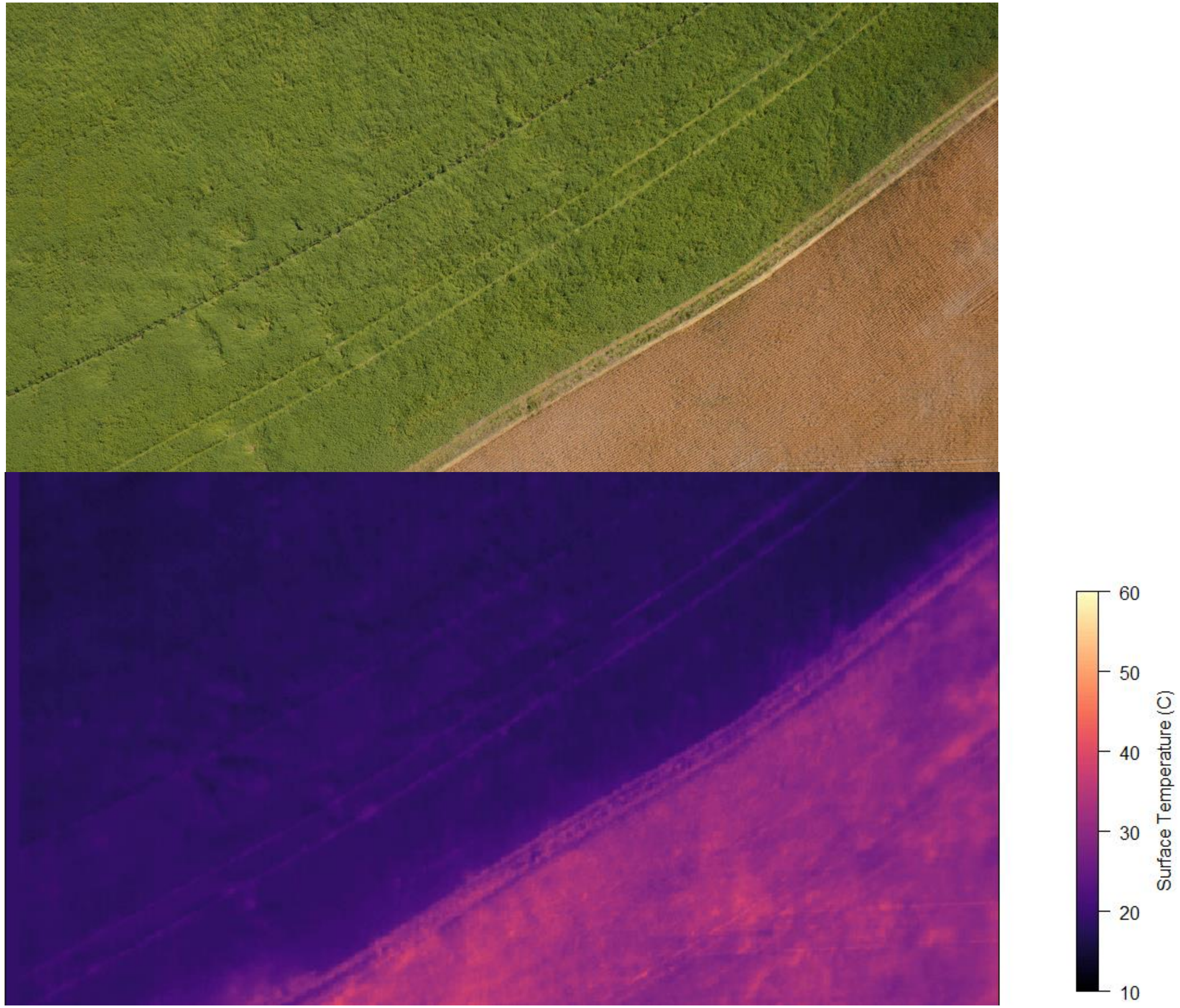
- Crop WUE respond to environmental factors
  - Increases with sunlight
  - Optimal range of air temperature
  - Decreases with increase vapor pressure deficit and water stress
  - Increases with CO_2
  - Decreases with wind speed
  - Very crop dependent
- A plant will conserve water at the expense of productivity



Beadle and Sands (2005)

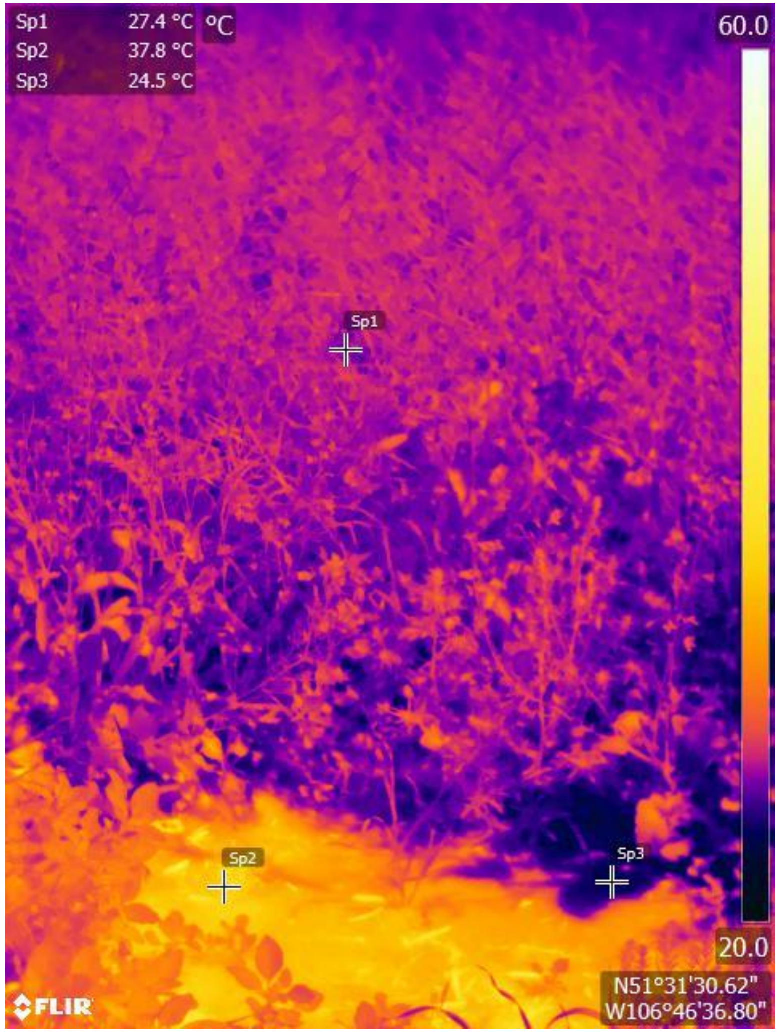
Transpiration paradox

- In obtaining CO_2 from the atmosphere water vapor is lost from the leaf.
- Complex interaction of energy and water exchange defined by plant physiology



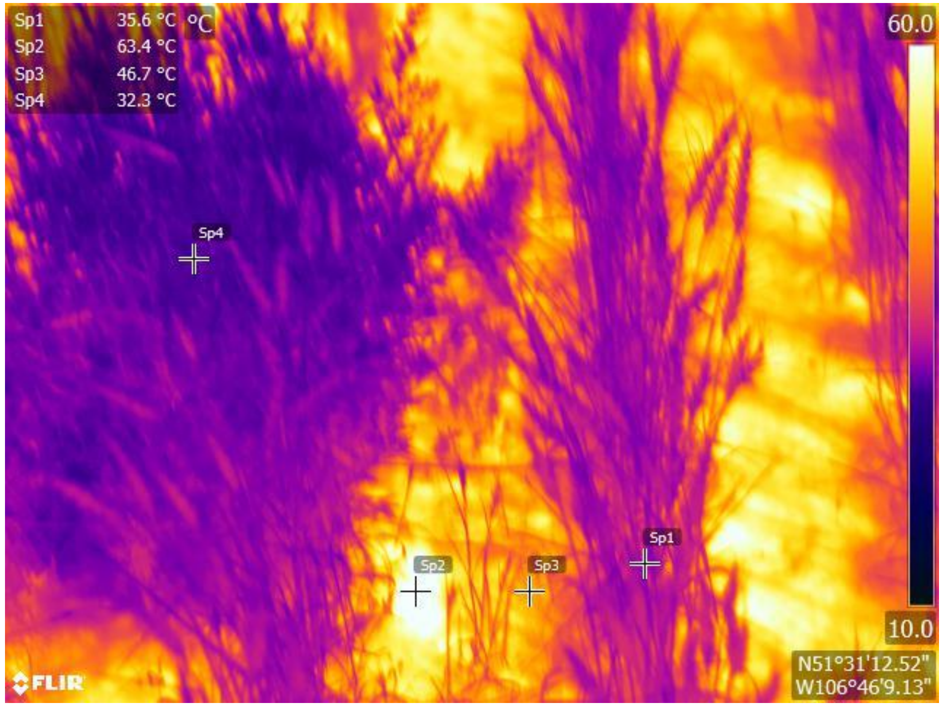
Energy limited

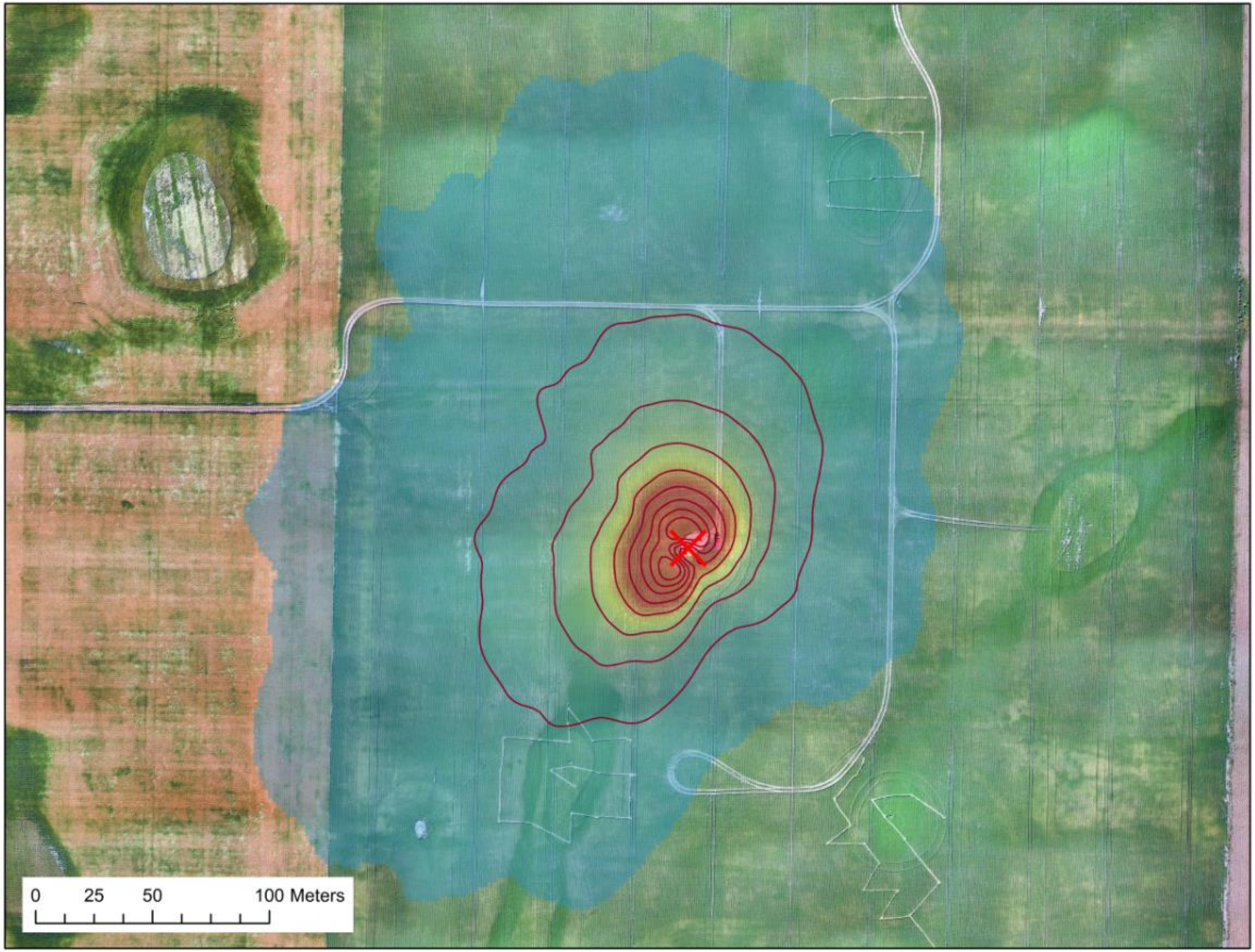
- Well-watered/ Irrigated situation
- Transpiration able to regulate plant temperature and maximize biomass/yield production



