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Economic feasibility of rangeland seeding in the arid southwest

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Abstract

Results from 6 years of seeding trials in the Chihuahuan Desert indicated that establishment of introduced and native grass species responded directly to soil moisture at the 1.22 cm (0.5 in) depth, soil temperature at the 5.08 cm (2 in) depth, and seedbed preparations of mulching and pits. The economic analysis indicated that seeding is not an advisable financial investment in the region under general circumstances. It also showed that when seeding is deemed necessary the best native species economic alternatives are blue grama [*Bouteloma gracilis* (H.B.K.) Griffiths] with either no seedbed preparation or with post seedbed preparation of mulch. The best introduced species economic alternative is Lehmann lovegrass (*Eragrostis lehmanniana* Nees.), with no seedbed preparation.

Key Words: rangeland seeding, economic feasibility, soil moisture, soil temperature, seedbed preparation, stand establishment.

Rangeland seeding is an intensive range improvement practice used to change the composition of rangeland vegetation. It can result in increased productivity of 100% to 1,000% within 1 to 3 years (Herbel 1983). Since natural revegetation processes can take more than 100 years, rangeland seeding can be an effective way to establish desirable vegetation in areas where vegetation has been severely depleted (Allison 1990). Because successful seeding is dependent on factors such as climate and weather conditions, there is a need to understand how climate affects seeding and to evaluate the likelihood of success or failure in establishing a viable stand. It is important for land managers to conserve and, where necessary, improve the range resource if a seeding project is to be successful (Buffington and Herbel 1965).

Some of the principles of seeding were outlined by Merkel and Herbel (1973) and Holechek et al. (1995) as: (1) remove or reduce competition of unwanted plants and (2) select plant materials and varieties that are adapted to the specific site being seeded. The most desirable time to seed rangeland for uniform seedling distribution is immediately before the season of the most reliable rainfall and when the temperature is favorable for plant establishment (Marietta and Britton 1989). Establishment is often difficult due to insufficient moisture, high temperatures, high evaporation rates, damage to seedlings by wind-blown particles, and slow growth during the seedling stage (Welch et al. 1962). The climate is uncontrollable, but other factors that are controllable (i.e., plant variety, seedbed preparation, and seeding technique) can also affect the success or failure of seeding.

Range seeding represents a means to increase land productivity in arid regions and/or to preserve soil and other resources. However, the risk and expense associated with seeding are significant. For land managers to successfully evaluate seeding as a range improvement alternative, they need to understand (1) how environmental and management factors affect seeding success and failure, (2) the resulting financial costs and returns, (3) the probabilities of success and failure, and (4) the expected economic consequences. The objectives of this study were to determine environmental and management conditions necessary for stand establishment in the arid Southwest and identify the expected economic returns from seeding.

Methods and Procedures

The analysis consisted of several major components: (1) estimating relationships that describe how environmental and management practices affect stand establishment, (2) estimating the net income from stand establishment if it is not achieved, (3) determining the probabilities of conditions needed for stand establishment, and (4) estimating the expected net returns of seeding. Analysis of existing biological data concerning rangeland seeding was an important aspect of this study. The other main components were the analysis and interpretation of the biological data in an economic context. The following sections describe (1) the rangeland seeding data, (2) estimation procedures for stand establishment relationships based on environmental and management factors, and (3) procedures used to analyze the economic feasibility of rangeland seeding.

Data

The data for this study were obtained from experiments conducted in 6 years of seeding trials [Herbel 1961–1966, unpublished rangeland seeding experiment data, Jornada Experimental Range, Agr. Research Service, USDA, N.M. State Univ., Las

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Cruces, N.M.; summarized in Sosebee and Herbel (1969), Herbel and Sosebee (1969), Herbel (1972a, 1972b), and Herbel et al. (1973)] in the arid desert grassland of the Jornada Experimental Range, located in the northern part of the Chihuahuan Desert north of Las Cruces, N. M.. These data typify all the Chihuahuan Desert, which covers over 450,000 km^2 (175,000 miles^2) and extends through southern New Mexico, southeastern Arizona, far west Texas, and northern Mexico (MacMahon 1988). These data provide information on soil types, soil moisture at different depths, soil temperature at different depths, air temperature, seedbed preparation, vegetation cover, and stand establishment from an extensive group of seeding trials/experiments. Time of seeding varied from early July to mid-August and multiple seeding rates were used in all experiments.

