Effect Of Brush Vegetation On Deep Drainage Using Chloride Mass Balance

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Introduction:

Groundwater is Earth's largest freshwater resource. Reduced reliability of surface water supplies in the Western U.S. with projected climate change during the next century may result in increased reliance on groundwater. Quantifying the current rate of groundwater recharge is a prerequisite for efficient and sustainable groundwater resource management in these dry areas where such resources are often the key to economic development. Environmental tracers such as Cl^- are produced naturally in the Earth's atmosphere and are used to estimate recharge rates. Chloride mass balance (CMB) (Allison and Hughes, 1978) has been used to estimate ancient recharge, but recharge from recent land-use change has also been documented, specifically where vegetation has been altered and deep-rooted species replaced with shallow-rooted grasses or crops (Allison et al., 1990, Scanlon et al., 2005). Since Cl^- is a conservative tracer (Davis et al., 1998) and most plant species do not take up significant quantities of Cl^- from soil water, water flux can be estimated from the degree of Cl^- enrichment in pore water as a result of evapotranspiration relative to the Cl^- concentration in precipitation (Scanlon, 2000).

Objectives:

- To assess the hypothesis that removal of woody-shrub vegetation and replacement with grasses increase deep drainage.
- To quantify the amount of deep drainage and "potential" groundwater recharge upon changes in land-use.
- To provide science-based data for a better understanding of changing land-use impacts on deep drainage.

Materials and Methods:

Sites description and sampling:

- Eight sites (soils) from five locations in West Texas were selected (Fig. 1 and 2). One location (two sites) was in Nolan County and four locations (six sites) in Taylor County. Mean annual precipitation is 598 and 619 mm and potential evapotranspiration is 1727 and 1631 mm for the county seats of Sweetwater and Abilene, respectively. Each location consisted of a pair of similar soils with contrasting vegetative cover, one dominated by woody-shrub (S) vegetation and the other where the woody-shrub vegetation had been cleared and grasses (G) are now present.

Fig. 1. Location of Nolan and Taylor Counties, TX.

Fig. 2. Location of paired and non-paired sites.

- Bulk samples, clods for bulk density, and portions for *in situ* water content were taken after the soils were described by horizon. Samples were taken and composited by horizon; horizons were split when their thickness exceeded 0.25 m.

Chloride extraction:

- Chloride was extracted by adding 20 ml of ultra-pure water to a 10-g sample of air-dried, ground soil. Extracts were analyzed by ion chromatography.

Chloride deposition:

- Chloride deposition rate for a 25-year period was interpolated as 0.22 mg L^{-1} in precipitation from the nearest NADP monitoring sites.

Inference:

- Soil Cl^- profiles were constructed for each site. The CMB for a soil profile at steady-state is:

$$R = P(Cl_p)/(Cl_s)$$

where R is the rate of deep drainage (mm yr^{-1}) to a depth of interest, P is precipitation (mm yr^{-1}), Cl_p and Cl_s are Cl^- concentrations (mg L^{-1}) in P and soil water, respectively.

- Comparison of variables such as soil moisture flux (deep drainage if below 200 cm), depth to maximum Cl^- concentration, maximum Cl^- concentration, cumulative Cl^- mass, and CMB ages to a depth of interest for paired sites were performed.

Results and Discussion:

Table 1. Summary of geochemical measurements and deep drainage estimates.

Property	S1	G2	S3	G4	S5	G6	G7	S8
Depth of sampling[a] (cm)	363	375	370	362	350	330	230	218
Cl^-, max (mg L^{-1})	8945	1336	102	16418	4516	192	1218	3272
Br^-, max (mg L^{-1})	26	5	NA	68	20	NA	NA	30
Total Cl^- to depth (g m^{-2})	3870	316	28	1961	1986	48	40	144
CMB age to depth (yr)	28165	2298	207	14781	14973	352	291	1049
Cl^-** (mg L^{-1})	7811	963	54	4803	3188	106	181	3272
Moisture flux (mm yr^{-1})	0.02	0.1	2.6	0.03	0.04	1.3	0.8	0.04
Mass Cl^-/Br^- ratio	356	154	NA	198	261	NA	NA	95
Correlation coefficient Cl^-, Br^-	0.98	0.97	NA	0.97	0.94	NA	NA	0.99

[a] Depth of sampling at which total Cl^- and CMB ages are reported

**Depth-weighed Cl^- concentration below 200 cm

NA, not available due to Br^- concentrations in soil-water extracts that were below the analytical detection limits.

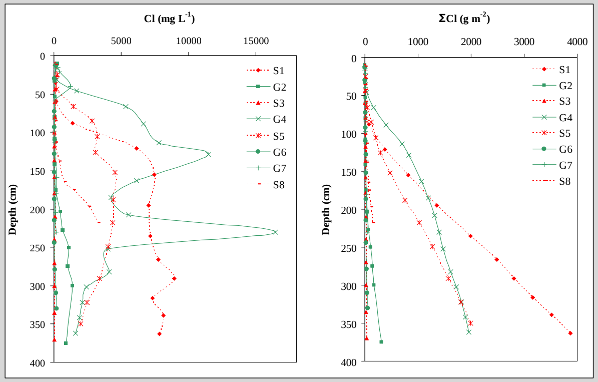

Fig. 3. Soil water Cl^- concentration and cumulative Cl^- mass with depth.

- Chloride profiles displayed wide variability in their maximum Cl^- concentrations.
- Lower Cl^- concentrations for grasslands (G2, G6, and G7) as compared to shrublands (S1, S5, and S8) and the greater depth of the Cl^- peak for grassland sites were observed.
- Both characteristics suggest that enhanced percolation since land clearing may be responsible for the downward solute front displacement and reductions in soil Cl^- concentrations.
- Estimated deep drainage under grassland settings ranged from 0.1 to 1.3 mm yr^{-1}; largely in response to low Cl^- concentrations.
- Deep drainage rates below 200 cm for shrublands were negligible due to high Cl^- concentrations.
- Apparently juniper woodlands appeared capable of allowing deep water percolation (2.6 mm yr^{-1}) as suggested by the S3 site.

Conclusions:

- Common features for three out of four shrubland sites included: (1) sharp increases in Cl^- concentration with depth and high Cl^- concentration gradients, (2) maximum Cl^- concentrations ranging from 3,272 to 8,945 mg L^{-1} at varying depths, but usually at depths shallower than in grasslands, and (3) Cl^- concentrations of >2,000 mg L^{-1} below 200 cm, suggesting negligible soil moisture fluxes.
- Common features for three out of four grassland sites included: (1) lower Cl^- concentrations (<1,400 mg L^{-1}) and Cl^- concentration gradients than shrublands, (2) maximum Cl^- concentrations ranged from 192 to 1,336 mg L^{-1} at depths >300 cm, and (3) downward displacement of solute fronts in the profile (>300 cm) possibly due to enhanced water percolation.
- Results underscore the ability of vegetation to regulate subsurface flow and indicate that changes in vegetation are likely to impact groundwater recharge.

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