

Chloride in Crop Production

Aicam Laacouri | Research Scientist

Pesticide Fertilizer Management Division

Salt Symposium 2020



Chloride and Plant Nutrition

Fate of Chloride in Soils

Sources of Chloride in the Soil

Fertilizer Sales in Minnesota as a Proxy for Chloride

Assessment of Chloride in MN Agricultural Soil and Water

Chloride and Plant Nutrition

Chloride is a plant **micro-nutrient**

- Macro-nutrients: N, P, Potassium (K)
- Micro-nutrients: **Chlorine (Cl)**, B, Cu, Mn, Mo and Zn
- Crop requirement: 3.5-7 lb/ac for average crop

HOWEVER

Chloride is applied at **comparable rates to potassium (K)** because **Potassium Chloride (KCl)** is the dominant fertilizer source for K **AND** has **equal amounts of K and Cl** (nearly 50% K and 50% Cl)

Potassium Chloride Fertilizer



Photo Credit: www.croplnutrition.com

Chloride and Plant Nutrition, Cont.

Role of chloride in plants:

- Photosynthesis
- Disease control
- Plant vigor and volume

Deficiency is very rare

- Reduced leaf growth
- Wilting
- Necrosis and stunted roots

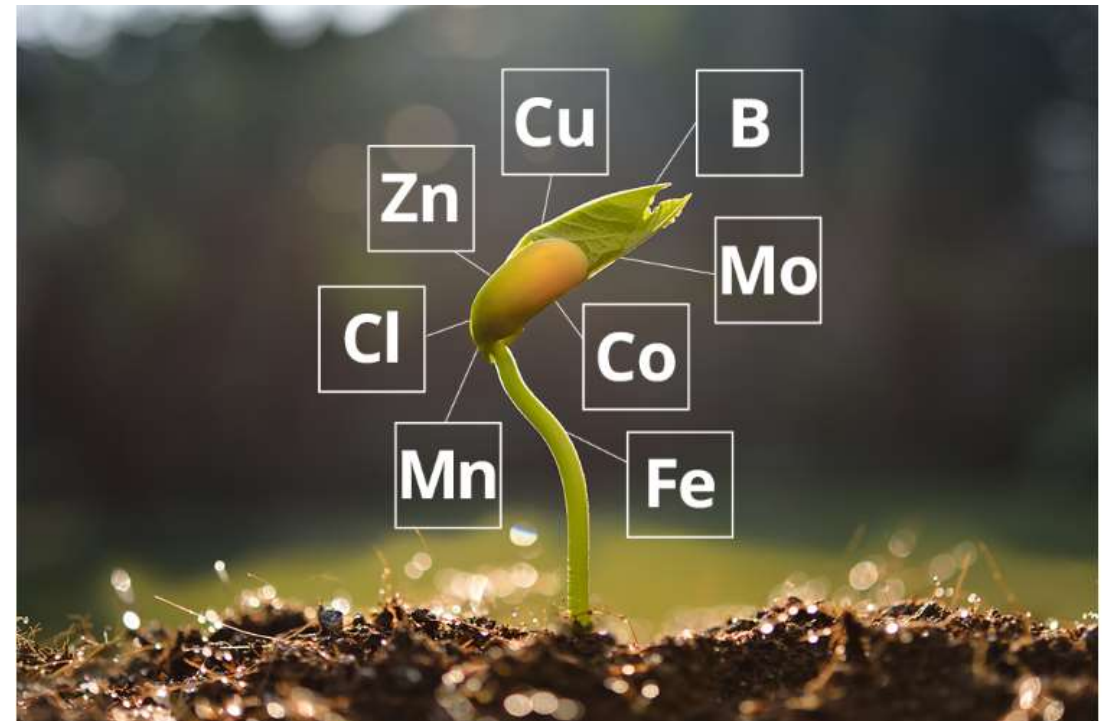


Photo Credit: <https://www.taurus.ag/>

Chloride and Plant Nutrition, Cont.

Plant **tolerance** to chloride **varies**

- 4-7 mg.g⁻¹ **Sensitive** plant species
- 15-50 mg.g⁻¹ **Tolerant** plant species

Chloride **toxicity** is most common in irrigated and dry regions



Chloride and Plant Nutrition, Cont.

- Uptake form: Plant uptake in **chloride form** (Cl⁻)
- **Distribution** in plant: Chloride is found mostly in the **crop residue**, not in crop grain
- A typical corn yield (150-200 bu/ac) will have about **4 lbs in corn grain** and **68 lbs in corn stover**

Table 1. Chloride removal by selected crops.