Data were obtained on 14 varieties of plants, which were grouped into 2 categories: (1) introduced species {Lehmann lovegrass (*Eragrostis lehmanniana* Nees.), boer lovegrass (*Eragrostis chloromelas* Steud.), old-world bluestem [*Bothriochloa ischaemum* (L.) Keng var. *ishaemum*], and rhodesgrass (*Chloris gayana* Kuneth)} and (2) native species {black grama [*Bouteloua eriopoda* (Torr.) Torr.], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], tobosa grass [*Hilaria mutica* (Buckl.) Benth.], vine mesquite (*Panicum obtusum* H.B.K.), alkali sacaton [*Sporobolus airoides* (Torr.) Torr.], sacaton (*Sporobolus Wrightii* Scribn.), fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], bush muhly (*Muhlenbergia porteri* Scribn ex Beal), blue grama [*Bouteloua gracilis* (H.B.K.) Griffiths], and little bluestem [*Schizachyrium scoparium* (Michx.) Nash]}. The introduced grasses are non-native species that have rapid establishment. The native species are those that are indigenous to the area and occupy a higher successional stage.

Stand establishment was measured as the number of seedlings/.09 m^2 (/ft^2). There were 5 categories of stand establishment used: (1) excellent, $\geq$ 9 seedlings/.09 m^2; (2) good, 7–8 seedlings/.09 m^2; (3) fair, 4–6 seedlings/.09 m^2; (4) poor, 1–3 seedlings/.09 m^2; and (5) failure (Herbel 1965).

Response Models

Empirical response models were developed for relationships between stand establishment and the explanatory environmental and management variables. Soil moisture and soil temperature are the most critical environmental factors affecting the success of rangeland seeding. Soil moisture and soil temperature relationships were estimated by using measurements at the 1.27, 5.08, and 10.16 cm (0.5, 2, and 4 in) depths averaged weekly.

The general mathematical structure for the stand establishment response models was based on conceptual and prior empirical evidence (Sherwood 1994). The resulting multiplicative model structure was:

$$SE_v = \beta_0 SR^{\beta_1} (SM1 + 1)^{\beta_2} (SM2 + 1)^{\beta_3} (SM3 + 1)^{\beta_4} \quad (1)$$
$$e^{\beta_5 SB_1 + \beta_6 SB_2 = \beta_7 SB_3 + \beta_8 SB_4 + \beta_9 SB_5 + \beta_{10} SB_6}$$
$$e^{\beta_{11} ST1 + \beta_{12} ST1^2 + \beta_{13} ST2 + \beta_{14} ST2^2 + \beta_{15} ST3 + \beta_{16} ST3^2}$$

where

SE_v = stand establishment seedlings/.09 m^2(ft^2) for species group v; v = I (introduced) or N (native);

SR = seeding rate in 1.12 kg/ha (lbs/acre);

SM1 = soil moisture (% days $\geq$ field capacity, July-September) at the 1.27 cm depth [field capacity is the level of soil moisture adequate to prevent permanent wilting, which varies with soil type, vegation, and soil and air temperature (Sherwood 1994)];

SM2 = soil moisture (% days $\geq$ field capacity, July–September) at the 5.08 cm depth;

SM3 = soil moisture (% days $\geq$ field capacity, July–September) at the 10.16 cm depth;

SBi = seedbed preparation dummy variable, i = 1,...,6; SB1 = 1 if seedbed preparation is pits, 0 otherwise; SB2 = 1 if seedbed preparation is root plowing, 0 otherwise; SB3 = 1 if seedbed preparation is emulsion, 0 otherwise; SB4 = 1 if seedbed preparation is mulch, 0 otherwise; SB5 = 1 if seedbed preparation is plastic, 0 otherwise SB6 = 1 if seedbed preparation is furrows, 0 .3- otherwise;

(If SB1 = SB2 = SB3 = SB4 = SB5 = SB6 = 0 there is no seedbed preparation.)[1]

ST1 = average maximum soil temperature (°C),July–September, at the 1.27 cm depth;

ST2 = average maximum soil temperature (°C), July–September, at the 5.08 cm depth;

ST3 = average maximum soil temperature (°C), July-September, at the 10.16 cm depth; and

β_i = estimated parameters.

All environmental data are micro-climate data taken at the experimental sites.

