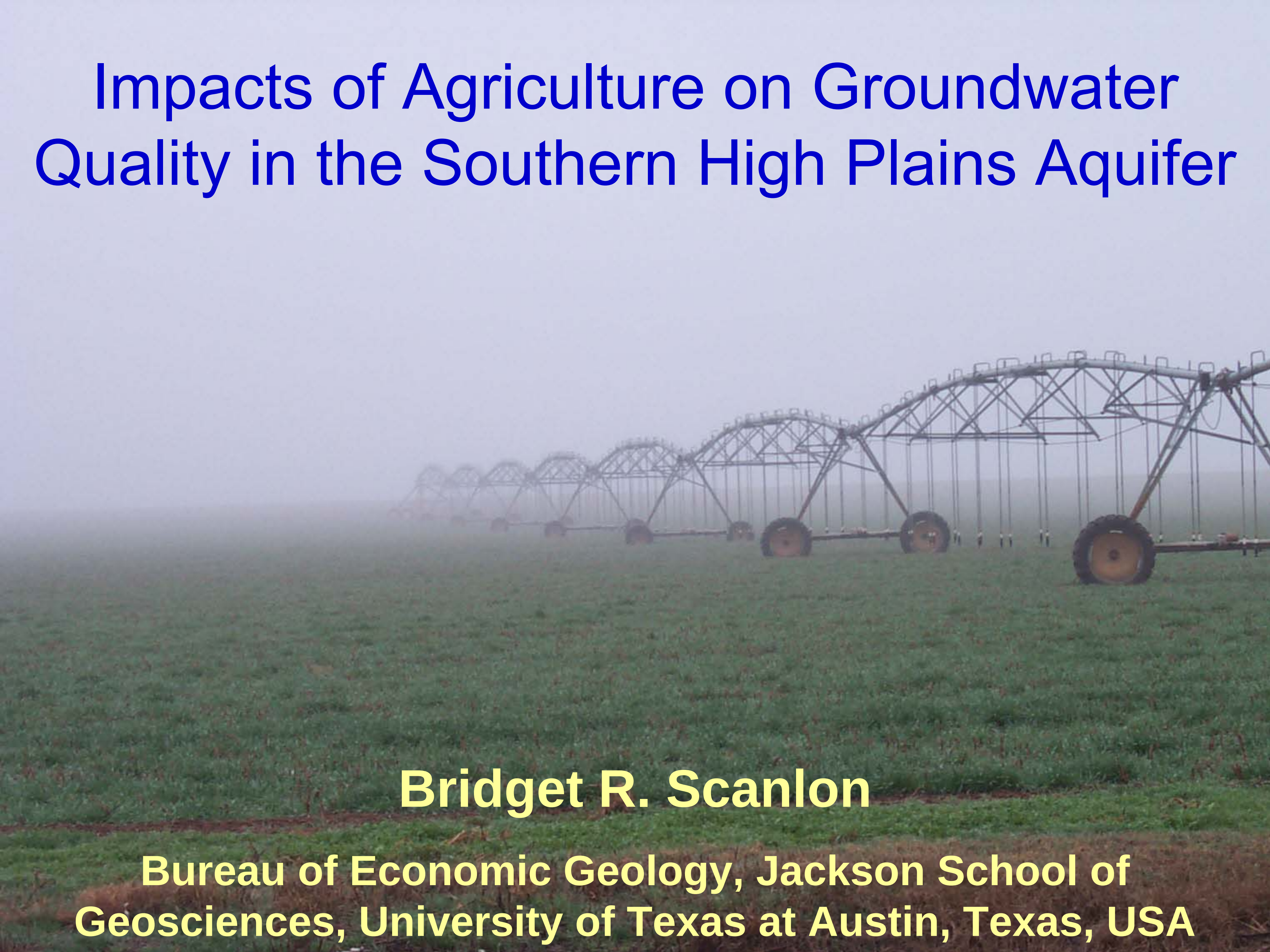
Impacts of Agriculture on Groundwater Quality in the Southern High Plains Aquifer



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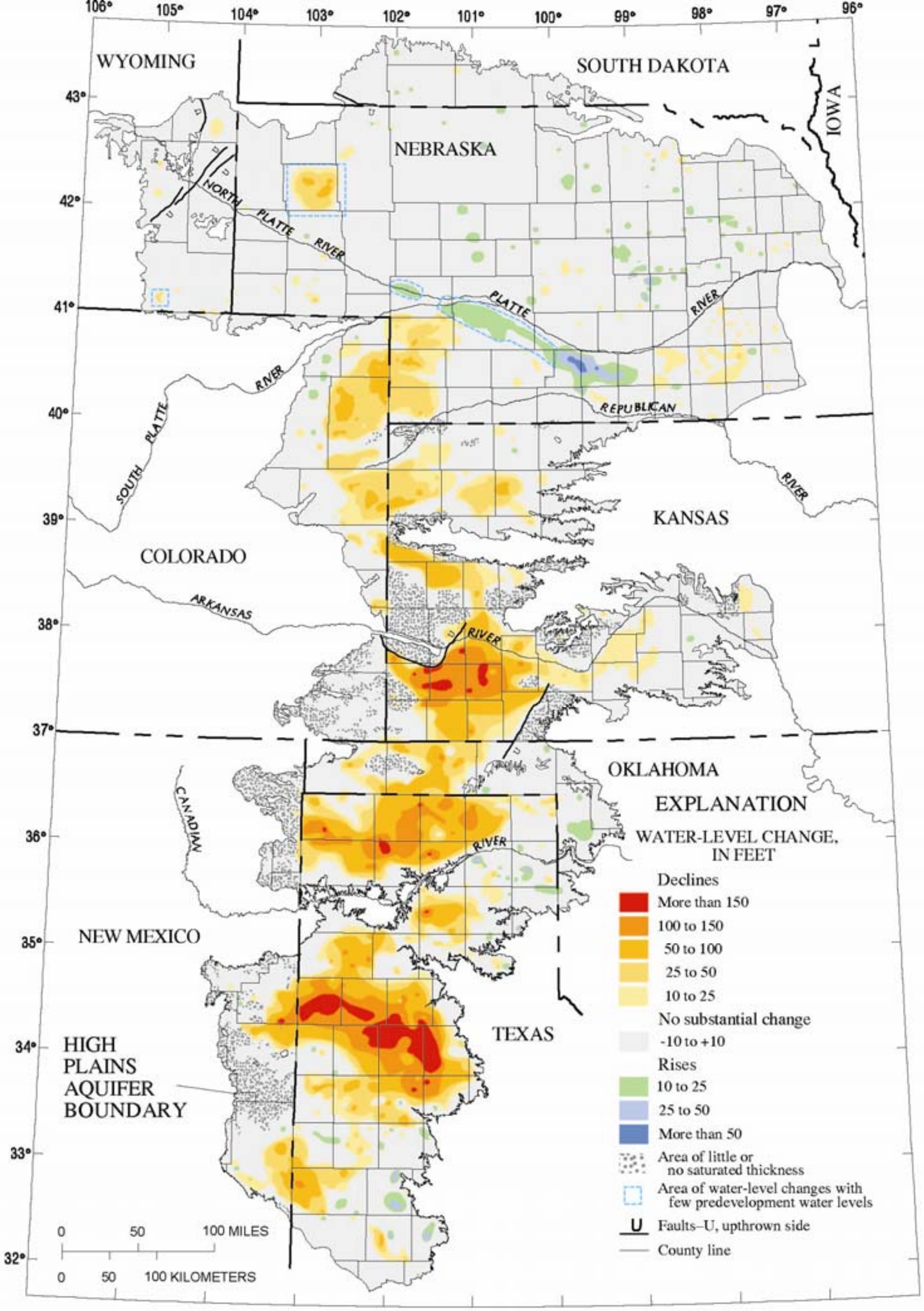
Basic Questions
Impacts of Agriculture on Groundwater Quality

- What impact does rain-fed (dryland) agriculture have on soil water and groundwater quality?
- How does irrigation affect soil water and groundwater quantity and quality?
- How can irrigation be managed to achieve sustainability with respect to water quantity and quality



Base from U.S. Geological Survey digital data, 1:2,000,000
Albers Equal-Area projection
Standard parallels 29° 30', central meridan -101°

