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Incorporating Precipitation - Induced Variation in Annual Forage Production into Economic Analyses *of Range Improvement Practices*

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Incorporating Precipitation-Induced Variation in Annual Forage Production Into Economic Analyses of Range Improvement Practices

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SUMMARY

The economic returns from livestock production are used as a basis for assessing economic feasibility of range improvement practices. These returns, which involve prices received and costs, are also a function of annual forage production. Forage production on a specific range site and range condition class is largely a function of annual precipitation. Therefore, estimates of annual forage and livestock production over long-term planning horizons should incorporate the variability associated with precipitation. However, most economic analyses of range improvement practices are based on normal precipitation in each year of the planning horizon following treatment.

This study presents procedures for (a) predicting stocking rates and range production under three precipitation regimes, (b) adjusting these yield estimates for the utility value of woody plants during unfavorable years, (c) estimating the economic feasibility of range improvement practices with the risks associated with annual weather variation incorporated, and (d) comparing these procedures to the previous method of using production estimates based only on normal rainfall during the planning horizon.

Precipitation variability can be assessed from historical rainfall records and probabilities established for the frequency of occurrence of varying annual amounts and years when forage production is expected to be favorable, normal, or unfavorable. Stocking rate estimates for each precipitation level and range condition class can be derived from range site and soil series descriptions available from the Soil Conservation Service (SCS). The procedure utilizes the dry matter forage requirement of an animal unit, an estimate of average utilization of total forage production, a factor to convert air-dry forage production reported in SCS documents to available dry matter forage, and an estimate of the average difference in forage production in favorable, normal, and unfavorable years.

South Texas woody plants have a utility value that may contribute significantly to carrying capacity in unfavorable years when herbaceous forage production is extremely limited on fair and poor condition ranges. A procedure was developed where utility values based on species and amount present, animal preference, and accesibility of woody plants can be used to adjust estimated stocking rates.

These procedures allow quick calculation of stocking rate estimates needed for multiple precipitation levels and condition classes after development of response curves for normal rainfall during the planning horizon. This produces response curves for economic analysis of improvement practices that includes the risk of precipitation variability and that are more realistic than non-risk curves reflecting only normal precipitation. A case study for a Clay Loam range site in the 19-31 Precipitation-Evaporation (PE) zone of the South Texas Plains revealed that the use of the risk method estimates the internal rate of return to be two percentage points lower than the traditional, non-risk method in an economic analysis for an aerial spray practice. Although the aerial spray practice in the case study resulted in slightly higher expected yearly cash flows than no treatment, it also resulted in relatively larger differences in cash flows between normal and unfavorable years compared to no treatment. This information can also be used by producers to better assess the relative merit of alternative practices.

While the procedures presented are limited in their capacity to yield more accurate estimates, these limitations (which also identify needed research) should not preclude the development of response curves for economic analyses that are superior to those based only on normal precipitation.

Keywords: Range evaluation/forage production/economic analysis/precipitation variability/woody plant utility/forage response/response curves.

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INTRODUCTION

Evaluation of the feasibility of range improvement and selection of specific practices for achieving improvement requires assessment of benefits and costs associated with each alternative practice or program. Costs such as quantities of resources (labor, equipment, time, and amount of chemical) required to implement the practice are relatively easy to estimate accurately (Scifres et al. 1985). Unfortunately, most benefits from range improvements are more difficult to estimate because they occur over several years after implementation of the practice. Moreover, benefits are achieved indirectly through the impact of the practice on vegetation and subsequent effects on livestock and/or wildlife production levels and costs. Thus, estimating benefits from range improvement practices requires estimating the annual changes in herbaceous and woody vegetation after practice implementation and then estimating expected changes in livestock and wildlife production.

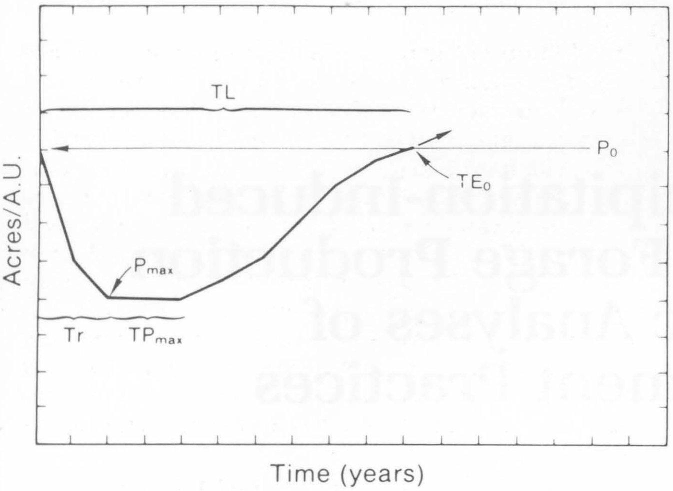
Livestock production levels are measured by annual stocking rate, animal gain per unit of time and/or land area, annual weaning weights, and conception rates. These biological responses must be converted into monetary terms so that economic benefits of the treatments can be compared to costs.