This functional form was used because it is conceptually consistant with hypothesized variable relationships and interrelationships. That is, stand establishment increases at a decreasing rate as seeding rate and soil moisture increase (marginal productivity of these inputs decreases). Stand establishment increases, then decreases, as soil temperature increases. Seedbed preparation shifts these relationships, and all of the variables are interactive in their effects on stand establishment.

The response model was linearized by logarithmic transformation to facilitate multiple linear regression estimation. The estimation form of equation 1 was:

$$\begin{aligned} \ln SEv = {} & \ln \beta_0 + \beta_1 \ln SR + \beta_2 \ln(SM1 + 1) + \beta_3 \ln(SM2 + 1) \\ & + \beta_4 \ln(SM3 + 1) + B_5\, SB1 + B_6\, SB2 \qquad (2) \\ & + B_7\, SB3 + B_8\, SB4 + B_9\, SB5 + B_{10} SB6 \\ & + B_{11} ST1 + B_{12} ST1^2 + B_{13} ST2 + B_{14} ST2^2 \\ & + B_{15} ST3 + B_{16} ST3^2 + \varepsilon \end{aligned}$$

where ln represents the natural logarithm and ε is the stochastic error term.

Economic Analysis

Economic feasibility is determined by comparing the costs associated with the implementation of a rangeland seeding project to the present value (PV) of expected additional revenue. The decision criterion is: if the expected present value of added revenue is greater than or equal to the costs, the seeding improvement is considered economically feasible. The following sub-sections address the estimation of costs, revenues, discounted net returns, and expected net returns.

Cost Estimates.

The costs of reseeding occur at the time of the initial improvement and are formulated as follows:

[1]The dummy variables shift the regression relationship up or down according to the effects of alternative seedbed preparations. Each shift is relative to no seedbed preparations.

$$TC = SC_v + SB + SO \quad (3)$$

where

TC = total cost of seeding,

SC_v = seed costs of either introduced species or native species,

SB = seedbed preparation cost used to prepare the soil for seeding operations, and

SO = is the seed application cost, not including seed costs.

SB costs are based on using farm-type equipment (tractors, plows, discs, etc.). There is a cost of seeding for each species and each type of seedbed preparation.

Revenue Estimates.

For this analysis, economic value was measured by converting the added yield from the stand establishment models to added livestock (cattle) production. The additional forage production was converted to livestock production by calculating an expected amount of marketable livestock that results from the increased grass production. Torell et al.(1991) estimated that in medium-size ranches in southwest New Mexico, where the sites are located, one animal unit year (AUY) produces: (1) 86.0 kg (189.5 lbs) of steer calf [i.e., 39% (1/2 of a 78% calf crop) of a 220.5 kg (486 lb) (sale weight) steer calf], (2) 52.8 kg (116.5 lbs) of heifer calf [i.e., 26% (1/2 of a 78% calf crop minus 13% replacement rate) of a 203.2 kg (448 lb) (sale weight) heifer calf], and (3) 59.0 kg (130 lbs) of cull cow [i.e., 13% (replacement rate) of a 453.6 kg (1,000 lb) cow]. The revenue generated from one AUY was calculated to be as follows:

$$PL = (PS * S) + (PH * H) + (PC * C) \quad (4)$$

where

PL = net value of livestock marketed per AUY ($143.82 per animal production unit),

PS = 1987–1991 average market price of a 181–227 kg. (400–500 lb) #1 medium frame steer [$2.22/kg ($100.60/cwt)],

S = marketable steer calf resulting from added grass production (86.0 kg),

PH = 1987-1991 average market price of a 181–227 kg #1 medium frame heifer ($1.88/kg),

H = marketable heifer calf resulting from added grass production (52.8 kg),

PC = 1987-1991 average market price of a commercial grade 2-4 cow ($1.02/kg), and

C = marketable cull cow resulting from added grass production (59.0 kg).

Market prices used for this analysis were average sale prices at San Angelo, Tex., (U.S. Dept. of Agr. 1987-1991). The 5-year average was chosen because it represents reasonably current price levels, but covers enough time to smooth major price fluctuations. The total value of range seeding is the product of the value of 1 AUY and the total increase in animal units resulting from the improvement.

Expected Net Present Value.

Four assumptions were applied to all situations: (1) the specified livestock prices were assumed to stay constant, in real terms, over the 20-year planning horizon; (2) there are no maintenance costs associated with seeding; (3) the resource is managed so that there is no deterioration in stand over time; and (4) rangelands are in a condition that will allow for seeding without additional vegetation removal by either mechanical or chemical means.

