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NOTA BREVE

Llama and Cattle Grazing Effects on Hydrological Function in a High-Elevation Mountain Rangeland

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ADDITIONAL KEYWORDS
Deferment.
Llamas.
Cattle.
Biomass.

SUMMARY

The impact of cattle versus llama grazing on hydrologic soil function was measured in poor and regular-condition high-elevation ecological sites, under deferred grazing system. A randomized, 2×2 factorial design with covariance was used, where the factors were animal species and rangeland condition, with repeated measures. Rangeland hydrology parameters were biomass, litter, soil bulk density, infiltration rate, and soil moisture. Results showed that following deferred grazing, there was more biomass and litter available in regular-condition paddocks, where hydric response was also better. Llama paddocks also had more biomass and litter and less soil compaction resulting in a greater infiltration rate than cattle paddocks. Further evaluation of the role of deferment and camelid grazing in maintaining and improving the hydrologic function of rangeland ecosystems is needed.

Efecto del pastoreo de llamas y vacunos en la función hidrológica de pastizales altoandinos

PALABRAS CLAVE
Diferimiento.
Llamas.
Vacunos.
Biomasa.

SUMMARY

Se evaluó el impacto del pastoreo de vacunos versus llamas en la función hidrológica del suelo en sitios ecológicos altoandinos de condición pobre y regular, pastoreados bajo un esquema diferido. Se utilizó un diseño completamente al azar con arreglo factorial 2x2 con covariancia, donde los factores fueron especie animal y condición del pastizal, con medidas repetidas. Los parámetros hidrológicos fueron biomasa, mantillo, densidad del suelo, tasa de infiltración, y humedad del suelo. Los resultados mostraron que luego del pastoreo diferido, hubo mayor acumulación de biomasa y mantillo en potreros de condición regular, donde la respuesta hídrica fue mejor. Potreros pastoreados con llamas tuvieron mayor biomasa y mantillo y menor compactación del suelo resultando en una mayor tasa de infiltración. Se recomienda evaluar el rol pastoreo diferido y pastoreo con camélidos para mantener y mejorar de la función hidrológica del pastizal.

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INTRODUCTION

A fundamental role of rangeland ecosystem management is to improve hydrological function of soils, which is determined by its physical properties, including apparent density, infiltration rate, and water storage capacity (Wilcox et al. 2017, p. 97). Overgrazing can affect these physical properties (Taddese et al. 2002, p. 132)80 km west of Addis Ababa. The objective of the study was to compare selected soil physical properties at different grazing pressures and slopes. The stocking rate was moderate grazing 1.8 animal-unit months per hectare (1.8 AUM/ha, starting a cascade of ecosystem effects, resulting in reduced infiltration and increased runoff (Castellano and Valone 2007, p. 105; Savadogo et al. 2007, p. 89). In the high-Andean rangelands of Peru, empirical evidence suggests that camelid trampling affects the physical properties of the soil less than cattle. This study evaluates the impact of deferred grazing with llamas versus cattle on the hydrological function in ecological sites of poor and regular condition in a high-Andean rangeland.

MATERIAL AND METHODS

The study was conducted in two rangeland sites located within the Cordillera Blanca peasant community, Ancash Region of Peru (238690 m, 8928917 m, UTM Coordinates) during the period of August 2010 to November 2011. The altitude of the area is 4095 meters above sea level with average temperature of 12 °C with cold, dry winds, and a total annual rainfall of 700 mm (Mamani, 2002, p.50). The study sites have a long history of heavy grazing, with communal management of herds of cattle, sheep, horses, and llamas (Rondán and Chávez, 2014, p.13, Grünwaldt et al, 2016, p.553). The herds are rotated among grazing areas every 1 to 2 months.

Vegetation accounted for 75% of cover on the poor rangeland site and 94% on the regular rangeland site. The dominant vegetation at both sites was an association of *Calamagrostis macrophylla*, *Scirpus rigidus*, *Nassella brachiphylla*, and *Festuca humilior*, with 35% and 60% litter, respectively. Physiographically, both sites have slightly sloping topography, with slopes varying between 2 and 5% and show signs of laminar erosion.

