

# Impact of 22-Year Rotational Grazing on the Soil Cover of a Grassland in Northern-Central Mexico

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## ABSTRACT

**Objective:** To evaluate the impact of 22-year rotational grazing on the soil cover change of a grassland in the northern-central region of Mexico.

**Design/Methodology/Approach:** In 2000, two transects were established in a grassland to measure soil and vegetation properties. The transects were established at the same time than the rotational grazing. Subsequently, additional information corresponding to 2002, 2003, 2004, 2005, and 2022 was registered. Each variable was subjected to an analysis of variance to identify the effect of rotational grazing.

**Results:** Rotational grazing increased the plant base, leaf litter cover, and soil cover, while it reduced bare soil and mature crust.

**Study Limitations/Implications:** Only few ranchers use rotational grazing in this region; consequently, no more ranches were included in this study.

**Findings/Conclusions:** Rotational grazing was fundamental to improve soil cover in the grassland. The increase of the plant base of perennial plants was associated with a precipitation increase.

**Keywords:** Plant base, leaf litter, soil cover.

**Citation:** Márquez-Madrid, M., Valdez-Cepeda, R. D., & Blanco-Macías, F. (2026). Impact of 22-Year Rotational Grazing on the Soil Cover of a Grassland in Northern-Central Mexico. *Agro Productividad*. <https://doi.org/10.32854/wmtr3044>

**Academic Editor:** Jorge Cadena Iñiguez

**Associate Editor:** Dra. Lucero del Mar Ruiz Posadas

**Guest Editor:** Juan Francisco Aguirre Medina

**Received:** May 16, 2025.

**Accepted:** December 28, 2025.

**Published on-line:** March XX, 2026.

*Agro Productividad*, 19(1), January, 2026. pp: 79-87.

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## INTRODUCTION

Native plants from grasslands mainly consist of grasses, grass-like plants, weed, and shrubs. Grasslands provide different ecosystem services and benefits to humans, including forage for cattle (Goodwin *et al.*, 2023).

Natural grasslands cover 4.9% (9,578,430 ha) of the Mexican territory (SEMARNAT, 2019) and are mainly located in its northern-central region. The cow-calf production system predominates in this area. This system consists of a continuous grazing, where animals have constant and unrestricted access to grasslands during a given period or the whole year. This system can make excessive use of certain areas and can potentially lead to overgrazing (Teague *et al.*, 2011).



In large paddocks, cattle graze selectively and tend to use preferred areas, consequently, increasing the animal load in those areas. When this type of grazing pattern is repeated year after year, a progressive deterioration of grassland takes place. This situation worsens during drought periods (Teague *et al.*, 2011; Wang *et al.*, 2020). Worldwide, grasslands have suffered a notorious degradation and desertification, as a consequence of the inappropriate use by humans (Teague and Dowhower, 2022).

In Mexico, deteriorated grasslands cover 3,794,283 ha, accounting for 39.61% of the natural grasslands (CONABIO, 2021). This situation leads to an increase of bare soils, erosion, and runoffs. In addition, it reduces infiltration, forage capacity, and ecosystem resilience (Teague *et al.*, 2013; Wang *et al.*, 2020).

Rotational grazing is an alternative to continuous grazing (Lawrence *et al.*, 2019, Wang *et al.*, 2022). This system consists of using fences to divide grasslands into several paddocks. Afterwards, cattle are moved between paddocks on a scheduled basis (Sandhage-Hofmann, 2023). The aim is to follow short grazing periods which involve a large animal load with long break periods in which plants and soil can rest and recover (Lawrence *et al.*, 2019).