Generalized methods are available for quantifying change in herbaceous forage production from improvement practices such as brush management (Whitson et al. 1979; Scifres et al. 1982, 1983). However, the rate and extent to which forage responds depends on many variables, including the characteristics of the practice, range site potential, post-treatment precipitation, initial range condition and past management, influences of concurrent management practices, and others. Published research often falls short of providing economists with the capability to make projections of production changes over long-term (10-20 years) planning horizons. This is because most range research is relatively short-term (5 years or less in duration) and normally deals with only a single aspect, such as brush management, while resource-wide productivity changes may also be influenced by other factors, such as grazing and wildlife management. This severely limits reliance on published research for projecting responses through a realistic timeframe relative to practical management applications.

Scifres et al. (1985) described the technique of Whitson and Scifres (1980) for recovering data by interview to build comparative response curves. Using the generalized response curve of Workman et al. (1965), the method incorporates published data, observations, and practical experience of selected technical experts to develop response curves (Figure 1). This technique assumes that each year in the planning horizon will be an average year in terms of precipitation and potential for forage yield. However, the likelihood of average annual precipitation over a 15- or 20-year period is highly improbable (Waldrip 1957). Thus, the generalized response method ignores the risk associated with weather variability which severely limits its application.

Conner et al. (1983) reported an economic analysis of range improvement practices which incorporates the risks associated with weather variability into response curves. The procedure requires estimates of annual production (stocking rates) for range sites in a specified condition class for three generalized levels of precipitation (favorable, normal, and unfavorable). Production levels are predicted over time based on range condition changes anticipated from treatment effects. United States Department of Agriculture, Soil Conservation Service (SCS) range site descriptions are used to convert recommended stocking rates into vegetation production, or alternatively, vegetation production into stocking rates. These site descriptions do not, however, provide information on production or stocking rates for multiple precipitation levels in each range condition class. Therefore, a technique to expand production or stocking rate information calculated from range site descriptions to include both favorable and unfavorable precipitation regimes is described in this report.

An additional limitation to predicting range production/stocking rates from range site descriptions is encountered when range condition class is less than good. The potential role of woody vegetation in providing stress condition forage resources for use by



P_o Pretreatment (initial) production of the site and/or management unit. If an entire management unit is to be evaluated, the curves need to be developed by site and final analyses weighted by the proportion of each site in the management unit. This is accomplished from the resource inventory used to assess production potential. P_o may change through the planning horizon.

TL Expected treatment life. The length of time (year) required for the production level to return to P_o.

TE_o The point at which the treatment effect is exhausted.

P_{max} Maximum level of production that will be achieved by treatment for each major range site.

TP_{max} Time (year) that maximum production will be sustained.

Tr Time required to reach P_{max} after application of a given treatment at P_o.

Figure 1. Components of a hypothetical response curve for economic evaluation of brush management alternatives (Scifres et al. 1985).

livestock becomes increasingly important in the lower condition classes. This required development of a procedure to determine the utility value for woody plants on fair and poor condition ranges, and for adjusting stocking rates to reflect carrying capacity in unfavorable years. Utility value is considered to be the usefulness of woody plants based on animal preference, amount present, accessibility, and other factors.

Thus, the objectives of this bulletin are to present procedures for (a) predicting stocking rates and range production under three precipitation regimes, (b) adjusting these yield estimates for the utility value of woody plants during unfavorable years, and (c) estimating the economic feasibility of range improvement practices with the risks associated with annual weather variation incorporated. The use of these procedures will also be compared to the previous method of using production estimates based only on normal annual rainfall during the planning horizon.

RATIONALE AND ASSUMPTIONS

Multiple Production Potential Based on Precipitation

Many factors contribute to annual variation in rangeland production, but amount of precipitation and its distribution within the year is the primary factor. U.S. National Cooperative Soil Survey interpretations for soil series recognize this variation by including estimates of annual production of the climax vegetation (natural potential vegetation) for soils during favorable, normal, and unfavorable years.

