Soil Erosion Studies in Buffelgrass Pastures

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Abstract.—The introduction of exotic grasses in native rangelands to increase the production of forage has been a good alternative for the cattle industry in North America. Different studies have demonstrated that buffelgrass (*Cenchrus ciliaris* L.), a plant introduced from Africa, increases the annual green forage production approximately three times in comparison to production in areas with native species in rangelands of Sonora, Mexico. However, soil erosion processes caused by natural circumstances and/or natural resources mismanagement can decrease productivity of buffelgrass pastures. Soil erosion rates for buffelgrass pastures in central Sonora, Mexico, were estimated using the Revised Universal Soil Loss Equation (RUSLE). Pastures differed in geographical location, environmental conditions and type of management. It was demonstrated that in buffelgrass pastures, soil loss caused by hydrologic factors is positively correlated with plant density, soil surface micro-relief, and erosion features. It correlates negatively with soil crust development and pasture management index. Stepwise regression analyses make evident the effect that soil surface erosion features, pasture management practices, and density of buffelgrass plants have on the soil loss rates of these grazing lands.

Introduction

In an attempt to increase the forage production in the rangelands of Sonora, Mexico, in the mid 1950s the African T-4464 buffelgrass (*Cenchrus ciliaris L.*) was introduced. According to Martin-R. and others (1995), the annual green forage production in pastures with this species increased approximately three times in comparison to production in areas with native species. However, many natural or anthropogenic processes that affect the functionality of these agroecosystems have not been completely studied. One of these processes is soil erosion caused by water.

Soil erosion is the process of detachment and subsequent removal of soil particles and small aggregates from land surfaces by wind and/or water in a specified time period (Brooks and others 1997; Nearing and others 1994). Soil loss due to erosion processes is a serious problem in many regions of the world.

Financial and material constraints make it impossible to estimate and monitor the soil loss effects of weather and land management practices in all ecosystems, and it is difficult to extrapolate beyond local study areas. One alternative approach is to develop simulation models to achieve these goals. Thus, in 1965, the USDA Soil Conservation Service created the Universal Soil Loss Equation (USLE) to predict soil erosion. The USLE is an empirical mathematical model designed to compute long time average soil losses due to sheet and rill erosion across the land surface. The equation has been modified through time; the most recent version is called Revised Universal Soil Loss Equation (RUSLE). It groups the interrelated physical and management parameters that influence erosion into six factors such that erosion is the product of those factors as follows:

$$A = R\ K\ (LS)\ C\ P$$

where: A = computed annual soil loss in tons per unit area (in this case, km).

R = a rainfall - runoff erosivity factor;

K = a soil erodibility factor, based on soil characteristics such as texture, structure, and permeability;

LS = a dimensionless topographic factor combining slope length, L, and slope steepness, S;

C = a dimensionless land cover-management factor; and

P = an erosion control factor, based on soil conservation support practices (Brooks and others 1997).

The principal objective of this study was to estimate the erosion rates in buffelgrass pastures exposed to different environmental conditions and management styles. These pastures are located in the central part of Sonora, Mexico.

Methods

Study Area

The study area covers the central part of Sonora, Mexico, from 28° 30′ N latitude to 29° 30′ N latitude and from the Gulf of California to the state border of Sonora (figure 1). Within this zone, there exists a east-west trending gradient of precipitation, temperature, and elevation. Mean annual precipitation values increase towards the east,