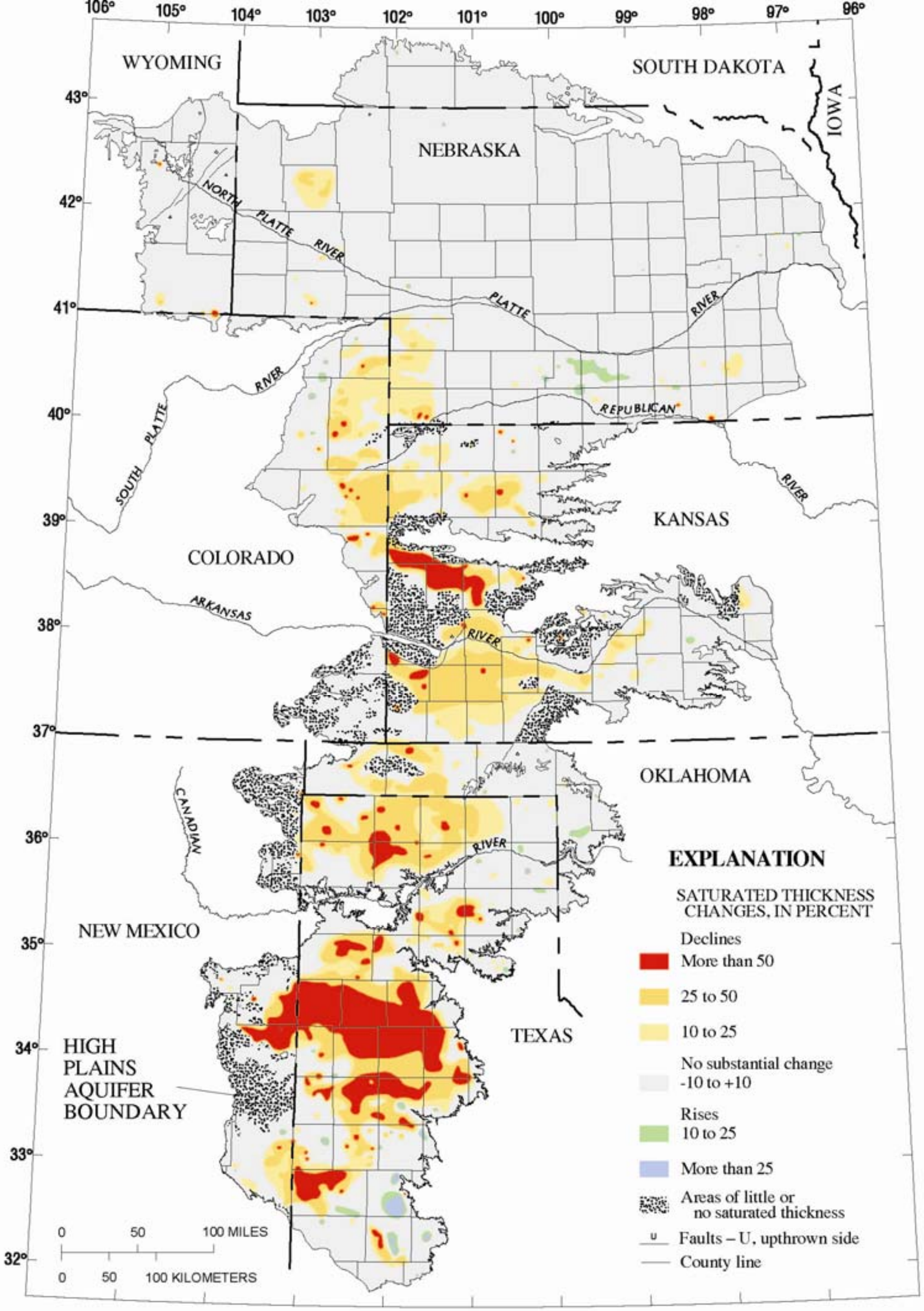
Water-level Changes ~ 1950s - 2007

Declines in SHP-N
30 m over 11,000 km^2
2% of area of HP
21% of change in water storage

McGuire et al., 2009

Percent Change in Aquifer Saturated Thickness

~1950 – 2007



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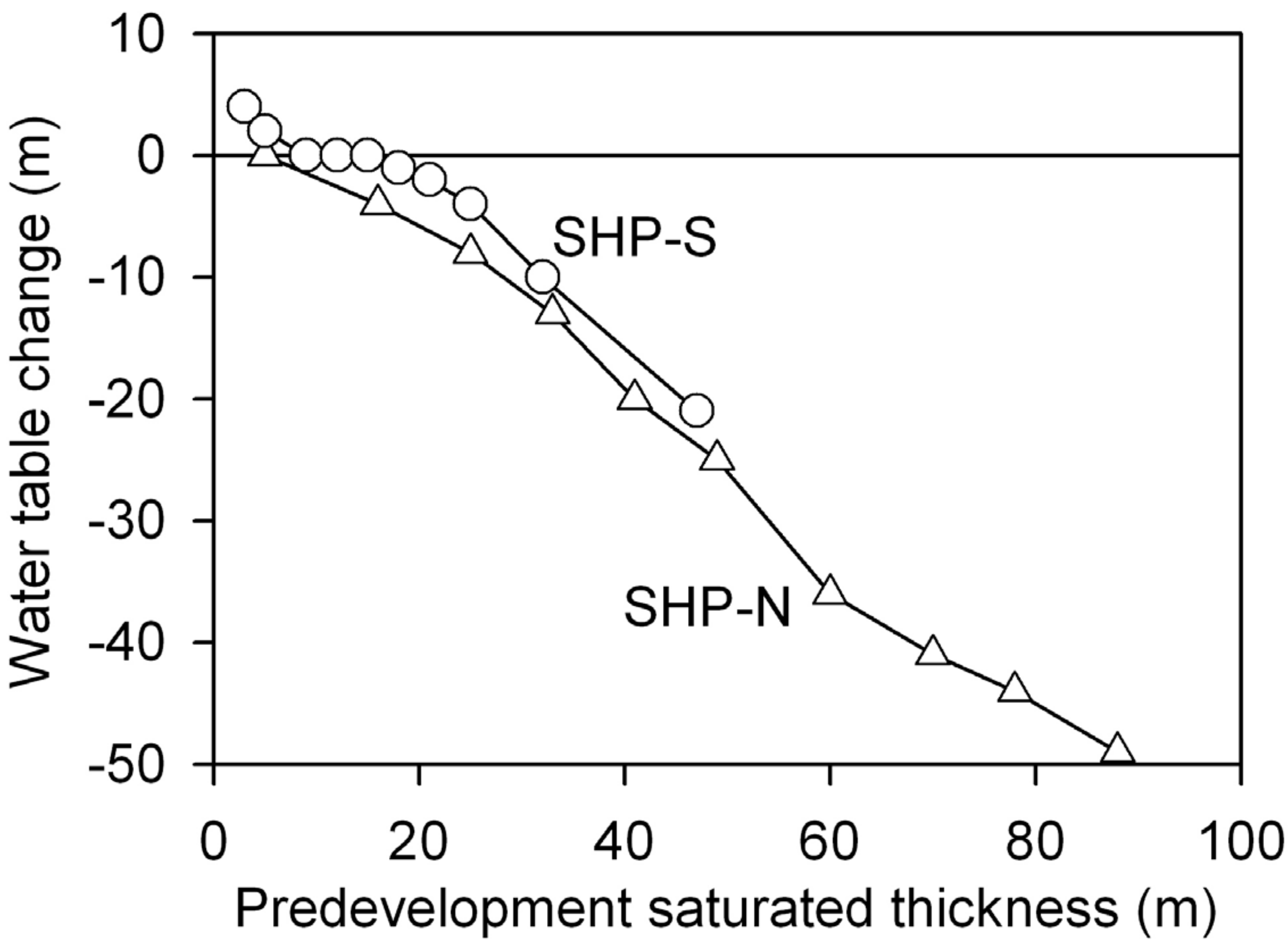
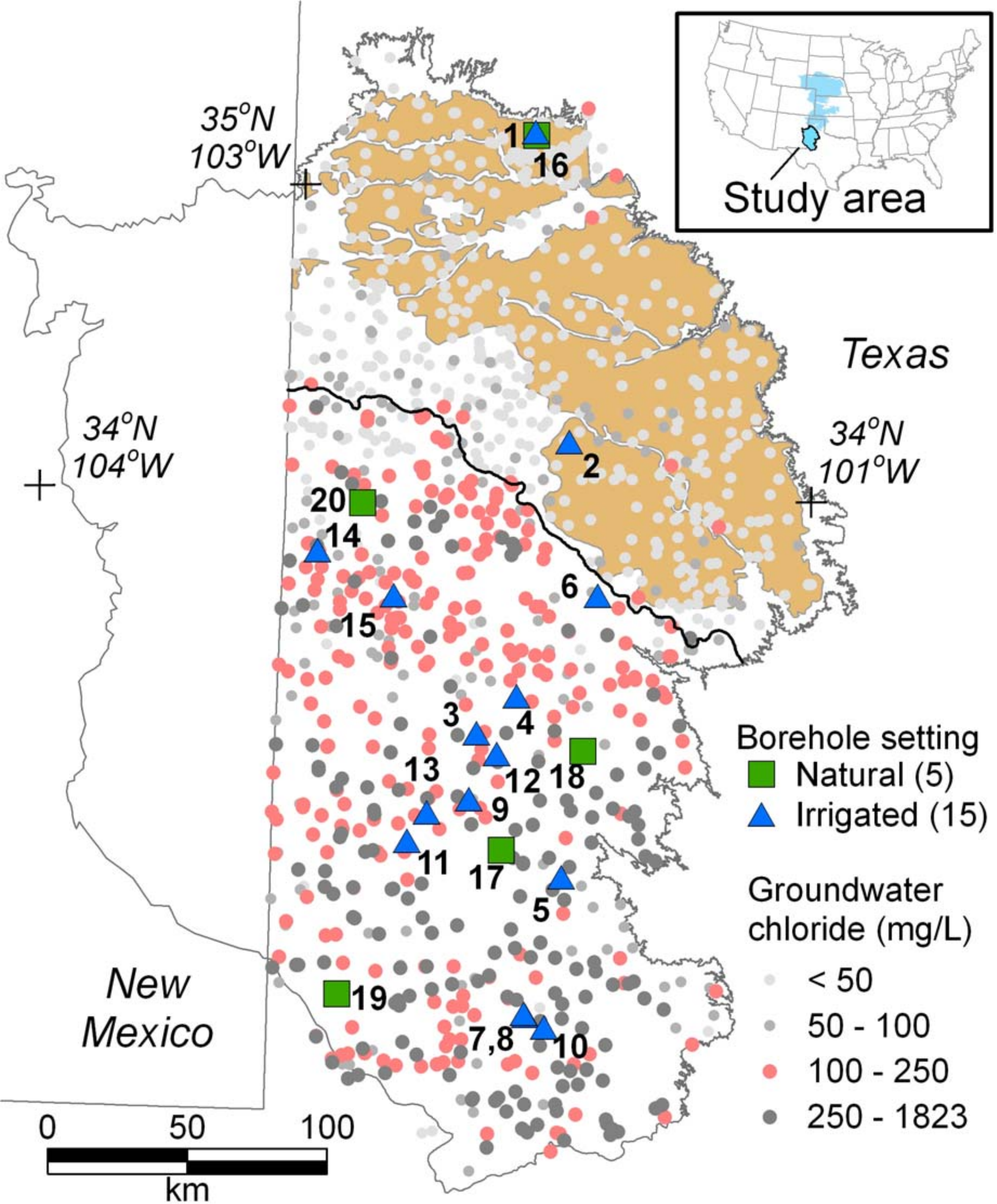
Relationship between Groundwater Declines and Aquifer Saturated Thickness