SCS range site descriptions also provide an estimate of total annual air-dry production of the climax plant community (or excellent range condition) for each range site for favorable and unfavorable years (USDA, SCS, 1976). These publications do not, however, precisely define the terms favorable, normal, and unfavorable with respect to annual precipitation levels or seasonal distribution.

A meeting of selected SCS personnel from within the western portion of the South Texas Plains was held at Carrizo Springs to obtain information on precipitation and annual forage production relationships. The meeting was attended by six SCS professional employees representing district offices at Uvalde, Crystal City, Cotulla, and Carrizo Springs. Those attending the meeting had long-term experience in working with South Texas ranchers on the development of range management plans. Two of the participants had over 40 years of combined work experience in South Texas.

Independent queries of SCS personnel at the meeting revealed that, in their experience, normal production could reasonably be expected when annual rainfall was within 20 percent either side of the historical (30-year) annual average. Favorable production levels were assumed to occur in years when annual rainfall exceeds the historical average by more than 20 percent, and unfavorable production levels result when annual rainfall is less than 80 percent of the historical average. This interpretation allows use of historical annual rainfall to establish probabilities of occurrence for three precipitation levels. The influence of seasonality of precipitation occurrence was recognized as a key factor in forage production; however, no attempt was made to incorporate seasonality into the generalized production estimates.

Estimating Site Production for Three Precipitation Levels

Once precipitation levels and probabilities of occurrence are estimated, stocking rate estimates for a specific range site must be related to each precipitation level in each of four range condition classes (excellent, good, fair, and poor).

SCS publications do not provide complete information on production or stocking rates for the three precipitation levels for all four range condition classes.

Range site descriptions provide estimates of the total annual air-dry matter yield of the climax vegetation or excellent range condition for range sites in favorable and unfavorable years. The guide to initial stocking rates in range site descriptions relates stocking rates to percent of climax vegetation remaining within four range condition classes. It was assumed that these stocking rates represented normal years.

Soil series descriptions provide total dry matter yield estimates of potential native vegetation (assumed to approximate excellent range condition) for the soil series in favorable, normal, and unfavorable years.

Range site descriptions were used to derive the expanded stocking rate estimates required. A procedure was developed to calculate stocking rates from those provided in the guide to initial stocking rates, for the four condition classes (Figure 2) or units of vegetation production (Figure 3) and for favorable and unfavorable years. Annual yield estimates from range site descriptions and yield estimates from soil series descriptions served as a basis for verifying the calculated estimates.

The Society for Range Management (1974) glossary of terms used in range management provides a conversion of pounds of forage to animal units. An animal unit is considered to be one mature cow (1,000 pounds) having an average daily consumption of 26 pounds of dry matter forage per day (9,490 pounds per year). Whitson et al. (1979) reported that adjustments for proper range utilization and losses, such as plant senescence, wind, insects, and trampling, would result in an expected utilization by cattle grazing native rangeland year-round of about 25 percent of the total vegetation produced. Thus, an animal unit would require an average of approximately 37,960 pounds (9,490 x 4) total dry matter production to meet annual forage requirements. The quotient from dividing 37,960 by the available annual dry matter production per acre can be used as an estimate of stocking rate (acres per animal unit per year). Conversely, stocking rates can be used to estimate pounds of dry matter production per acre by dividing 37,960 by the stocking rate.

Range site descriptions, however, report pounds of annual vegetation production per acre for range sites on an air-dry rather than oven-dry (dry matter) basis. This results in the conversion from recommended stocking rate to pounds per acre of production using the procedure described above consistently yielding a lower estimate of forage production per acre than that estimated from the range site descriptions, the soil series descriptions, and the calculated production from stocking rates.

Range site descriptions for five major range sites in the 19-31 PE zone of South Texas were analyzed to estimate the average difference between recommended stocking rates and pounds of annual vegetation production per acre based on the dry matter forage requirement for an animal unit. A factor of 1.2 times the vegetation production levels derived from recommended stocking rates yielded production estimates with an average deviation of 8.2 percent from the average of those obtained from all sources. Six of the 15 estimates varied less than 5 percent from the average of all sources.