Rotational grazing efficiently improves the use of resources from grasslands and prevents the deterioration caused by overgrazing (Xiaoyan *et al.*, 2019). In some countries, the benefits of rotational grazing in commercial cattle ranches have been clear for many years (Teague *et al.*, 2008). In the United States of America, particularly in California and Wyoming states, two thirds of the surveyed cattle-raisers used rotational grazing and reported more ecological, economic, and social benefits than cattle-raisers that used continuous grazing (Roche *et al.*, 2015). Likewise, cattle-raisers from the northern-central region of Texas that used eight or more paddocks reported more ecological improvements in their grasslands than cattle-raisers that used continuous grazing (Becker *et al.*, 2017). However, some studies suggested that, unlike continuous grazing, rotational grazing—which uses multiple paddocks— does not improve vegetation and animal production (Briske *et al.*, 2008; Chowdhury *et al.*, 2020). The debate on the superiority of rotational grazing over continuous grazing is still on. The champions of both systems agree that carrying out comprehensive research is required to optimize management decisions regarding grazing (Harmel *et al.*, 2021). In addition, Rouquette *et al.* (2023) pointed out that grazing systems must be considered as “a work in progress”. Consequently, this research focused on the evaluation of the impact of 22-year rotational grazing on the soil cover change of a grassland in the northern-central region of Mexico.

## MATERIALS AND METHODS

### Study Area

The research was conducted in La Copa Ranch, located in the municipality of Sombrerete, Zacatecas, México (23° 39' 09" N and 103° 27' 49" W, 23° 39' 36" N and 103° 26' 59" W, 23° 40' 15" N and 103° 27' 23" W, and 23° 39' 42" N and 103° 28' 18" W, and 2,261 m.a.s.l.). The ranch has an irregular topography, with small plains and low hills. The ranch has shallow limestone soils, with a sandy texture. The region has a medium dry climate, with summer rains (BS<sub>1</sub>kw), a mean annual precipitation of 462.9

mm, and a mean annual temperature of 15.2 °C (CNA, 2023; García, 1981). This natural grassland mainly consists of foraging species (Poaceae) of the genera *Bouteloua* and *Aristida*. In addition, the presence of huizache (*Acacia farnesiana*) increased in the area, during the 22 years that lasted the research.

### **Grazing and Cattle Management**

La Copa Ranch has 406 ha (390 ha for grasslands and 16 ha for agriculture). Its grasslands were used for continuous grazing for many years. Rotational grazing started in 2000, with an Angus herd. The ranch had a grazing area of 11 paddocks and each paddock had an average of 35 ha. Cattle grazed for four days in each paddock during the fast-growing season of grass, followed by a 40-45-day break period. Meanwhile, during the low-growing season, cattle grazed 6-8 days, followed by a 60-80-day break period. The herd grazed in the grassland all year long. All the calves and some heifers were sold during weaning, when they were seven months-old. In addition, cull cows were commercialized to adjust the animal load to the forage production of each year, which changed depending on precipitation. The animal load of the ranch was flexible, recording 47, 51, 53, 69, 65, and 55 animals units during 2000, 2002, 2003, 2004, 2005, and 2022, respectively. During the dry season, feed was complemented with oat (*Avena sativa* L.) forage produced at the ranch.

### **Sampling Procedure**

Two monitoring transects were strategically distributed in the grassland. Monitoring sites were selected at random for each transect. The properties of several plant and soil were measured at each site. These properties included different percentages, including bare soil, leaf litter area, rock covered areas, perennial plant base, and soil cover area. In addition, on the bare soil area, the percentages of mature, immature, recent, and broken crust were recorded. The first measurement was conducted in 2000, the same year that rotational grazing started in the ranch. Subsequently, measurements were carried out in 2002, 2003, 2004, 2005, and 2022. In the Results section, these periods are mentioned as year zero (0), two (2), three (3), four (4), five (5), and twenty-two (22) of rotational grazing, respectively. In 2000, 2002, and 2004, 66 monitoring points were randomly selected for both transects, while in 2003, 2005, and 2022, 100 monitoring points were selected per transect. Monitoring was performed at the beginning of the autumn of all the years, using the Early Warning Biological Monitoring-Rangelands and Grasslands method (ASCHM, 1999).