Four experimental treatments resulted from combining two ecological rangeland condition (poor vs regular) and two animal species (cattle vs. llamas). All treatments used a stocking rate of 3 Animal Units (UA/ha/year) or its equivalent of 9 Llama Units (ULl/ha/year). The treatments were applied under a deferred-grazing scheme, with 5 days of grazing and 55 days of rest, in 625 m^2 experimental paddocks. The experimental plots were deferred from September 2010 to May 2011, and grazed after seed dispersal.

Five samples of biomass and litter were collected separately per treatment using a 1.0 m^2 quadrat, at the beginning of deferment; end of deferment, and after grazing, with litter being collected before clipping biomass. The samples were dried at 105 ºC for 24 hours, obtaining dry matter yield (AOAC, 2000).

Soil density was estimated using the cylinder method, with soil samples collected at 4 meters' distance along 30-meter fixed linear transects, using metal cylinders, 4.3 cm in diameter and 6.5 cm high, at a depth of 5 to 12 cm from the top layer of the soil (USDA 2001, p. 9). Soil moisture was estimated using five soil samples extracted from 15 cm depth. Soil samples were dried at 105 °C for 24 hours and soil moisture was calculated (Pierson et al. 2002, p. 561) where modelers have assumed that diverse rangeland types can be lumped or averaged together in some way to develop one algorithm or equation to describe a process or relationship across the entire spectrum of rangeland types. These assumptions and modeling approaches based on the universal concept may not be appropriate for diverse rangeland types. This paper presents a comprehensive data set of vegetation, soils, hydrology, and erosion relationships of diverse western rangelands, and utilizes the data to assess the validity of the various assumptions/generalizations for rangelands. The data set emphasizes the difficulty in understanding hydrologic responses on semiarid rangelands, where the relationship between plant/soil characteristics and infiltration/erosion is not well established. When all sites were pooled together, infiltration and sediment production were not correlated with any measured vegetation or soil characteristic. A myriad group of factors determine infiltration and erosion, and is dependent on rangeland type and site conditions. The infiltration and erosion responses and correlation/regression analyses presented highlight the risk of using generalized assumptions about rangeland hydrologic response and emphasize the need to change the current modeling approach. Universal algorithms to represent the response of all rangeland types, such as the pooled multiple regression equations presented, will not provide sufficient accuracy for prediction or assessment of management. We need to develop a rationale to organize rangeland types/vegetation states according to similarities in relationships and responses. These functional rangeland units would assist in the development of more accurate predictive equations to enhance model performance and management of rangelands. Infiltration rate was estimated using two concentric cylinders and two samples per treatment. Readings were taken at 1, 5, and 10 minutes intervals until the differential infiltration rate was constant and used then used to develop infiltration curves.

The experimental design used was a randomized, 2 × 2 factorial, with repeated measures, where the factors were species and rangeland condition. The covariate added to this analysis was represented by the state of each evaluated parameters at the start of deferment. All parameters evaluated at the beginning and end of deferment were positively correlated ($p < 0.01$), justifying the adjustment of the state of the variables at the end of the experiment with those observed at the beginning. Finally, all parameters were analyzed using an ANCOVA ($\alpha = 0.05$) to assess the impact of species and range condition on range hydrology function.

RESULTS

There was no significant interaction between range condition and grazing species factors. Range sites grazed with llamas, following deferred grazing, showed significantly greater biomass availability and litter accumulation, lower soil densities, soil moisture and higher water infiltration tendencies than sites grazed by cattle **(Table 1)**. Regular condition sites after grazing deferment presented significantly higher soil hydrology parameters than poor condition sites. Although sites grazed with llamas and regular condition show higher soil infiltration rates than sites grazed by cattle and poor condition, no significance difference was found (**Figure 1**).

DISCUSSION

Hydrologic status after Deferment

The significant increase in plant biomass following deferment for both sites corroborates the idea that

Table I. **Rangeland condition and grazing species effect on soil hydrology factors, statistical significance is indicated as *: P < 0.05, **: P < 0.01, and ***: P < 0.0001** (Efecto de condición del pastizal y especies sobre factores hidrológicos del suelo, significancia estadística se indica cómo *: P < 0.05, **: P < 0.01, y ***: P < 0.0001).