In addition to the moisture differential between air-dry and dry matter, it is assumed that the factor also accounts for that part of total vegetation that is not available to grazing animals, or the fact that stocking rates contained in the site descriptions may be purposely conservative. Therefore, to estimate stocking rate from annual air-dry production per acre, first divide air-dry production per acre by 1.2 and then divide 37,960 by the quotient. Alternatively, to estimate annual air-dry production per acre, divide 37,960 by the recommended stocking rate and then multiply the quotient by 1.2. Range site descriptions may be used with this method to estimate the annual production for range sites in all condition classes for normal precipitation years.

McBryde (1983) used soil series descriptions for 20 major range sites in the 19-31 PE zone of the South Texas Plains to estimate the average diference between potential dry matter production in favorable, normal, and unfavorable years for ranges in excellent condition. Favorable production averaged approximately 125 percent of normal, while production during unfavorable years was 63 percent of normal. These percentages were used to calculate stocking rates during favorable and unfavorable years based on stocking rates in normal years for all range condition classes less than excellent.

It is probable that the percentage differences in annual yield between normal and favorable or unfavorable years is not the same for all other range condition classes as for excellent. Therefore, estimates obtained in this manner should be compared with estimates from other sources, such as long-term research data or other yield estimates that provide concurrent rainfall records.

Correcting Stocking Rates for Woody Plant Utility Value

The same group of selected SCS personnel (page 2) were asked to review the stocking rate/forage production data generated by the procedure for five range sites and for three precipitation levels in each range condition class. The rationale for the procedure and production estimates for range sites in each condition class and rainfall level were generally accepted, except for fair and poor range conditions in unfavorable years. The long-term experience of the reviewers indicated that stocking rates generated by the procedure for unfavorable years were below those actually possible in South Texas without range abuse. The primary reason offered by the reviewers for rejecting these production estimates was the failure to account for the contribution of woody plants to carrying capacity.

The SCS personnel believed that a typical[1] mixed

[1]Woody plant composition on the site of 30 to 50 percent based on canopy cover and consisting of 8 to 15 of the most commonly occurring species. Vertical structure places approximately 50 percent of browsable material within the browse line.