Water Limited

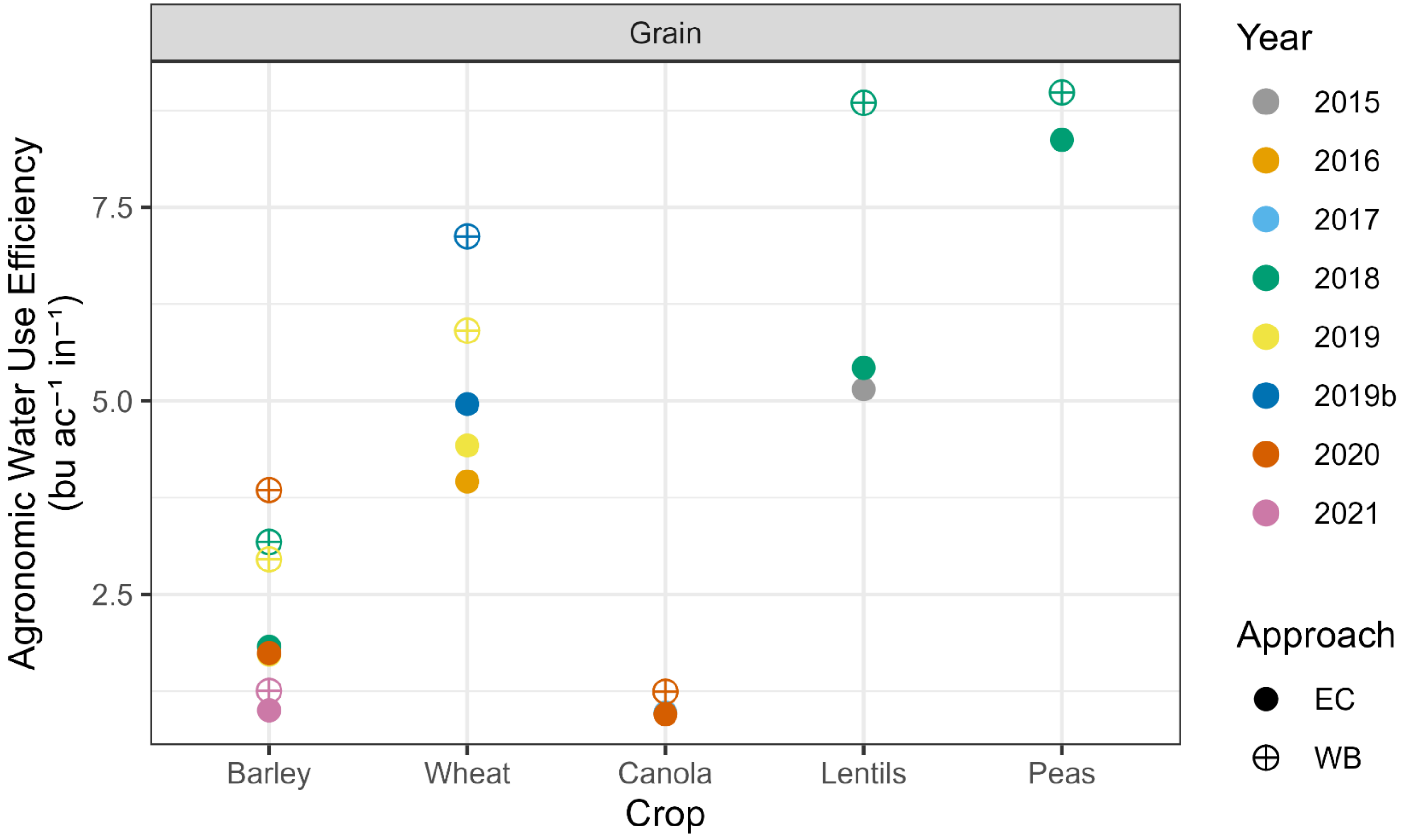
- Dryland/Drought situation
- Transpiration unable to regulate plant temperature and heat stress damages yield potential




0
25
50
100 Meters

Seasonal Agronomic WUE

- Water balance approach has high variability in WUE
  - Spatial representation challenges
- Relatively stable WUE estimates besides 2021 drought



Harder et al. (2023)

Has WUE changed over time?

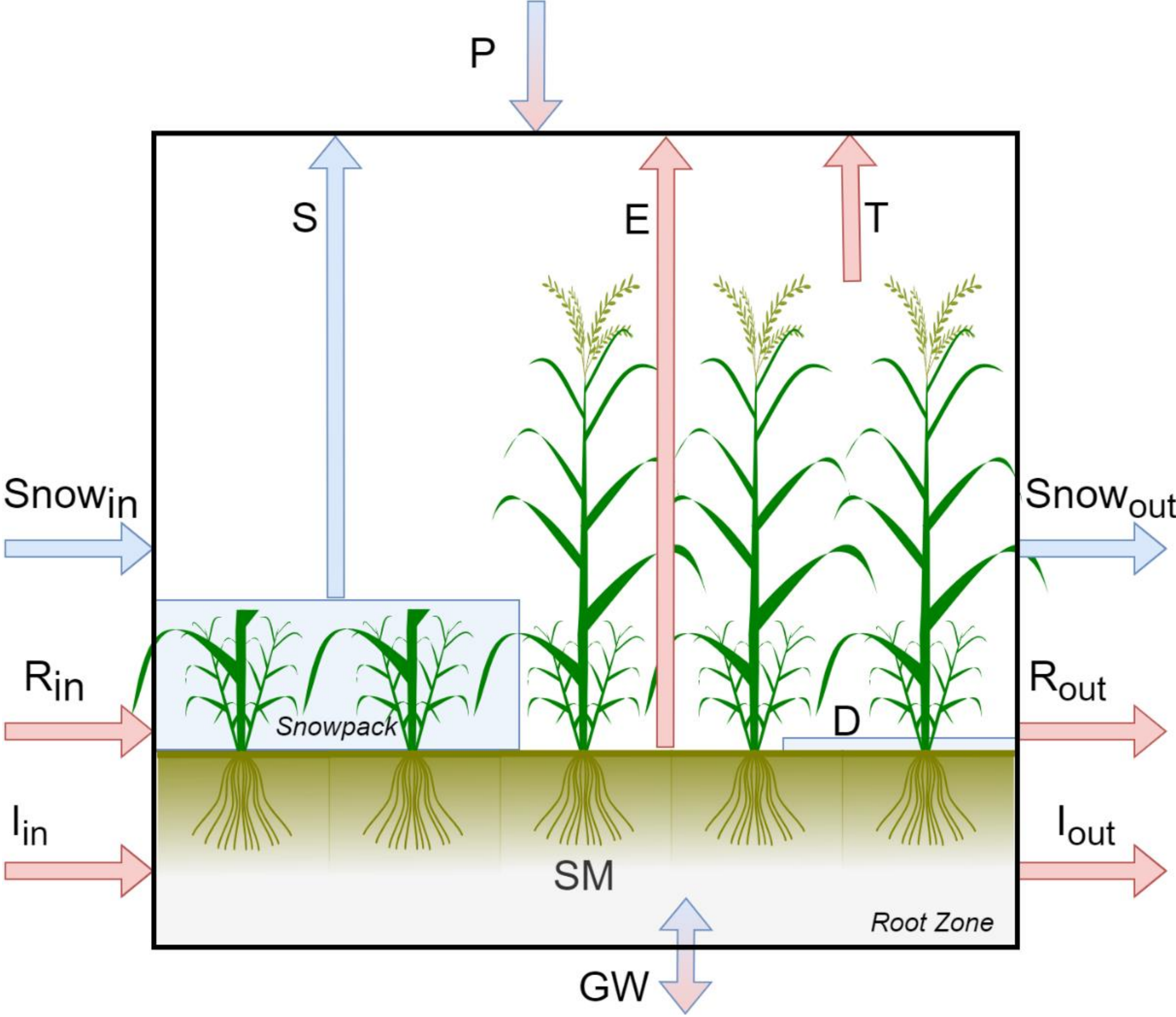
- Agronomic water use efficiency (bu ac^{-1} in^{-1}) published from studies in the Canadian Prairies.
- Large ranges in reported values
  - Variable conditions
  - Water balance approach limitations
- Lentils have made huge gains due to an increased harvest index.

Crop	Observed	Literature		
	Mean	Mean	Min	Max
Barley	4.9	4.8	2.4	7.6
Wheat	3.9	4.0	2.1	9.1
Canola	2.7	2.2	0.9	4.1
Lentils	4.6	1.8	1.0	2.3
Peas	7.3	3.2	0.2	11.0
Corn	7.8	17.1	5.5	30.3

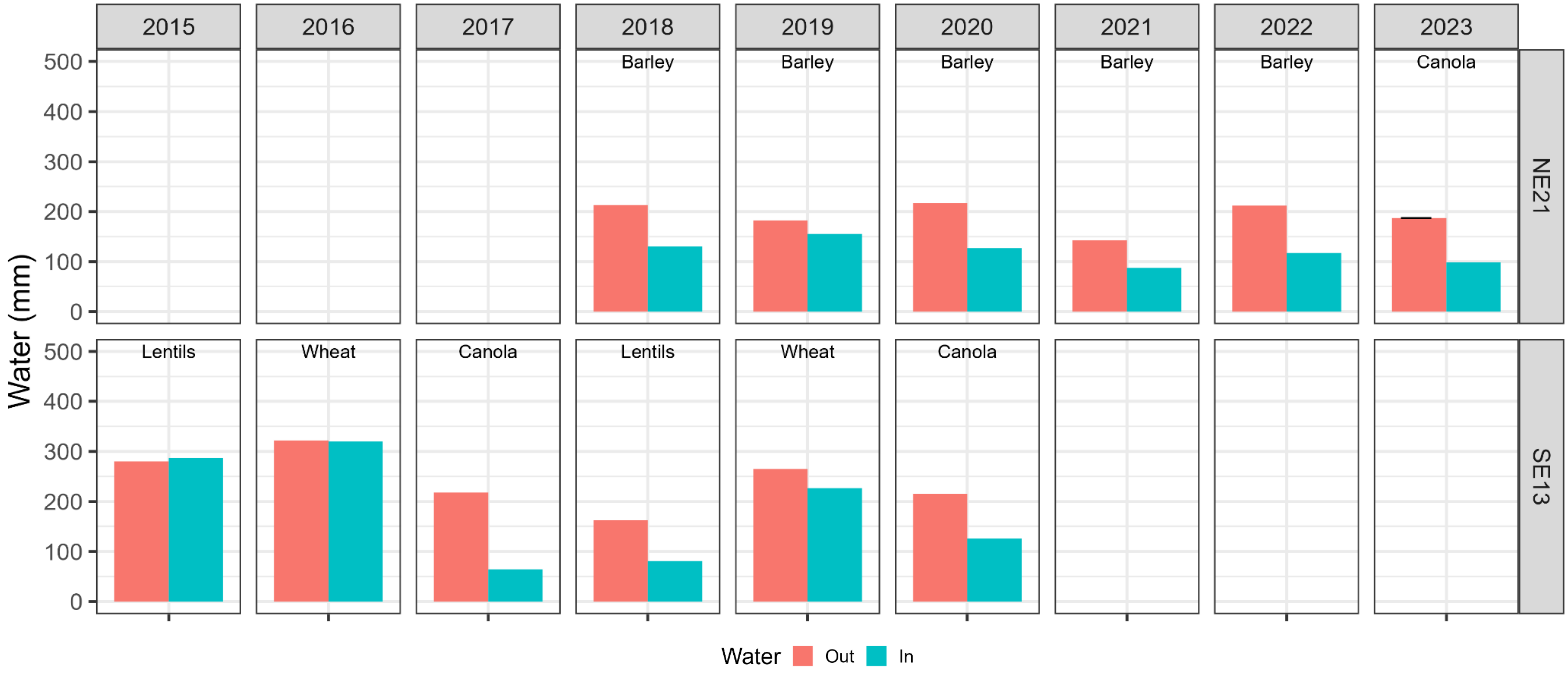
Sources for **Barley:** Azooz and Arshad, 1998; Gan et al., 2000; Henry, 1990**, Wheat:** Angadi et al., 2008; De Jong and Cameron, 1980; Gan et al., 2000, 2009; Henry, 1990; Hu et al., 2015; Jefferson and Cutforth, 2005; Miller et al., 2002, 2001; Wang et al., 2007**, Canola:** Angadi et al., 2008; Azooz and Arshad, 1998; Cutforth et al., 2006; De Jong and Cameron, 1980; Gan et al., 2009; Henry, 1990; Hu et al., 2015, **Lentils**: Angadi et al., 2008; Cutforth et al., 2002; Miller et al., 2002, 2001**, Peas:** Angadi et al., 2008; Cutforth et al., 2002; Gan et al., 2009; Miller et al., 2002, 2001**, Corn:** Green and Read, 1983; Guyader et al., 2018, and **Forage**: Elliot and Efetha, 1999; Jefferson and Cutforth, 2005

