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Vegetation changes ten years after contour furrowing in a Short Grass Prairie at northern Sonora, Mexico

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Abstract

Large areas of short grasslands have undergone vegetational changes in northern Mexico. Overgrazing, droughts, fire reduction, and climate are among the main factors responsible for these changes. This study was conducted in Cananea, Sonora, Mexico, to compare vegetation changes in *Bouteloua-Aristida* grassland under regular conditions, with and without contour furrowing. Contour furrows, 3 m wide at the base and 1 m tall, were constructed at 30 cm elevation intervals using a disk furrower pulled by a D-6 bulldozer. The topography at the site is characterized by flat ranges with less than a 5% slope. Soils have a deep loamy sand texture. The climate is semi-warm and dry, with a mean annual precipitation of 425 mm and an average temperature of 15 °C. Changes were measured in three permanent plots of 400 m² each. Plant density, height, basal coverage, and forage production were monitored during the summer from 2013 to 2022 in ten permanent quadrants of 1 m² each per plot. A randomized block design was used, and the data were analyzed by ANOVA ($P \leq 0.05$). Precipitation was near average for 4 years, below average for 3 years, and above average for 3 years. All variables were higher ($P \leq 0.05$) in the contour furrowed areas than in the control plots. Plant density averaged 10.7 plants/m² in the control plots and increased by 116.8% ten summers after treatment in the contour furrowed areas. Plant cover increased by 67.5% in the same plots, and plant height increased by 47% ten summers after treatment in the contour furrowed plots. Total annual forage production averaged 635.8 kg D.M. ha⁻¹ in the control and 1,546.5 kg D.M. ha⁻¹ in the contour furrowed areas, resulting in an increase of 143.2%. We conclude that water harvesting through contour furrowing is an effective method to promote the establishment, development, and productivity of native grass species in short grass prairies.

Introduction

Overgrazing, climate change and severe droughts have caused strong changes in rangelands where a reduction in vegetation cover and an increase in the loss of soil and water through runoff can be seen. Grasslands are plant communities where short and medium-sized grasses predominate with few trees and shrubs (Holechek et al., 2010). They are of ecological and economic importance and constitute strategic areas for the North American livestock industry. Most grasslands are used for raising cattle, horses and large and small wildlife and are considered sources of food, fiber and fuel, contributing to climate regulation, pollination, purification and recharging of aquifers, control of invasive species and carbon sequestration (Milchunas and Lauenroth, 1993; CONABIO, 2023).

Water is a fundamental element to produce forage and for livestock farming, since it is a vital input for the nutrition of animals and for the pasture and irrigation of crops, so the availability of water and the production of food is the main concern for the future of the human population. We believe Short Grass Prairies in regular condition require only the application of water conservation practices to restore productivity. This study was conducted in Cananea, Sonora, Mexico, to compare vegetation changes in a *Bouteloua-Aristida* grassland under regular condition, with and without contour furrowing during a 10-year period.

Methods

The study was carried out during the summers of 2013 to 2022 at the Experimental Ranch of the University of Sonora, located 15 km east of the city of Cananea, Sonora, (30° 58'00" Lat. N and 110° 08'30" Long. W). In a short grass prairie in fair condition, at an elevation of 1,417 meters above sea level, with relatively uniform topography with flats and low hills, slopes that vary from 3 to 7%. The soil type corresponds to haplic chestnut with a sandy loam texture and an average depth greater than 50 cm. The climate is temperate semi-dry BS1 kw (x') (e'). The average annual precipitation and temperature is 425 mm and 15 °C, respectively (García, 1973). The vegetation is composed of native grasses of the *Bouteloua-Aristida* genera (COTECOCA, 1988). An area of 1 ha surface was selected, where 6 experimental plots (20 x 20 m) each were randomly chosen, 3 in areas with level furrows and 3 in untreated flat areas (control), excluding grazing. The furrows 3 m at the base and 1 m high were built on contour lines at intervals of 30 cm in height, with an 8-36" diameter disk furrower pulled by a D6 bulldozer. Main grass species in the study area were: Blue grama *Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths., Sideoats grama *Bouteloua curtipendula* (Michx.) Torr., Sprucetop grama *Bouteloua chondrosioides* (Kunth) Benth. ex S. Wats., Green sprangletop *Leptochloa dubia* (Kunth) Nees, Common wolfstail *Lycurus phleoides* Kunth, and Sixweeks Threawn *Aristida adscensionis* L. (Rendowski, 2006).