Crop	Plant part	Cl content	Reference
Alfalfa	Shoot	7.6 lb/ton (dry wt)	NRC, 1981
Barley	Grain	0.024 lb/bu ¹	Fixen, 1993
Potatoes	Tubers	0.06 lb/cwt	Saffigna et al., 1977
Sweet clover	Shoot	7.4 lb/ton (dry wt)	NRC, 1981
Wheat	Grain	0.026 lb/bu	Fixen, 1993
Wheat	Grain + straw		Schumacher, 1988
	Low soil Cl	0.17 lb/bu	
	High soil Cl	0.44 lb/bu	

Fixen, 1993

Fate of Chloride in the Soil

- Chloride **movement** from soil solution to plant root mainly via **mass flow**
- Chloride is **negatively charged**: Potential to **leach** below the root zone
- Chloride is **not altered** by soil microbes: Often used for soil **water flow tracing**
- Chloride movement in the soil profile controlled by ET and precipitation with the **potential to buildup in soils** where **ET > Precipitation** (not from carry over)

Sources of Chloride in the Soil

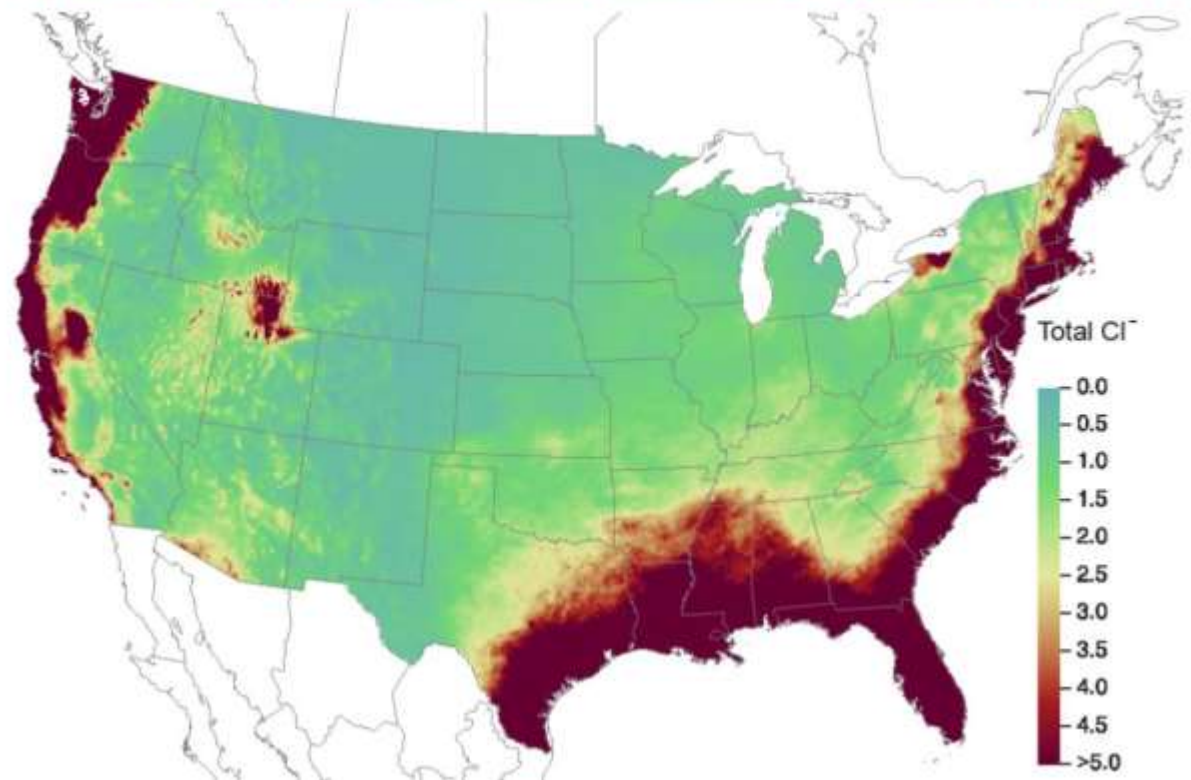
Natural sources

- Atmospheric deposition
- Parent material/shallow water table (capillarity forces)

Other sources

- **Crop residue** decomposition
- **Manure** amendment
- Commercial fertilizer (**Potash**)

Figure 10-5 TDep Total Deposition Estimates of Total Cl^- ($\text{kg ha}^{-1} \text{ yr}^{-1}$) for 2016