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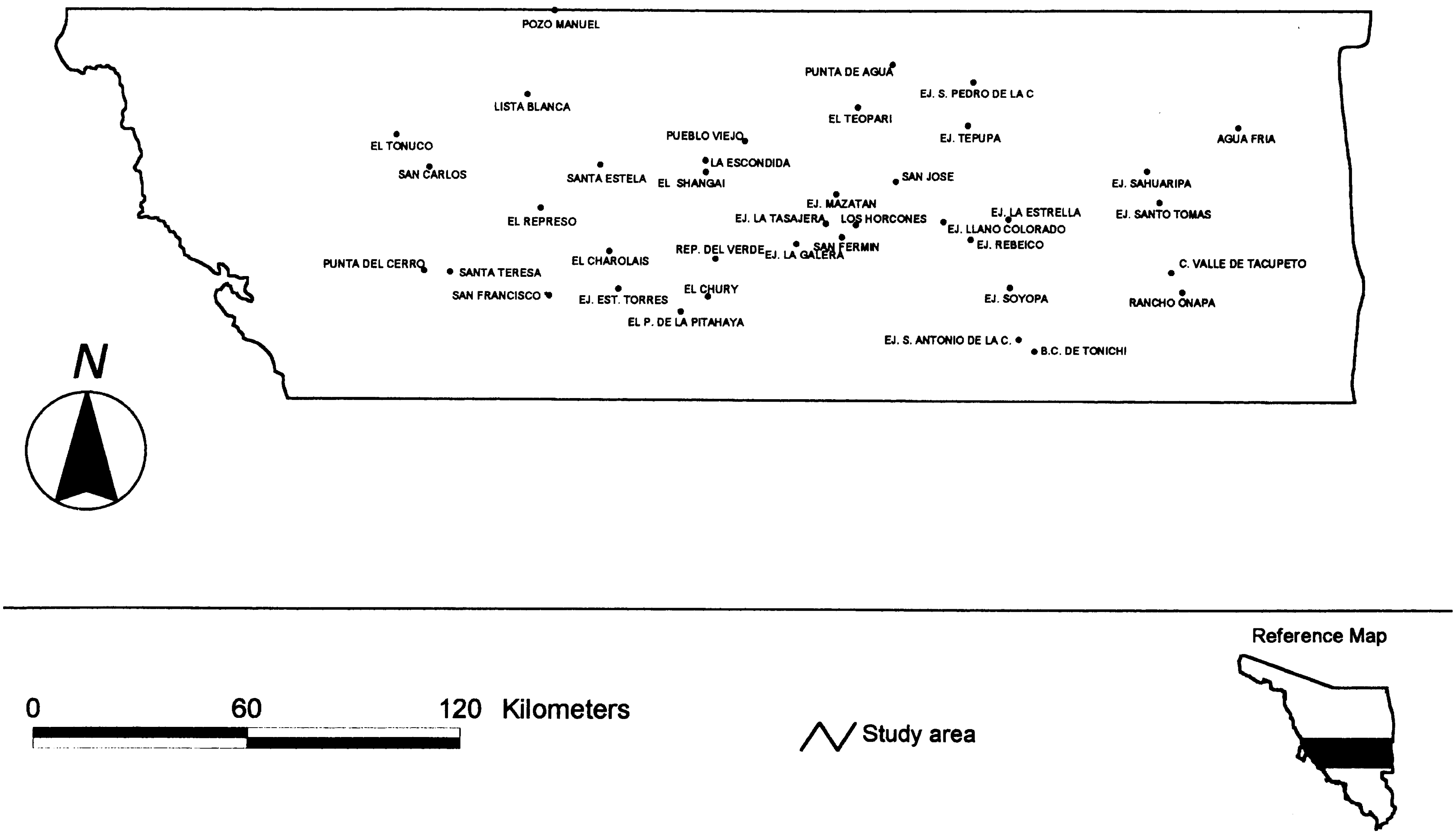

Figure 1. Distribution of sampling sites in the study area.

ranging from less than 150 mm at the western extent to over 800 mm in the east. Mean annual temperature values decrease over the same area, ranging from more than 25°C to less than 21°C. Thirty-seven ranches were arbitrarily selected within the study area in order to represent the greatest number of possible environmental and management scenarios.

Equation Parameters

The original soil erosion equation was created using data gathered from experiments done in the U.S.A.; in consequence, its extrapolation and applicability in other countries is limited. However, different authors have created equations that permit the users to obtain values for the RUSLE parameters using the unique data available in their regions or countries. In this particular project, there is only rainfall monthly data and, given the fact that there are no isoerodent maps for the study area, the R value was estimated using the climate index C created by Fournier and subsequently modified by FAO:

$$C_1 = \sum_{i=1} p_i^2/P$$

where C_1 = climate index
p_I = rainfall in month i
P = annual rainfall

This index summed for the whole year was found to be linearly correlated with R factor of RUSLE as follows:

$$R = b + a\,(C_1)$$

where the constants a and b vary widely among different climatic zones of the world (Lal and Elliot 1994). For this study, we assumed to be in an area with same values for constants a and b, such as the western region of the USA., where the value for intercept b is –3 and for coefficient a 0.66.

Given the chemical and physical characteristics of the soils like texture, organic matter content, soil structure, and permeability, the corresponding K factor values were determined using a special nomograph (Morgan 1995).

The LS factor values for buffel pastures were determined by using published tables where a slope-length relationship is calculated for different soil conditions and land uses (Renard and others 1994). The C and P factor values were also determined from tables created by the government (Morgan 1995). Because all pastures were found in an overgrazed condition, were given a C value of 0.1. The corresponding P value for the entire number of pastures was 0.5.

Additional Information

To relate the erosion rates to other factors, a number of measurements and estimations were performed in the study sites. Thus, density, basal area and relative yield were determined as plant attributes. As soil characteristics, we measured percentage of litter cover, percentage of crust development, soil microrelief, and surface erosion features. Microrelief refers to the vertical variation of soil surface. Smooth surfaces are given low values, while rough surfaces are given high values. Certain soil features (rills, scarps, flow lines, pedestals) indicate erosion, deposition or surface water flow (Tongway and Smith 1989). They were rated on a scale of zero to one according to the prominence of the features. For the entire pasture, parameters like PMI (pasture management index) and PCI (pasture condition index were also determined to perform the association with erosion rates.