Prairie Ag-Water Balance

- WUE is relatively conservative
  - Cultivar specific stressors will reduce potential
- To increase productivity, need to maximise crop available water



Growing Season Water Balance



Harder et al., submitted

Seasonal Water Balance

Harder et al., submitted

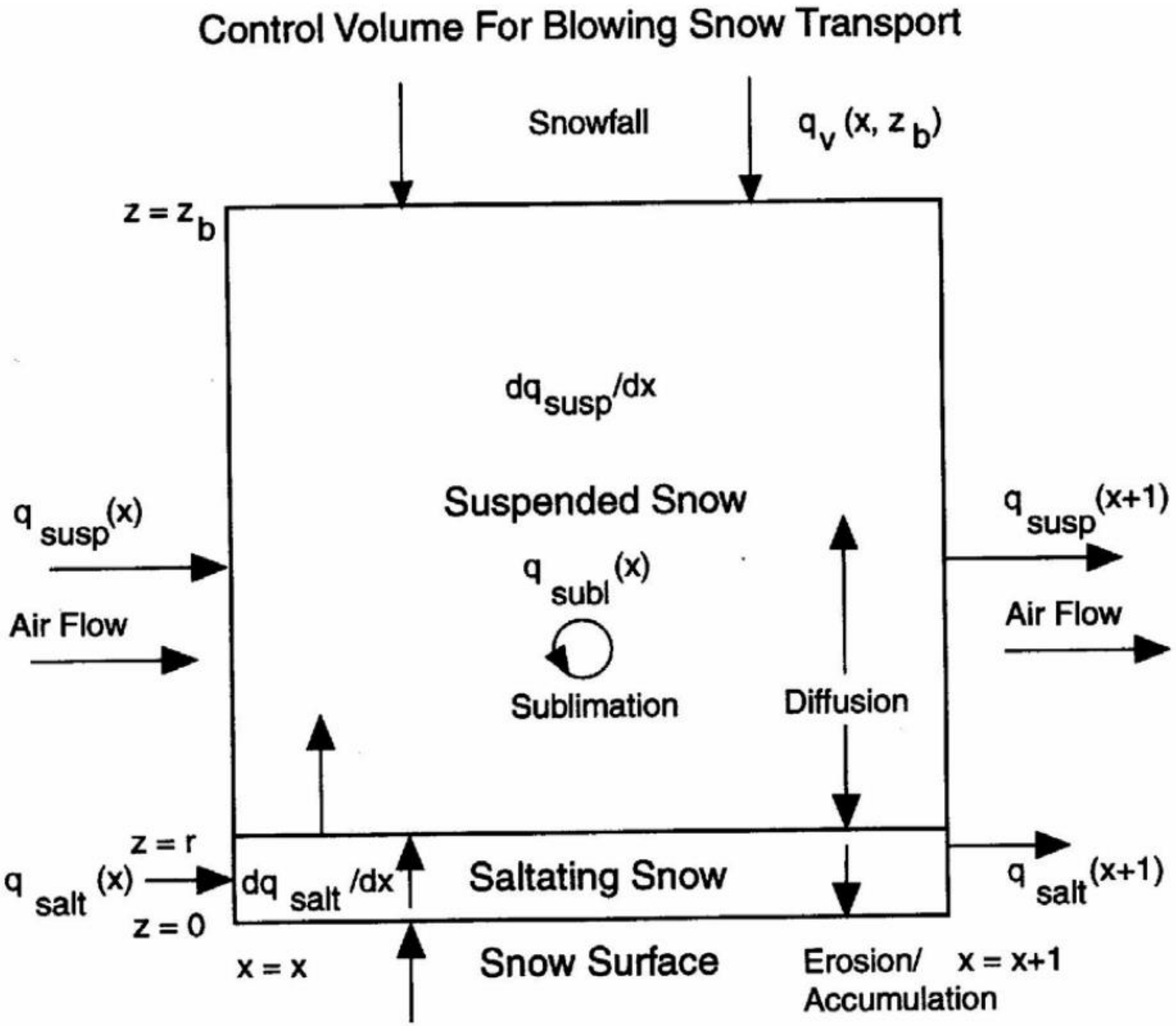
Management Opportunities

Precipitation is what it is, but we can manage snow accumulation and soil evaporation

"Grain is greater than or equal to Rain"

Blowing Snow Processes

- Creep: movement of snow particles by rolling on the snow surface
- Saltation: the bouncing of snow particles along the snow surface
- Suspension: snow particles entrained in the airflow above the surface
- Sublimation: suspended snow particles sublimate in the turbulent unsaturated airflow



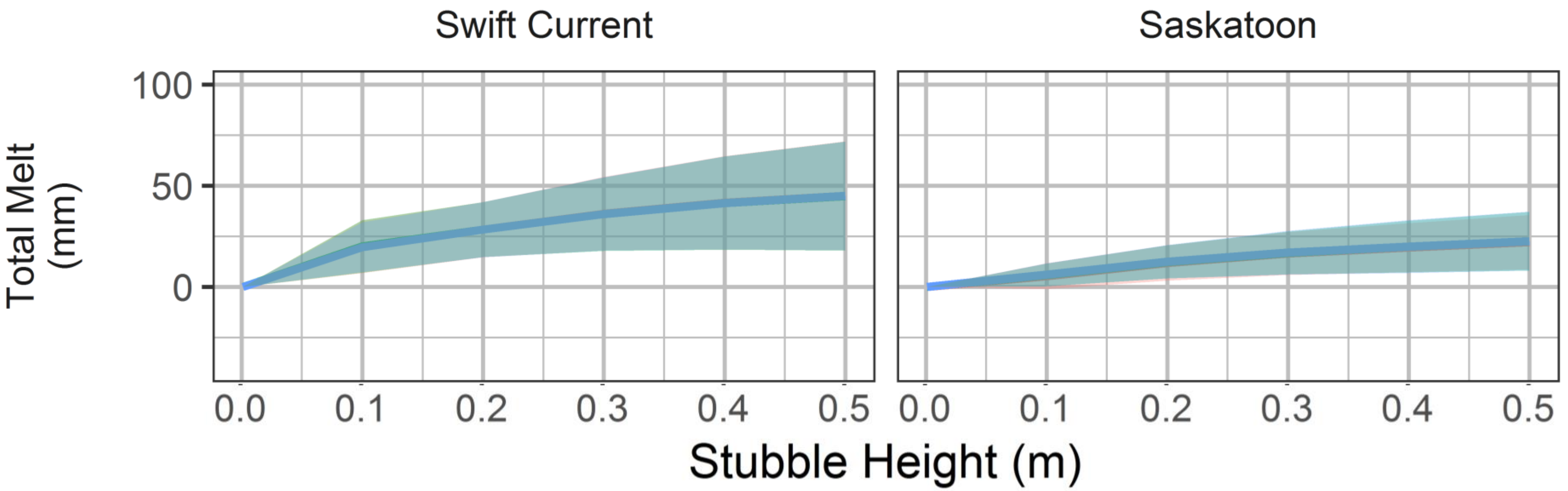
45 cm Wheat Stubble

15 cm Wheat Stubble

Blowing Snow

Snow Management with Stubble

- Increasing surface roughness suppresses blowing snow
- Influence varies with local climate



Harder et al, 2019

Site (Winter Temperature and Wind Speed)	Land Cover	Snowfall (mm)	Transport (%)	Sublimation (%)	Accumulation (%)
Prince Albert (−11.6 °C, 4.5 m/s)	Fallow	103	13	27	60
	Stubble	103	9	23	68
Yorkton (−10.6 °C, 4.7 m/s)	Fallow	125	13	23	64
	Stubble	125	8	15	77
Regina (−8.9 °C, 6.0 m/s)	Fallow	113	36	41	23
	Stubble	113	19	34	48
Swift Current (−6.7 °C, 6.6 m/s)	Fallow	132	29	29	42
	Stubble	132	11	22	67

Pomeroy and Gray, 1993

Stripper Stubble

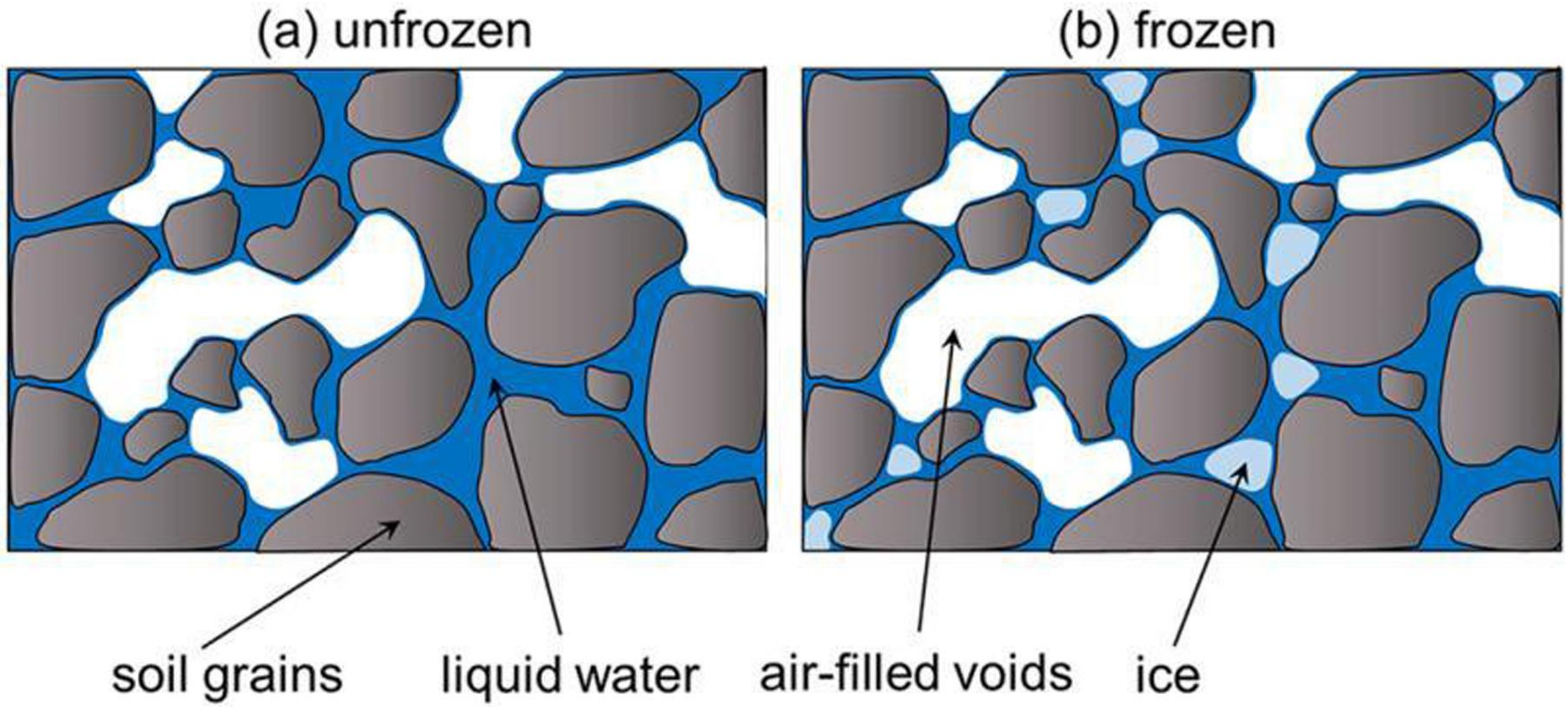
- Greatest snow retention potential
- Stubble-Snow-Soil thermal interactions increase infiltration potential on stripper stubble

Growth on adjacent stripper vs conventional durum stubble (Matthew Gould)
Snow accumulation on adjacent stripper vs conventional durum stubble

	Stubble height (cm)	Snow depth (cm)	Density (kg/m3)	SWE (mm)	Snow-Soil Temp (°C)
Elrose Feb 9					
Durum	25	23	235	53	-5
Tall Canola	30-45	29	251	73	-5
Stripper Canola	90	34	227	78	-2
Consort AB Mar 13					
Lentils	nil	18	233	41	-5
Wheat	75	46	238	110	-2