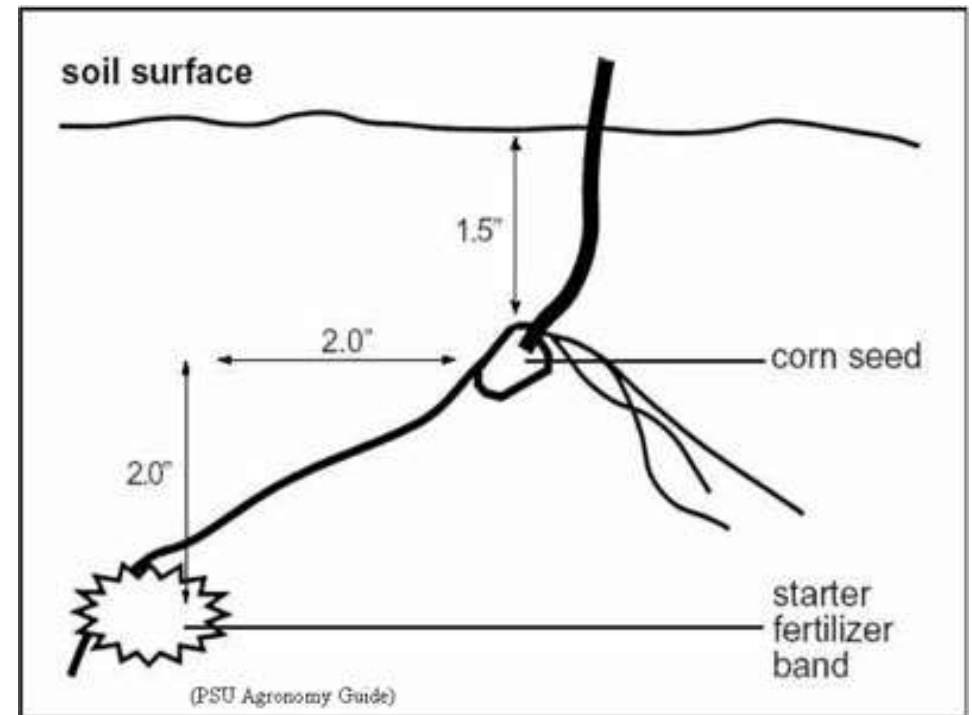
Sources of Chloride in the Soil, Cont.

- Chloride is applied to soils mainly as **Potassium Chloride** KCl (Muriate of Potash: MOP):
 - Chloride is a “byproduct” of potash
 - **Cost effective** (provides both K, and Cl)
 - Logistics: **available** at local coops
 - Potash is **50% Chloride** and 50% K (58-62% K₂O)
 - **Alternative K fertilizer** sources: Potassium sulfate (SOP), potassium Mg. Sulfate

Sources of Chloride to the Soil, Cont.

Field Application (MOP):

- Applied **before or at planting**
- Broadcasted or banded
- **No soil test for chloride**
- Rate **dictated by K** soil test
- KCl **rate** can be **reduced by half** if fertilizer is **banded**