The next steps involved accounting for the time value of resources (discounting) and the probabilities of stand establishment being achieved. After the forage response functions are known for each stand establishment and given adequate growing conditions to maintain the stand and no grazing deferment, added revenue was estimated for each future year in which the seeding was effective. This added revenue was discounted to a present value of seeding as follows:

$$PVAP = \sum_{t=1}^{n} \left[\frac{VAGPt}{(1+r)^t} \right]$$

where PVAP is the present value of added production from the time of seeding to time period n, $VAGP_t$ is added revenue from seeding in year t, and r is the discount rate. There is a PVAP for each level of stand establishment (excellent, good, fair, poor, and failure). The sum of the added revenues from each of the 5 forage levels was discounted using rates of 3 and 7% to test the sensitivity of the results to real interest rate variability. The 3% rate represents a real (adjusted for inflation) long-term rate while the 7% represents a high real discount rate. With proper maintenance and grazing practices, a given stand of later successional stage native species should last at least 20 years (n = 20). Net returns beyond 20 years are increasingly uncertain and have little effect on present value.

The probability of achieving a given stand establishment is determined by the probabilities of soil moisture and soil temperature conditions occurring that will result in that stand. Probabilities for stand establishment categories of excellent [≥ 9 seedlings/.09 m^2 (ft^2); carrying capacity 12 animal units yearlong (AUY)/ 259 ha (section)[2]], good (7–8 seedlings/.09 m^2; 7.8 AUY/section carrying capacity), fair (4–6 seedlings/.09 m^2; 4.2 AUY/section carrying capacity), poor (1–3 seedlings/.09 m^2; 1.2 AUY/section), and failure are dependent on conditions both outside (weather conditions) and within (seed planting depth, drill calibration, etc.) the control of the range manager. It was assumed that the carrying capacities of seeded rangeland before seeding was effectively zero, so that these carrying capacities also represent change in capacity. Nonetheless, probabilities of alternative soil moisture and soil temperature conditions occurring were estimated directly from the data set. The data provided the proportion of time that each combination of soil moisture and temperature necessary to achieve stand establishment in given year of excellent, good, fair, poor, and failure.

The expected net present value E(NPVAP) of a seeding scenario was determined as:

$$E(NPVAP_i) = \sum_j NPV_i^j (P^j)$$

where $E(NPVAP_i)$ is the expected net present value of additional production, i is the species, NPVij (= PVAP - TC_s) is the net present value for species i with stand establishment j (j = excellent, good, fair, poor, and failure), P^j is the probability of achieving SM1 and ST2 that will result in stand establishment j. Thus, if $E(NPVAP_i)$ is greater than zero, the improvement can be considered a financially feasible project.

[2]These carrying capacities assume grazing 40–45% of usable forage, depending on the level of stand establishment (Sherwood 1994).

Results

Stand Establishment

Results from the stand establishment for native (SEN) and introduced (SEI) species models are presented in Table 1. Variables for which the coefficients were not statistically significant were excluded from the estimated equations. The estimated regression coefficients represent the effects of soil temperature (ST2) measured at the 5.08 cm depth during the growing season, soil moisture (SM1) measured at 1.27 cm depth during the growing season, and (3) seedbed preparations of pits (SB1), asphaltic emulsion (SB3), and mulch (SB4). The t-statistics indicated that all variables shown were statistically different from 0 at the 95% confidence level. The 2 models are discussed below.

Table 1. Regression estimates for stand establishment for introduced (SEI) and Native (SEN) species.

Variable	Estimated coefficient	Standard deviation	t-ratio at .05 level
--------- Introduced Species (dependent variable - ln SEI) ---------			
Constant	-63.381	7.112	- 8.912
SB3	-1.937	0.135	-14.324
Ln (SM1 + 1)	2.281	0.658	3.461
ST2	1.199	0.131	9.148
$ST2^2$	-0.0055	0.0006	-9.113
n = 71, d.f. = 66, adjusted R^2 = 0.7834, F = 64.20			
--------- Native Species (dependent variable - ln SEN)---------			
Constant	-37.512	5.016	-7.478
SB1	0.449	0.124	3.628
SB3	-1.039	0.105	-9.857
SB4	1.232	0.266	4.638
Ln (SM 1 + 1)	2.115	0.353	5.994
ST2	0.722	0.097	7.462
$ST2^2$	-0.0030	0.0004	-7.174
n = 142, d.f. = 135, adjusted R^2 = 0.686, F = 52.426			