Chloride (mg/L)



Median Cl SHP-N
21 mg/L
Aquifer thick:45 m
Water table: 63 m

Median Cl SHP-S
180 mg/L
Aquifer thin: 25 m
Water table:16 m

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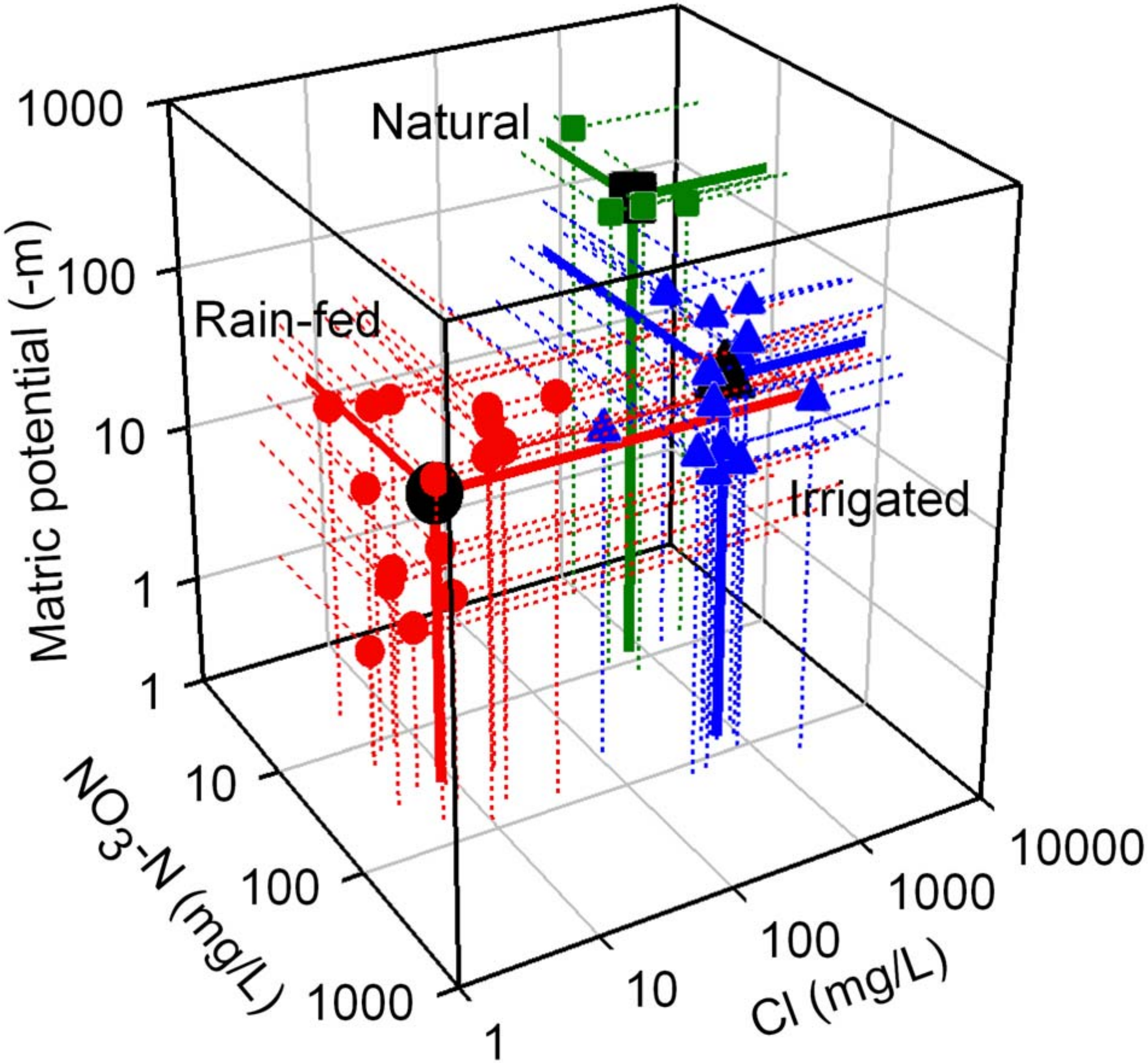
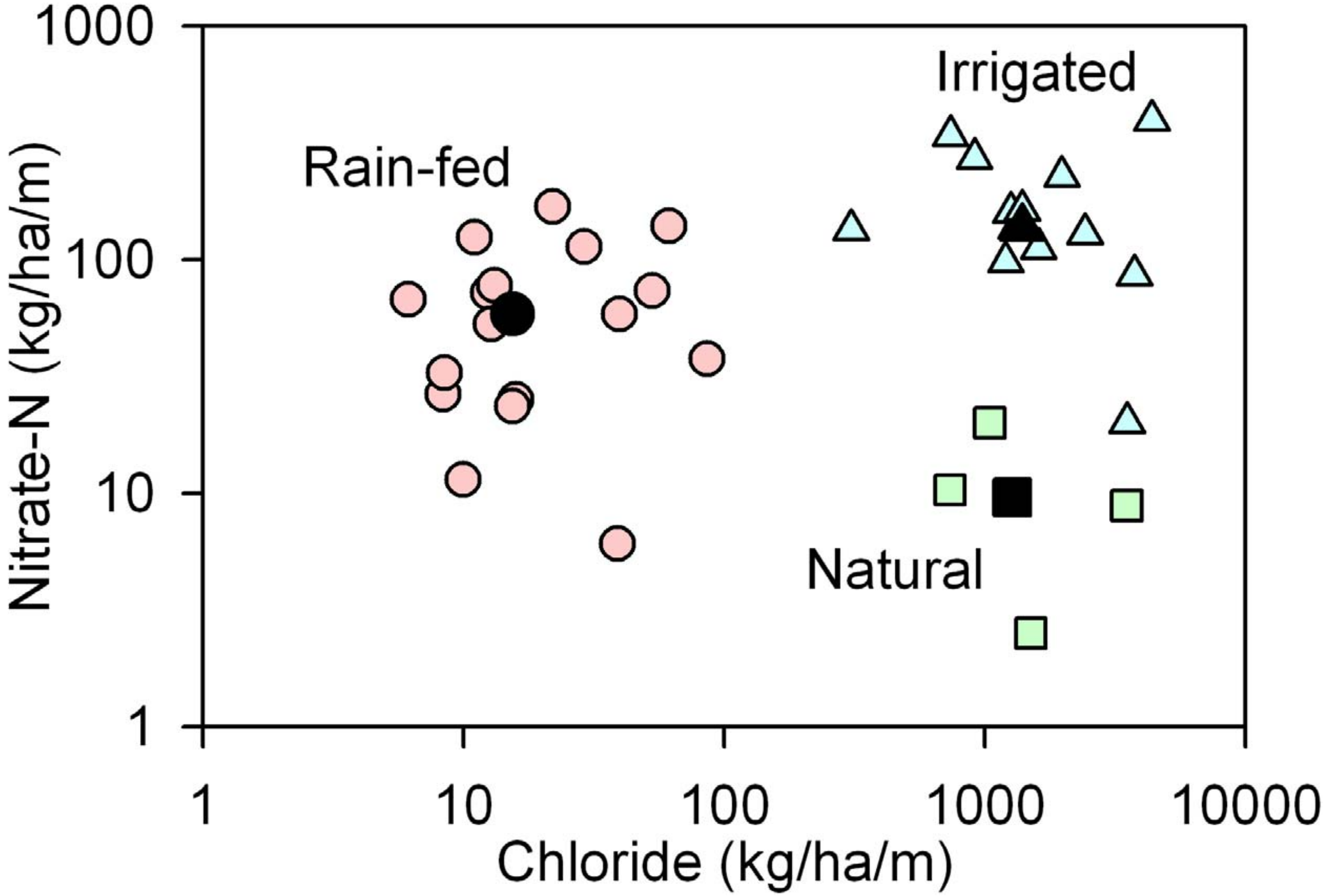
Soil Water Related to Different Land Uses



Natural:
MP: -200 m
Cl: 780 mg/L
NO3-N: 8.1 mg/L

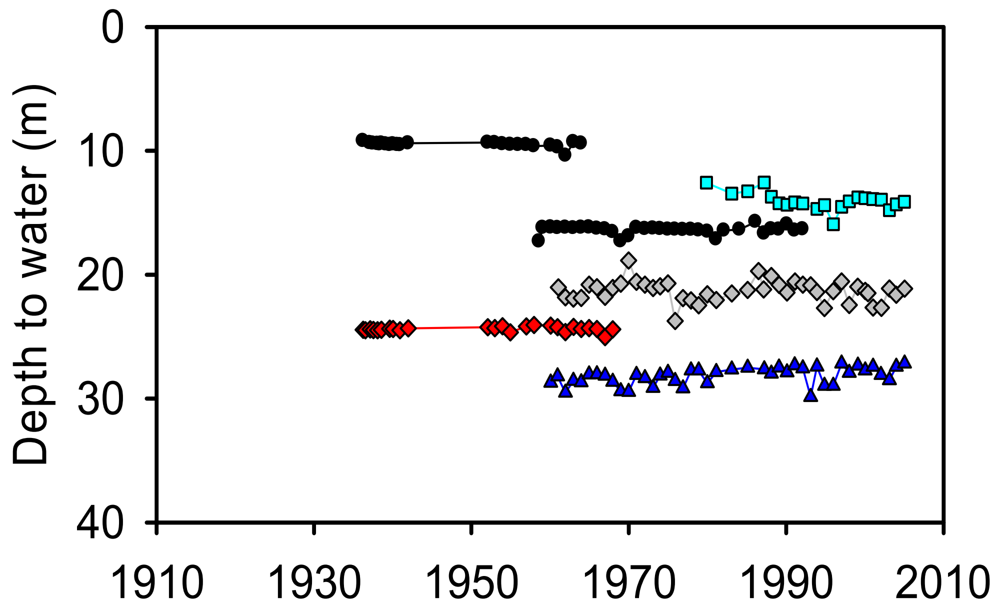
Rain-fed
MP: -14 m
Cl: 8 mg/L
NO3-N: 32 mg/L