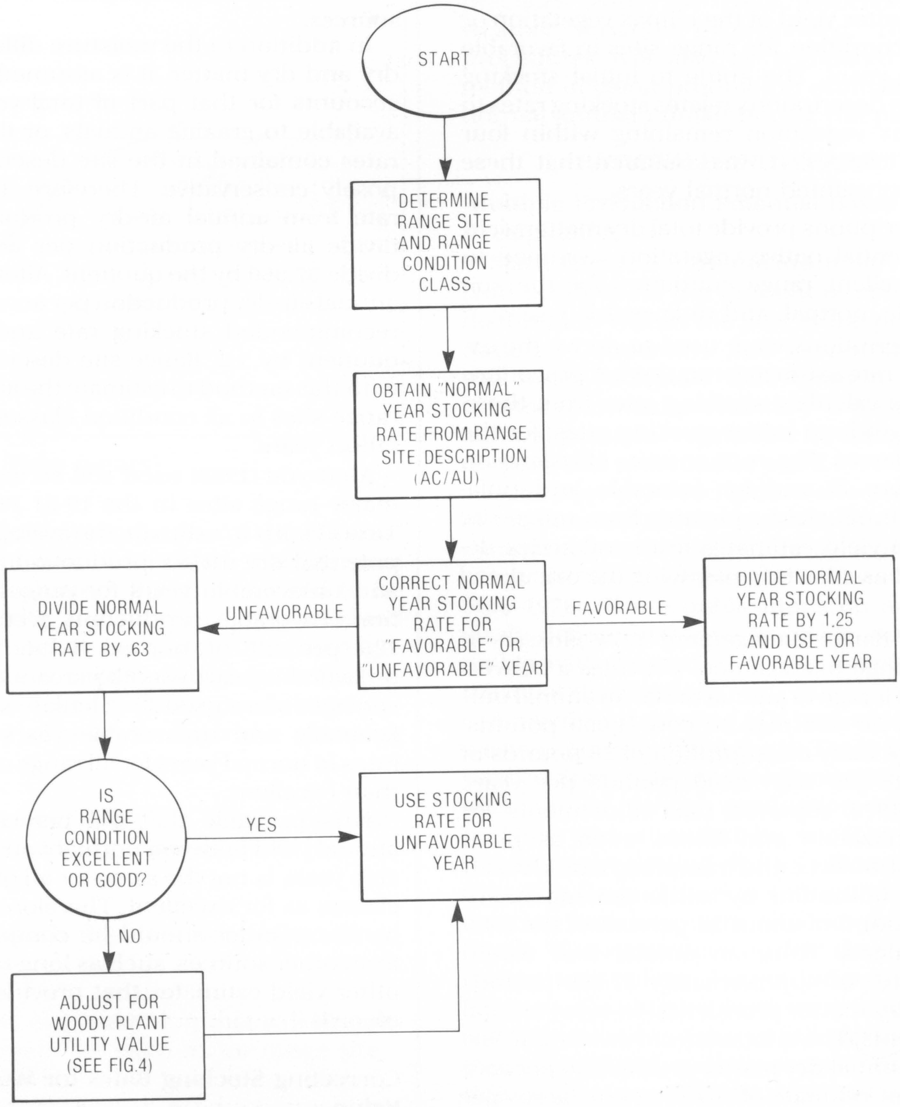


Figure 2. Flow chart for estimating stocking rates for three precipitation regimes from recommended stocking rates in SCS range site descriptions.

brush composition in the area, present in increasing amounts as range condition retrogressed from good to poor, contributes increasingly significant amounts of forage in years when herbaceous production is severely limited. The importance of browse in cattle diets under limited availability or low quality of herbaceous forage has also been reported by Cook and Harris (1968), Lesperance et al. (1970), Everitt et al. (1981), Galt et al. (1982), Holochek et al. (1982), and Kirby and Stuth (1982a). The SCS personnel also agreed that if the typical mixed brush had been altered by a brush control practice that significantly reduced the amount or quality of browse available, the stocking rates calculated by dividing normal year stocking rate by 0.63 (Figure 2) were acceptable. This reduction in woody plant values, as a result of brush control practices, is described by Hamilton et al. (1981).

Although the value of browse to animals has been reported, there is no published procedure for quantitating the utility of a multi-species brush stand for a specific kind of livestock or wildlife. Moreover, no published basis for relating woody plants to range carrying capacity in South Texas exists. The following procedure was developed to estimate a correction factor for unfavorable year stocking rates for range in fair and poor condition based on woody plants present and their accessibility and acceptability to cattle (Figure 4).

Woody plants commonly encountered in South Texas were placed into utility groups for cattle. Selected SCS personnel from Uvalde, Pearsall, and Temple, a South Texas ranch manager, and a range researcher familiar with South Texas brush species were asked to review the placement and suggest changes. A final placement of woody plants was developed as a consensus of those participating in the