Frozen Soil Infiltration

- Ice crystals complicate water movement through soils
- Average storage potential is 60% of air-filled pore space at start of infiltration



Mohammed et al., 2018

Frozen Soil Infiltration

1. Unlimited (predominantly gravity flow): soils are capable of infiltrating most or all available meltwater.

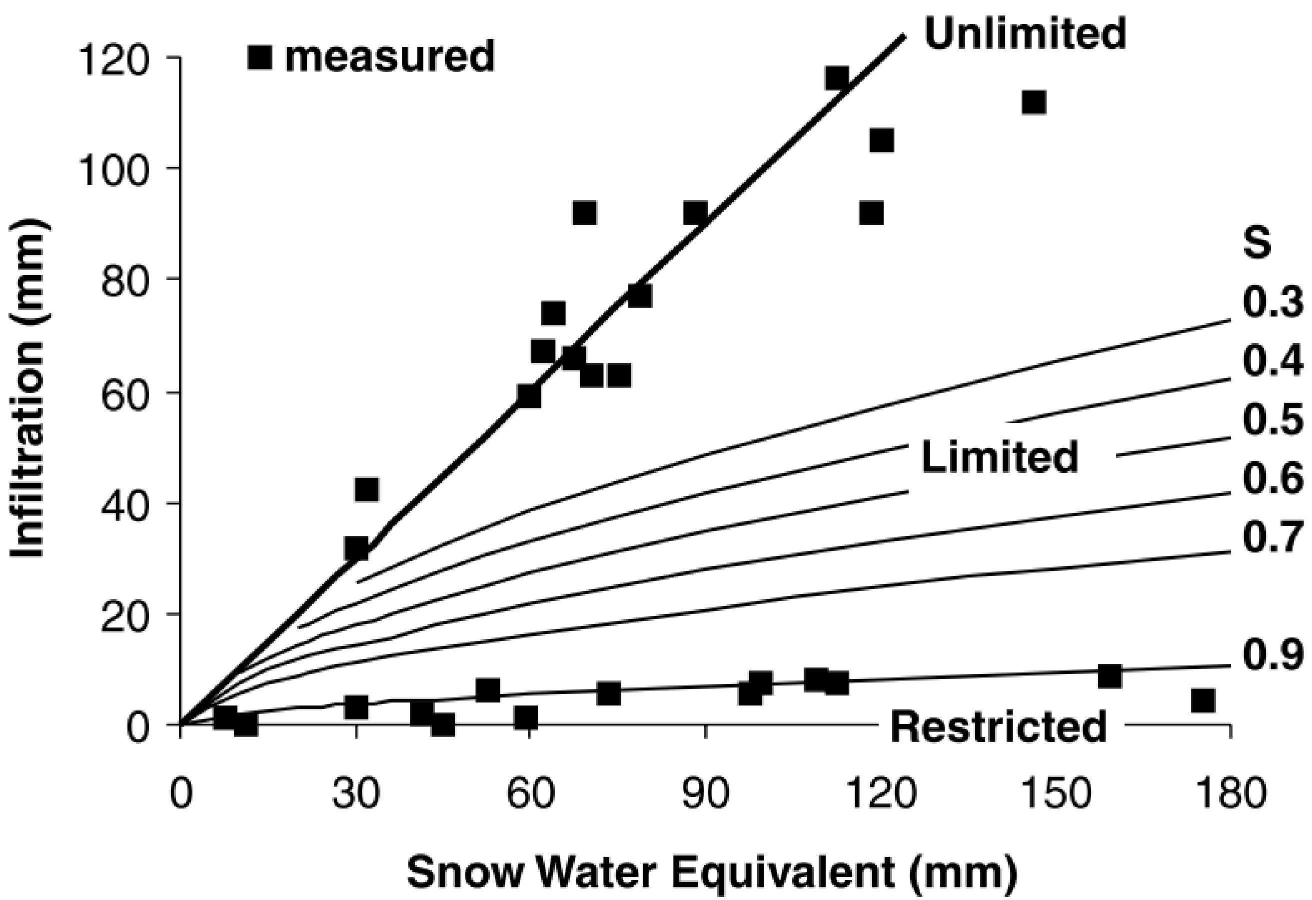
   Dry, cracked, coarse, or permeable soils

2. Restricted

   Infiltration restricted by an impervious surface such as a basal ice lens or saturated soil ("concrete frost")

3. Limited (predominately capillary flow):

   Function of **fall soil moisture content** and **soil temperature** at the start of snowmelt and the **duration of snowmelt**.



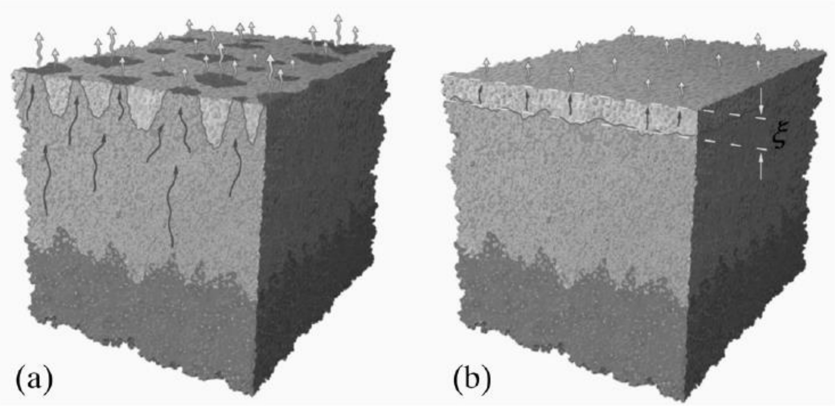
Gray et al., 2001

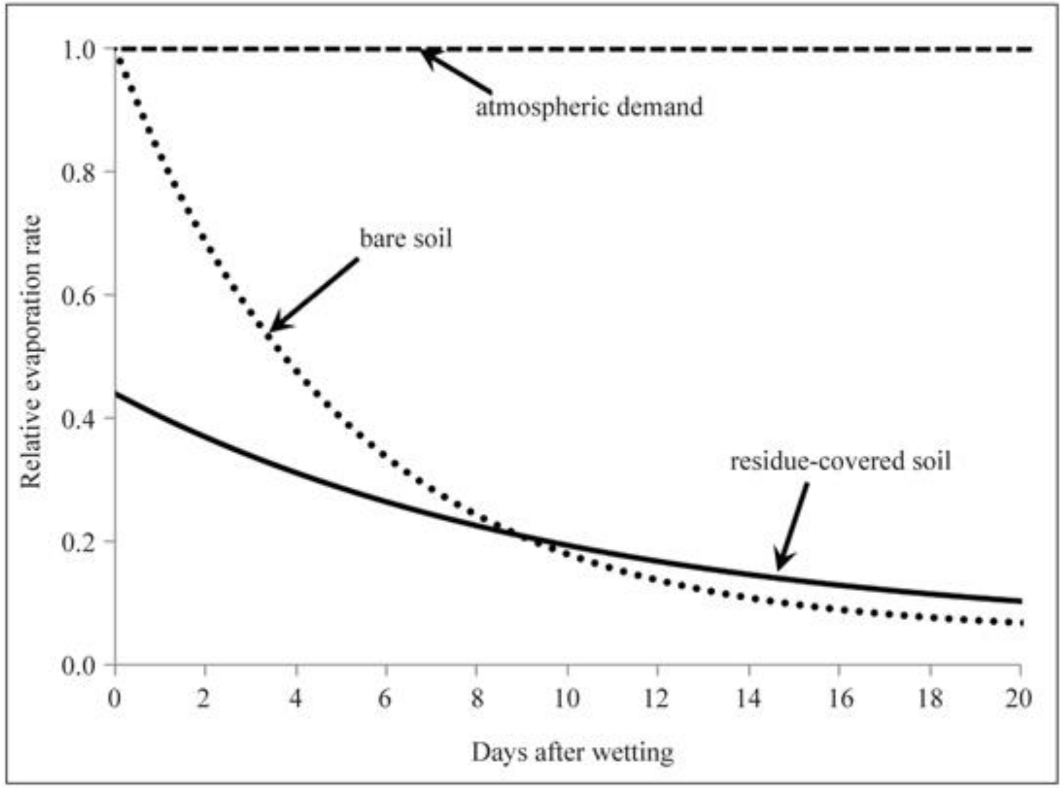
Snow and Ag Practices: Residues

- Complex water and energy interactions

Crop residues and soil evaporation

- Residues serve to:
  - reduce energy at soil surface
  - disrupt the water vapor gradient between soil and atmosphere
- Observed to reduce soil evaporation between 10-65%
  - 5% ↓in E for every 10% ↑cover
- Tillage increases soil evaporation by disrupting drying front and mechanically moving moisture to surface
  - Dependent on soil moisture situation
  - Up to 15 mm H_2O loss/pass



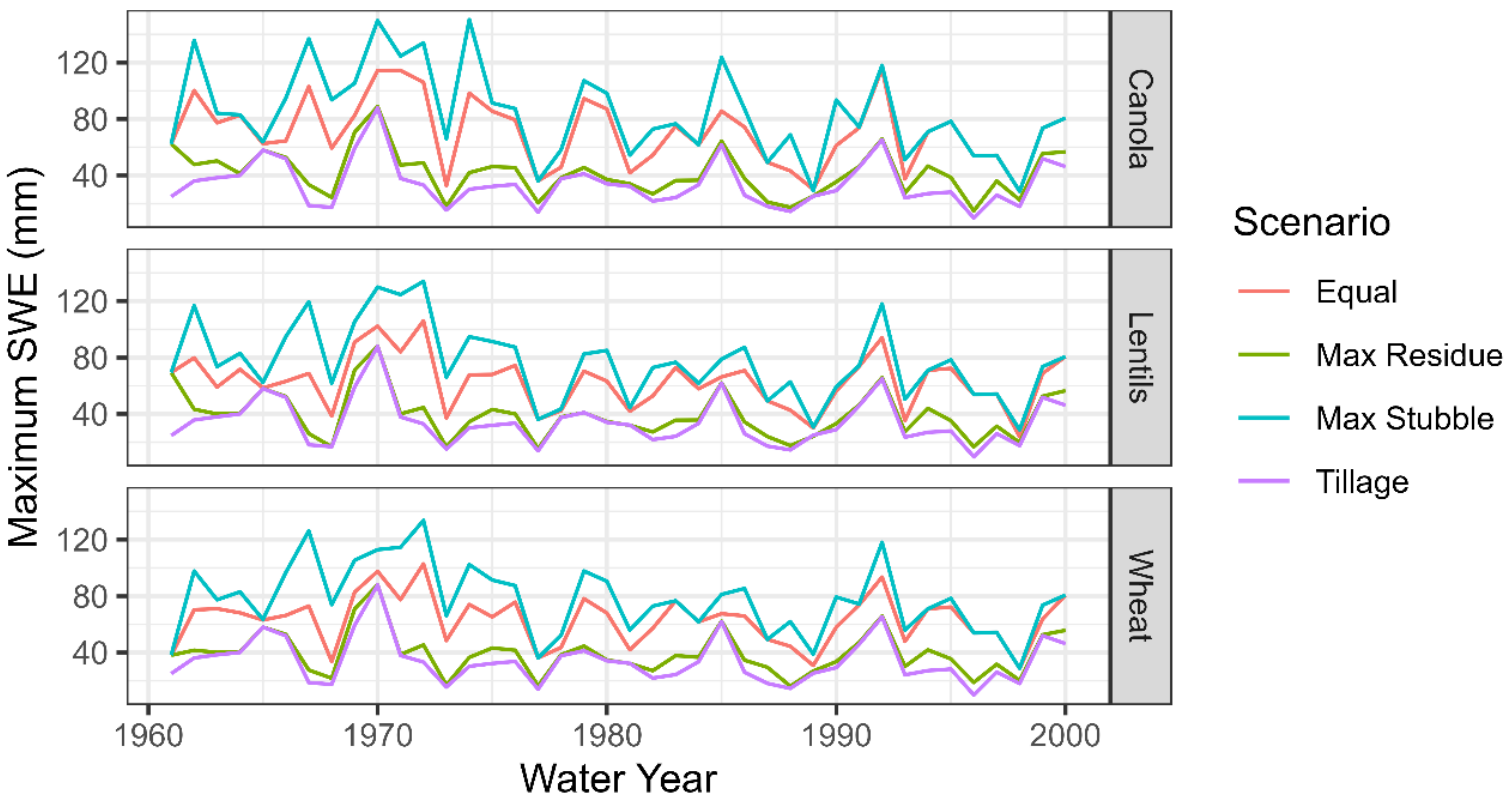


Ag-Water Interactions

Modelling the water related stubble and residue management implications on yield.