MP: -40 m
Cl: 720 mg/L
NO3-N: 71 mg/L



1000
100
10
1
Nitrate-N (kg/ha/m)
1
10
100
1000
10000
Chloride (kg/ha/m)
Irrigated
Rain-fed
Natural

Natural Ecosystems

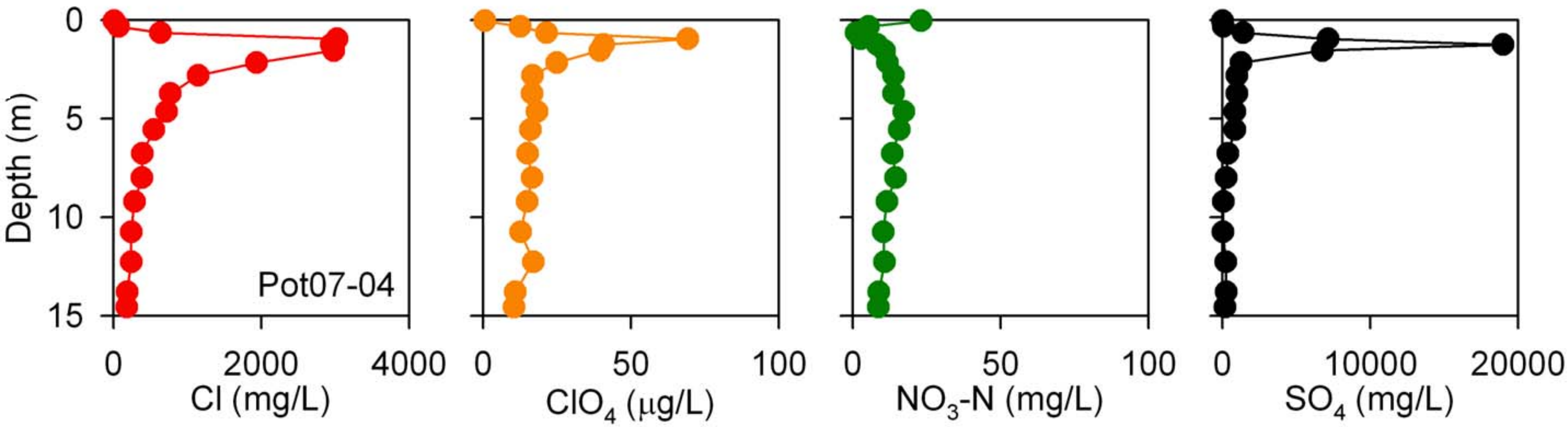


Very little to no recharge under natural ecosystems

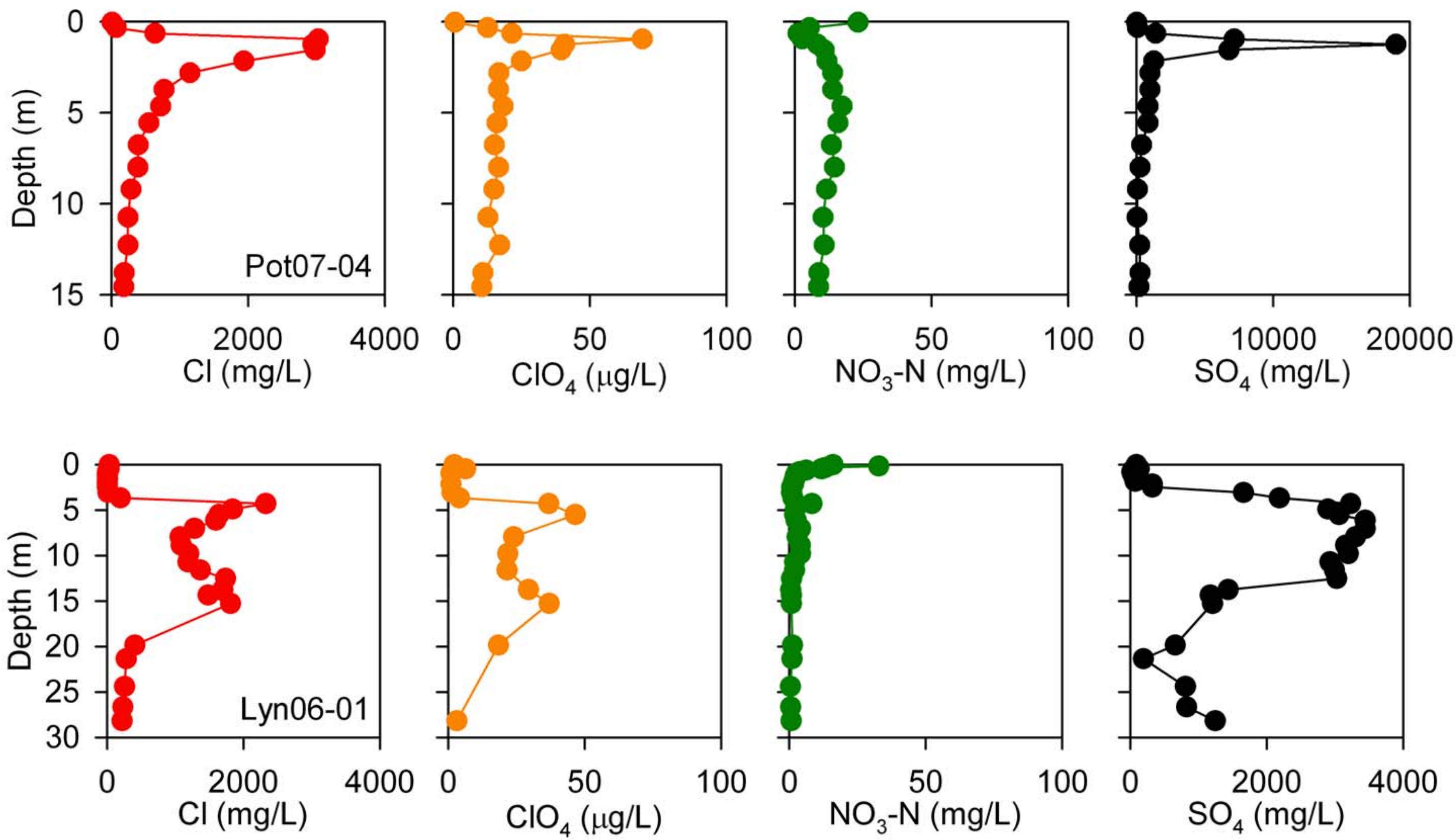
Chloride as a Tracer of Water Movement

Plants exclude chloride during ET

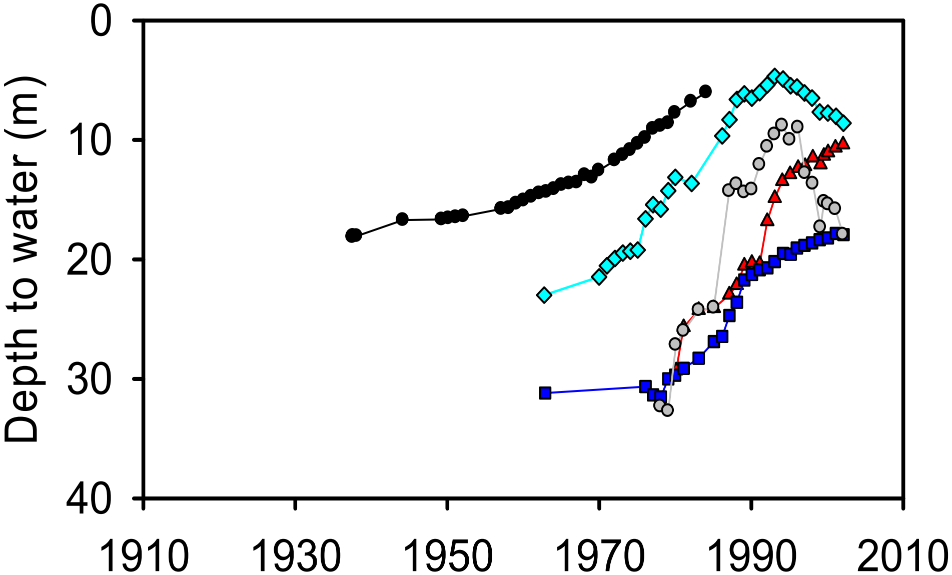
Salt Distribution Beneath Natural Ecosystems



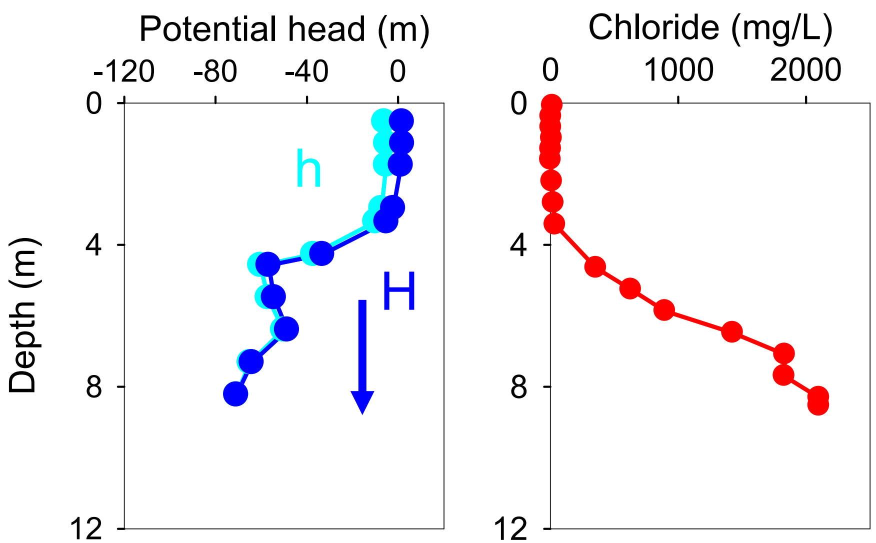
Salt Distribution Beneath Natural Ecosystems