Chloride from Statewide Commercial Fertilizer Sales

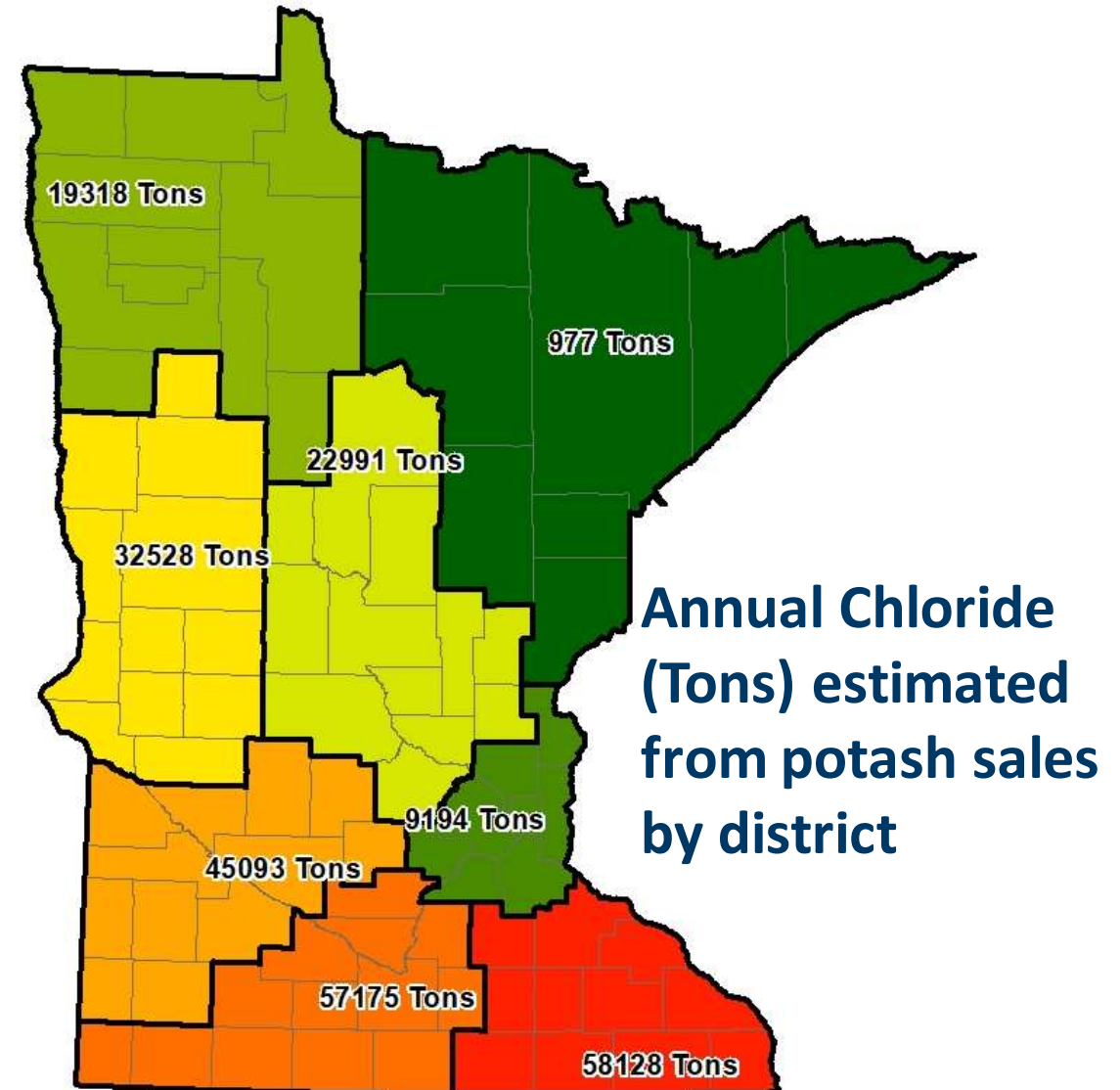
Procedure for estimating chloride from fertilizer

- MDA annual **fertilizer sale** records of KCl (2010-2017)
- Converting KCl mass to **chloride mass**
- **Averaging over eight years** to reduce bias due to inter-annual storage
- Spatial aggregation (**counties to districts**) to reduce bias due to cross-county purchases

Chloride from Statewide Commercial Fertilizer Sales

Statewide chloride use from fertilizer estimate : **245,362 tons/year**

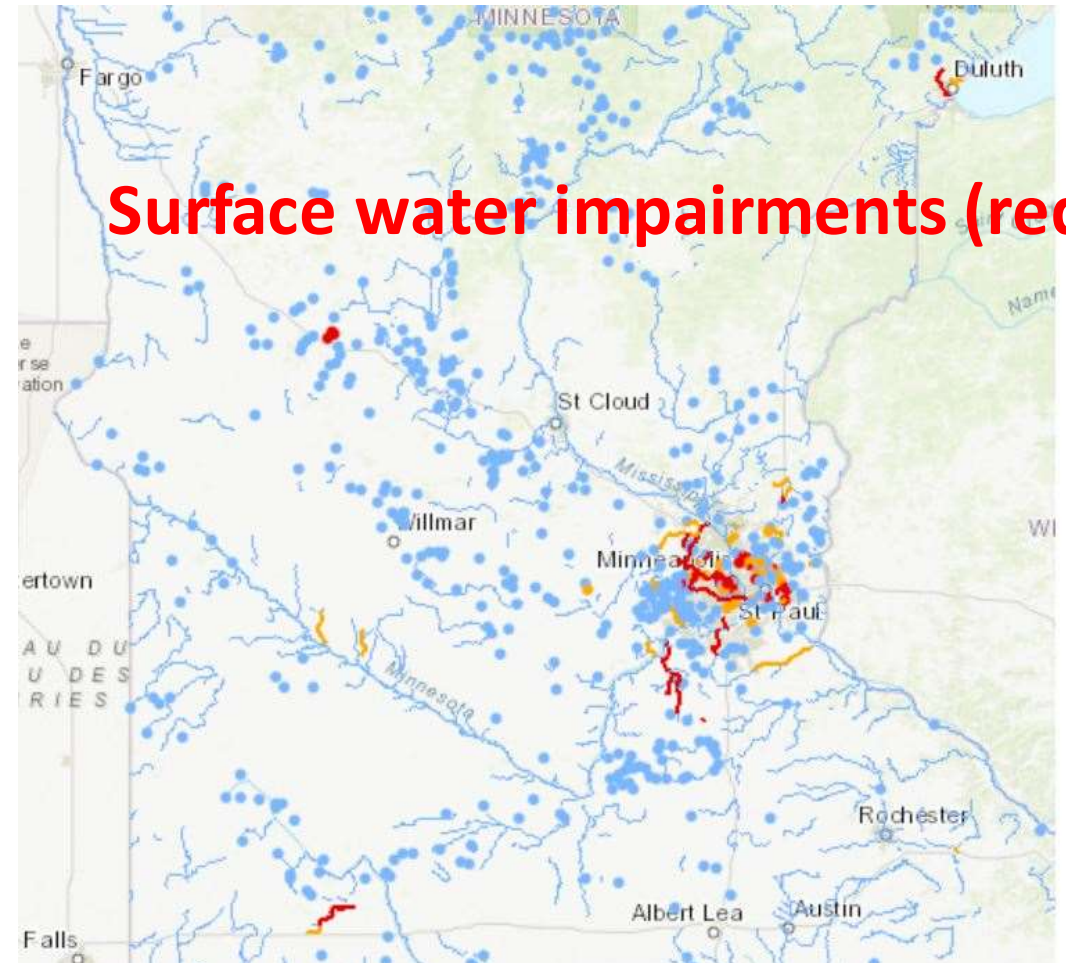
- More in SE MN (low native soil K)
- Less in NW MN: Wheat requires lower amounts of K
- **9194 tons/year** in the seven metro counties