	Rangeland condition			Grazing species			2 × 2
	Regular	Poor	*p-value*	Llama	Cattle	*p-value*	*p-value*
Biomass availability (kg DM/ha)	1540	1084	0.0004**	1398	1226	<.0001***	0.0755
Litter quantity (kg DM/ha)	64	51	0.0008**	65	50	<.0001***	0.0431*
Soil density (g/cc)	0.84	0.90	<.0001***	0.86	0.88	0.0236*	0.5361
Infiltration rate (cm/min)	0.17	0.10	0.7613	0.16	0.12	0.313	0.8933
Soil moisture (%)	30	25	0.0014**	29	26	0.0142*	0.2601

deferred grazing improves rangeland biomass (sensu Ash et al. 2011, p. 223). Increased litter following deferment helps improve hydrological function (sensu Pierson et al. 2007, p. 672) as well as the physical properties of the soil.

The measured soil densities all indicated high porosity (Houlbrooke et al. 1997, p. 434). The low soil density in regular-condition sites may be due to the greater amounts of biomass and litter, which could diminish trampling effects, thus helping to improve the physical properties and hydrological response of the soil (Tate et al. 2004, p. 414). The poor-condition sites showed greater susceptibility to soil compaction, which could result in reductions in water infiltration and diminishing forage supply (Castellano and Valone 2007, p. 105).

Llama vs Cattle Grazing Effects on Soil Hydrology

The significant impacts across variables indicate that llamas cause fewer negative impacts on soil structure and function than an equivalent stocking of cattle at both regular and poor-condition sites. The higher amounts of litter and biomass in llama grazing areas should help improve soil conditions. High amounts of vegetative biomass – including high litter – play a key role in rainfall interception and water infiltration, leading to less surface runoff and less soil loss (Ravi et al. 2010)shifts in vegetation composition, accelerated soil erosion processes, and disturbances have rendered these landscapes susceptible to rapid degradation that has important feedbacks on regional climate and desertification. Even though the role of hydrologic-aeolian erosion and vegetation dynamic processes in accelerating land degradation is well recognized, most studies have concentrated only on the role of one or two of these components, and not on the interactions among all three. Drawing on relevant published studies, here we review recent contributions to the study of biotic and abiotic drivers of dryland degradation and we propose a more holistic perspective of the interactions between wind and water erosion processes in dryland systems, how these processes affect vegetation patterns and how vegetation patterns, in turn, affect these processes. Notably, changing climate and land use have resulted in rapid vegetation shifts, which alter the rates and patterns

