

Effects of Agricultural Terraces on the Reestablishment of Bluestem Grasslands

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Abstract

The effects of agricultural terraces on the reestablishment of a bluestem grassland were evaluated 5 years after seeding. Terrace intervals (the slopes extending between terraces), terrace channels, terrace ridges, and terrace slopes (2 meters downslope from the terrace ridge) in both burned and unburned areas were evaluated. Canopy cover for all seeded native grasses averaged higher on terrace locations than on terrace intervals. Little bluestem (*Andropogon scoparius*) and Indiangrass (*Sorghastrum nutans*) were best established in terrace-channels, whereas sideoats grama (*Bouteloua curtipendula*) and blue grama (*B. gracilis*) were most abundant on terrace-ridges. Big bluestem (*Andropogon gerardii*) coverage was greatest on terrace-channels in burned and terrace-slopes in unburned areas. Canopy cover of nonseeded grasses and forbs averaged highest on terrace-ridges and terrace-slopes; forbs were markedly reduced as a consequence of burning but foxtail (*Setaria* spp.) increased. Total productivity was substantially greater on terrace locations (6,757 kg/ha) than on terrace intervals (3,620 kg/ha). Burning reduced total biomass the year of the burn with the reduction most pronounced in the terrace-channel where productivity was highest. This study indicates that terraces provide microhabitats which result in species distributions that differ markedly from those expected for native prairies. In addition, terrace conditions appear to slow the process of establishing a continuous stand of native perennial grasses. Thus, it appears to be advisable to remove terraces and redistribute terrace soil prior to reseeding with native grasses.

Prior to the arrival of European settlers in the middle and late 1800's, the vegetation of eastern Nebraska was predominantly bluestem prairie (*Andropogon-Panicum-Sorghastrum*) (Küchler 1964). Extensive cultivation since that time, however, has substantially reduced the extent of the native prairies and only scattered remnants remain (Nebraska Game and Parks Commission 1972) of which most are either hayed or grazed by cattle (Bose 1977). Recently there has been an increased interest in maintaining native prairies and in reestablishing native grass stands (U.S. Dep. Agr. 1969; Jenkins 1973) as well as in setting aside native grasslands as research natural areas (Anderson 1946; Kilburn 1970; Christisen 1973; Hulbert 1973; Nyhoff 1975; Riskind and Collins 1975; Riskind and Davis 1975; Darnell 1976). Prairie research areas may be divided into (1) prairie preserves, which are native, unplowed prairies, and (2) reestablished (or restored) grasslands in which previously

cultivated land is reseeded to native prairie species. When managed to approximate pristine conditions, both types of prairie research area play an important role in range management studies by providing base-line information with which the effects of cattle grazing and haying can be compared (Lemon 1975; Schumacher 1975). In addition, research areas provide sites for basic ecological studies of grassland communities.

Studies on various aspects of grassland reestablishment have been reported in Oklahoma, Kansas, Wisconsin, Michigan, Illinois, Utah, and Nebraska (Daniel et al. 1942; Cornelius 1946; Cornelius and Atkins 1946; Cox et al. 1951; Greene and Curtis 1953; Cottam and Wilson 1966; Anderson and Cottam 1970; Bland 1970; Ode 1970; Schulenberg 1970; Hull 1973; Becic and Bragg 1978). Few of these studies, however, refer to burning as a management tool in grassland reestablishment and fewer still deal with the effects of agricultural terracing, a common practice designed to reduce soil erosion and water runoff on sloping, cultivated fields. Cox et al. (1951) noted that terracing in the bluestem-grama prairie region of north-central Oklahoma reduced overall grass production by an average of 31%. Grass biomass averaged 1,350 kg/ha on a terraced field in comparison to 4,380 kg/ha on an unterraced field. This difference in productivity was attributed to the removal of permeable top-soil from terrace intervals during the establishment of the terraces. Exposed sub-surface soils on the terrace intervals were unable to take in water readily, thus accounting for 13% more runoff from terraced than from unterraced fields. On terraced fields, Daniel et al. (1942), Cox et al. (1951), and Hull (1973) found that the best grass stand developed in the terrace-ridges or terrace-channel. Productivity on the terrace intervals averaged lower than terrace-ridges or terrace-channels; terrace-ridges were either intermediate or lower than other locations.