- 1961-2000 at Saskatoon
- Wheat-Canola-Lentil rotation
- Management Scenarios:
    - Equal: Equal partitioning of biomass to residue and stubble
    - Max Residue: Maximum residue (90% of biomass allocated to residue) to crop residue layer
    - Max Stubble: 90% of biomass allocated to standing stubble
    - Tillage: fully exposed soil and 0.01m stubble height

Snow Water Equivalent



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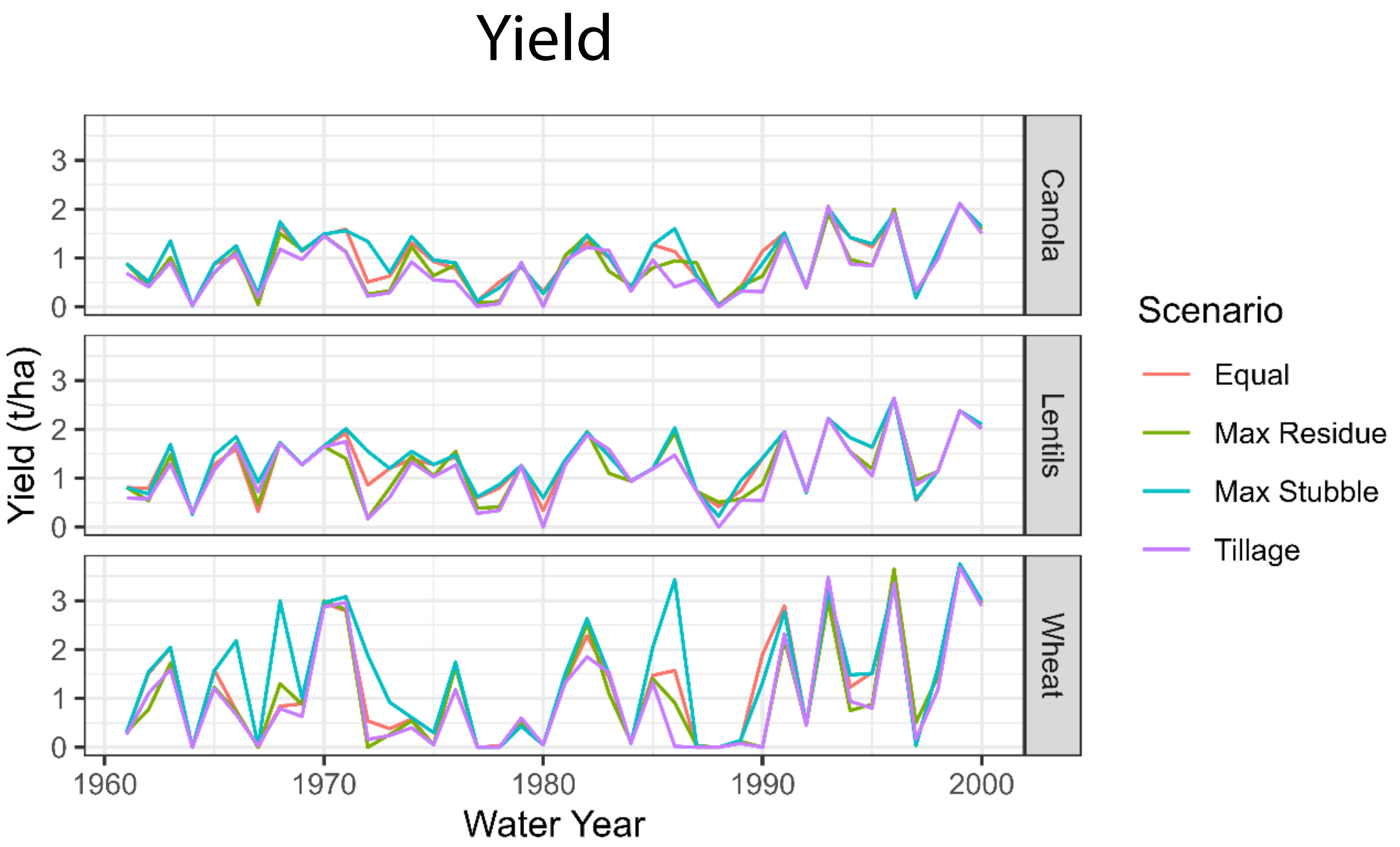
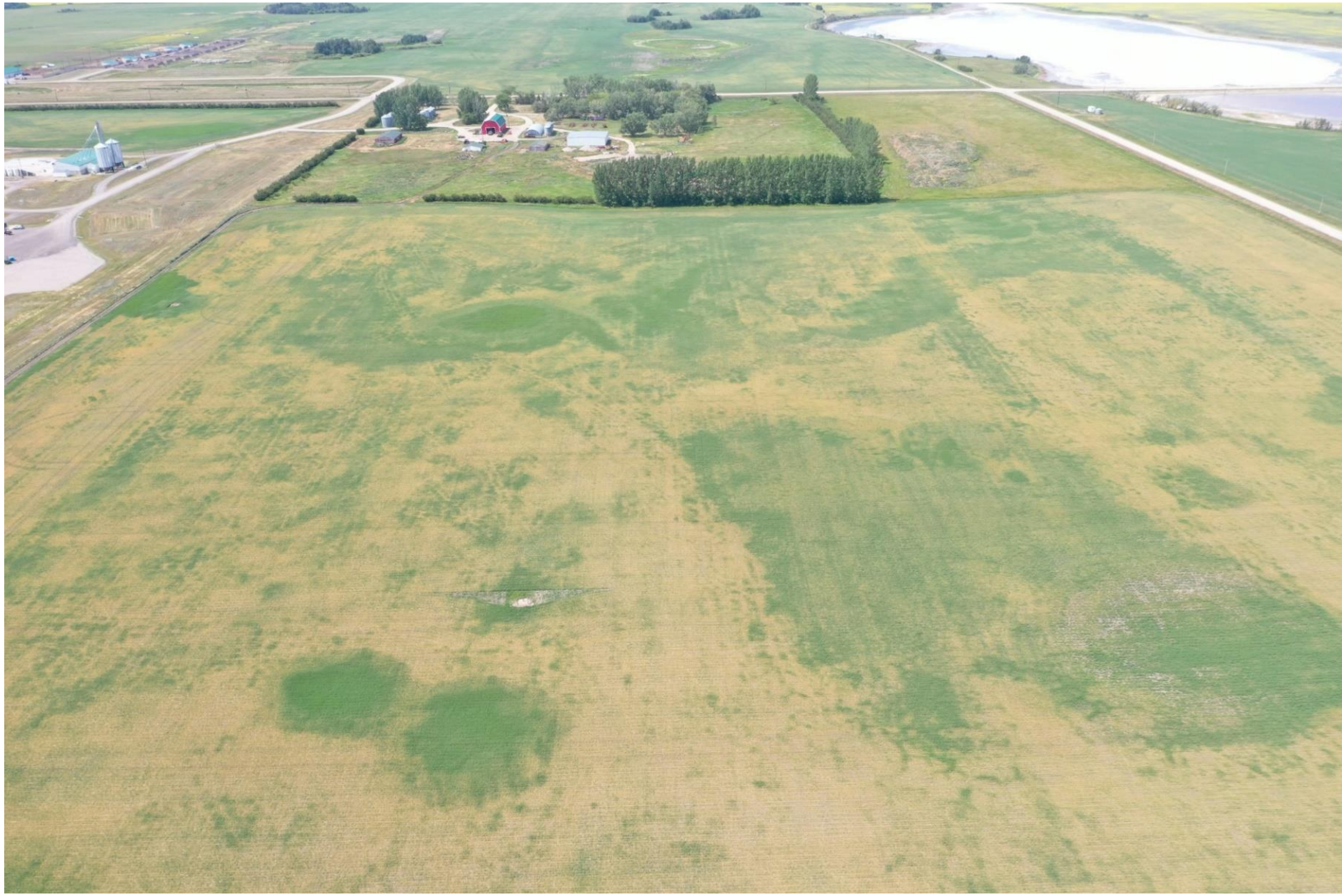
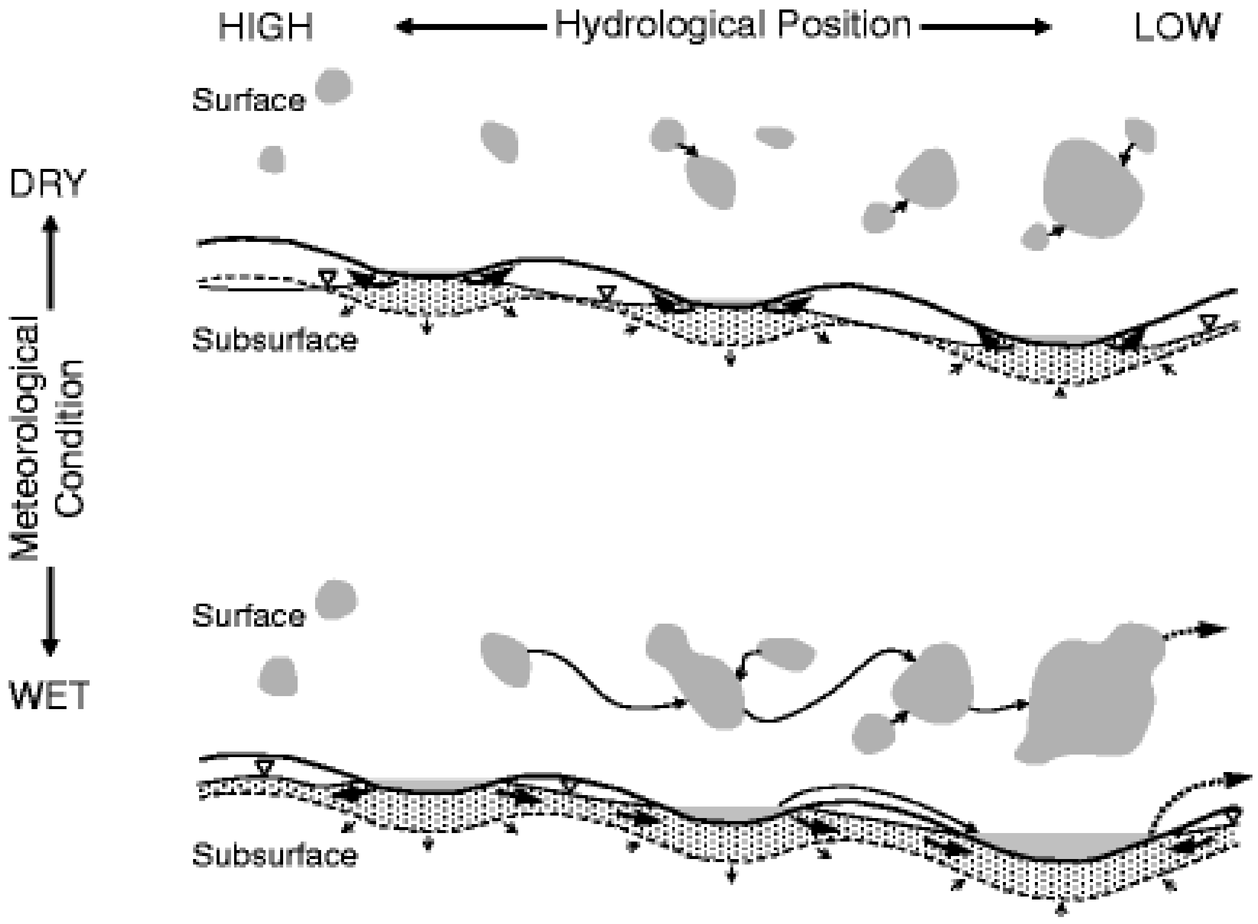


Spatial Variability. . .