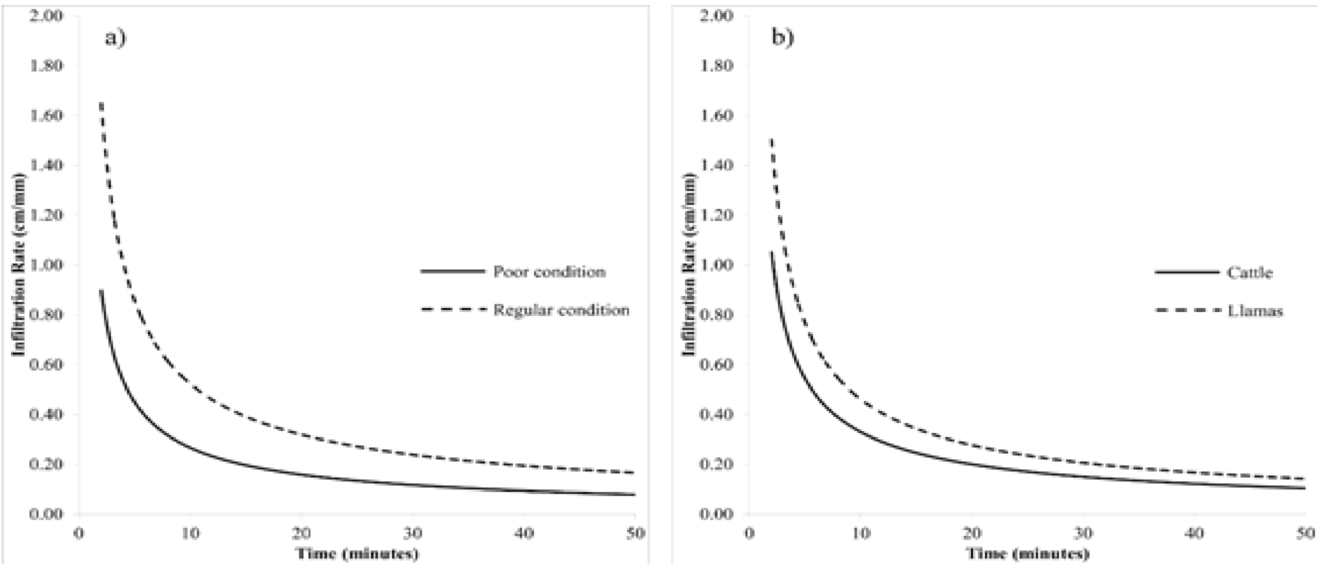

Figure 1. **Soil infiltration rate curves for (a) rangeland condition and (b) grazing species. Measurements were conducted at the end of the grazing period** (Curvas de tasa de infiltración del suelo para (a) condición del pastizal y (b) especies. Medidas se condujeron al final del período de pastoreo).

of soil erosion in dryland systems. With the predicted increase in aridity and an increase in the frequency of droughts in drylands around the world, there could be an increasing dominance of abiotic controls of land degradation, in particular hydrologic and aeolian soil erosion processes. Further, changes in climate may alter the relative importance of wind versus water erosion in dryland ecosystems. Therefore acquiring a more holistic perspective of the interactions among hydrologic-aeolian erosion and vegetation dynamic processes is fundamental to quantifying and modeling land degradation processes in drylands in changing climate, disturbance regimes and management scenarios. Litter improves the hydrological response of rangelands, assists with the soil nutrient cycle, and exerts a dampening effect on pressure exerted on the soil (Prosdocimi et al. 2016, p. 195)mulching has been successfully applied to reduce soil and water losses in different contexts, such as agricultural lands, fire-affected areas, rangelands and anthropic sites. In these contexts, soil erosion by water is a serious problem, especially in semi-arid and semi-humid areas of the world. Although the beneficial effects of mulching are known, further research is needed to quantify them, especially in areas where soil erosion by water represents a severe threat. In the literature, there are still some uncertainties about how to maximize the effectiveness of mulching to reduce the soil and water loss rates. Given the seriousness of soil erosion by water and the uncertainties that are still associated with the correct use of mulching, this study review aims to (i.

Soil density differed over the 5 to 12 cm of measured soil depth, due to the effect of animal trampling. Llama hooves produced less pressure (0.54 kg/cm^2) than cattle (1.43 kg/cm^2), as estimated from the live weights of animals and hoof-area measurements for both species. The trampling effect by cattle has been shown to negatively impact soil density and erosion (Dunne et al. 2011, p. 67). The lower grazing pressure and padded hooves of llamas could explain why they had a lower impact on soil density.

Higher soil moisture and infiltration rates found in llama grazing areas can increase biomass and topsoil, reducing water loss through evapotranspiration and deep drainage (Echavarría Cháirez et al. 2007, p. 178). These significant differences could be associated with the amount of vegetation present, levels of residual dry matter (García-Hernández et al. 2008, p. 22; Tate et al. 2004, p. 416), and soil compaction (Lado et al. 2004, p. 240)and (ii.

CONCLUSIONS

Llamas' grazing has a lower impact on biotic integrity and hydrological function of rangelands than cattle grazing under deferred grazing because llamas remove less forage per unit area and alter to a less extent the ecological conditions of the site allowing a greater accumulation of standing biomass and litter on the soil. The next step would be to assess llamas grazing effects on a much larger scale to take a greater advantage of their longer evolutionary and adaptation history on Andean rangelands.

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