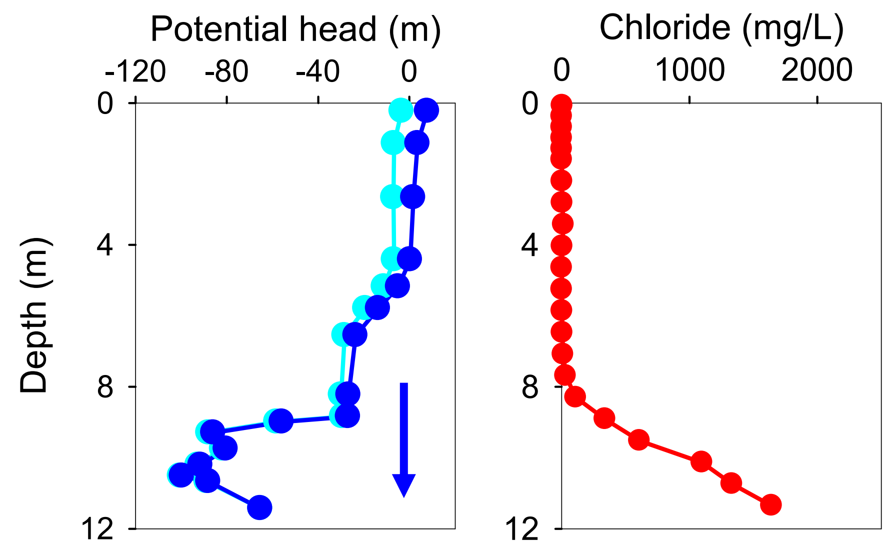


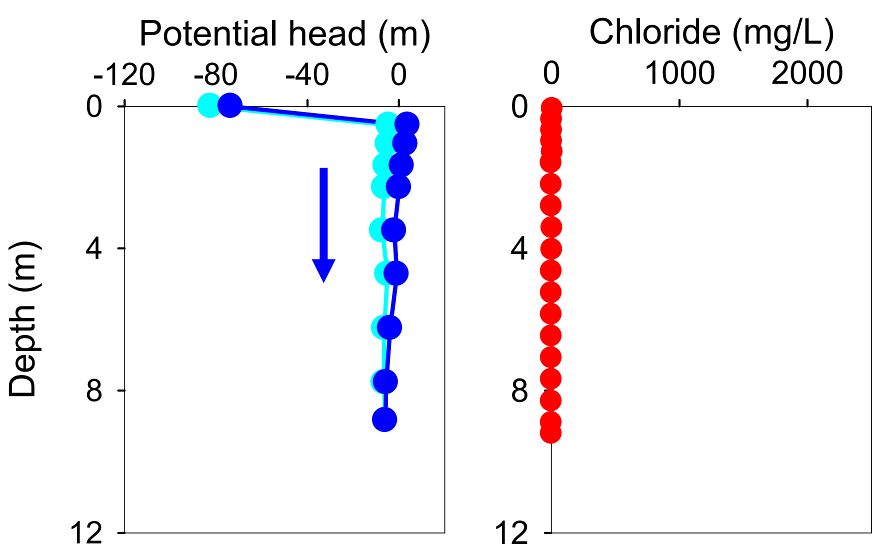
Rain-fed Agriculture



Impact of Rainfed Agriculture

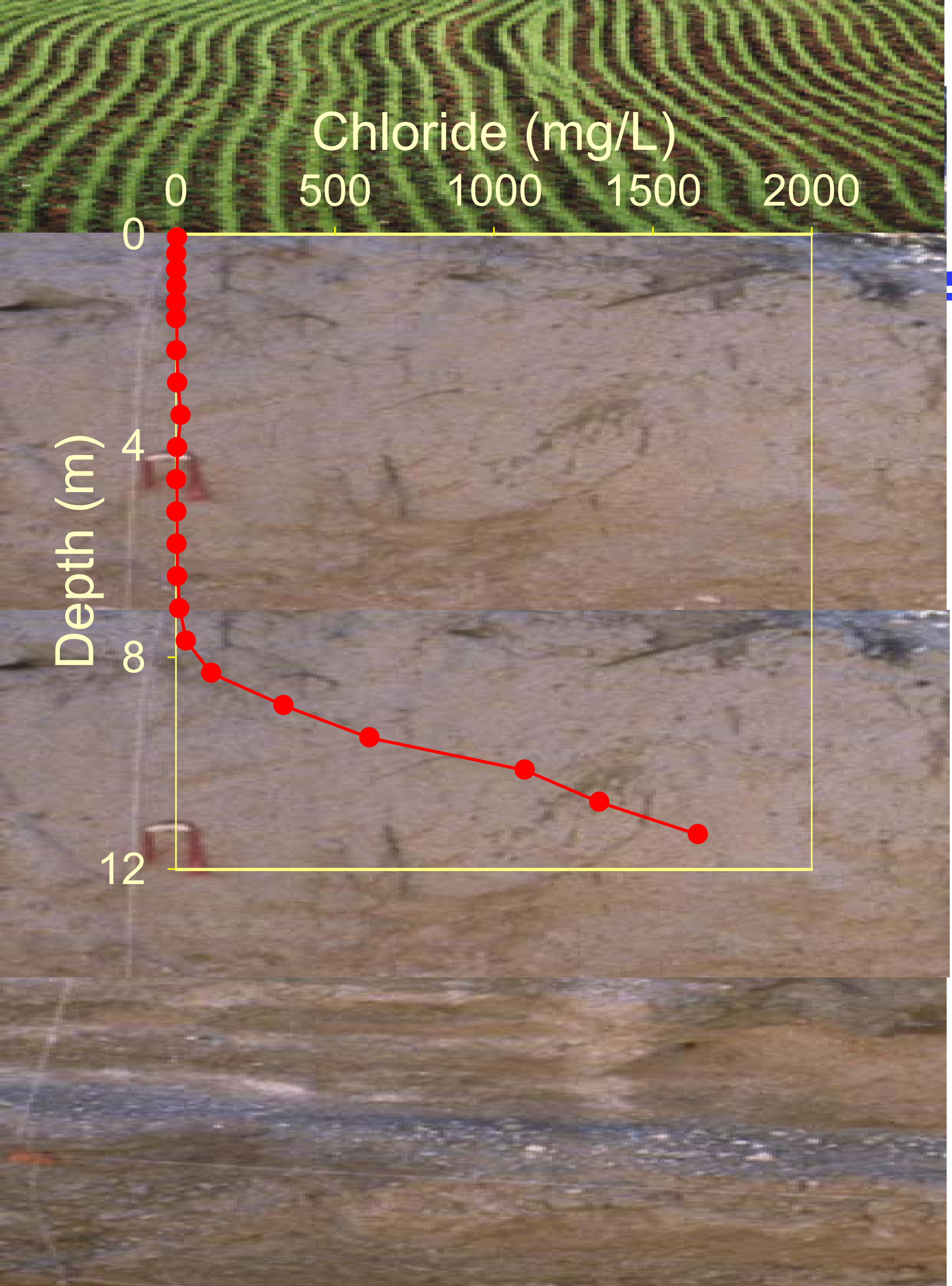




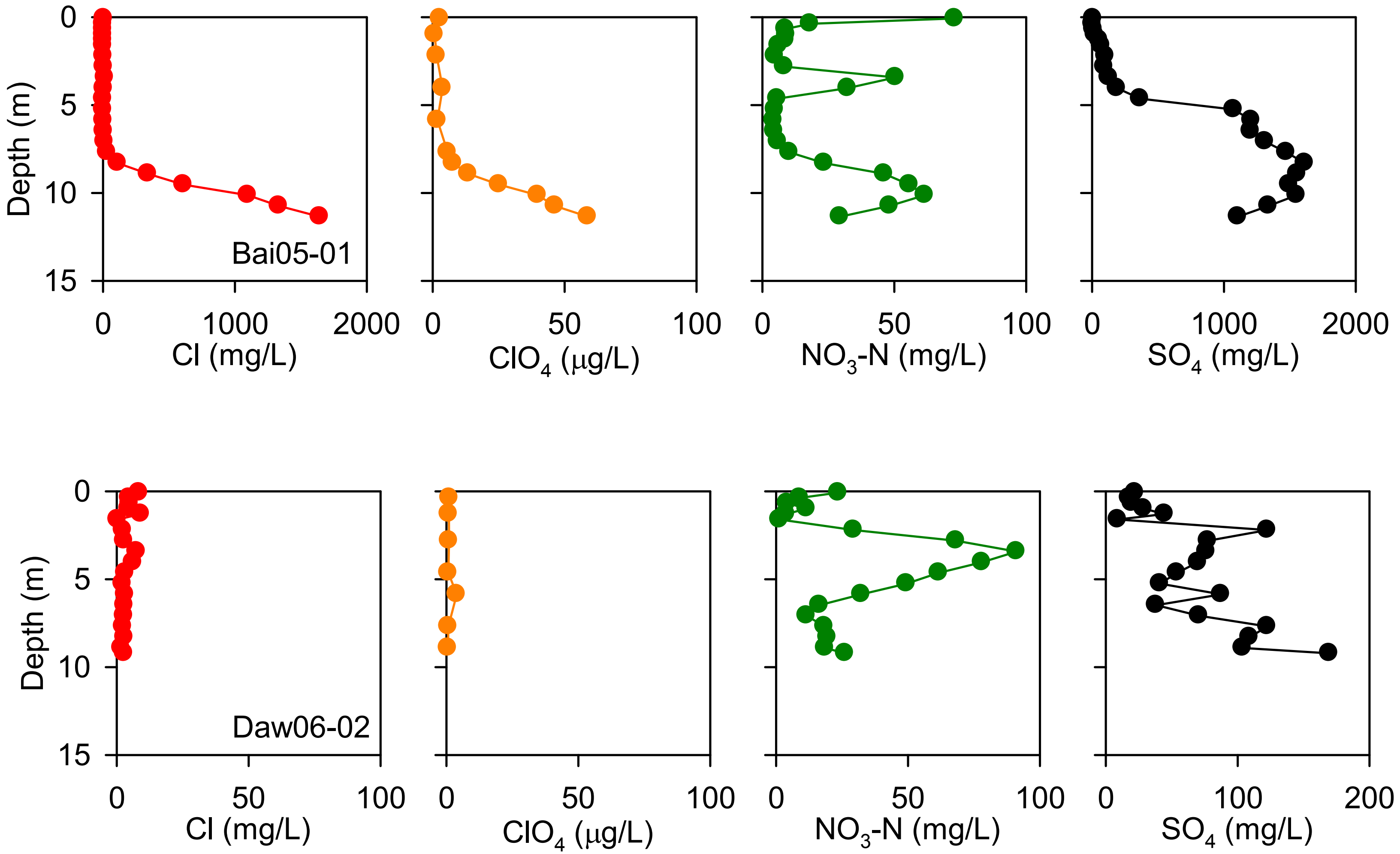


Downward head gradients
Low Cl….flushed zone
drainage/recharge

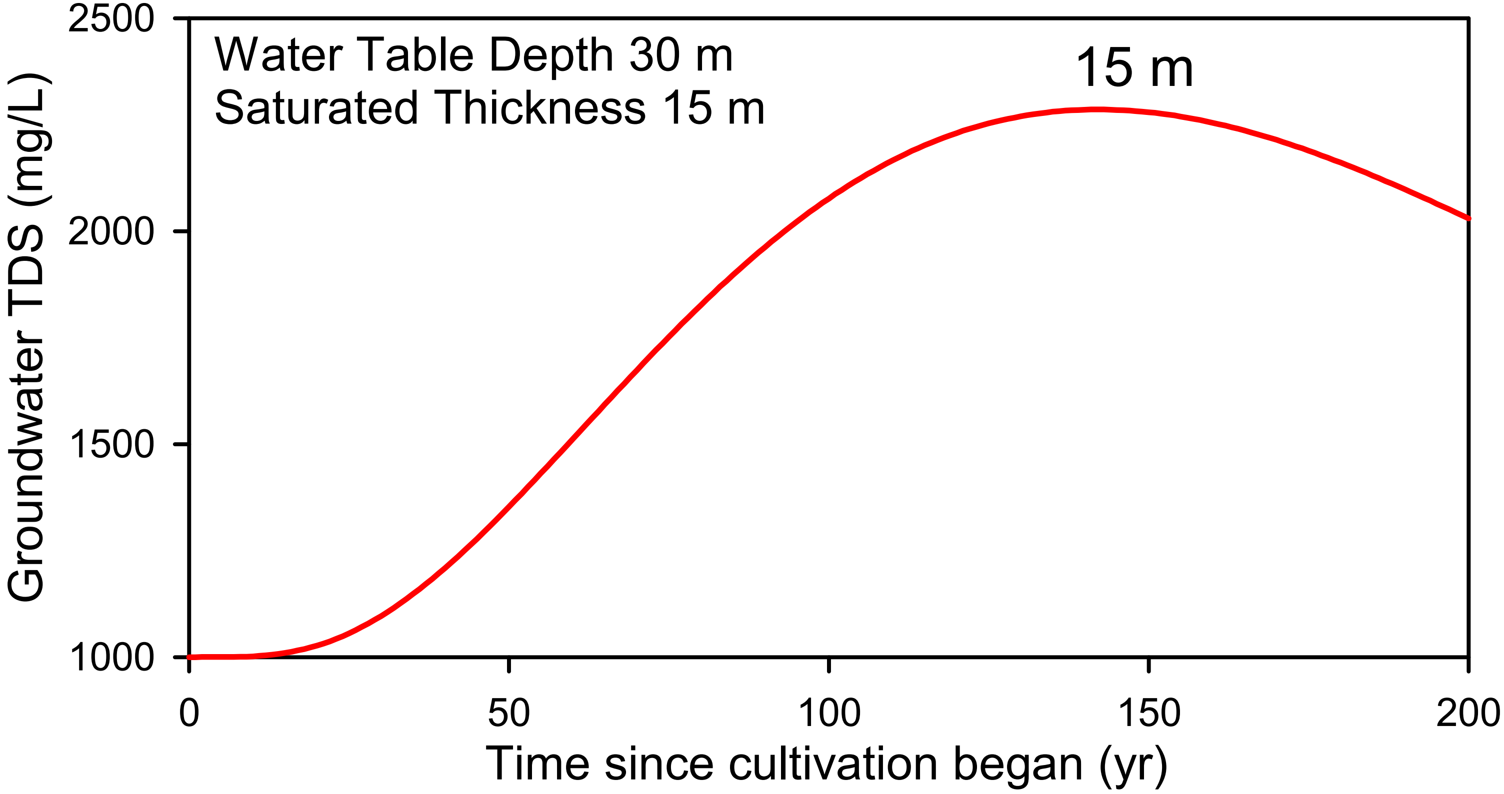
Chloride Profile beneath Rainfed Agriculture



Flushing of Salts under Rainfed Agriculture