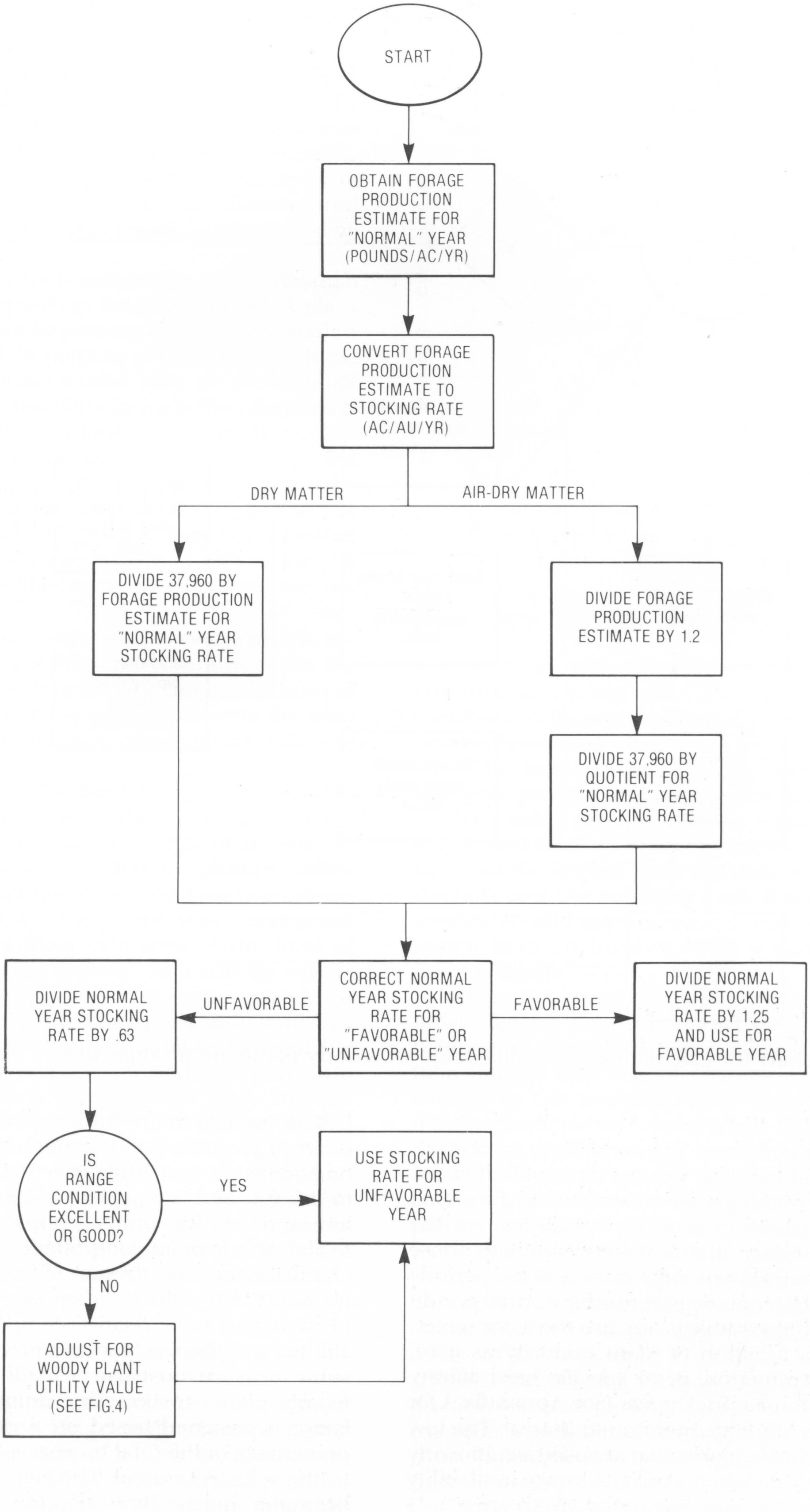


Figure 3. Flow chart for estimating stocking rates for three precipitation regimes from forage production estimates.