In the SEI equation, the SB3 (asphaltic emulsion) variable indicated that the use of asphaltic emulsion resulted in a decrease of 1.94% in grass seedlings/.09 m^2 for introduced grass species relative to no seedbed preparation. This may be from chemical composition or heat absorbing characteristics of black asphaltic emulsion, or both. Because it showed an inverse relation, asphaltic emulsion was concluded to be an infeasible method of seedbed preparation. A 1% increase in the July to September days that soil moisture at the 5.08 cm depth was ≥ field capacity (SM1) caused SEI to increase by 2.28%. Soil temperature at the 5.08 cm depth had both direct and inverse effects on SEI, depending on the range of ST2. The optimal level of ST2 derived from the estimated equation, with all other variables held at mean levels of the data set, is 42.8°C (109°F). As ST2 approaches 42.8°C, an increase in average soil temperature between July and September increased SEI. As ST2 exceeds 42.8°C, an increase in ST2 resulted in fewer seedlings/.09 m^2. Note that the effect of soil temperature on stand establishment is not independent of the level of other variables, notably soil moisture. In fact, the temperature-moisture "windows" for stand establishment are relatively small within the overall range of environmental conditions (see table 2). The SEI model explained 78.3% of the seedling stand establishment variation in the data.

For native species (SEN), a one unit increase in SM1 resulted in a 2.1% increase in the number of seedlings/.09 m^2. The optimal soil temperature at the 5.08 cm depth for native species of grass derived in the same manner as for SEI, is 42.8°C, the same as for SEI (this was mere happenstance), although the response was "flatter" (stand establishment did not decline as quickly as soil temperatures deviated from the optimum). Pits (SB1) caused seedlings/.09 m^2 to increase by 0.45%, asphaltic emulsion (SB3) caused stand establishment to decrease by 1.04%, and hay mulch (SB4) increased stands by 1.23%. Pits and hay mulch were technically viable seedbed preparations, but asphalt emulsion was not because it reduces stand establishment. These differences in the impact of seedbed preparations on SEN were probably due to the way each seedbed preparation method affects the micro-environment. That is, pits collect water, mulch lowers soil temperature, and asphalt absorbs heat and raises soil temperature. The adjusted R^2 value indicates that the SEN model explained about 69% of the variation in stand establishment in the data.

These results indicate that the microclimate variables that affect stand establishment are soil moisture at the 1.27 cm depth and soil temperature at the 5.08 cm depth. Given the seedlings/.09 m2 required, the probabilities of achieving excellent, good, fair, and poor stands for the different viable seedbed preparations are shown in Tables 2 and 3. Since the probability of failure is 1 minus the probabilities of the other four outcomes, the probability of a failed stand is 0.76 with introduced grass species and varies from 0.25 to 0.61 with native species, depending on seedbed preparation.

Table 2. Combinations of SM1 and ST2 that achieve stand establishment levels of excellent, good, fair, and poor for introduced grass species, no seedbed preparation.

SEI-seedlings/.09 m^2	SM1[1]- soil moisture (units) 1.27 cm depth	ST2[2]- soil temp. (°C) 5.08 cm depth	Probability
Excellent stand ≥ 9	.29 ≤ SM1 ≤ .89	35.5 ≤ ST2 ≤ 51.11	0.02
Good 7 ≤ stand ≤ 8	.26 ≤ SM1 ≤ .92	37.17 ≤ ST2 ≤ 51.94	0.10
Fair 4 ≤ stand ≤ 6	.20 ≤ SM1 ≤ .98	32.22 ≤ ST2 ≤ 53.79	0.04
Poor 1 ≤ stand ≤ 3	.09 ≤ SM1. ≤93	29.72 ≤ ST2 ≤ 53.06	0.08
Failure <1			0.76

[1]Measured as the percent of days that SM1 is greater than or equal to field capacity.
[2]Measured as the average maximum soil temperature during the growing season (July–Sept.).