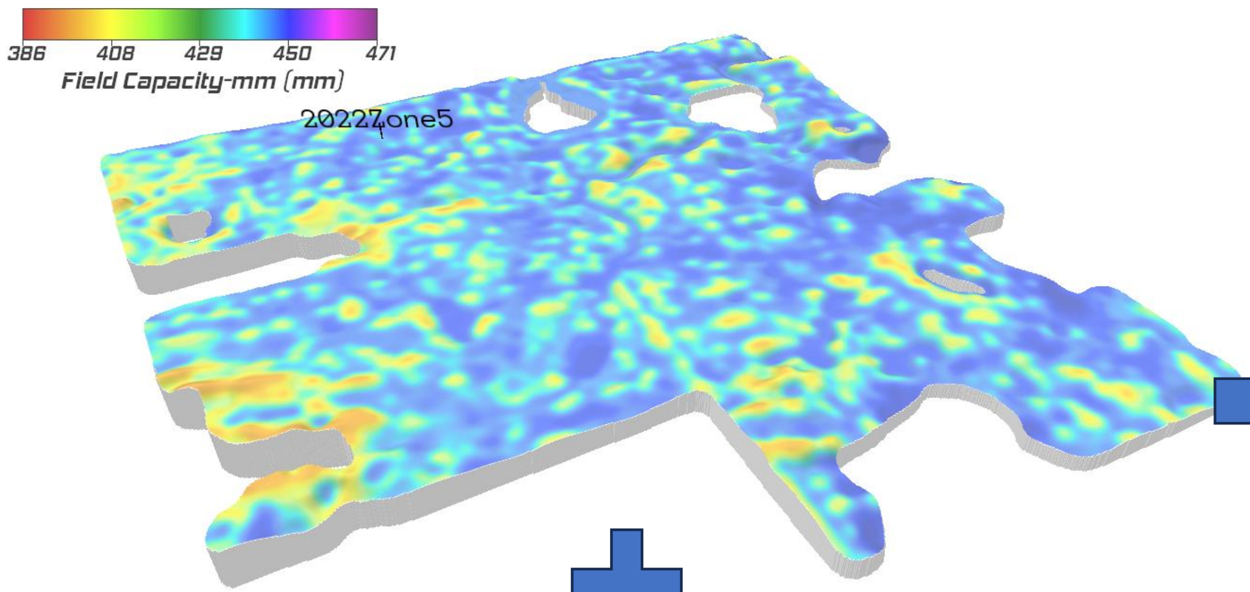


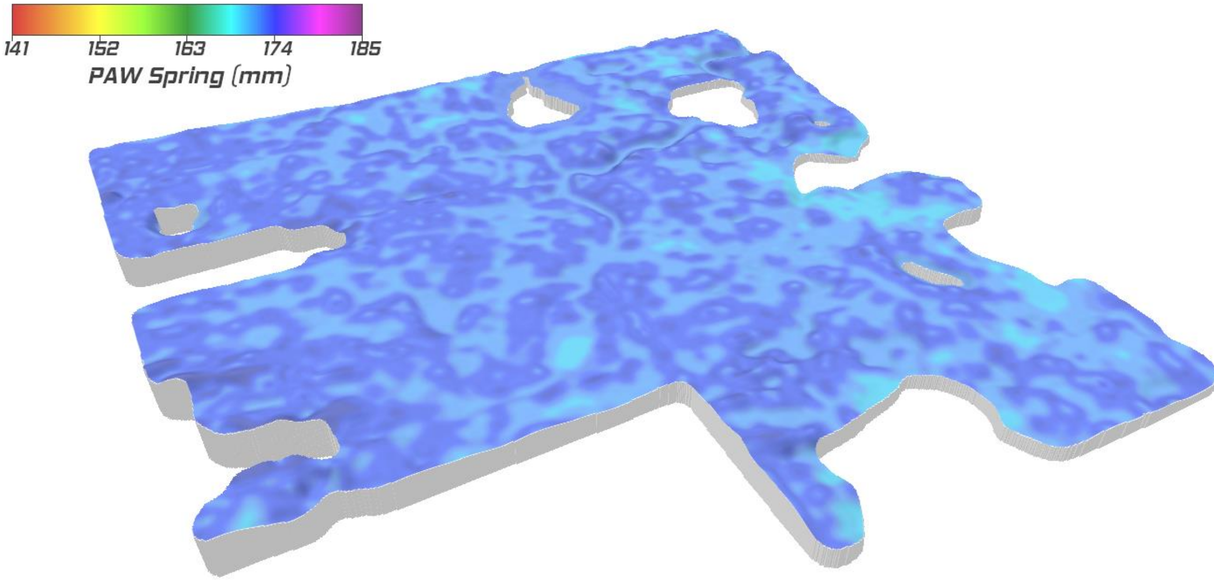
Spatial and Temporal Variability of Water



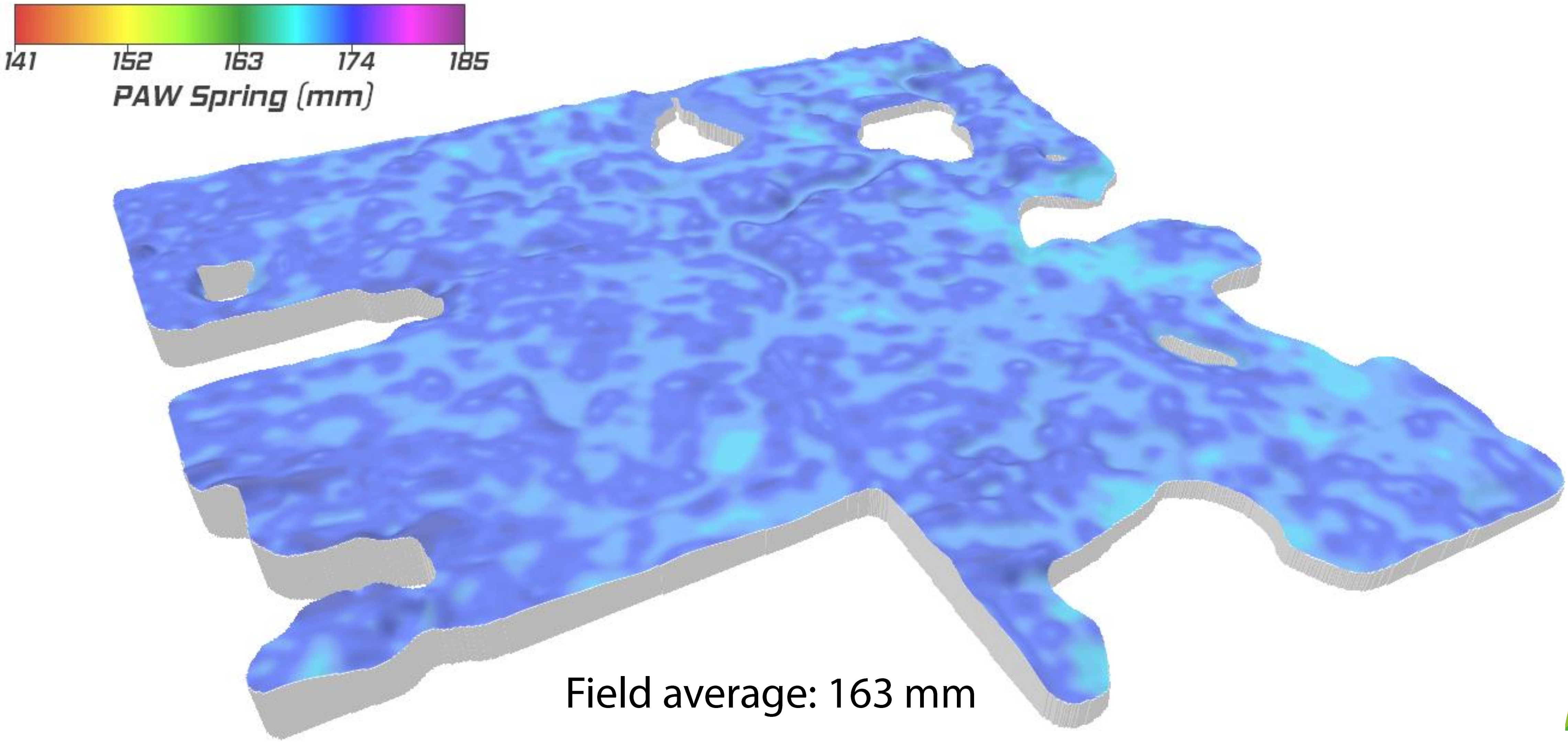
Euliss et al. 2004

SWAT WATER – What's going on?