Comparing Chloride from Fertilizer to Road Salt Chloride in the Metropolitan Area

In the **Metropolitan Area** where the majority of chloride impairments are located (**39/50**):

- Farm fertilizer chloride estimate:
9,194 tons/yr
- Road salt chloride estimate:
210,000 tons/yr (Novetny et al., 2008)
- **Chloride fertilizer** is not applied to impervious surfaces unlike road salts
- Chloride from fertilizer have a different fate in the environment

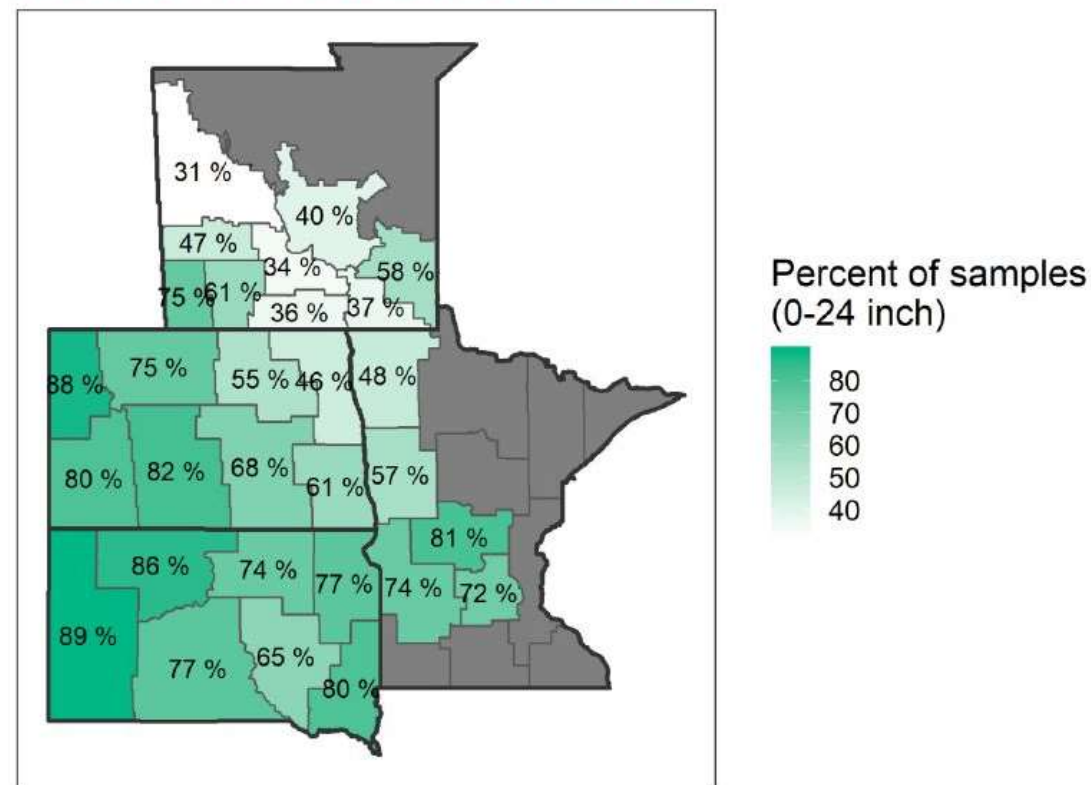


Assessment of Chloride in MN Agricultural Soil and Water

Chloride in soils:

- Based on Agvise soil analysis
 - Residual soil test (taken after harvest)
 - 2 feet soil sample (0-24")
- Majority of soils in **central MN** have less than **5ppm** of chloride (40lb/ac)
- Soils in **NW MN** have more chloride likely due to a combination of soil and weather conditions (salinity)

Soil samples with soil test chloride below 40 lb/acre in 2019



Data not shown where n < 100
AGVISE Laboratories, Northwood, ND

Water Quality Assessment: Edge of Field Monitoring

- **Discovery Farm Minnesota:**

- Led by the **MAWRC** in partnership with the MDA
- Long term monitoring of agricultural water quality attributes
- Chloride in **tile** and **surface runoff**
- Different cropping systems/management

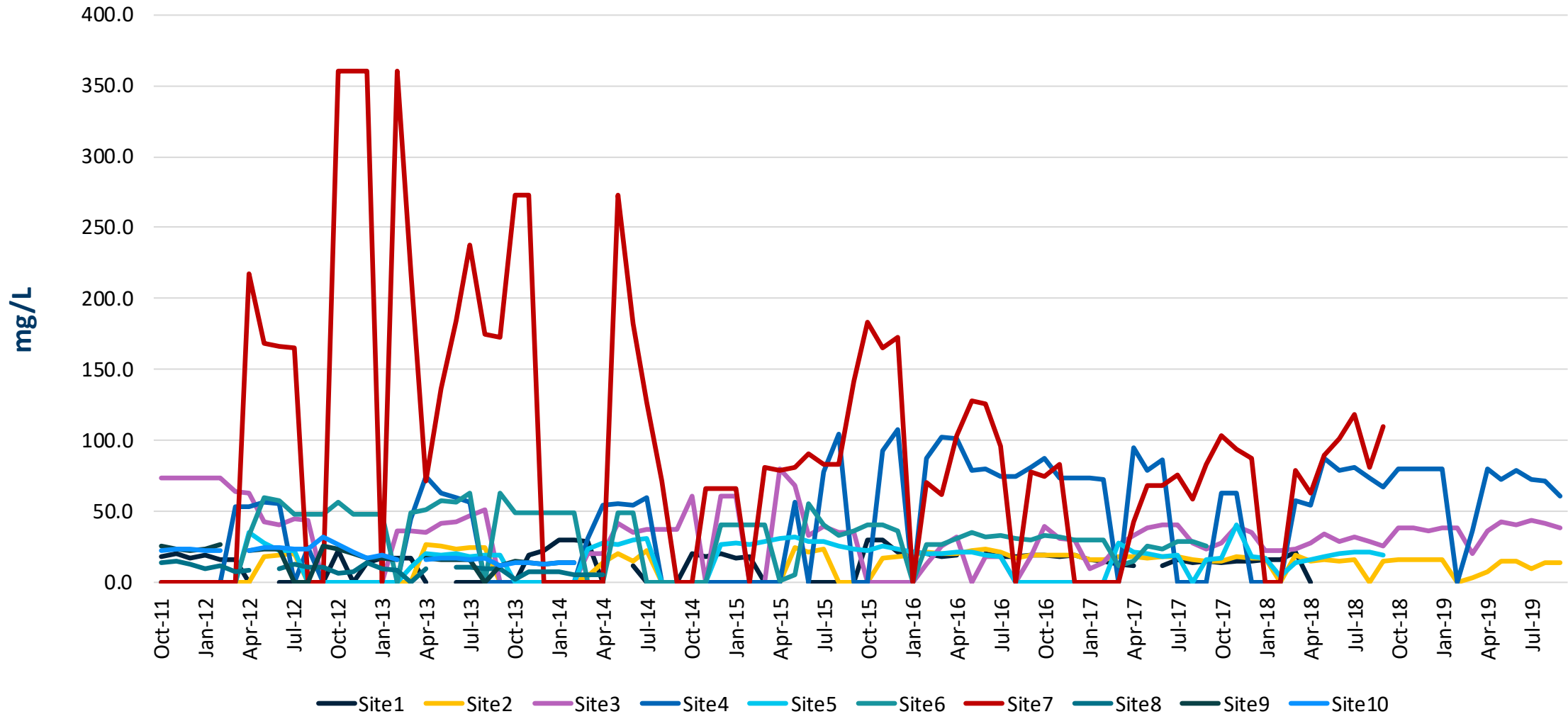
- **Root River Field to Stream Partnership**