### **Precipitation**

Precipitation values were analyzed to determine the annual surplus or deficit regarding the annual mean (462.9 mm) of the last 49 years of observation. The precipitation data were obtained from El Arenal weather station, managed by the Comisión Nacional del Agua (CNA, 2023). The weather station is located at 200 m from the northern border of the study area.

Rotational grazing in the ranch started in 2000. During the first two years (2000-2001) of the implementation of rotational grazing, annual precipitation was lower than the mean.

However, between 2002 and 2010, annual precipitation was higher than the mean. From 2011 to 2022 —except for 2015 and 2018—, annual precipitation was lower than the mean (Figure 1).

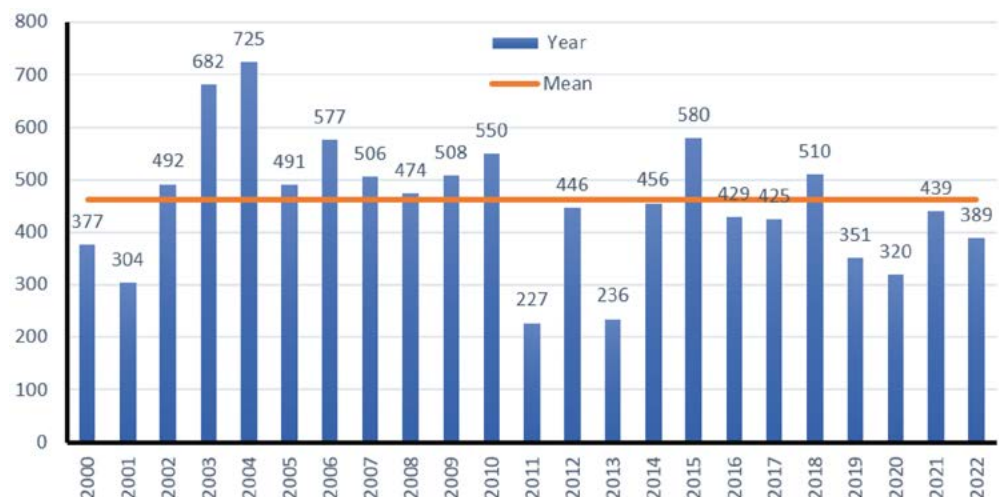
### Statistical Analysis

The response variables of the rotational grazing included the percentages of bare soil area, leaf litter area, rock covered area, perennial plant base, and soil cover area. In addition, the percentages of mature, immature, recent, and broken crust were determined. Each variable was subjected to an analysis of variance, taking into account the year as source of variation. The statistical analysis was conducted with the Minitab<sup>®</sup> 16 software, using the General Linear Model procedure. The Tukey's range test ( $\alpha=0.05$ ) was used to compare means, when significant effects were identified in any variable.