Costs

Costs associated with stand establishment occur at the time of seeding. They include seed, seedbed preparation, and seed drilling. Estimated costs are summarized in Table 4. In the case of introduced (lower successional) species, the analytical results indicate no seedbed preparation is optimal, and thus there are no seedbed preparation costs. For native (higher successional) species, no seedbed preparation, pits, and mulch are technically feasible approaches. Total costs, which can be determined from

Table 3. Combinations of SM1 and ST2 that achieve stand establishment levels of excellent, good, fair, and poor for native species, by seedbed preparation.

SEN-seedlings/ .09 m^2	SM1[1]- soil moisture, 1.27 cm depth	ST2[2]- soil temp. (°C) 5.08 cm depth	Probability
No seedbed preparation			
Excellent- stand ≥ 9	.34 ≤ SM1 ≤ .91	35.56 ≤ ST2 ≤ 51.67	0.00
Good- 7 ≤ stand ≤ 8	.28 ≤ SM1 ≤ .96	33.33 ≤ ST2 ≤ 53.06	0.12
Fair- 4 ≤ stand ≤ 6	.19 ≤ SM1 ≤ .90	30.56 ≤ ST2 ≤ 50.28	0.06
Poor- 1 ≤ stand ≤ 3	.04 ≤ SM1 ≤ 1.0	22.28 ≤ ST2 ≤ 53.33	0.57
Failure-<1			0.25
Seedbed preparation-pits			
Excellent- stand ≥ 9	.24 ≤ SM1 ≤ .84	32.22 ≤ ST2 ≤ 48.89	0.14
Good- 7 ≤ stand ≤ 8	.20 ≤ SM1 ≤ .89	30.33 ≤ ST2 ≤ 50.00	0.03
Fair- 4 ≤ stand ≤ 6	.12 ≤ SM1 ≤ .96	28.89 ≤ ST2 ≤ 52.22	0.06
Poor- 1 ≤ stand ≤ 3	.10 ≤ SM1 ≤ .34	27.89 ≤ ST2 ≤ 30.56	0.22
Failure- <1			0.55
Seedbed preparation-mulch			
Excellent- stand ≥ 9	.12 ≤ SM1 ≤ .97	28.61 ≤ ST2 ≤ 52.22	0.24
Good 7 ≤ stand ≤ 8	.09 ≤ SM1 ≤ 1.00	27.78 ≤ ST2 ≤ 53.06	0.15
Fair- 4 ≤ stand ≤ 6	.14 ≤ SM1 ≤ .34	28.89 ≤ ST2 ≤ 30.86	0.00
Poor- 1 ≤ stand ≤ 3	.05 ≤ SM1 ≤ .27	26.11 ≤ ST2 ≤ 28.33	0.00
Failure-<1			0.61

[1]Measured as the percent of days that SM1 is greater than or equal to field capacity.
[2]Measured as the average maximum soil temperature(°C) during the growing season (July–Sept.).

Table 4, vary depending on which option is exercised. A more complete description of seedbed preparation techniques is available in Sherwood (1994).

Revenues and Expected Net Present Values

Estimated livestock production and revenues for each of the five outcomes--excellent, good, fair, poor, or failed stand establishment--are shown in Table 5. The streams of income discounted over the 20 year life of the improvement are also shown.

The final results from combining discounted revenues, investment costs, and probabilities of the various stands occurring are summarized in Table 6. Results for the 7% discount rate are not shown (all are more negative than at the 3% rate). These results indicate that none of the species under any of the conditions evaluated provided a positive expected net return on the investment. That is, the practice is not viable on its merits as a financial investment. However, if circumstances dictate that seeding be done, blue grama with mulch (Table 6) appears to be the most viable (least cost) alternative, followed closely by lehmann lovegrass (introduced species) and blue grama, both with no seedbed preparation.

Table 4. Estimated costs associated with rangeland seeding.

Seed variety	Seed costs[1]	Seedbed prep.- farm equipment[2]	Drilling costs[3]
Native species	($/.4047 ha)		
sideoats grama	11.00	6.50	6.75
tobosa grass	40.00	6.50	6.75
vine mesquite	23.00	6.50	6.75
sacaton (giant)	26.00	6.50	6.75
alkali sacaton	20.00	6.50	6.75
black grama	40.00	6.50	6.75
fourwing saltbush	12.00	6.50	6.75
bush muhly	40.00	6.50	6.75
blue grama	8.00	6.50	6.75
little bluestem	11.00	6.50	6.75
Introduced species			
lehmann lovegrass	5.75		6.75
boer lovegrass	13.00		6.75
old world bluestem	11.00		6.75
rhodesgrass	7.25		6.75

[1]The assumed seeding rate was 2.24 kg/ha for native and 1.12 kg/ha for introduced species (average seeding rates within the data).
[2]Average custom rate (Curtis & Curtis Seed Co., Clovis, N.M., and Richardson Seed Co., Lubbock, Tex., Mar. 1992) for the use of farm type equipment to do similar work as that required for rangeland seedbed preparation; cost is the same for pits and mulch.
[3]Average custom seeding rate for rangeland grasses in the semi-arid desert region of West Texas.