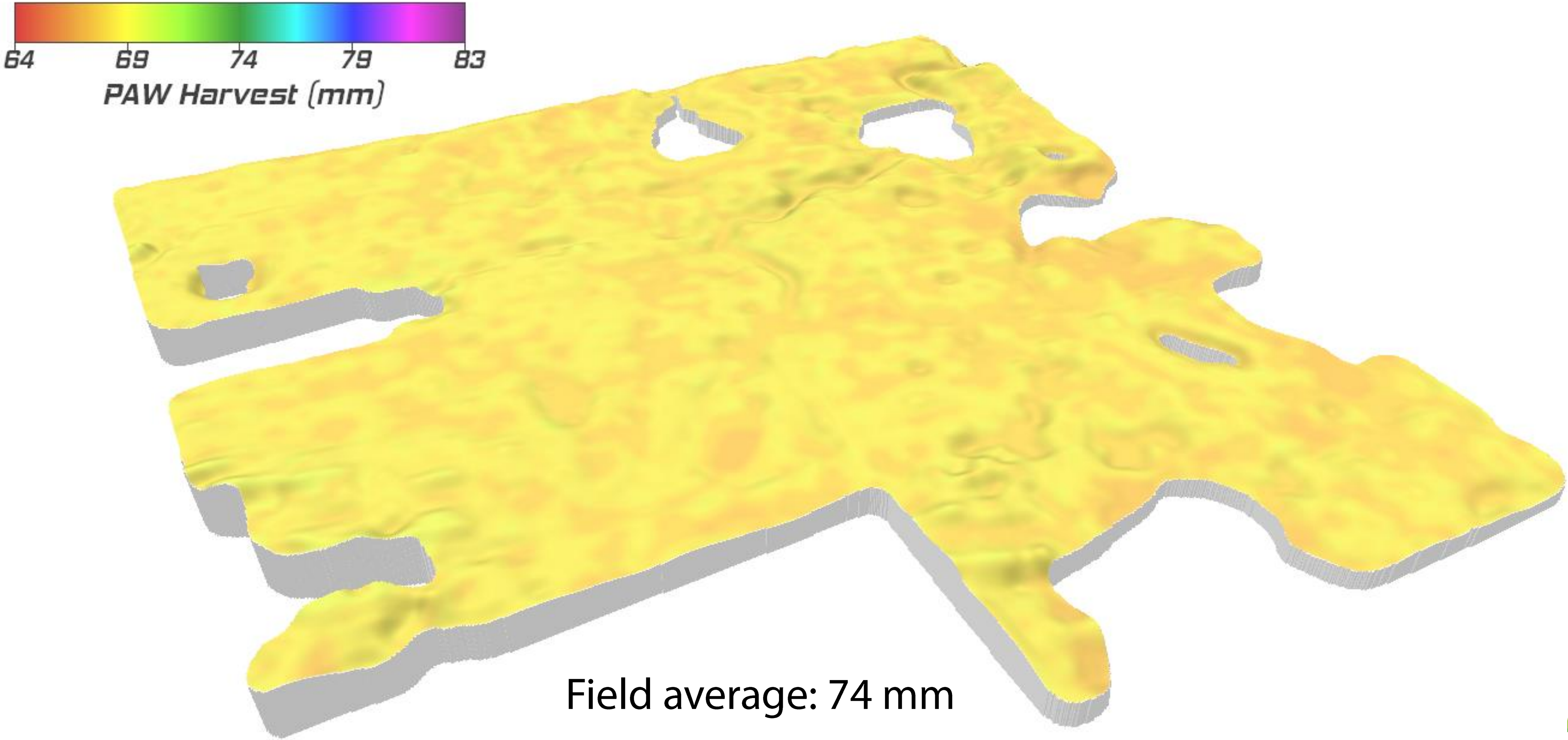


Plant Available Water- Spring



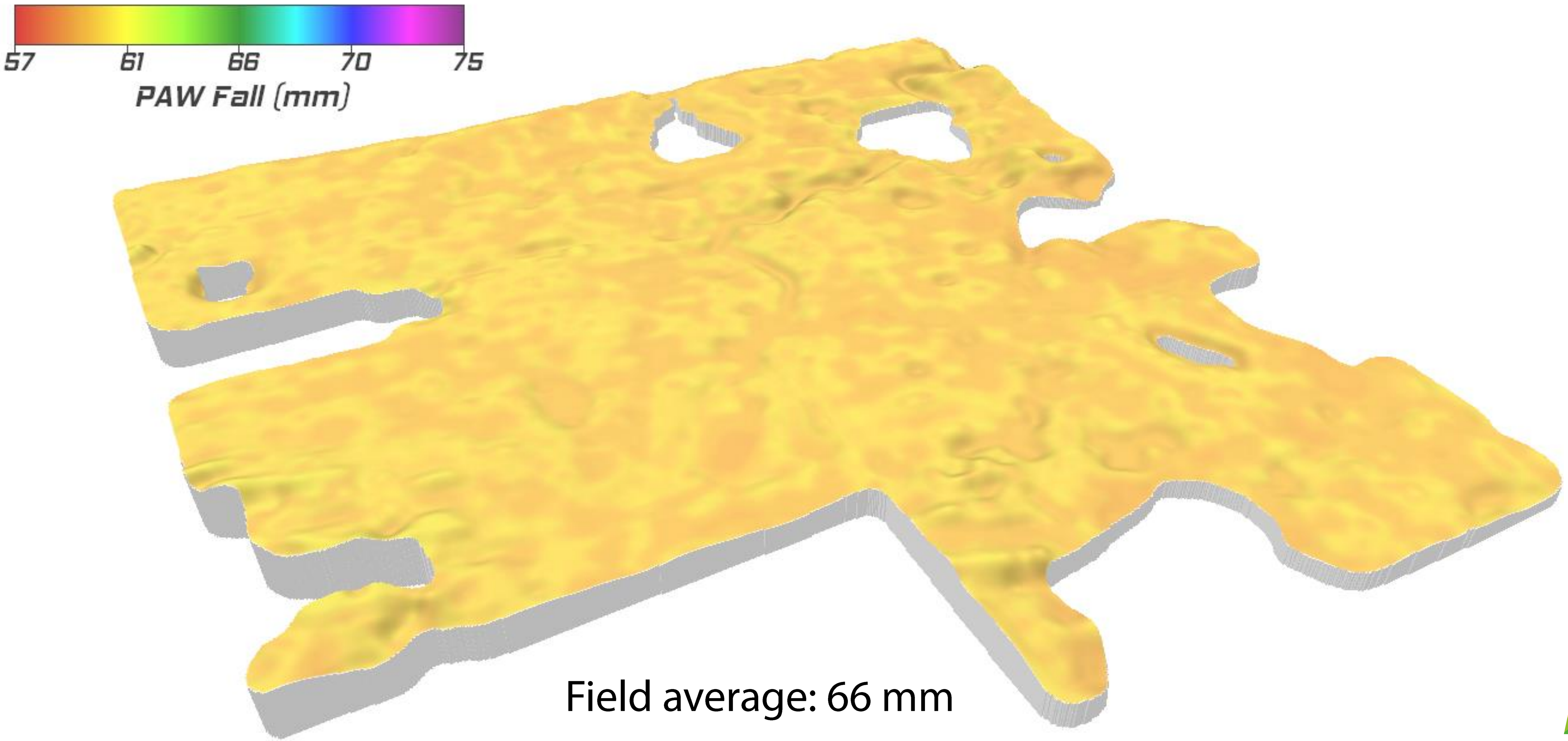
Field average: 163 mm

Plant Available Water- Harvest



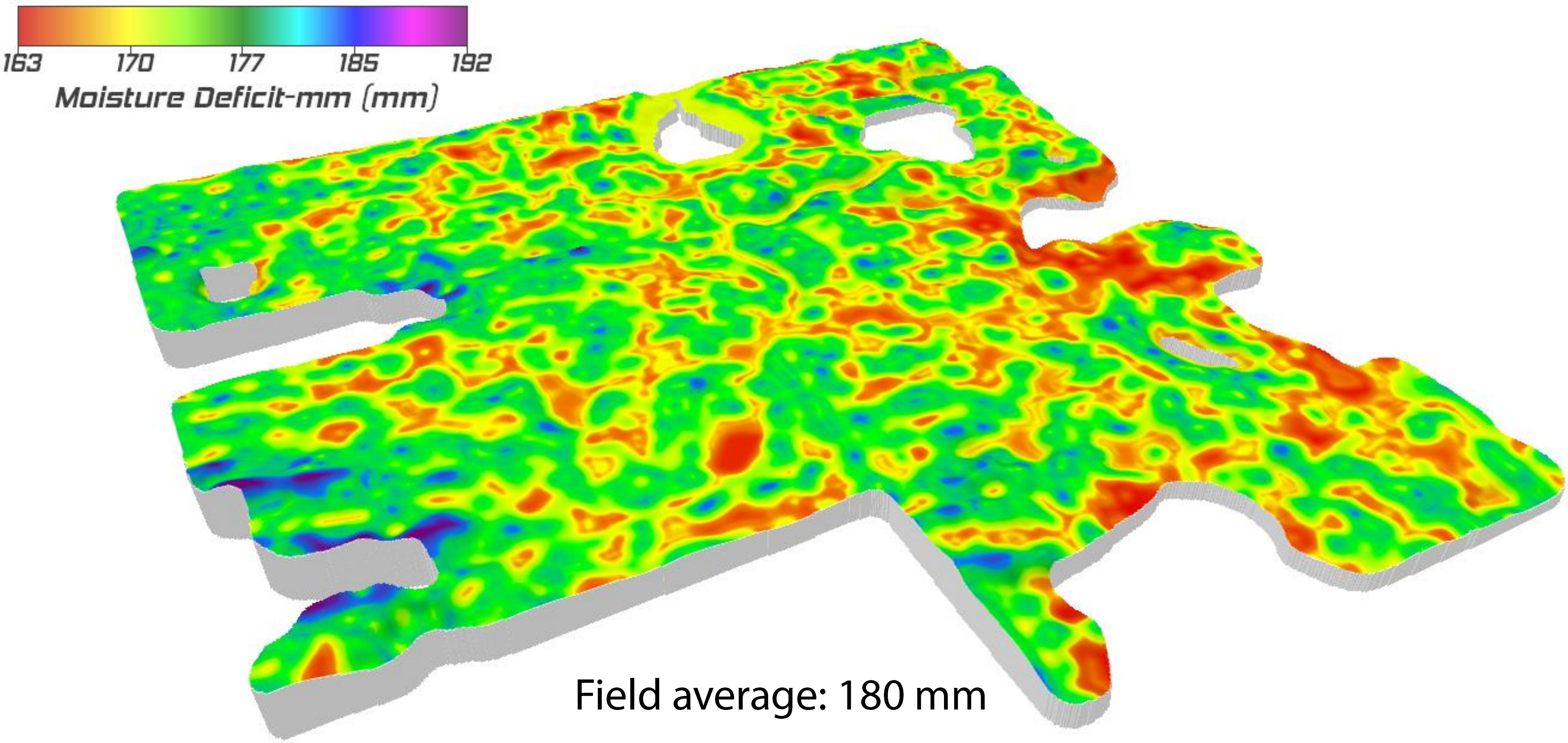
Field average: 74 mm

Plant Available Water- Fall



Field average: 66 mm

Fall Moisture Deficit

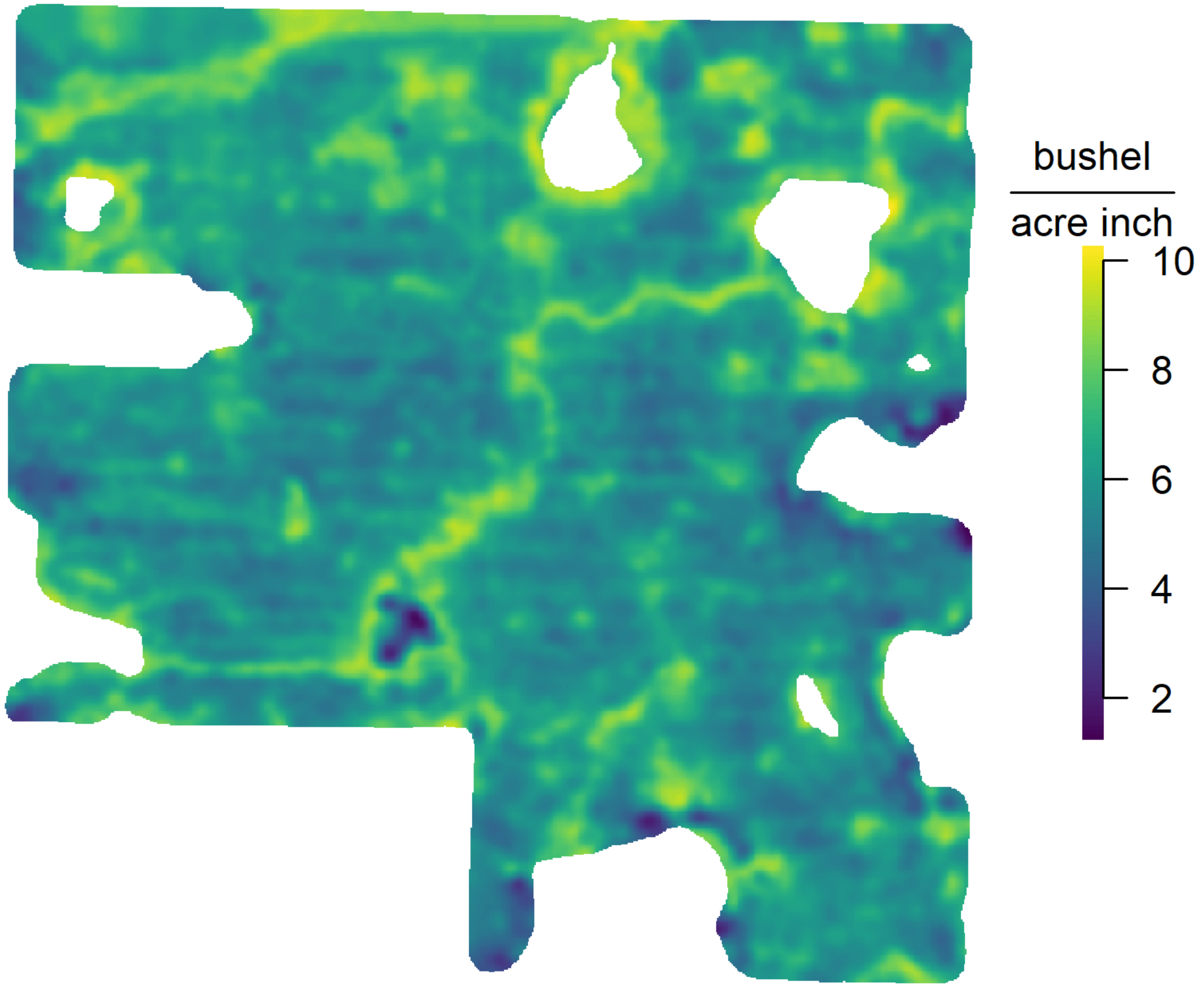


Field average: 180 mm

Crop Water Use Efficiency

$$WUE = \frac{Yield}{Crop\ Water\ Use}$$

- Provides critical information to understand the where, why, and by how much water is influencing production and its interactions with soils



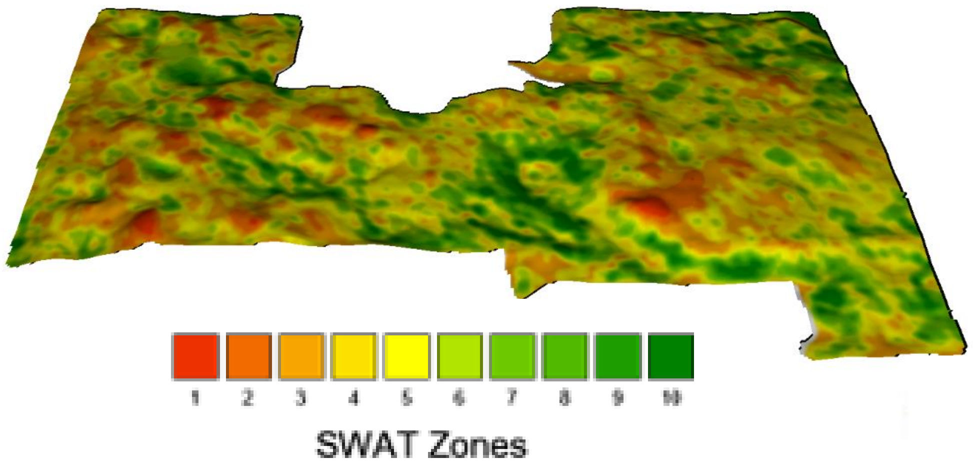
VR Intercrops and Seed Rates

Colin Rosengren, Midale SK

Let's farm for the variability of the landscape!