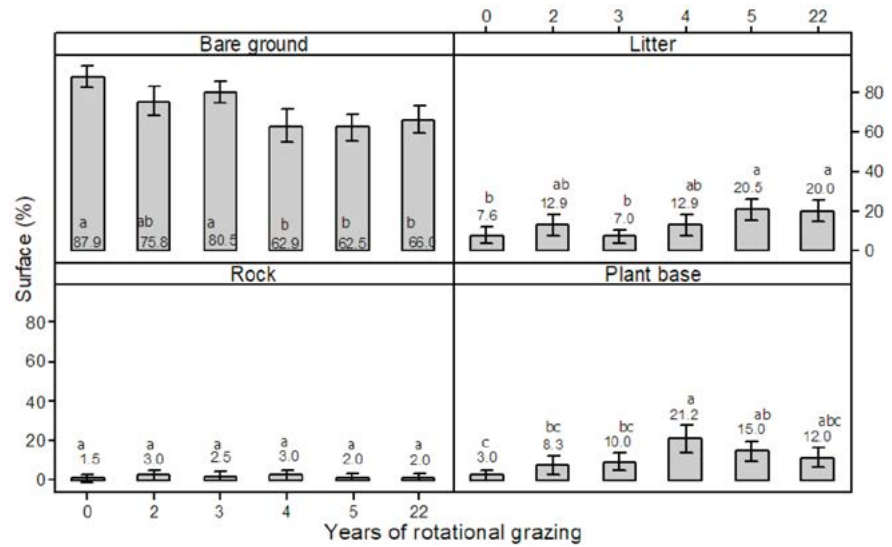
## RESULTS AND DISCUSSION

Significant differences ( $p<0.01$ ) were recorded in the rotational grazing (RG) implemented in La Copa Ranch (LCR), including bare soil area, leaf litter area, perennial plant base, soil cover area, mature crust area, immature crust area, recent crust area, and broken crust area (Figures 2 and 3). Rock covered area did not record significant differences (Figure 3).

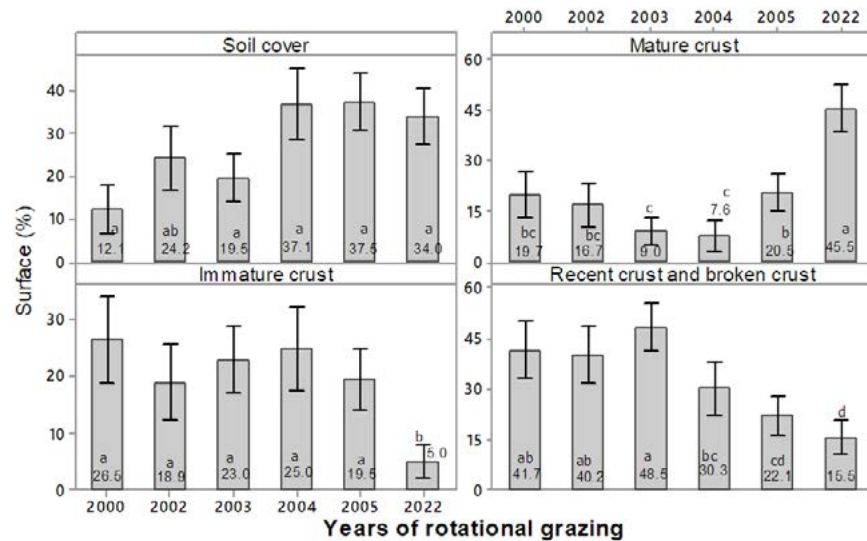
When the RG started, bare soil covered 87.9% of the LCR area. Four years later, that percentage decreased by 25 percentage points. This percentage recorded minimal differences from year 4 (62.9%) to year 22 (66%) (Figure 2). The reduction of bare soil area is the result of the increase of plant base area and leaf litter area during the study. The decrease of bare soil in the LCR was significant; however, the extension of bare soil remained significant. Teague et al. (2011, 2022) reported similar results. They pointed out that the RG implementation led to a bare soil area reduction.



**Figure 1.** Annual mean precipitation (mm) in the study area during the 2000-2022 period (CNA, 2023). The orange horizontal line (annual mean precipitation: 462.9 mm) is the climatological normal of the last 49 years.



**Figure 2.** Percentages of bare soil area, leaf litter area, rock covered area, and perennial plant base area in the LCR grassland, during 22 years of rotational grazing. Means with different letters are significantly different, based on Tukey’s test ( $p < 0.01$ ). The bars represent the mean  $\pm$  1 standard error.



**Figure 3.** Soil cover area, mature crust, immature crust, recent crust, and broken crust percentages on the grassland of La Copa Ranch, after 22 years of rotational grazing. Means with different letters are significantly different, based on the Tukey’s test ( $p < 0.01$ ). The bars represent the means  $\pm$  1 standard error.

The objective is to reduce the bare soil area. Bare soils increase the risk of erosion, as a consequence of the lack of coverage that softens the impact of rain drops (Teague *et al.*, 2011). This situation can lead to the formation of superficial crusts, which negatively affect infiltration rate and speed up the loss of organic matter (Smith *et al.*, 2012). In addition, the increase or loss of temperature can negatively impact infiltration and evaporation rates, nutrient retention, and biological functions essential for the correct functioning of the ecosystems (Teague *et al.*, 2011).