Variables evaluated were plant density, basal cover, height and biomass production. Plant density, basal cover and height were monitored during the summers of 2013 to 2022, in ten permanent quadrats 1 m² per plot. Plant density and basal cover were estimated for each species by counting the total number of plants and the sum of their crowns, respectively. Height was determined by measuring the length of the plants from the soil surface to the apex. Forage production was estimated by clipping in 10 quadrats of 1 m² distributed randomly by plot, species and total production. For the determination of dry matter, the forage samples were dried in a forced air oven at 60 °C for 72 hours. A completely randomized block design was used with two treatments and three repetitions (Steel and Torrie 1980). All variables were analyzed by ANOVA (P<0.05), using Duncan's Multiple Range test for the comparison of means. Statistical analyzes were conducted using the SAS package (SAS, 1988).

Results

Precipitation was near average for 4 years, below average for 3 years, and above average for 3 years. All variables were higher (P<0.05) in the contour furrowed areas than in the control plots. Plant density

averaged 10.7 plants/m² in the control plots and increased by 116.8% ten summers after treatment in the contour furrowed areas. Plant cover increased by 67.5% in the same plots, and plant height increased by 47% ten summers after treatment in the contour furrowed plots. Total annual forage production averaged 635.8 kg D.M. ha⁻¹ in the control and 1,546.5 kg D.M. ha⁻¹ in the contour furrowed areas, resulting in an increase of 143.2% (Table 1). Forage production of main grass species was consistently greater ($P \leq 0.05$) on plots where water was harvested and varied from 25.4 to 204.3 kg of dry matter (DM)/ha on untreated plots and varied from 134.4 to 318.3 kg of dry matter/ha on contour furrowing plots. Biomass of individual grass species was consistently increased from 18.9 to 64.18% on the contour furrowing plots (Table 2).

Table 1. Plant density, basal cover, plant height and biomass production of range grasses in a short grass prairie ten years after contour furrowing at Northern Sonora, Mexico.

Variables	Contour Furrowing	Untreated Check	Percent of change
Plant density (p/m ²)	23.2 a	10.7 b	116.8
Basal cover (%)	16.08 a	9.6 b	67.5
Plant height (cm)	96.46 a	65.62 b	47.0
Biomass Production (kg DM/ha ⁻¹)	1,546.50 a	635.8 b	143.2

** Means between treatments with different lowercase letter are different ($P \leq 0.05$).

Table 2. Total Forage production (kg DM/ha⁻¹) of several grass species at a short grassland with and without contour furrowing after ten years of treatment at Northern Sonora, Mexico.

Species	Contour Furrowing	Untreated Check	Percent of change
Blue grama	264.5 a	148.6 b	56.18
Sideoats grama	318.3 a	204.3 b	64.18
Sprucetop grama	234.7 a	77.5 b	33.02
Green sprangletop	249.1 a	92.5 b	37.13
Common Wolfstail	147.0 a	30.7 b	20.88
Sixweeks Threawn	198.5 a	56.8 b	28.61
Others	134.4 a	25.4 b	18.89
Total	1,546.5	635.8	

* Means between treatments with different lowercase letter are different ($P \leq 0.05$).

Discussion

The purpose of creating contour furrow is to control the surface runoff and increase vegetation establishment and forage productivity. The runoff water is stored in soil profile for plant growth during prolonged periods of moisture stress (Kugedera et al., 2018). Studies conducted with sorghum in Kenya show that the increase in soil moisture content accelerated the crop growth, leaf size, panicle length, number of tillers and above-ground biomass yield (Mwami et al., 2024). Appropriate application of *in situ* and micro-catchment techniques could improve the soil water content of the rooting zone by up to 30% (Biazin et al., 2012). It has been shown that soil and water conservation practices reduce runoff and increase the water content in the soil by 13 to 22% up to one meter deep (Mondaca et al., 2024).

In this study all grass species on disk furrowed plots showed greater plant density, height, basal cover as well as greater forage production as compared to the control. Similar results are reported by Ali et al. (2010), suggesting that water harvesting in micro-structures in the soil captures excessive runoff for subsequent use by plants, helping the development of roots and foliage and reducing the mortality rate of new seedlings. Other studies carried out in Jordan show that forage production increased from 380 to 1,151 kg ha⁻¹ with the use of water retention practices (Abu-Zanat et al., 2004). Traditional *in situ* water harvesting improves soil moisture retention by 59% and effectively reduces runoff by 53% and soil loss by 58.66%,

demonstrating their robust water and soil conservation benefits (Tefera et al., 2024). In Sudan, increases of 2.25 to 3.65 tons ha⁻¹ of forage are reported in rangelands with rainwater retention, compared to the control with 0.65 tons ha⁻¹ (Ezzat et al., 2013).

Conclusion

Contour furrowing in soils of Short Grass Prairies favored the density, basal growth and height of grasses, which together, increased the individual and total forage production of the pastures. The practice allowed the capture and conservation of additional water. Rainwater harvesting resulted in an increase in the biomass production of plants in soils with high runoff potential, thereby increasing soil cover and the production potential for feeding livestock and wildlife. Water harvesting through contour furrowing is an effective method to promote the establishment, development, and productivity of native grass species in Short Grass Prairies.

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