Daniel et al. (1942) noted that 2 years after seeding, different species of native prairie plants were best established on different terrace locations. Switchgrass (*Panicum virgatum*) dominated the vegetative cover in the terrace-channel with terrace-ridges and intervals dominated by annual weedy grasses. Canopy cover of blue grama (*Bouteloua gracilis*) and Indiangrass (*Sorghastrum nutans*) was greatest on terrace-ridges and intervals, while little bluestem coverage was greatest in terrace-channels. Dropseed (*Sporobolus* spp.) cover was low in all locations but higher on terrace-ridges than elsewhere. Individual species of native prairie plants that were seeded to previously cultivated but unterraced land were arranged in habitat groupings corresponding to soil-moisture conditions (Cottam and Wilson 1966; Anderson and Cottam 1970). Differences in soil-moisture may also account for the species

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segregation noted on the various terrace-locations.

This study was initiated to evaluate the effects of agricultural terraces on the reestablishment of grasslands in the bluestem prairie region of eastern Nebraska with consideration given to the effects of burning management.

Study Site

The study was conducted on the 65-ha Allwine Prairie Preserve located approximately 16 km northeast of the University of Nebraska at Omaha and situated in the bluestem prairie region of eastern Nebraska (Bragg 1978). The Preserve, managed by the Department of Biology, includes 56-ha of previously cultivated and terraced cropland that was seeded to native prairie grasses in the spring of 1970. A 53-ha portion, termed the Tallgrass Area, was seeded with big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon scoparius*), sideoats grama (*Bouteloua curtipendula*), Indiangrass, and Switchgrass at rates of 2.8, 1.7, 1.1, 1.1, and 0.6 kg/ha pure live seed. An additional 3-ha, designated the Midgrass Area, were seeded with little bluestem, sideoats grama, blue grama, and buffalograss (*Büchloe dactyloides*) at 2.2, 3.4, 2.2, and 2.2 kg/ha pure live seed. A small amount of big bluestem, switchgrass, and Indiangrass was accidentally introduced into the Midgrass Area, apparently in the seeding equipment or in the seed mixture.

Soils of the site are predominantly silt and silty clay loams that developed on loess substrate (Bartlett 1975). The topography is gently rolling with slopes averaging 11%. Terraces are a distinctive feature of the slopes and represent a difference in elevation of approximately 3 meters. Monthly precipitation normally averages 10.0 cm from April through July, although an average of 7.5 cm fell during these months in the year of the study.

Methods and Analysis

The Midgrass Area and portions of the Tallgrass Area were burned in late April 1975. The Midgrass Area had not been previously burned but the Tallgrass Area was burned on May 1, 1974. The portion of the Tallgrass Area not reburned in 1975 was designated as the unburned area for the purpose of this study.

Vegetative Evaluations

Vegetative evaluations were made during June and July, 1975, in three management areas: the burned Midgrass Area, the burned Tallgrass Area, and the unburned Tallgrass Area. Upper, middle, and lower slopes were separately evaluated within each area. At each of the three slope locations, four strata were evaluated: (1) the *terrace interval*, situated halfway between terraces, (2) the *terrace-channel*, the depressed area immediately upslope from the terrace, (3) the *terrace-ridge*, directly on top of the terrace, and (4) the *terrace-slope*, situated 2 meters downslope from the terrace ridge. The latter three categories combined are termed terraced locations. Vegetative composition of each study stratum was determined within five, systematically located, 2 by 10 meter plots. Within each plot, the canopy cover of all species was evaluated in each of ten, randomly located 1-dm² (10cm by 10 cm) quadrats (canopy coverage techniques from Daubenmire 1959). Coverage categories used were: less than 5% cover, 5 to 25%, 25 to 50%, 50 to 75%, 75 to 95%, and greater than 95% cover. Comparisons of species coverage values between study strata were first tested for normality using frequency distribution curves, then evaluated at the 0.05 level of probability using an analysis of variance. Paired differences in species coverage between each study stratum were tested for significance using the Scheffé Test (Nie et al. 1975) at the 5% level.

In addition to species composition, biomass for each study stratum was sampled using three systematically located 0.5 by 1.0-meter plots situated along each midslope location. All above-ground vegetation in each plot was clipped, separated into grasses and forbs, oven dried at 54°C for 48 hours, and weighed.