During this study, the area covered by leaf litter showed a growing trend. Five years after the RG started, the leaf litter cover had increased by 12.9%, changing from 7.6% to 20.5%. This percentage did not change until year 22 of the RG, recording only a slight reduction of 0.5% (Figure 2). Teague *et al.* (2011) recorded similar results, identifying the positive effect of rotational grazing on the increase of leaf litter area.

The impact of RG on the increase of leaf litter area is the result of the short grazing periods and the slight to moderate defoliation of the plants during the fast-growing season. This situation allows plants to remain in their best vegetative conditions, favoring a higher production level (Teague *et al.*, 2011). Consequently, the forage available surpasses the demand, resulting in a higher forage accumulation (Teague *et al.*, 2011). Meanwhile, during the low-growing season, cattle consume the accumulated forage and stamp on part of the leaves that will become leaf litter.

Leaf litter is fundamental for the grassland ecosystems. High leaf litter levels improve soil moisture retention and enhance and stabilize plant production (Deutsch *et al.*, 2010). Döbert *et al.* (2021) pointed out that rotational grazing helps leaf litter to improve the ecological processes of the grasslands, as it increases water infiltration by facilitating a more efficient incorporation of leaf litter into the soil surface, resulting in a better soil structure and a higher organic matter content.

The rock covered area of the grasslands was small ( $\leq 3\%$ ) and did not significantly change during the research (Figure 2). This area is a physical indicator that is hardly influenced by the management of the grassland or rainfall patterns.

At the beginning of the RG, only a small part (3%) of RLC was covered in plant base. After four years, it significantly increased, reaching a maximum of 21.2%. However, during year 5, the cover decreased by 6.2 percentage points and, after 22 years of RG, it decreased again by 3 percentage points (Figure 2).

During the first two years of RG, precipitation was lower than the annual mean (Figure 1). Along with the final impact of continuous grazing, it resulted in a small plant base area; however, the area covered by plants increased 21.2% during year four of RG. This situation suggests that both RG and the higher precipitation favored this increase.

Although precipitation during both periods was lower than the mean, the plant base area was notably greater after 22 years of RG than during the first two years. The plant base area reported in year 22 was the result of a long period of moisture deficit (2016-2022). Overall, precipitation recorded lower values than the annual mean, except for 2018 (Figure 1 and 2). These results match the findings of Teague *et al.* (2011, 2022), who reported that RG increased plant base.

An increase in the covered areas of foraging plants efficiently reduces soil erosion and improves rainfall infiltration (Teague and Kreuter, 2020). In addition, cover protects the soil from the impact of raindrops and influences plant production (Smith *et al.*, 2012). Areas covered with vegetation and leaf litter reduce temperature and decrease evaporation, improving growing conditions for plants and adding organic matter to the soil (Teague *et al.*, 2011).

The soil cover area showed a growing trend during the study period (Figure 3). At the beginning of the experiment, the soil cover area in the grassland was small (12.1%); after four years, a significant increase took place and, during year five, the highest percentage (37.5%) of soil cover area was recorded. However, during year 22 of RG, a 3.5 percentage points reduction was observed (Figure 3).

The increase of soil cover area could be the result of the increase of leaf litter and of the plant base area. These results are similar to those reported by Sanjari *et al.* (2009), who recorded an increase in soil cover with RG. These authors pointed out that this improvement in soil cover was the result of the effect of the long break periods of the RG, which provided a recovery and sprout opportunity during the humid seasons. In addition, McDonald *et al.* (2024, 2018) reported that the soil cover area increased after the adoption of rotational grazing. Furthermore, McDonald *et al.* (2024) recorded a higher soil cover area (57.9%) in plots where the annual mean precipitation was similar to the study area. These results could indicate that the soil cover area in the research can potentially increase. For their part, Leys *et al.* (2023) mentioned that soil cover areas reduce wind erosion.