Impact of Increased Recharge on Groundwater Salinity



Impact of Mobilizing Salt Inventories by Increased Recharge under Rain-fed Agriculture

- Cl ↑ by ~ 150 mg/L
- SO_4 ↑ by 480 mg/L
- TDS ↑ by ~ 1000 mg/L
- ClO_4 ↑ by 21 ug/L
- NO_3-N ↑ by 17 mg/L

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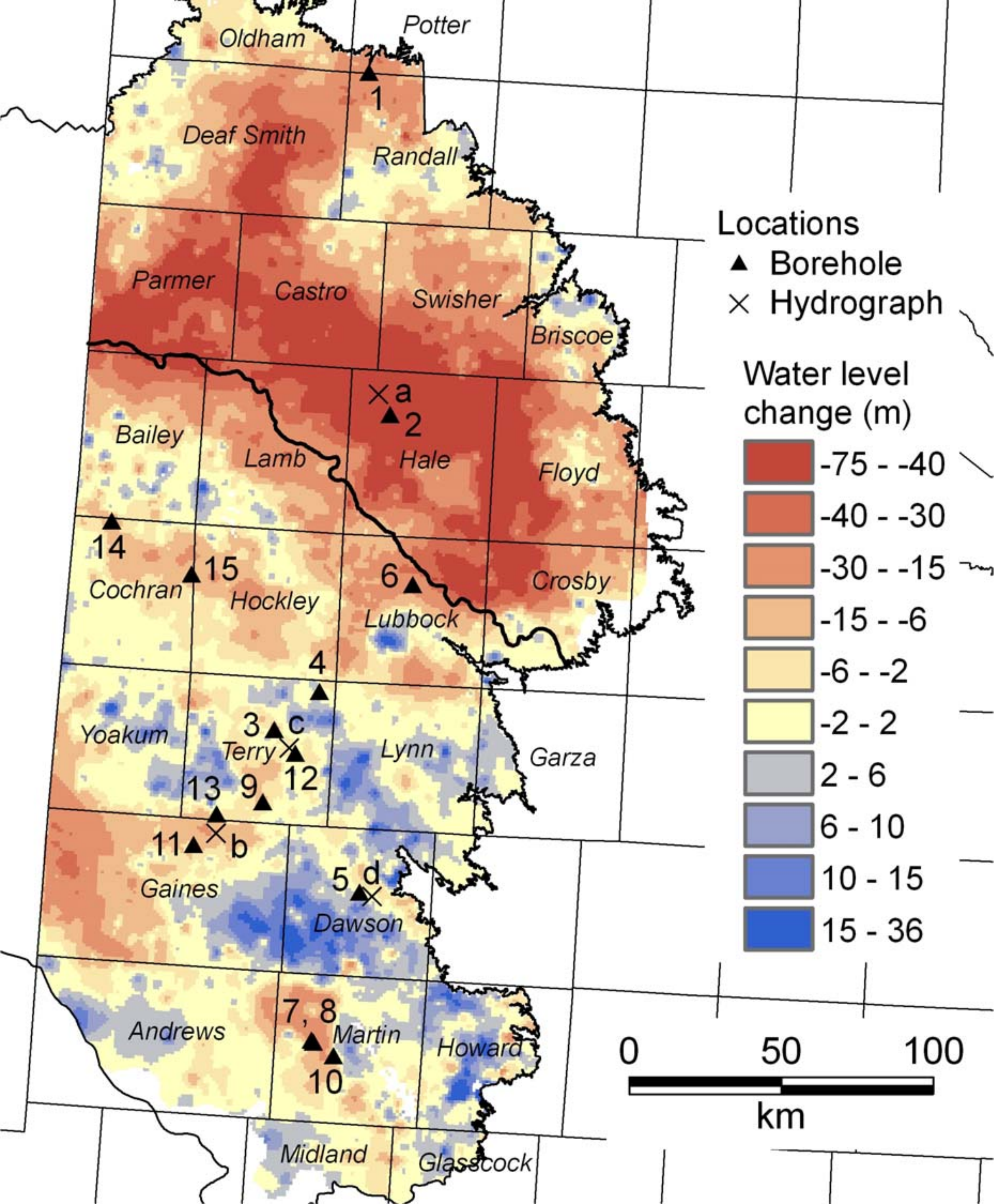
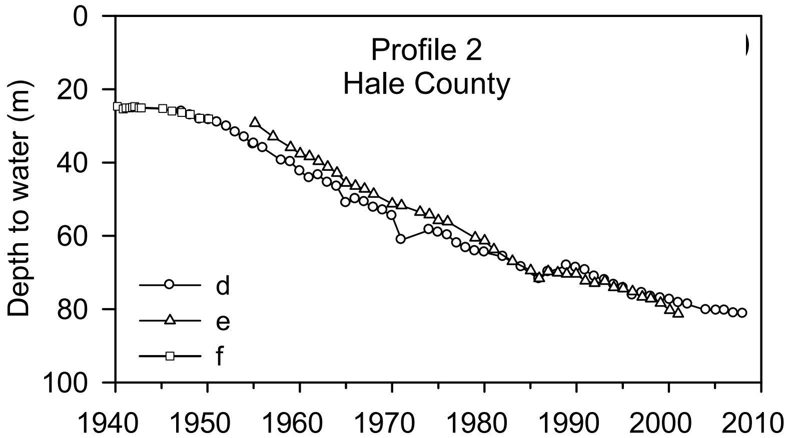
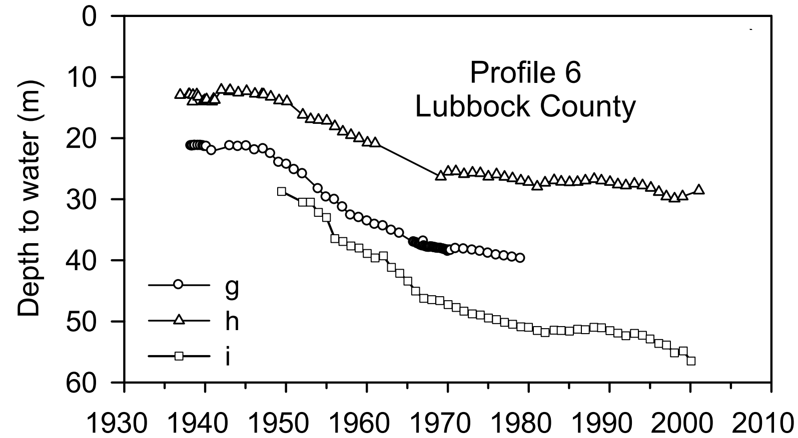
Water-Level Change