Measurement of Soil Variables

Soil-moisture was evaluated at a depth of 23 cm using a tensio-

meter-type soil moisture probe. Five measurements were recorded along each stratum of the middle slope location at each of the three management areas. In addition, soil samples of the upper 23 cm of the solum were collected. Soil pH, residual nitrate, phosphorous, potassium, and percent organic matter were determined by the Soil Testing Laboratory, Cooperative Extension Service, University of Nebraska-Lincoln. Additional samples were used to determine soil texture.

Results and Discussion

Five growing-seasons after being seeded with native prairie grass species, big bluestem dominated the burned and unburned Tallgrass Area, averaging 57% cover, and little bluestem dominated the Midgrass Area, averaging 67% cover. Coverage values for individual species, however, differed among study strata and burning management areas (Table 1). The methods used for seeding were assumed to have relatively evenly distributed the same proportion of each species of grass seed. Variations in vegetative composition, therefore, were considered to be primarily the result of differential competitive success under the specific conditions existing along each study stratum. Large values obtained for standard deviation of means reflect uneven distribution, which is characteristic of many species evaluated.

Vegetative Composition with Respect to Terrace Location

Canopy coverage of each seeded grass species was consistently highest on one of the three terrace locations; in no instance was coverage greatest on the terrace interval (Table 1, Fig. 1). In the Tallgrass Area, big bluestem coverage was greatest in terrace-channels and terrace-slopes, little bluestem and Indiangrass were best established in terrace-channels, and sideoats grama was most abundant on terrace-ridges. In the Midgrass Area, little bluestem was most abundant in the terrace-channels with sideoats grama and blue grama coverage highest on terrace-ridges. Sideoats and blue grama are common in well-drained prairie sites that frequently are more xeric than those in which big bluestem, little bluestem, and Indiangrass dominate. The occurrence of these species with respect to soil-moisture differences along terraces (Table 2) appears to be consistent with the conditions under which each is expected to occur in native prairies.

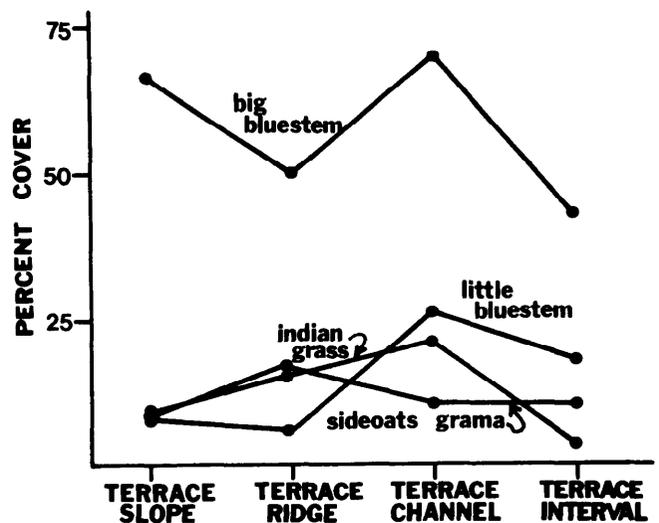


Fig. 1. Canopy coverage differences of seeded perennial grasses on four study strata of the Tallgrass Area. Values represent combined burned and unburned data.

Table 1. Average percent canopy cover¹ (±SD) of plant species recorded on burned and unburned study strata. Only species intentionally seeded or species with a frequency greater than 15% in at least one management area are included.