Meanwhile, the physical crusts of the soil showed an irregular trend (Figure 3). At the beginning of the RG system, the soil of the grassland had 19.7% mature crust. However, four years later, it was smaller (7.6%). Nevertheless, a significant increase was recorded on year 22. The 12.1 percentage points reduction recorded during the first four years of RG are important, because mature crusts reduce the efficiency of hydrological cycles and mineral content in grasslands (Savory, 2005).

Rotational grazing includes small grazing periods with large densities of cattle, causing the herd effect that can break physical crusts and facilitate the integration of dead plant material into the soil (Savory, 2005). The immature crust area did not record significant changes during the first five years of RG (Figure 3). The smallest percentage (5.0%) was recorded on year 22 of RG.

The recent and broken crust area recorded higher percentages during the first years of RG. The maximum percentage was 48.5% and was recorded during year 3 (Figure 3). From that moment on, a significant decrease was reported, until a 15.5% crust cover was recorded on year 22 of RG (Figure 3).

The irregular trend recorded in the bare soil area condition —particularly regarding the presence of mature crust— matched the results reported by Döbert *et al.* (2023), who pointed out that stamping has a short-lived effect on soil crust.

Overall, the results of this research indicate a positive effect of rotational grazing on the soil of the grassland. Significant changes ( $p < 0.01$ ) were recorded regarding the bare soil area, plant base area, and soil cover variables from year 4 of RG; meanwhile, significant changes were reported for leaf litter in year 5.

The improved performance of the plant soil cover could be due to precipitation level that surpassed the annual mean. These results match the findings of Bartley *et al.* (2023), who pointed out that rotational grazing can improve vegetation, soil, and land condition, although it takes about 3-5 years or even longer to observe statistically significant improvements, particularly in degraded areas.

## CONCLUSIONS

Rotational grazing proved to be an important management practice to change the soil in the grassland of the study area. Rotational grazing increased covered by the plant base area, leaf litter area, and soil cover. At the same time, it decreased bare soil and mature crust. The positive changes in the soil cover area of the grassland were clear after 3-5 years of the implementation of rotational grazing. Subsequently, they kept improving. The increase of the perennial plant base area was associated with precipitation levels.