- Edge of field monitoring
- Stream monitoring

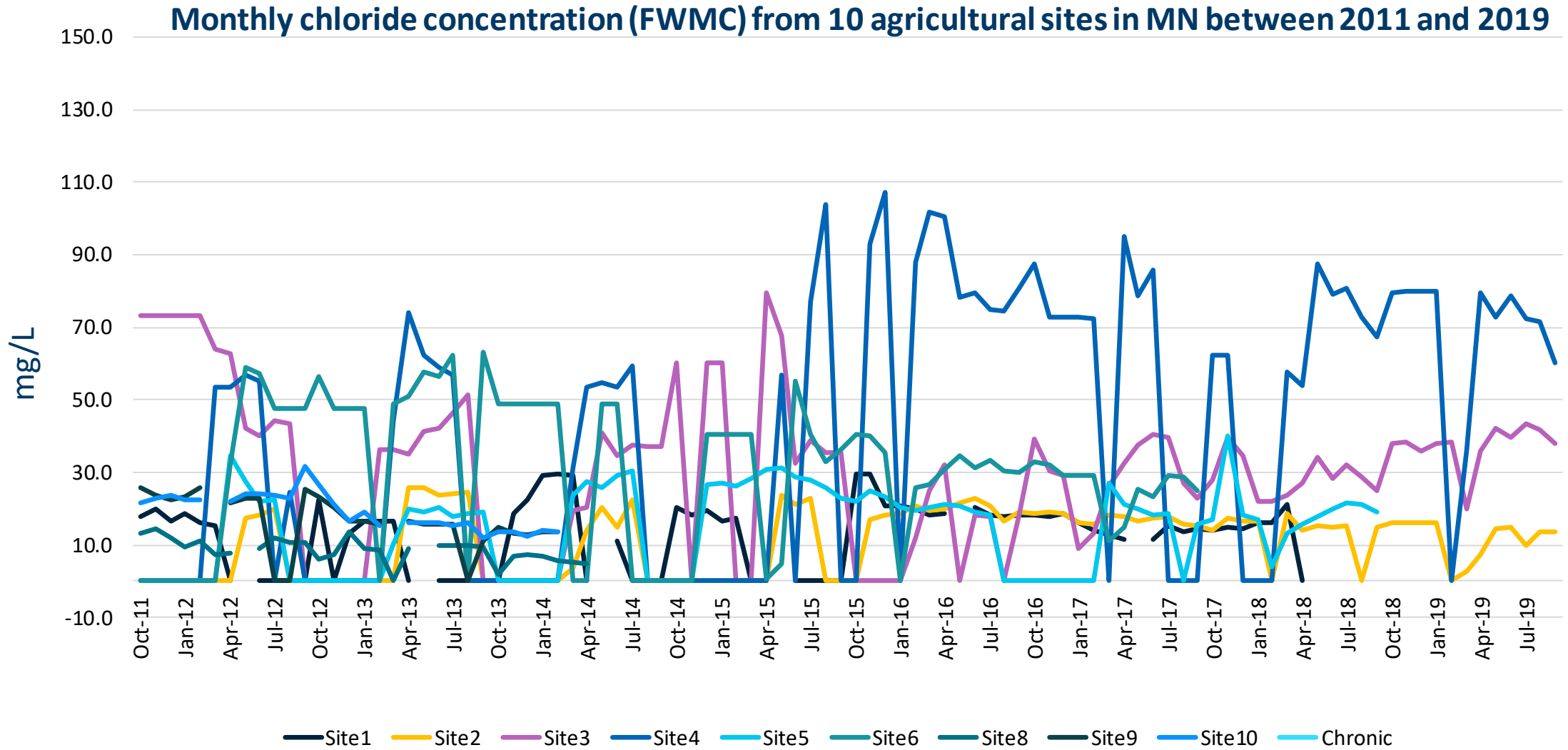


Water Quality: Edge of Field Monitoring (Discovery Farm)

Monthly chloride concentration (FWMC) from 10 agricultural sites in MN between 2011 and 2019



Water Quality: Edge of Field Monitoring (Discovery Farm)



Water Quality: Edge of Field Monitoring (Discovery Farm)