Species	Unburned tallgrass area				Burned tallgrass area				Burned midgrass area			
	I	t-C	t-R	t-S	I	t-C	t-R	t-S	I	t-C	t-r	t-S
Seeded perennial grasses												
Big bluestem (<i>Andropogon gerardii</i>)	39±41	63±38	50±42	67±38	47±39	76±29	49±46	67±42	0	0	1±12*	13±32*
Little bluestem (<i>Andropogon scoparius</i>)	16±33	23±37	9±23	11±27	20±34	29±38	5±18	5±17	53±36*	82±22*	64±37*	69±40*
Sidecoats grama (<i>Bouteloua curtipendula</i>)	10±21	8±20	18±31	12±27*	12±25	13±26	16±29	5±20	30±30*	35±32*	55±34*	28±35*
Indiangrass (<i>Sorghastrum nutans</i>)	6±20	25±34	16±31	10±24	2±10	17±29	17±34	8±25	+	0	0	0
Switchgrass (<i>Panicum virgatum</i>)	2±11	3±13	2±12	1±10	3±11	6±18	9±26	12±30	0	0	1±9	3±12
Blue grama (<i>Bouteloua gracilis</i>)	0	0	0	0	0	0	0	0	3±11	4±12	9±22	3±12
Buffalo grass (<i>Buchloe dactyloides</i>)	0	0	0	0	0	0	0	0	+	+	+	+
Nonseeded perennial grass												
Smooth brome (<i>Bromus inermis</i>)	0	1±6	3±17	3±12	0	+	5±19	0	+	2±8	1±8	1±4
Annual grasses												
Foxtail grass (<i>Setaria glauca</i>)	0	0	2±10	0	0	+	1±6	1±6	0	+	6±18	17±27
Foxtail grass (<i>Setaria viridis</i>)	0	0	5±16	1±6	0	+	29±36*	37±40*	+	1±3	3±11	4±11
Forbs												
Wild lettuce (<i>Lactuca canadensis</i>)	2±10*	7±9*	20±26*	12±20*	+	1±3	5±15	11±24	+	1±3	2±8	2±6
Horseweed (<i>Conyza canadensis</i>)	9±17*	13±15*	10±19	17±25	+	1±4	+	0	+	+	+	+
Red clover (<i>Trifolium pratense</i>)	16±30*	10±26	2±10	3±11	+	+	1±4	+	2±12	0	0	0
Wood sorrel (<i>Oxalis dellenii</i>)	2±5*	2±5	3±8	3±6	+	+	4±11	2±5	+	2±5	4±8	12±16
Yellow sweet clover (<i>Melilotus officinalis</i>)	12±29	+	0	1±7	0	0	0	0	6±22	1±4	+	0
Lamb's quarters (<i>Chenopodium album</i>)	0	0	4±14	1±3	0	1±3	6±15	2±7	0	0	1±4	+
Smartweed (<i>Polygonum pensylvanicum</i>)	0	0	1±7	+	0	+	3±9	2±8	+	2±6	1±4	2±5
Open soil	6±22	2±6	6±14	4±12	45±37	5±11	4±13	2±6	-	7±12	3±8	1±3

¹ Significant differences in canopy cover values within a management area are indicated by different levels of horizontal underlining; statistical similarity within a management area is indicated by common horizontal underlining. *** = statistically different from same terrace location in another management area. '+' = less than 0.5% cover. I = terrace interval, t-C = terrace-channel, t-R = terrace-ridge, t-S = terrace slope.

Table 2. Soil characteristics of study strata; management areas combined.

Soil characteristic	Average Value ± Standard Deviation of Mean				Number of Samples
	Terrace interval	Terrace-Location			
		Channel	Ridge	Slope	
Soil-moisture (centibars tension) ¹	27.0±3.3	17.1±3.8	25.0±4.2	22.7±4.6	15
Organic matter (%)	1.7±0.6	1.4±0.1	1.5±0.2	1.8±0.3	3
Residual nitrate (ppm)	1.4±0.1	1.6±0.2	1.6±0.2	1.5±0.3	3
pH	6.4±0.1	7.1±0.6	7.2±0.4	7.1±0.4	3
Phosphorus (ppm)	4.0±2.7	3.7±2.4	4.1±2.5	3.6±0.8	3
Potassium (ppm)	183±19	190±14	185±27	211±5	3
Soil texture: sand (%)	12.0±1.0	9.0±2.6	16.3±7.1	21.7±5.5	3
silt (%)	56.0±0.0	60.3±4.0	52.0±8.0	48.3±4.0	3
clay (%)	32.0±1.0	30.1±1.5	31.7±1.5	30.0±2.0	3

¹ Values are inversely related to soil-moisture.

Of the four study strata, terrace intervals averaged lowest in soil-moisture, residual nitrate, pH, and potassium (Table 2). These differences, while slight, may account for the poor establishment of seeded grass species on this study stratum. Cox et al. (1951) related lower productivity of terraced fields to reduced permeability which occurred with the exposure of less permeable sub-surface soils during the establishment of terraces. Low soil-moisture values in the terrace-interval, as recorded in the present study, support this conclusion.