## REFERENCES

- Allan Savory Center for Holistic Management (ASCHM). 1999. Early Warning Biological Monitoring- Rangelands and Grasslands- Albuquerque, New Mexico. USA. Center for Holistic Management. 31 p.
- Bartley, R., Abbott, B. N., Ghahramani, A., Ali, A., Kerr, R., Roth, C. H., & Kinsey-Henderson, A. (2023). Do regenerative grazing management practices improve vegetation and soil health in grazed rangelands? Preliminary insights from a space-for-time study in the Great Barrier Reef catchments, Australia. *The Rangeland Journal*, 44(4), 221-246. <https://doi.org/10.1071/RJ22047>.
- Becker, W., Kreuter, U., Atkinson, S., & Teague, R. (2017). Whole-ranch unit analysis of multipaddock grazing on rangeland sustainability in North Central Texas. *Rangeland Ecology & Management*, 70(4), 448-455. <http://dx.doi.org/10.1016/j.rama.2016.12.002>.
- Briske, D. D., Derner, J. D., Brown, J. R., Fuhlendorf, S. D., Teague, W. R., Havstad, K. M., Gillen, R.L., Ash, A.J & Willms, W. D. (2008). Rotational grazing on rangelands: reconciliation of perception and experimental evidence. *Rangeland Ecology & Management*, 67(1), 3-17. doi: 10.2111/06-159R.1.
- Comisión Nacional del Agua (CNA). (2023). Base de datos de la precipitación pluvial (1970-2022) de la estación climatológica 'El Arenal'. Compartida por el Departamento de Hidrometeorología de la Dirección Local Zacatecas. Comisión Nacional del Agua.
- Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). 2021. Ecosistemas de México. Pastizales. Consultado en línea 30/08/ 2023. <https://www.biodiversidad.gob.mx/ecosistemas/pastizales>.
- Chowdhury, I. U. A., Wang, T., Jin, H., & Smart, A. J. (2020). Exploring the Determinants of Perceived Benefits of Rotational Grazing in the US Great Plains.
- Deutsch, E. S., Bork, E. W., & Willms, W. D. (2010). Soil moisture and plant growth responses to litter and defoliation impacts in Parkland grasslands. *Agriculture, Ecosystems & Environment*, 135(1-2), 1-9. doi:10.1016/j.agee.2009.08.002.
- Döbert, T. F., Bork, E. W., Apfelbaum, S., Carlyle, C. N., Chang, S. X., Khatri-Chhetri, U., Silva Sobrino, L., Thompson, R. & Boyce, M. S. (2021). Adaptive multi-paddock grazing improves water infiltration in Canadian grassland soils. *Geoderma*, 401, 115314. [tps://doi.org/10.1016/j.geoderma.2021.115314](https://doi.org/10.1016/j.geoderma.2021.115314).
- García, E. 1981. Modificaciones al sistema de clasificación climática de Köppen: para adaptarlo a las condiciones de la República Mexicana. UNAM.
- Goodwin, J., Porensky, L. M., Meiman, P., Wilmer, H., Derner, J. D., Iovanna, R., Monlezun, A. C., Vandever, M. W., Griggs, J., Price, F., Spiegel, S.A., Padilla, N., Voth, D., maher, A., O'Connor, R., Hoover, D. L., Pluhar, J., Estep, C. & Fox, W. (2023). Rangeland Ecosystem Services: Connecting nature and people. Society for Range Management. Rangeland Ecosystem Services. 42 p. <https://rangelands.org/rangelands-provide-five-ecosystem-services/>
- Harmel, R. D., Smith, D. R., Haney, R. L., Angerer, J., Haile, N., Grote, L., Grote, S., Tiner, K., Goodwin, J., Teague, R. & Derner, J. (2021). Transitioning from conventional continuous grazing to planned rest-rotation grazing: A beef cattle case study from central Texas. *Journal of Soil and Water Conservation*, 76(6), 534-546. <https://doi.org/10.2489/jswc.2021.00159>.
- Lawrence, R., Whalley, R. D. B., Reid, N., & Rader, R. (2019). Short-duration rotational grazing leads to improvements in landscape functionality and increased perennial herbaceous plant cover. *Agriculture, Ecosystems & Environment*, 281, 134-144. doi: 10.1016/j.agee.2019.04.031.
- Leys, J., Heidenreich, S., White, S., Guerschman, J., & Strong, C. (2023). Dust-storm frequencies, community attitudes, government policy and land management practices during three major droughts in New South Wales, Australia. *The Rangeland Journal*, 44(5-6), 343-355. <https://doi.org/10.1071/RJ22059>.
- McDonald, S. E., Reid, N., Waters, C. M., Smith, R., & Hunter, J. (2018). Improving ground cover and landscape function in a semi-arid rangeland through alternative grazing management. *Agriculture, Ecosystems & Environment*, 268, 8-14.