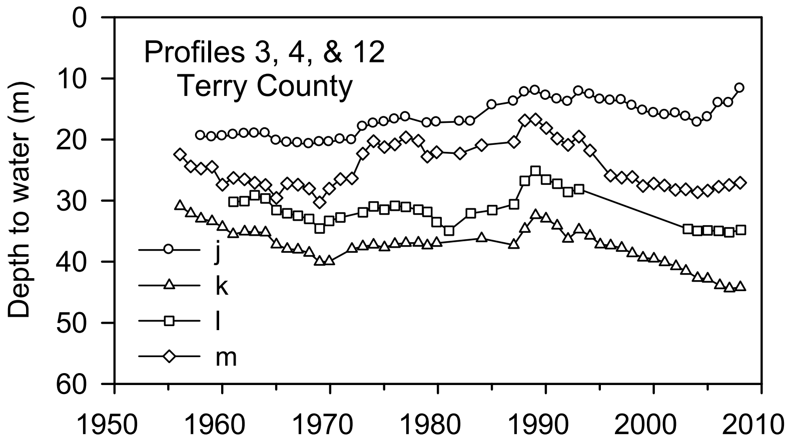


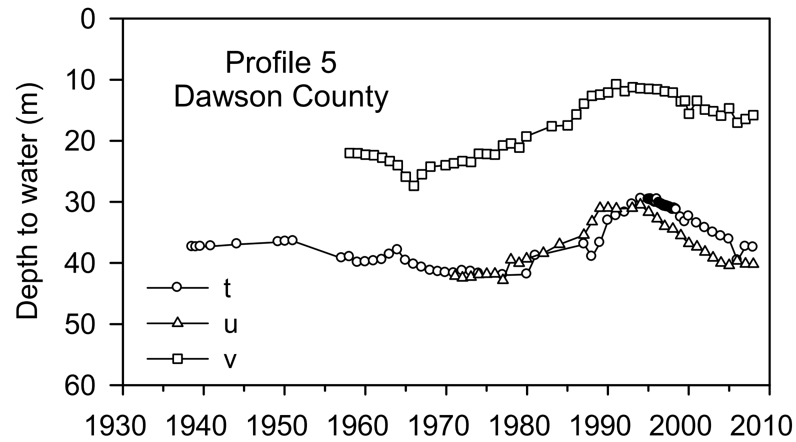
Large water-level declines in irrigated areas in north

Representative Hydrographs in Irrigated Regions







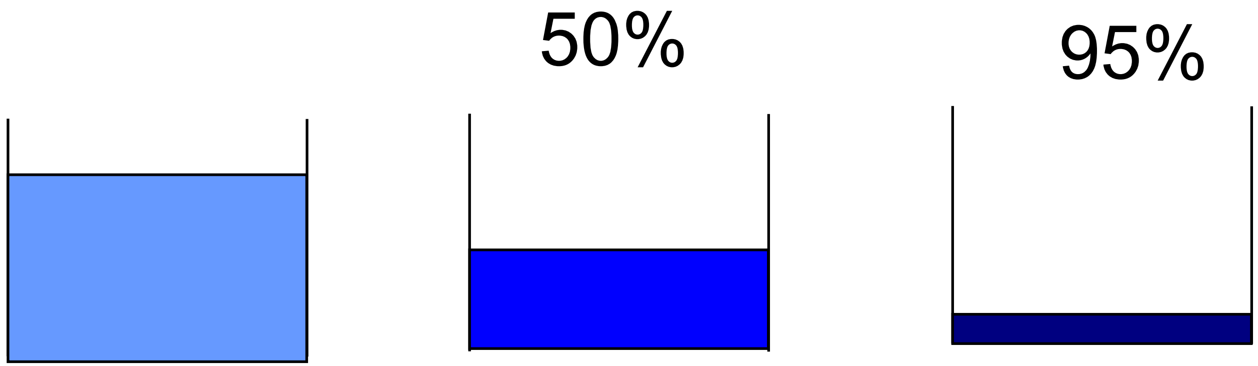


Impact of Irrigation on Basin Status

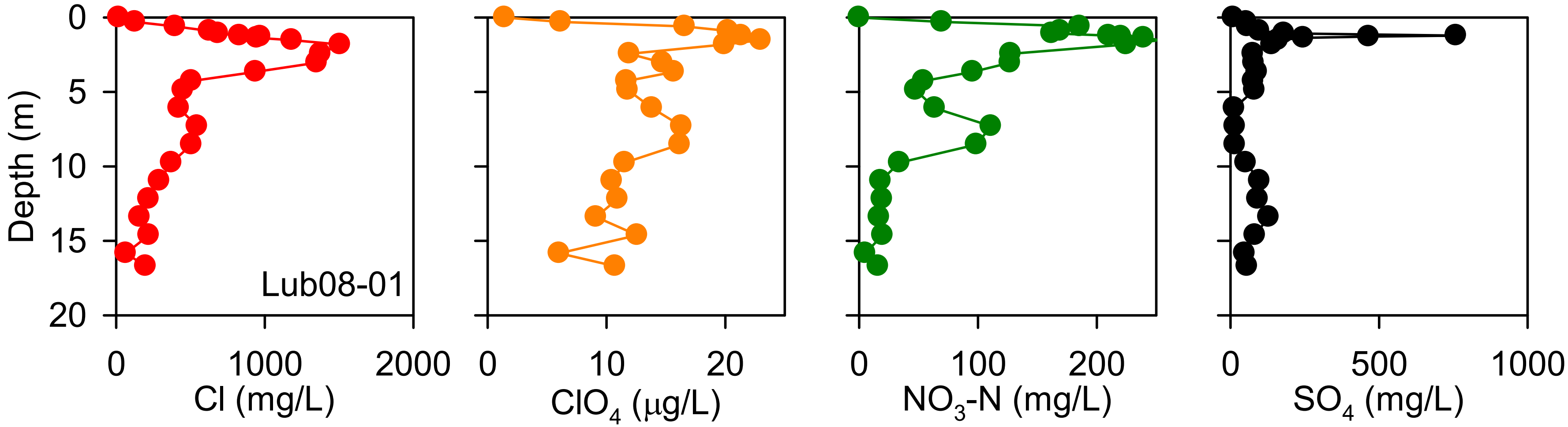
- Prior to irrigation, recharge = discharge
- After irrigation, added discharge through irrigation pumpage, ~ 95% of groundwater discharge
- Where does irrigation pumpage come from?
  - Groundwater storage
  - Reduced discharge
  - Increased recharge
- High Plains aquifer is essentially a closed basin with most discharge through pumpage

Impact of Irrigation on Soil Water and Groundwater Quality

- How is irrigation similar to desalinization?
- What impact does irrigation have on soil water quality?