When soil-moisture and nutrient availability are adequate, taller species, such as big bluestem, are likely to approach their maximum height and thus more effectively out-compete shorter grasses for light, water, or nutrients. In unburned terrace-channels, for example, canopy coverage values of sideoats grama, a mid-height grass, averaged lower than taller grasses. As previously indicated, the maximum coverage of this species occurred on terraced-ridges where soil-moisture and other soil conditions may have restricted the growth of taller grasses. Differences in coverage between big and little bluestem in terrace-channels may also reflect the advantage of height; little bluestem, a shorter grass, is consistently lower in coverage than big bluestem. Differential success among other tall grasses may be related to soil-moisture or nutrient conditions as well, but further studies are needed to substantiate this hypothesis.

Terrace-slopes were found to support the greatest coverage of weedy grasses and forbs with which seeded native grasses had to contend (Fig. 2). Grasses consisted mostly of foxtail; forbs were species common to disturbed areas but uncommon in established native prairies. Field observations indicated that the success of the weedy species in the terrace-slope was partly the result of the poor establishment of native, perennial grasses.

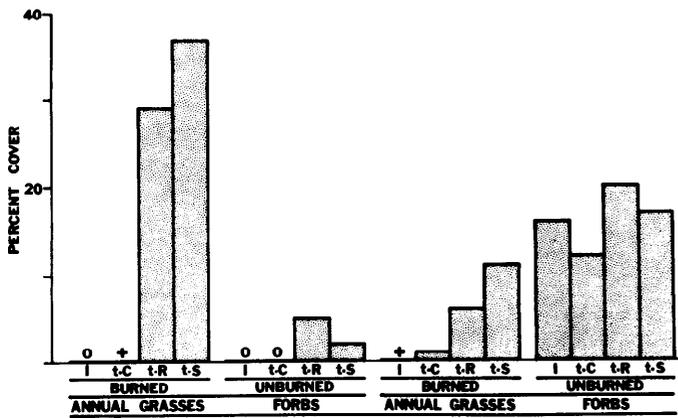


Fig. 2. Weedy grasses and forbs on burned and unburned study strata "o" = absent, "+" = less than 0.5% cover, I = terrace interval, t-C = terrace-channel, t-R = terrace-ridge, t-S = terrace-slope.

This terrace stratum is situated in such a way that seeding may have been difficult thus preventing a good application of grass seed. Poor success as a consequence of competition with weedy species, however, cannot be excluded as a possibility. Where present, seeded grasses grow tall and full, but bare soil is abundant between the individual grass clumps, thus providing an ideal situation for invasion by the weedy species.

Vegetative Composition with Respect to Terrace Location and Burning

Canopy cover of big bluestem and switchgrass averaged 5% greater on burned than on unburned strata (Table 1). Differences between burned and unburned strata were greatest on the terrace-channel for big bluestem (13%) and on the terrace-slope for switchgrass (11%). The maximum coverage of big

bluestem occurred in the burned terrace-channel; the highest canopy cover in the unburned area was on terrace-slopes. In contrast, burning decreased Indiangrass coverage by an average of 2% with the greatest reduction (8%) occurring in the terrace-channel. The terrace-channel accumulates a greater amount of plant material than other terrace strata thus, when dry, it may support a hotter fire. This is likely to have a greater effect on species that are more sensitive than others to the effects of burning.

Burning significantly reduced the coverage of many forbs but increased that of foxtail (Table 1, Fig. 2). The absence of burning had the opposite effect, substantially reducing foxtail but increasing forb canopy cover. As previously indicated, the area designated as the unburned Tallgrass area was burned in 1974, the year previous to this study. Substantial differences can be seen between the burned and the unburned areas indicating that the effects of a single burning may be short-lived.

Biomass Production with Respect to Terrace Location and Burning

In the Tallgrass Area, above-ground vegetative biomass averaged 3,260 kg/ha on terrace intervals in comparison to 6,757 kg/ha for all other terrace strata combined (Fig. 3). This difference is probably due to the soil-moisture and nutrient differences previously discussed. Cox et al. (1951) noted that productivity was lowest on terrace-ridges. His study, however, was conducted on slopes that were more gentle with less distinct terraces than those used for the present study. These variations, in combination with differences in climate and soil, are likely to account for the observed differences in productivity.