- McDonald, S. E., Simmons, A. T., Harden, S., Orgill, S. E., Guerschman, J., & Strong, C. (2024). Managing grazing to increase ground cover in rangelands: using remote sensing to detect change. *The Rangeland Journal*, 46(4). <https://doi.org/10.1071/RJ24021>.
- Minitab (2016). Software estadístico, versión 16. Minitab Incorporation, State College.
- Roche, L. M., Cutts, B. B., Derner, J. D., Lubell, M. N., & Tate, K. W. (2015). On-ranch grazing strategies: context for the rotational grazing dilemma. *Rangeland Ecology & Management*, 68(3), 248-256. doi: 10.1016/j.rama.2015.03.011.
- Rouquette Jr, F. M., Sollenberger, L. E., & Vendramini, J. M. (2023). Grazing management and stocking strategy decisions for pasture-based beef systems: experimental confirmation vs. testimonials and perceptions. *Translational Animal Science*, 7(1), txad069. <https://doi.org/10.1093/tas/txad069>.
- Sandhage-Hofmann, A. (2023). Rangeland Management. pp. 88-101. In: Goss, M. J., Oliver, M. (Eds.). *Encyclopedia of Soils in the Environment* (Second Edition). Academic Press. ISBN 9780323951333. <https://doi.org/10.1016/B978-0-12-822974-3.00117-8>.
- Sanjari, G., Ghadiri, H., Yu BoFu, Y. B., & Ciesiolka, C. A. (2010). Increase in ground cover under a paddock scale rotational grazing experiment in south-east Queensland. <http://hdl.handle.net/10072/37511>.
- Savory, A. 2005. Manejo holístico. Un nuevo marco para la toma de decisiones. Secretaría del Medio Ambiente y Recursos Naturales. Instituto Nacional de Ecología. Fondo Mexicano para la Conservación de la Naturaleza.
- Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). 2019. Informe de la Situación del Medio Ambiente en México, edición 2018. SEMARNAT. México. 490 p.
- Smith, L., Ruyle, G., Dyess, J., Meyer, W., Barker, S., Williams, S. M., Maynar, J. L., Bell, D. & Stewart, D. (2012). Guide to rangeland monitoring and assessment: Basic concepts for collecting, interpreting and use of rangeland data for management planning and decisions. Arizona Grazing Lands Conservation Association, Tucson, Arizona, USA.
- Teague, W.R., S.L. Dowhower and J.A. Waggoner. 2004. Drought and grazing patch dynamics under different grazing management. *Journal of Arid Environments* 58: 97-117. doi.org/10.1016/S0140-1963(03)00122-8.
- Teague, R., Provenza, F., Norton, B., Steffens, T., Barnes, M., Kothmann, M., & Roath, R. (2008). Benefits of multi-paddock grazing management on rangelands: limitations of experimental grazing research and knowledge gaps. *Grasslands: ecology, management and restoration*. Hauppauge, NY, USA: Nova Science Publishers, 41-80.
- Teague, W. R., Dowhower, S. L., Baker, S. A., Haile, N., DeLaune, P. B., & Conover, D. M. (2011). Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. *Agriculture, Ecosystems & Environment*, 141(3-4), 310-322. doi: 10.1016/j.agee.2011.03.009.
- Teague, R., Provenza, F., Kreuter, U., Steffens, T., & Barnes, M. (2013). Multi-paddock grazing on rangelands: why the perceptual dichotomy between research results and rancher experience? *Journal of Environmental Management*, 128, 699-717. doi: 10.1016/j.jenvman.2013.05.064.
- Teague, R., & Kreuter, U. (2020). Managing grazing to restore soil health, ecosystem function, and ecosystem services. *Frontiers in Sustainable Food Systems*, 4, 534187. doi: 10.3389/fsufs.2020.534187.
- Teague, R., & Dowhower, S. (2022). Links of microbial and vegetation communities with soil physical and chemical factors for a broad range of management of tallgrass prairie. *Ecological Indicators*, 142, 109280. doi.org/10.1016/j.ecolind.2022.109280
- Wang, T., Jin, H., Kreuter, U., Feng, H., Hennessy, D. A., Teague, R., & Che, Y. (2020). Challenges for rotational grazing practice: views from non-adopters across the Great Plains, USA. *Journal of Environmental Management*, 256, 109941. doi: 10.1016/j.jenvman.2019.109941.
- Wang, T., Jin, H., Kreuter, U., & Teague, R. (2022). Understanding producers' perspectives on rotational grazing benefits across US Great Plains. *Renewable Agriculture and Food Systems*, 37(1), 24-35. doi: 10.1017/S1742170521000260.
- Xiaoyan, G., Zirui, J., Yingying, Y., Dengsheng, W., & JianPing, L. (2019). Research on Dynamic Rotational Grazing Assignment Model based on Grass Resource Leveling. *Procedia Computer Science*, 162, 696-703.