Results and Discussion

Table 1 shows the resulting values in soil erosion for all studied pastures. There is a notable variability in erosion rates among all of them provoked by the contrast in soil characteristics, climate, and topography. These values are smaller than those obtained by Valdez-Zamudio (1994) for natural rangelands in northern Sonora. Performing an experiment on Australian soils, McIvor and others (1995) found that runoff and soil movement were greatest in native plant communities and least in developed pastures. In 1998, Perramond confirmed these results and concluded that "contrary to conventional wisdom, results indicate that buffelgrass is a very effective soil cover, and that soil rates are twice as high in native vegetation".

Statistical analyses demonstrated that buffelgrass erosion rates are positively correlated with plant densities, soil microrelief and erosion features values, while relationships with soil crust development and pasture management index are negatives. All these correlation results are understandable except the one related to plant density, because lower erosion rates would be expected as plant density increased. Probably the reason is that ranchers usually enlarge their herds of grazing animals beyond the carrying capacity of the ecosystem, increasing the erosion rates in the pastures.

Table 1. Parameter and erosion rate values for study sites.

No.	SITE	R	K	LS	C	P	A
1	SANTA TERESA	50	0.03	0.62	0.1	0.5	0.040
2	SAN FRANCISCO	58	0.01	0.50	0.1	0.5	0.019
3	SANTA ESTELA	57	0.12	0.26	0.1	0.5	0.087
4	EL TONUCO	53	0.10	0.50	0.1	0.5	0.138
5	SAN CARLOS	54	0.09	0.50	0.1	0.5	0.123
6	PUNTA DEL CERRO	66	0.10	0.50	0.1	0.5	0.172
7	POZO MANUEL	63	0.13	0.50	0.1	0.5	0.205
8	EL REPRESO	57	0.14	0.26	0.1	0.5	0.106
9	E. ESTACION TORRES	59	0.13	0.26	0.1	0.5	0.100
10	LISTA BLANCA	62	0.09	0.38	0.1	0.5	0.107
11	EL CHAROLAIS	59	0.12	0.26	0.1	0.5	0.090
12	EL POZO DE LA P.	60	0.08	0.62	0.1	0.5	0.145
13	EL CHURY	60	0.09	0.26	0.1	0.5	0.071
14	LA ESCONDIDA	58	0.09	0.62	0.1	0.5	0.164
15	PUEBLO VIEJO	66	0.13	0.26	0.1	0.5	0.112
16	E. TEPUPA	92	0.10	0.26	0.1	0.5	0.124
17	SAN PEDRO CUEVA	87	0.07	0.26	0.1	0.5	0.074
18	E. MAZATAN	84	0.12	0.62	0.1	0.5	0.305
19	E. LA GALERA	75	0.09	0.50	0.1	0.5	0.171
20	E. LA TASAJERA	77	0.20	0.38	0.1	0.5	0.285
21	REPRESO DEL VERDE	61	0.04	0.50	0.1	0.5	0.059
22	AGUA FRIA	95	0.09	0.62	0.1	0.5	0.268
23	E. SAHUARIPA	97	0.10	0.50	0.1	0.5	0.252
24	ONAPA	99	0.09	0.50	0.1	0.5	0.225
25	PUNTA DE AGUA	79	0.09	0.38	0.1	0.5	0.137
26	EL SHANGAI	62	0.09	0.26	0.1	0.5	0.073
27	EL TEOPARI	76	0.07	0.26	0.1	0.5	0.064
28	E. REBEICO	106	0.08	0.50	0.1	0.5	0.207
29	LLANO COLORADO	102	0.26	0.38	0.1	0.5	0.504
30	SAN FERMIN	80	0.07	0.26	0.1	0.5	0.068
31	SAN JOSE	85	0.08	0.26	0.1	0.5	0.086
32	S. ANTONIO HUERTA	93	0.12	0.74	0.1	0.6	0.483
33	C. TONICHI	89	0.09	0.26	0.1	0.5	0.105
34	SANTO TOMAS	101	0.07	0.26	0.1	0.5	0.085
35	E. LA ESTRELLA	102	0.14	0.74	0.1	0.6	0.648
36	E. SOYOPA	86	0.05	0.50	0.1	0.5	0.112
37	LOS HORCONES	83	0.16	0.26	0.1	0.5	0.168

Stepwise regression analyses (p = .25) demonstrated a significant positive association between soil erosion and plant densities and soil erosion features. A negative relation exists between soil erosion and pasture management index, indicating that the best-managed buffel pastures have the smallest erosion rates.

Summary and Conclusions

This study illustrates the potential use of soil erosion models for making environmental assessments, especially in rangelands areas. It is evident that erosion is affecting the buffelgrass pastures of central Sonora, Mexico. Increments in plant density and surface erosion features, in combination with inefficient pasture management, are the main causes of erosion in buffelgrass pastures of central Sonora. Soil erosion potential rates in buffelgrass pastures define an evident tendency of soil deterioration in central Sonora. Soil conservation programs need to be implemented in buffel pastures of Sonora to control the erosion processes and improve the actual conditions of those agroecosystems.

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