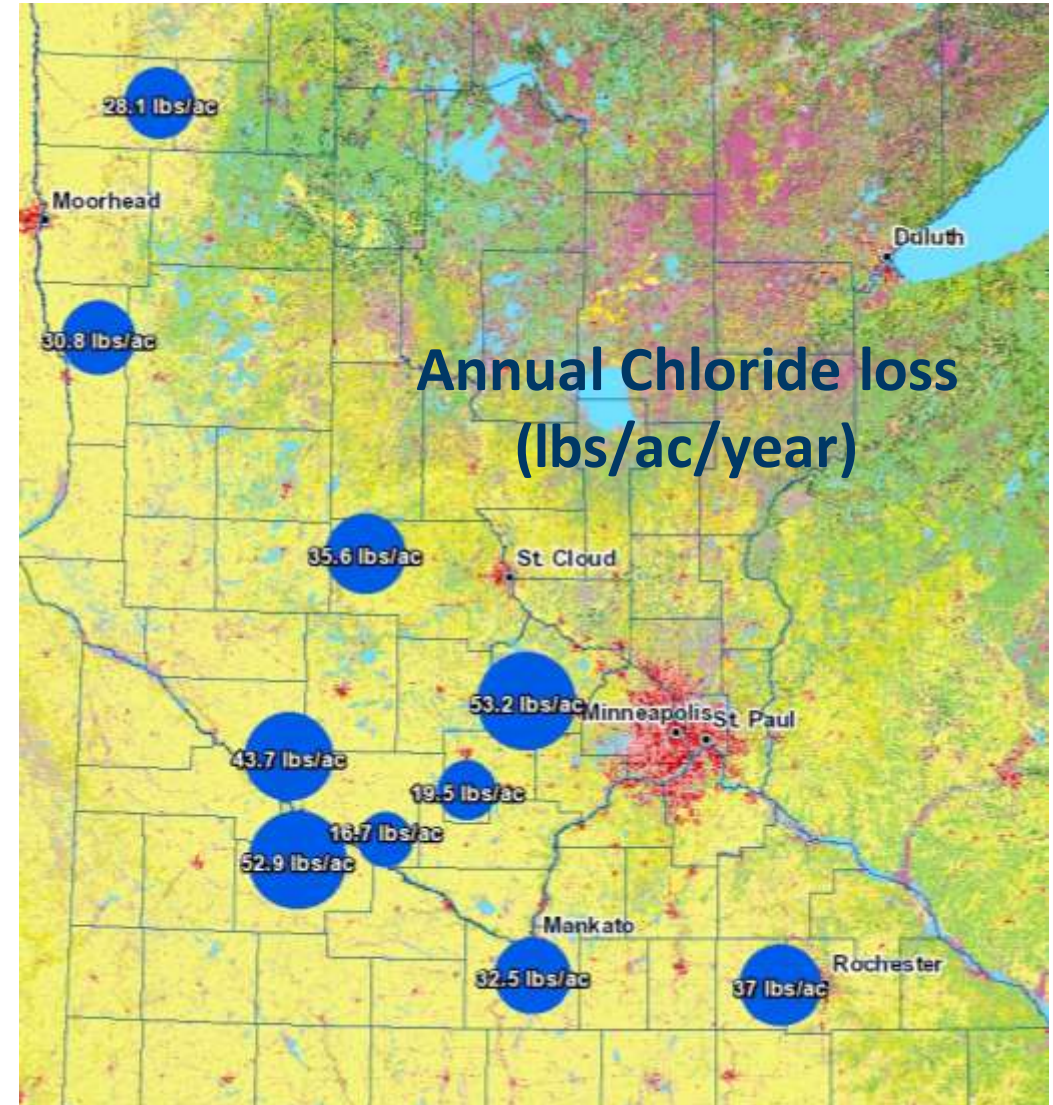
- Significant variability between sites
- Significant interannual variability
 - Higher concentration (early spring and late fall)
- Chloride mean concentration (FWMM):
 - **31.4 mg/l**



Edge of Field Monitoring: Discovery Farm

Annual chloride yield (tile and surface runoff)

- Tile Drainage loss: **35 lb/ac/yr**
- Surface runoff: **5.8 lb/ac/yr**
- Large **variability** between **sites/years**:
19-53 lb/ac/year
- Annual average loss: **40.8 lb/ac/year**
- **Tile** loss accounts for **86%** of the loss



Water Quality : Root River Field To Stream Partnership

Field to stream dilution

- **Field** drainage water chloride : **21 mg/l**
- Stream chloride (**Headwaters**) : **17.2 mg/l**
- Stream chloride (**Downstream**): **6.6 mg/l**



Conclusion

- **Chloride is a by product of Potash**
- **Over 245,000 tons used every year**
- **Leaching occur with significant spatial and temporal variability**
- **Improvement to potassium fertilizer management can help reduce chloride use**
- **Soil test for K, variable rate K application, promote use of non-chloride K fertilizer**

Thank you!

Aicam Laacouri

Aicam.laacouri@state.mn.us