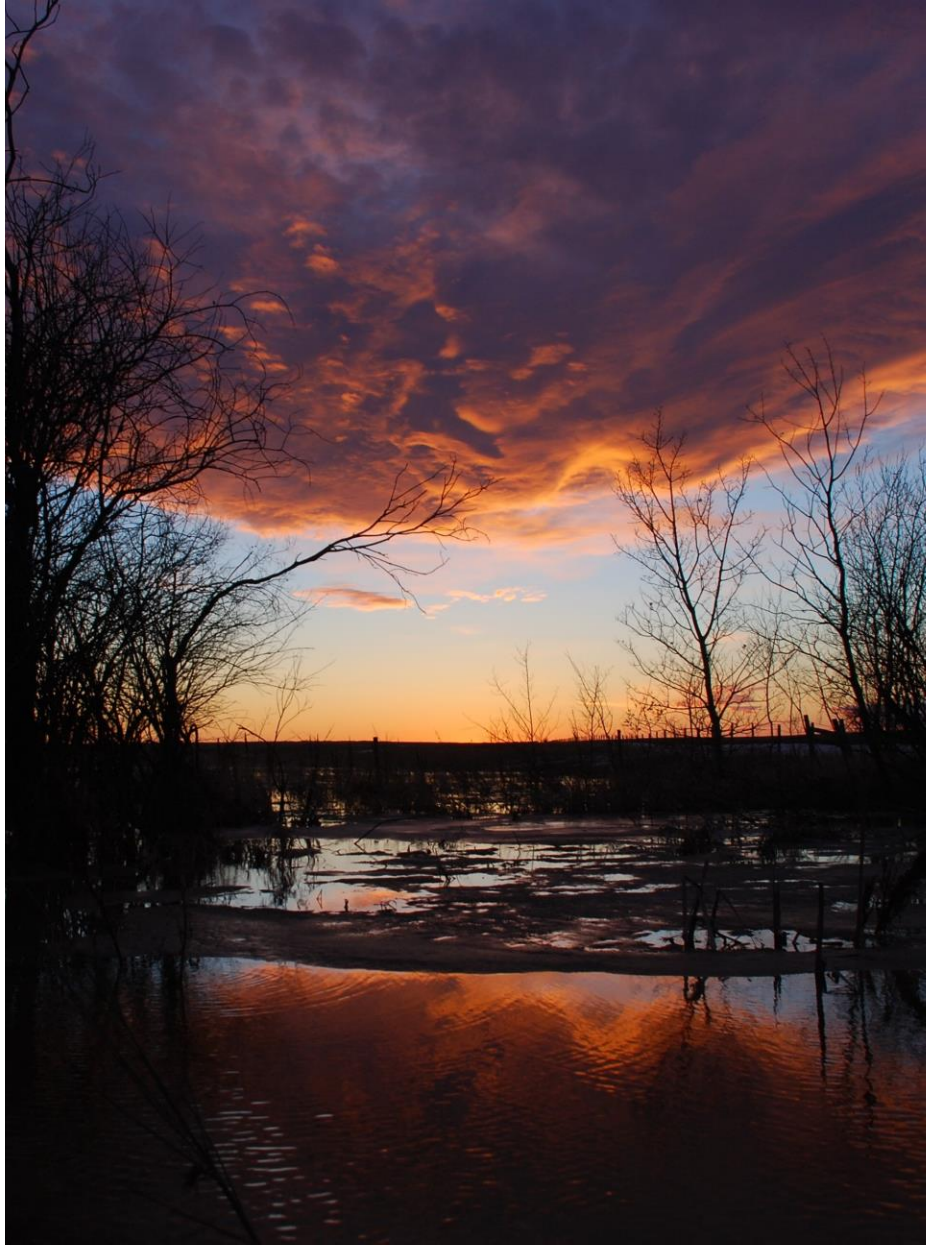
	Acres	Canola Layer #1	Peas Layer #2	Lentils Layer #3
	5.6	2.8	30	65
	12.4	2.8	45	65
	48.7	2.8	150	50
	98.5	2.8	150	40
	120.5	2.8	150	40
	103.2	2.8	150	40
	64.9	2.8	150	40
	41.8	2.8	150	30
	23.7	5.9	130	15
	10.9	6.2	110	15
Total Acres	530	3	144.6	39.3
		Averages		

- Align crop types and density with crop available water
- Lentils dominate hills and canola in depressions



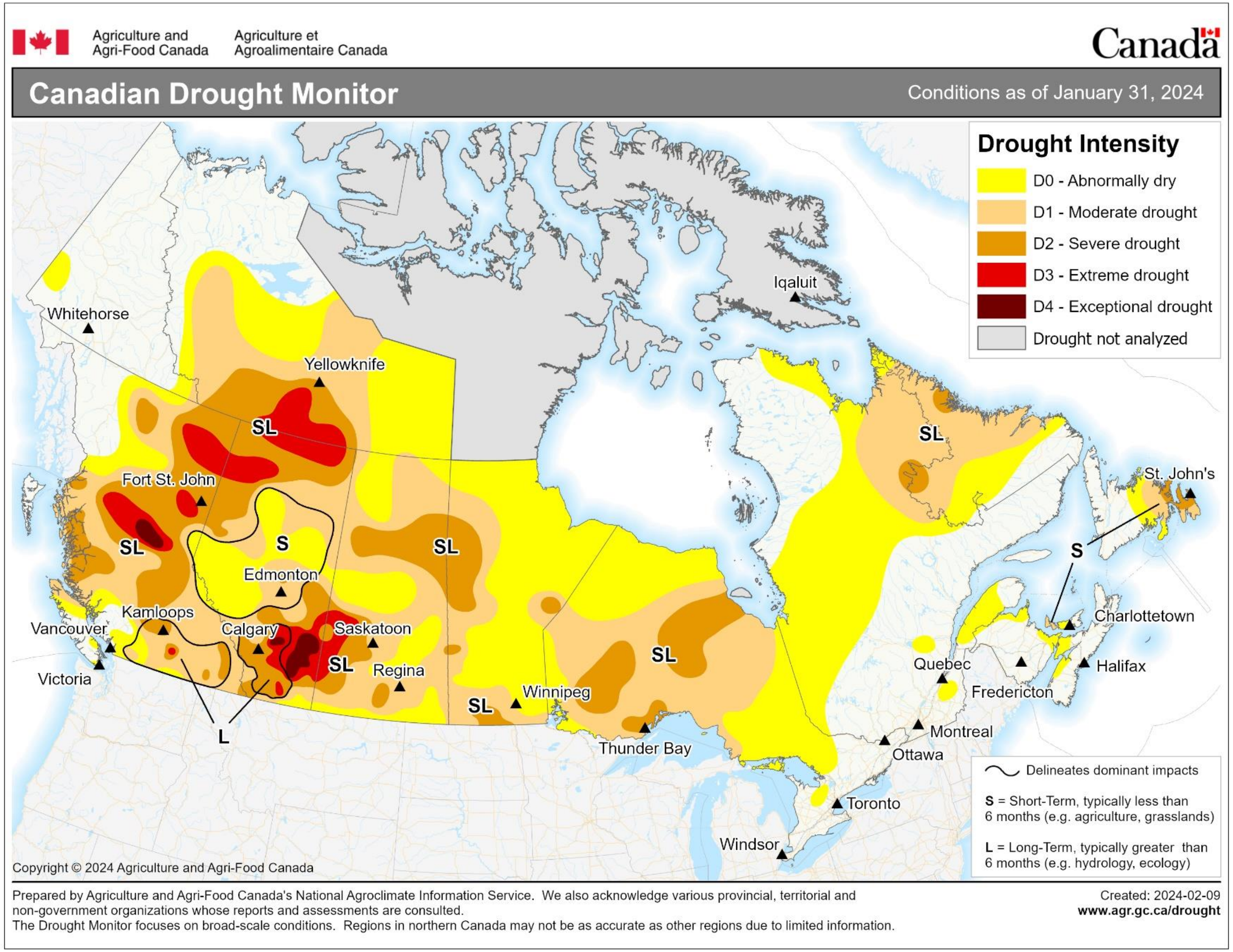
How, and by how much, can we mitigate water related production impacts with management practices?

- Ag-water response in Canadian Prairies
  - Defined by complex WUE interactions
  - Primarily driven by water availability and evaporative demand
- Opportunities
  - Optimisation of fertility to soil water status/potential which requires information
    - Increased efficiency
  - Ag management practice optimisation of stubble and residues to increase water availability
    - Increased production - 0 to 50%
  - Many spatial management opportunities for ag-water optimisation
    - Increased efficiency



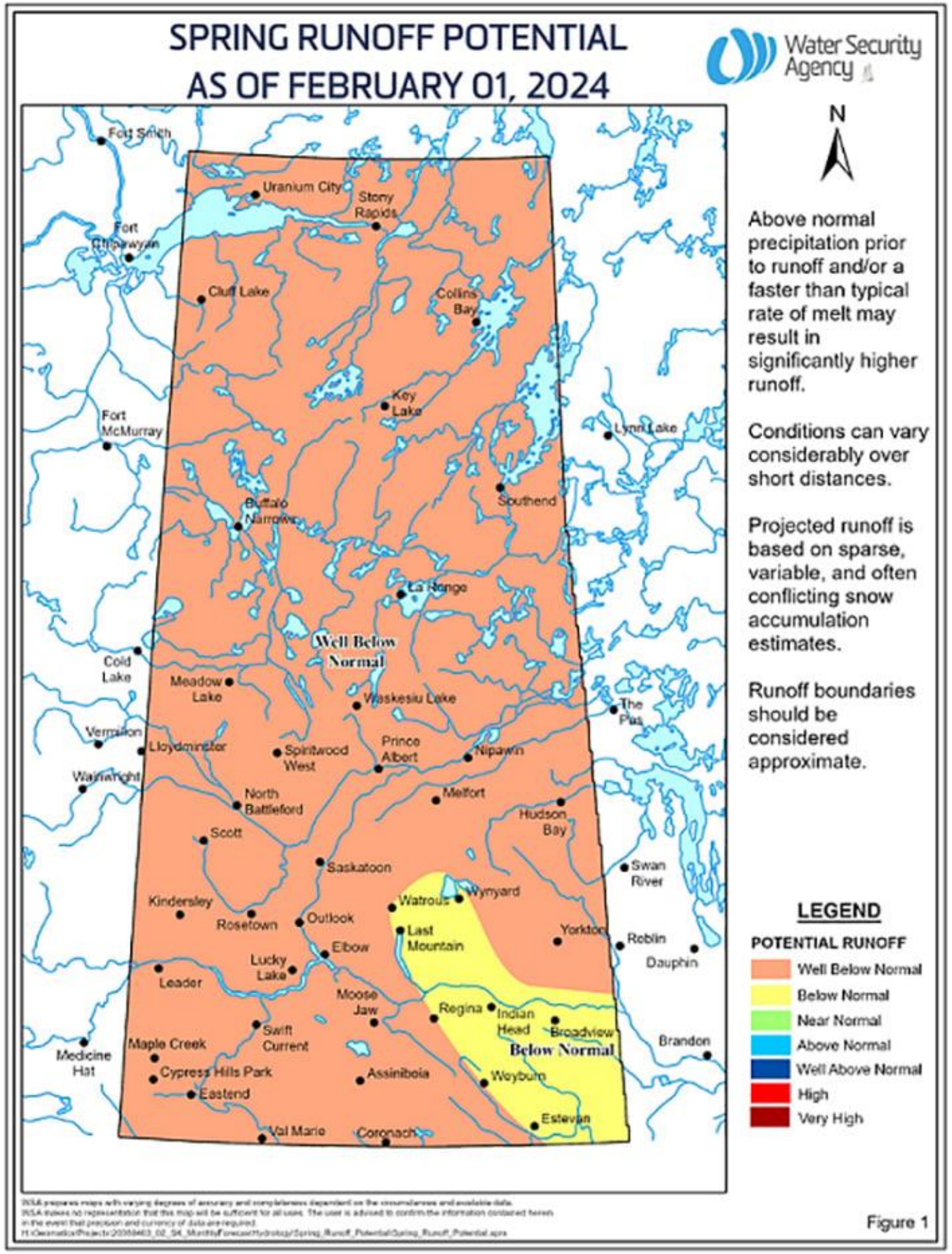
2024 Prospects

- Plan for water limitations….
- Current crops are very efficient users of water
  - Greater range of tolerance but leave less behind
- Soil moisture at depth is not recovering



2024 Prospects

- WSA forecast is calling for well below normal runoff
- But….



2024 Prospects

- February 24: negligible

2024 Prospects

- March 4: >50 mm of water equivalent

2024 Prospects

- Runoff has already happened
- Fall rain, limited snow and its melt and runoff have left a wet/frozen surface layer
- Further snow/melt has a high runoff potential irrespective of how dry subsurface is.
- Plan for high variability in crop available water

East Central SK in February 2023. Photo credit Joe Widdup

Questions!

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