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?
Water-level Changes
~ 1950s - 2007

Declines in SHP-N
30 m over 11,000 km²
2% of area of HP
21% of change in water storage

McGuire et al., 2009
Percent Change in Aquifer Saturated Thickness

~1950 – 2007

McGuire et al., 2009
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
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

![Graphs showing salt distribution](image_url)
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

Water Table Depth 30 m
Saturated Thickness 15 m

Time since cultivation began (yr)

Groundwater TDS (mg/L)
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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Large water-level declines in irrigated areas in north
Representative Hydrographs in Irrigated Regions

Profile 2
Hale County

Profile 6
Lubbock County

Profiles 3, 4, & 12
Terry County

Profile 5
Dawson County
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?

50% 95%
Profiles under Irrigated Sites

Cl (mg/L)

Depth (m)

ClO₄⁻ (µg/L)

NO₃-N (mg/L)

SO₄ (mg/L)

Lub08-01
Profiles under Irrigated Sites

![Profiles under Irrigated Sites](image)
Impact of Mobilizing Salt Inventories by Increased Recharge under Rain-fed Agriculture

Min. Saturated Thickness (6 m)

- $\text{Cl} \uparrow$ by $\sim 700$ mg/L
- $\text{SO}_4 \uparrow$ by 860 mg/L
- TDS $\uparrow$ by $\sim 2500$ mg/L
- $\text{ClO}_4 \uparrow$ by 18 ug/L
- $\text{NO}_3$-N $\uparrow$ by 42 mg/L
Groundwater Solute Hydrographs

- **TDS (mg/L)**
  - Dawson
  - Gaines
  - Lubbock
  - Martin
  - Terry

- **NO₃-N (mg/L)**
  - Dawson
  - Gaines
  - Lubbock
  - Martin
  - Terry
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Sustainable Irrigation in the South

The diagram illustrates the relationship between sustainable irrigated area (% of cultivated area) and irrigation rate (mm/a). The current condition is marked by a red dot, indicating a high irrigation rate and a lower sustainable area. The black dot represents a scenario with a lower irrigation rate achieving a higher sustainable area.
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