Summary and Conclusions

Potential benefits from rangeland seeding result from environmental forces that affect stand establishment, range carrying capacity, and economic returns. The objective of this study was to evaluate seeding success and financial feasibility of rangeland seeding. Experimental data were used to estimate stand establishment relationships for introduced and native species. Stand establishments were defined by soil moisture and soil temperature conditions, and by seedbed preparation implemented before and/or after seeding. The response models indicated micro-environmental "windows" for each of 5 stand establishment levels, with window size dependent on the species and the type of seedbed preparation. These micro-environment windows defined levels of soil moisture and soil temperature required to achieve each stand establishment level and the probability of each stand establishment being achieved.

Costs of seeding included seedbed preparation activities when appropriate and seedbed application costs for each species examined. Revenues were estimated by considering expected increases

Table 5. Annual returns generated.

Stand establishment	Carrying capacity AUY/259 ha	Annual revenue	Present value of income over 20 years at discount rate 3%	7%
		($/259 ha)		
Excellent	12.00	1,726	25,676	18,283
Good	7.80	1,122	16,689	11,884
Fair	4.20	604	8,987	6,399
Poor	1.20	173	2,566	1,828
Failure	0	0	0	0

[1]Assumed to also represent the change in carrying capacity.

Table 6. Expected net present values of seeding arid ranges, 3% discount rate; selected grasses.

Species	Expected net present value No seedbed preparation	Pits	Mulch
Native species	------------ ($.4047 ha) ------------		
sideoats grama	−11.53	−15.90	−10.73
tobosa grass	−40.53	−44.90	−39.73
vine mesquite	−23.53	−27.90	−22.73
giant sacaton	−26.53	−30.90	−25.73
alkali sacaton	−20.53	−24.90	−19.73
black grama	−40.53	−44.90	−39.73
fourwing saltbrush	−12.53	−16.90	−11.73
bush muhly	−40.53	−44.90	−39.73
blue grama	− 8.53	−12.90	− 7.73
little bluestem	−11.53	−15.90	−10.73
Introduced species			
lehmann lovegrass	− 8.26	——	——
boer lovegrass	−15.51	——	——
old world bluestem	−11.53	——	——
rhodesgrass	− 9.76	——	——

in carrying capacity and budgeted returns and variable livestock costs, discounted over a 20 year investment life. Net expected returns considered costs, discounted revenues for each level of stand establishment, and probabilities of each level of stand establishment occurring.

Results showed that none of the species had a positive expected net present value under any of the conditions examined. Therefore, the conclusion is that seeding in those arid environments is not financially viable as an investment if the only objective is livestock production. Results showed that blue grama with mulch, blue grama with no seedbed preparation, and lehmann lovegrass with no seedbed preparation had the lowest expected losses. Thus, the conclusion suggested is that if seeding is deemed necessary or desirable for any reason other than a financial investment (e.g., erosion control, land reclamation, wildlife cover), those three seeding situations are most attractive economically.

Several conclusions regarding management of arid rangelands are supported by the results from this study. The negative investment returns underscore the importance of taking care of the fragile land resource so as to avoid the need for seeding. Alternatively, should seeding be considered, the investment potential is not likely to improve unless the probability of seedling establishment can be increased by such factors as being able to anticipate a wet season that is not too warm or too cool. Ways in which the probabilities of achieving desirable environmental conditions may be a productive area for future research. An overall conclusion is that if rangeland revegation in the arid Southwest is to be successful, ways to deviate from traditional methods of seeding must be found.

The study has 2 notable limitations. The experimental data are from sources that are about 30 years old and there may have been some genetic advancements in grasses. Additional alternatives could alter the outcome. Also, these results cannot be extended to higher rainfall or cooler regions; the probabilities of the microenvironment windows being achieved would be different.

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