Profiles under Irrigated Sites



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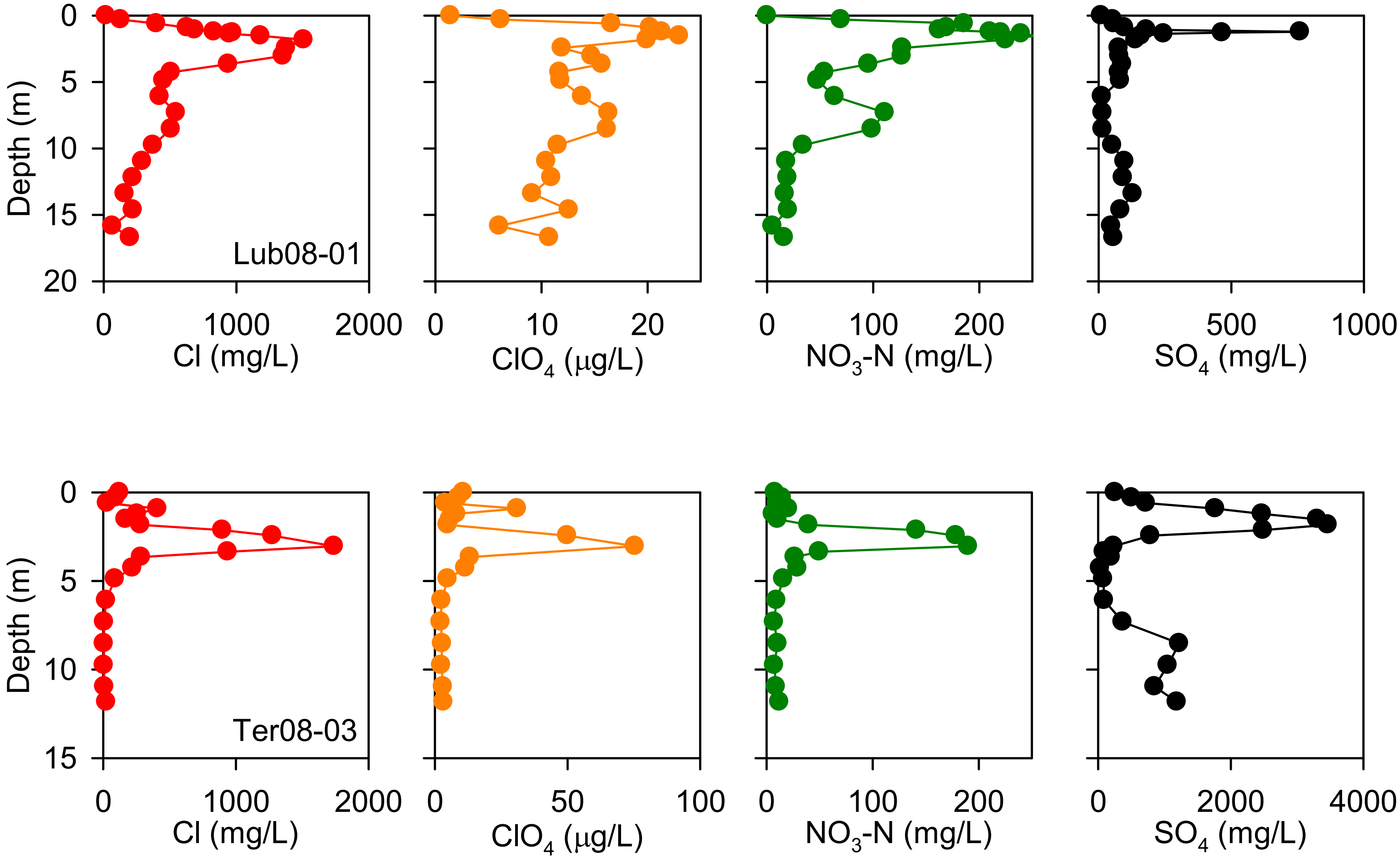
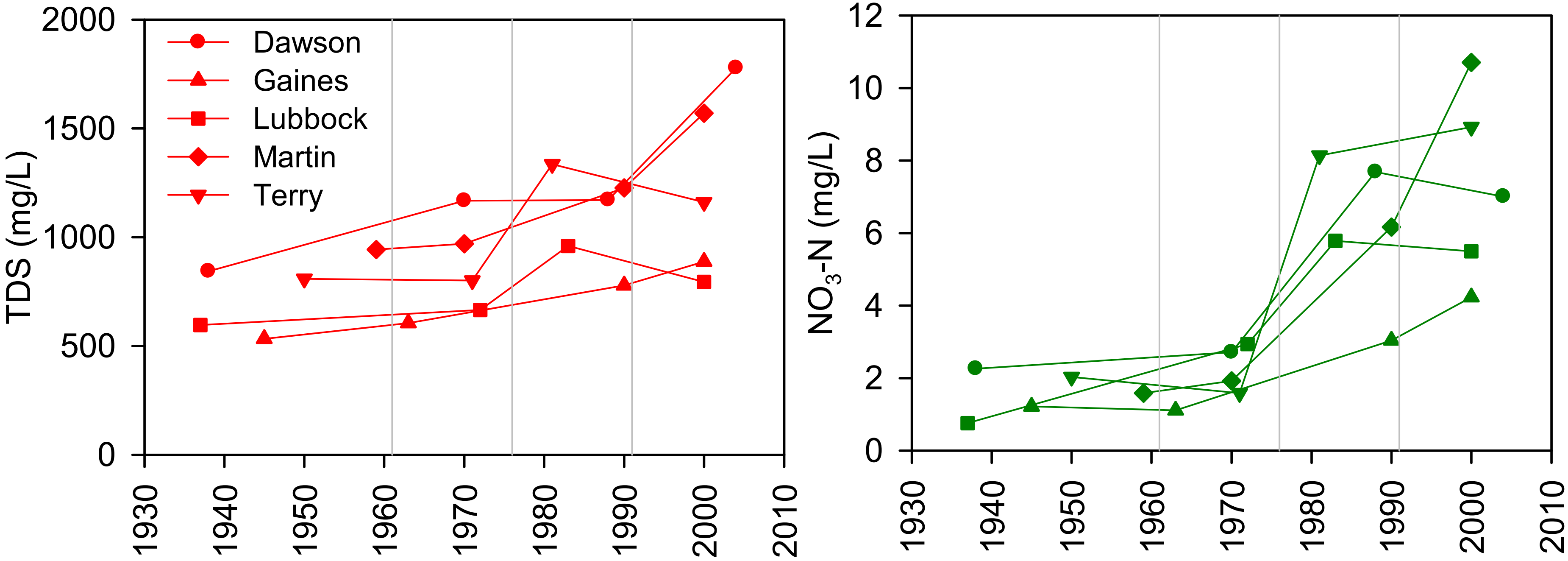


Impact of Mobilizing Salt Inventories by Increased Recharge under Rain-fed Agriculture

Min. Saturated Thickness (6 m)

- Cl ↑ by ~ 700 mg/L
- SO_4 ↑ by 860 mg/L
- TDS ↑ by ~ 2500 mg/L
- ClO_4 ↑ by 18 ug/L
- NO_3-N ↑ by 42 mg/L

Groundwater Solute Hydrographs



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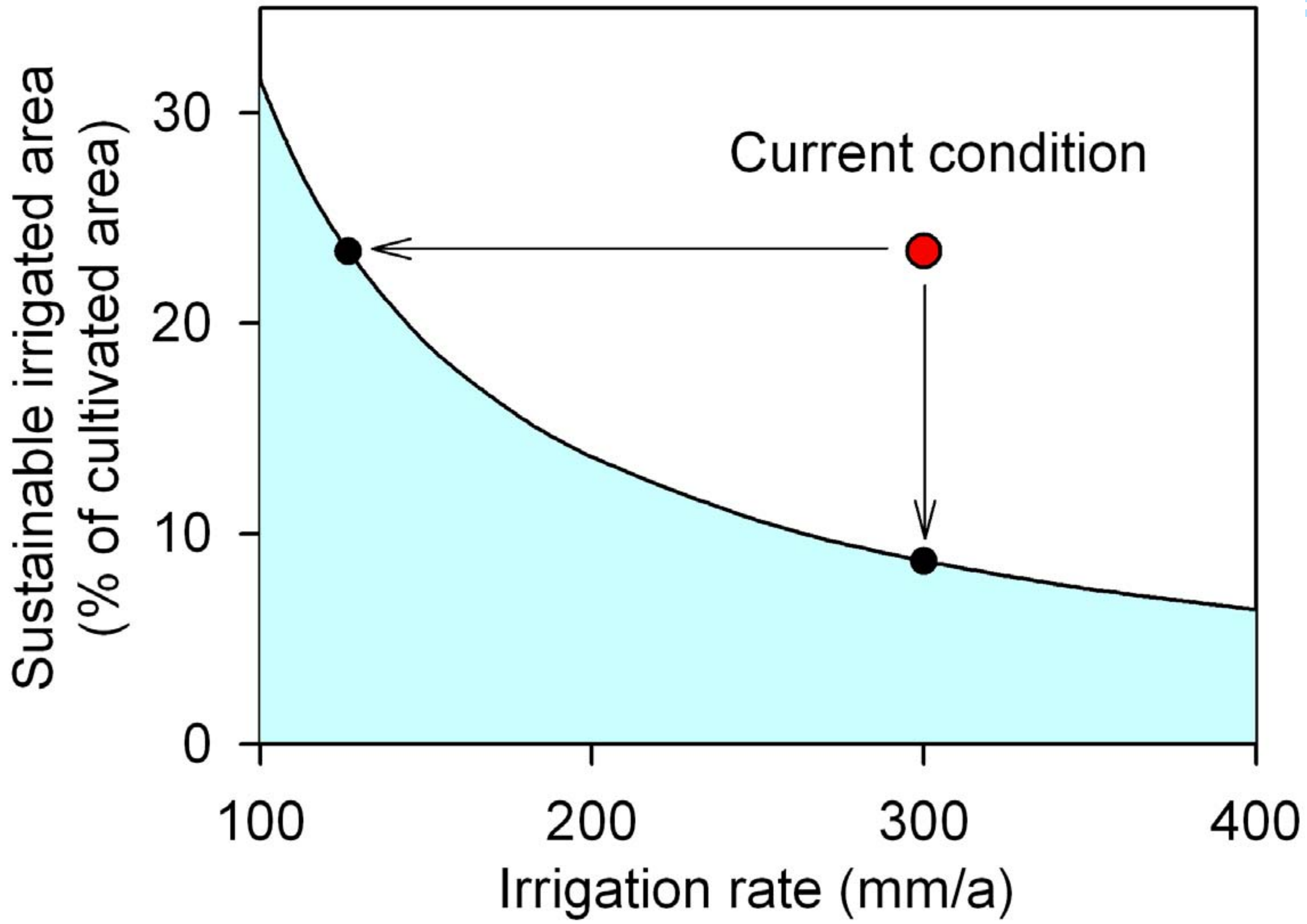
Sustainable Irrigation in the South



Sustainable Practices from Water Quality Perspective

- To reduce salt buildup in soils, need to irrigate with more water
- To reduce N leaching, need to reduce N application, account for N in irrigation water
- Grow winter cover crop to take up N
- To reduce groundwater degradation, need to rotate between irrigated and rain-fed agriculture

Summary

- Large salt accumulations under rangeland from long-term drying since Pleistocene
- Rain-fed agriculture:
  - increases recharge to median 24 mm/yr
  - flushes salts into aquifer
- Irrigated agriculture:
  - Recharge similar to rain-fed agriculture
  - Continues to flush salts that accumulated under native vegetation
  - Accumulates salts in soil profile
  - Redistributes salts from groundwater to soil water
  - Recirculating salts will increase concentrations in groundwater depending on saturated thickness or assimilative capacity
  - Introduced salts, such as nitrate, will continue to increase if applications continue