•Woody plant encroachment has occurred in grass-dominated ecosystems around the world during the past century due to livestock grazing and fire suppression .
•Consequences include alterations of above- and belowground productivity, changes in the quality of litter inputs, modifications to rooting depth and distribution, and changes in hydrology and energy balance.
•Many of the encroaching woody species are symbiotic N_2 fixers that add N to N-limited ecosystems.
•Alterations in ecosystem properties and processes following woody encroachment into grasslands have strong potential to modify soil C and N storage.

Vegetation, Land Use History, and Patterns of Soil Organic Carbon in the Southern Great Plains

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Background

- Woody plant encroachment has occurred in grass-dominated ecosystems around the world during the past century due to livestock grazing and fire suppression .
- Consequences include alterations of above- and belowground productivity, changes in the quality of litter inputs, modifications to rooting depth and distribution, and changes in hydrology and energy balance.
- Many of the encroaching woody species are symbiotic N_2 fixers that add N to N-limited ecosystems.
- Alterations in ecosystem properties and processes following woody encroachment into grasslands have strong potential to modify soil C and N storage.

Significance

- Woody encroachment adversely affects 20% of the world's population by jeopardizing the sustainability of livestock grazing systems.
- Prescribed fire, root-plowing, shredding and herbicides have been used to control woody proliferation. These management strategies also have strong potential to alter soil C and N.
- Despite potentially large impacts of woody encroachment and efforts to control it on ecosystem structure and function, little is known about how these phenomena influence the size and distribution of soil C and N pools.

Objective

Evaluate the impact of woody encroachment and herbicide treatment on the distribution and abundance of SOC and total N in a mixed-grass mesquite savanna in the Rolling Plains region of north-central Texas.

Hypotheses

- SOC and total N will be higher in soils beneath woody plant canopies compared to grass-dominated inter-canopy zones.
- Encroachment by deep-rooted mesquite trees will increase SOC and total N in deeper portions of the soil profile.
- Herbicide treatment of shrubs will cause a decline in SOC and total N, and reduce storage of SOC and total N in the deeper portions of the profile.

Study Area

- **Location:** Waggoner Ranch (33° 51′ N, 99° 27′ W; elevation = 350-400 m) in the eastern Rolling Plains region of north-central Texas near Vernon.
- **Climate:** Semi-arid continental (MAP = 665 mm; MAT = 17°C).
- **Soils:** Alluvial clay loams (fine, mixed, thermic Typic Paleustolls - Tillman series).
- **Vegetation:** Mixed-grass mesquite savanna (mixture of C_3 and C_4 grass species in the herbaceous layer, and honey mesquite (*Prosopis glandulosa*) in the tree layer).

Experimental Design

The entire study area was sprayed with 2,4,5,-T in 1965. This herbicide caused significant topkill and reduced mesquite canopy cover, but most plants subsequently regenerated via basal sprouting. In 1977, this same area was subdivided into plots that received no further herbicide treatment (controls; N = 2; Fig.1), and plots which received aerial application of Triclopyr + Clopyralid (1:1 mix) in 1979 (N = 4; Fig. 2). At the time of this study in 1998, mesquite cover was 55% on control plots and 24% on Triclopyr + Clopyralid plots.

Fig. 1. Ground-level and aerial photos (taken in 2000) of a control plot treated with 2,4,5-T in 1965 (photos-J. Ansley)

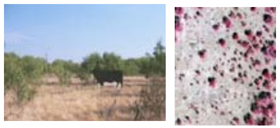

Fig. 2. Ground-level and aerial photos (taken in 2000) of a plot treated with Triclopyr+Clopyralid in 1979 (photos-J. Ansley)

Methods

- Soil cores (1.5 m deep) were collected in 1998 in controls and in areas that were treated with Triclopyr + Clopyralid in 1979. In both treatments, soils were collected under mesquite tree canopies and in grass-dominated intercanopy zones.
- Cores were divided into 10 cm depth increments, and bulk density determined by the core method.
- Soils were passed through a 2 mm sieve, pulverized, and analyzed for %C, %N, $\delta^{13}C$, and $\delta^{15}N$ using an elemental analyzer/mass spectrometer.