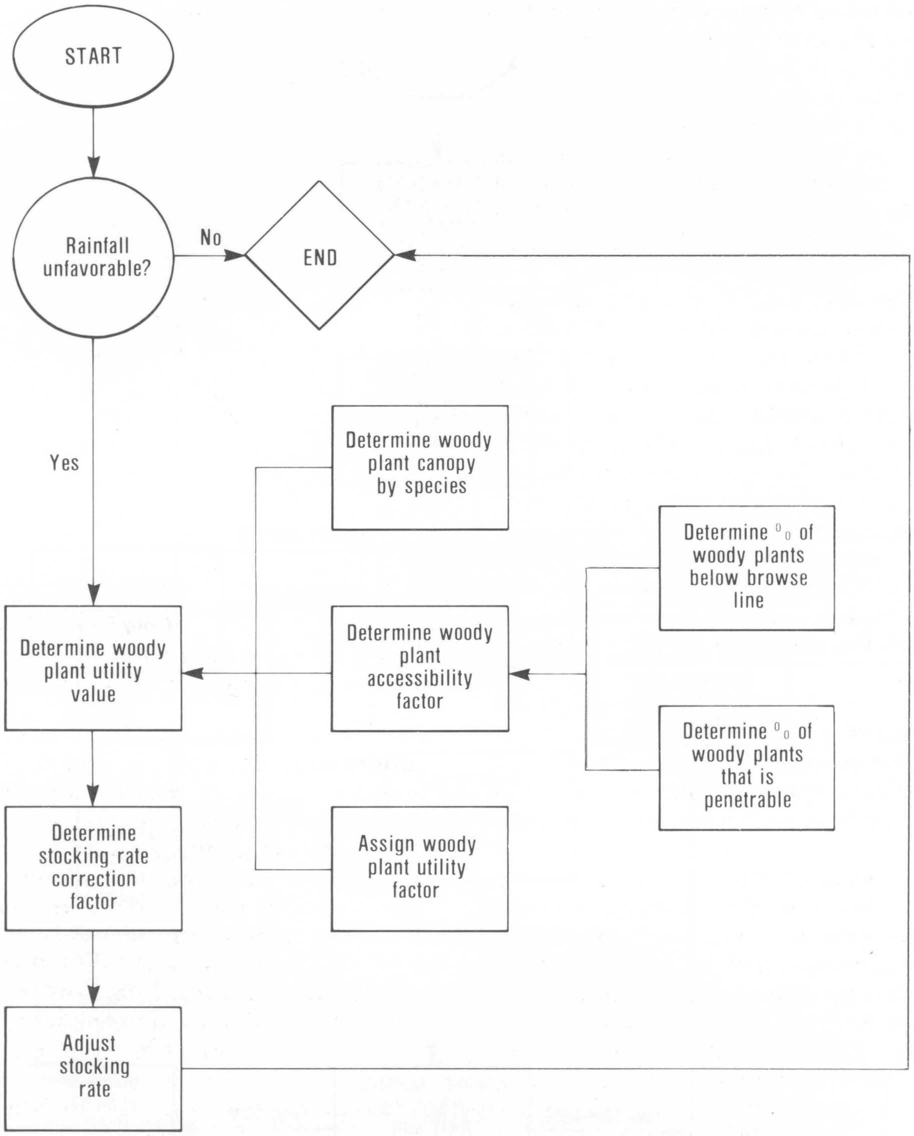


Figure 4. Flow chart for calculating the utility value of woody plants on a range site.

process.

Utility groups consist of plants of high, secondary, variable, low, and very low value. Plants of high value are known to be highly preferred by cattle and are used frequently regardless of growing conditions on the rangeland. Secondary plants were defined as those species that are used frequently during stress periods and seasonally to some degree during normal conditions. Plants in the variable group are those for which utility may be a function of plant maturity as it relates to mast production, or to specific herd affinity for a species, such as pricklypear (See Appendix A for scientific names of plants mentioned in text). The low utility group includes plants that are used significantly only during periods when alternate forage availability is extremely low. The very low utility group are plants that receive no discernible use by cattle, regardless of range conditions.

A numerical value (utility factor) was assigned in order to place the utility groups into relative positions on a scale of 0 to 1. The numerical values of 1.0, 0.7, 0.3 to 0.7, 0.3, and 0 represent high, secondary, variable, low, and very low utility groups, respectively.

The woody plant component on range sites may be characterized by means of randomly-located line transects that yield an adequate sample of the species present and their relative composition based on absolute canopy cover (Parker and Savage 1944). However, some measure must also be made of accessibility of the woody plants to browsing animals. An accessibility factor is assigned based on a visual estimate of the percentage of the total browse volume that is available to the selected animal. The factor considers both the browsing height (browse line) and the penetrable distance into the plants from an accessible perimeter below the browsing height.

The browse line on woody plants was determined by measuring from the soil surface to an average height of 6 ft (See Appendix B for conversion of English to metric units). The penetrable distance was determined by visually estimating the percentage of the woody plants below the browse line that was accessible to cattle. Penetrable distance considered both the perimeter of the plants that could be reached and the distance into the interior of the canopy that could be penetrated by the animals.

The accessibility factor is assigned to each individual woody plant intercepted on the line transect. A plant that is judged to have 50 percent of its volume within the browse line and 50 percent of the browse volume accessible to the animal would have an accessibility factor of 0.25. The accessibility factor is then developed as a weighted average of plants within each species. The weighted average is calculated by multiplying canopy cover by the percent within the browse line by the percent that is penetrable for each plant of the species and dividing by the total canopy cover for that species. The sum of these weighted values for the individual plants is the accessibility factor for the species.

A utility value for each species in the transect is obtained as the product of the percent canopy cover, the utility factor, and the accessibility factor. The sum of the utility value for each species represents the total utility value of the woody plant component for the site (Appendix C).

Woody plant utility value for the range site is used to develop a correction factor to adjust calculated stocking rate for fair or poor condition range in an unfavorable year. This is accomplished by plotting utility values on a curve that generates stocking rate correction factors (Figure 5). The curve was conceptualized by the authors from estimates of the level of contribution to carrying capacity for cattle by woody plants on a Clay Loam site. The curve provides a maximum of 25 percent reduction possible in land area required per animal unit attributable to available browse. Stocking rate may be improved by 25 percent (a stocking rate correction factor of 0.75 times the calculated stocking rate expressed in land area per animal unit) due to very high woody plant utility value, or it may remain essentially unchanged from the calculated value if the browse has a very low utility value. The curve used to produce stocking rate correction factors from utility values should be adjusted by verification of actual stocking rates on similar ranges with low herbaceous forage production.