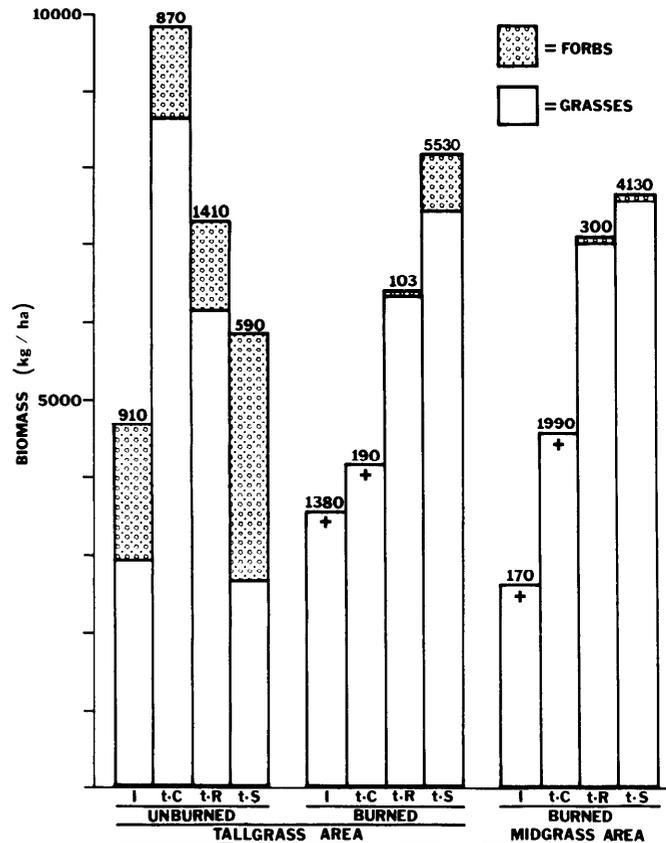


Fig. 3. Grass and forb biomass on burned and unburned study strata. Values above each bar indicate standard deviation of means for total biomass. "+" = forb biomass of less than 50 kg/ha, I = terrace interval, t-C = terrace-channel, t-R = terrace-ridge, t-S = terrace-slope.

The principal effect of burning on net above-ground productivity was a substantial reduction in vegetative biomass, with the amount of the reduction occurring in direct proportion to the amount of biomass accumulated prior to the burn. Biomass accumulation was estimated by comparing the data from the burned and from the unburned Tallgrass Areas (Fig. 3). Biomass values were higher in the terrace-channel (9,790 kg/ha) than on other study strata (5,930 kg/ha). The reduction in biomass as a consequence of burning was greater in terrace-channels (a decrease of 5,630 kg/ha) than on other terrace locations (average decrease of 1,000 kg/ha); biomass increased 2,330 kg/ha on terrace intervals. These results suggest that when a substantial amount of previous-years' growth accumulates in some terrace location, a fire may be more destructive than in areas where the accumulation is not as great. This situation is likely to be particularly true in reseeded grasslands where the standing dead is primarily grass. The relationship between productivity and terrace location appears to be similar for both the burned Tallgrass and the burned Midgrass Areas. No unburned Midgrass Areas were available for comparison but pre-burn observations indicate that litter accumulation in the Midgrass terrace-channels was substantial.

As previously indicated from canopy coverage data, forb biomass declined sharply as a consequence of burning. Grass biomass (Fig. 2) includes a substantial amount of foxtail (Table 1) thus the success of seeded perennial grasses is less than that indicated by total grass biomass values. Coverage data, however, indicates that burning either favored or did not substantially reduce coverage of the seeded perennial grasses.

Conclusions

The combined results of this study show that 5 years of vegetative growth and competition on a reestablished grassland resulted in the differential establishment of species with all seeded native grass species favoring some terrace location over terrace intervals. Terracing also provided conditions that supported substantially different amounts of net aboveground productivity. This appears to have affected the establishment of certain, short-statured species and also appears to have altered the effect of burning on species composition. Terraces, thus, provide artificial micro-habitats that alter the distribution of vegetation from that expected for native prairies. In addition, poor conditions on some terrace locations slow the process of establishing a continuous stand of native prairie grasses. These factors, in conjunction with others, such as the alteration of natural water runoff patterns as well as the potential for severe erosion between time of seeding and time of vegetative establishment, must be considered in relation to the desired use of the future grassland. The results of this study, however, indicate that whenever possible it is advisable to remove terraces and redistribute terrace soil prior to seeding cultivated land to native grasses.

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