Results

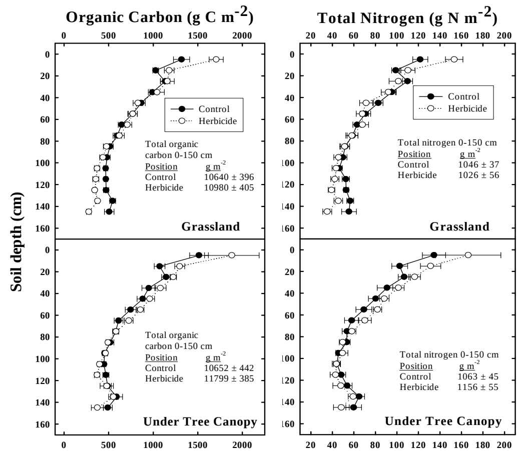

Fig. 3. SOC and soil total N in control vs. herbicide-treated plots, and in open grassland vs. under mesquite tree canopies. Each dot is the mean ± S.E. of 10 replicate soil cores.

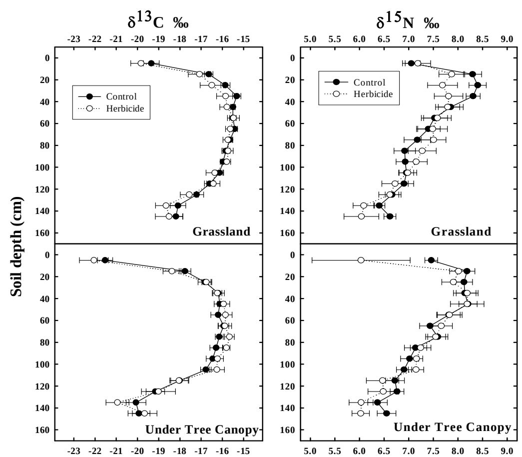

Fig. 4. $\delta^{13}C$ of SOC and $\delta^{15}N$ of soil total N in control vs. herbicide-treated plots, and in open grassland vs. under mesquite trees. Each dot is the mean ± S.E. of 10 replicate soil cores.

Table 1. Effects of herbicide treatment, vegetation type, soil depth, and their interactions on soil organic C, total N, $\delta^{13}C$, and $\delta^{15}N$. The experimental design was a split plot with herbicide treatment as the main plot and vegetation type as the split plot. Soil depth was treated as a repeated measures variable.

Source of variation	Soil organic C	Soil total N	$\delta^{13}C$	$\delta^{15}N$
Herbicide Treatment	NS	NS	NS	NS
Vegetation Type	**	*	***	NS
Soil Depth	***	***	***	***
Herbicide x Vegetation Type	*	NS	NS	NS
Herbicide x Soil Depth	***	***	NS	NS
Vegetation x Soil Depth	NS	NS	***	NS
Herbicide x Vegetation x Soil Depth	NS	NS	NS	NS

NS = not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Conclusions

- Soils beneath mesquite trees stored 10-15% more SOC and total N in the 0-10 cm depth than those under grassland; however, vegetation type had little effect on SOC at depths >10 cm (Fig. 3).
- $\delta^{13}C$ values suggest the additional SOC stored under mesquite canopies was primarily from C_3 plants (i.e. mesquite) rather than C_4 grasses present in the understory (Fig. 4).
- Interactions between herbicide treatment (HT) and soil depth occurred because HT increased SOC and total N by 15-30% in the upper 20 cm of the profile under both grassland and mesquite. In contrast, HT reduced SOC and total N by 20-45% at depths >100 cm in grasslands, but not under mesquite canopies (Fig. 3).
- $\delta^{13}C$ values indicated that herbicide-induced shifts in SOC were not due to shifts in the relative importance of SOC inputs derived from C_3 vs. C_4 plants (Fig. 4).
- Counter to expectations, reductions in mesquite cover by herbicide application 20 y ago elevated rather than decreased SOC and TN in the upper 20 cm of soil. This may reflect a combination of herbicide –induced inputs of shrub litter and stimulation of grass production that more than compensated for reductions in shrub production.
- Woody encroachment and efforts to manage it with herbicides clearly have the potential to influence SOC and total N storage and distribution in the upper 1.5 m of the profile. Additional studies are required to determine the mechanisms responsible for these observed changes.