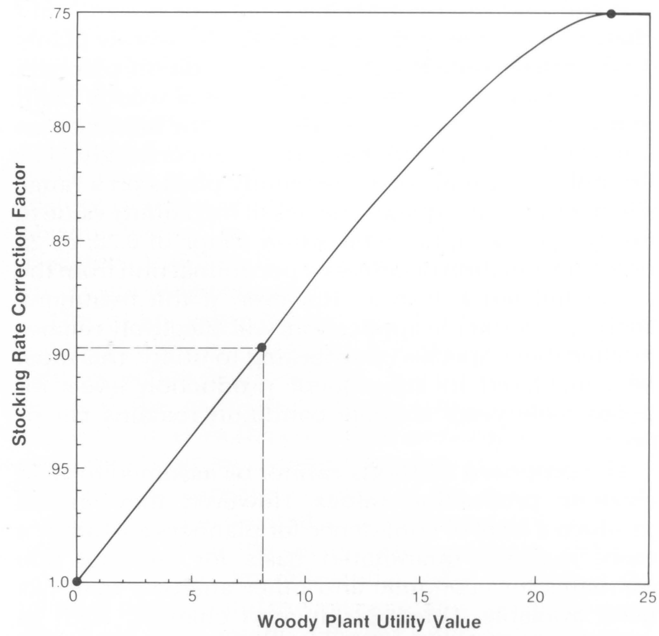


Figure 5. A conceptual curve for converting woody plant utility value to a stocking rate correction factor.

Response Curves Incorporating Multiple Production Potentials

Probabilities for rainfall occurrence, estimates of forage production or stocking rates for three precipitation levels, and correction of estimated production based on woody plant utility value should produce more realistic response curves for economic analyses of improvement practices than those reflecting only normal precipitation (Whitson and Scifres 1980; Conner et al. 1983). Economic evaluations assuming continuous normal precipitation and those with weather risk incorporated would utilize the same procedure, however, with the risk assumption, cash flows would be developed for favorable, normal, and unfavorable precipitation and production levels for each year. Analysis using the risk method, as compared to non-risk, would result in the economic indicators including much of the impact from the variation in annual production and the resulting cash flows. Thus, the risk method should more accurately estimate the expected return from an investment in a particular improvement program.

In the process of developing response curves, it is most effective for experienced observers to estimate production changes based on normal rainfall. Also, the total change and rate of change in range condition caused by the treatment over the planning horizon may be predicted with confidence. Actual herbage production data from similar treatments on the same (or closely related) range site and range condition class, and actual precipitation records also provide bases for predicting similar responses. In each instance, the techniques described herein can be used to incorporate weather-related risks by facilitating estimates of favorable and unfavorable production, as well as providing a basis for converting herbage production estimates to stocking rates. This allows economist/range scientist teams quick access to the high number of production levels required for effective risk analyses. For example, a typical non-risk response curve for a 15-year planning horizon would require development of 15 post-treatment production estimates, or one for each year. Risk analysis would require 45 production estimates, one for each of three levels of precipitation for each year.

If the applied treatment(s) results in a significant change over time in the contribution of woody plants on the range while in fair and poor condition, planners may estimate such effects on the initial woody plant utility value and increase or decrease the influence on unfavorable year stocking rates accordingly. For example, an initial survey of woody plants on a range site may identify enough species of high utility value to justify a stocking rate correction factor of 0.75, or 25 percent reduction of land area per animal unit from the calculated stocking rate. However, if the treatment, such as a herbicide application, will effectively remove or alter those species contributing to utility, this must be considered in subsequent production levels for unfavorable years if range condition remains fair or poor.

The proposed methods cannot be assumed to yield absolute production values. However, they should produce a level of confidence for planners and allow a more realistic, quantitated basis for stocking rate estimates for economic and other analyses than has been available. Other production changes, such as weaning weights and conception rates, are not addressed directly by these methods and must still be based on experience and observations pertinent to each individual assessment.

CASE STUDY

The South Texas Plains is composed of approximately 20 million acres in southwest Texas (Gould 1975), and is commonly referred to as the brush country because of the extensive cover of woody plants on native rangeland (Scifres 1980). Contemporary shrublands are relatively stable communities, often composed of 15 or more species (Scifres et al. 1985). Many of the shrub species provide nutritious browse for livestock and wildlife (Varner et al. 1979; Huston et al. 1981).

Average annual precipitation (16 to 35 inches) increases from west to east. The 19-31 PE zone is largely composed of a two-county tier parallel to the Rio Grande River. Rainfall in this western area is subject to high annual variation and significant dry periods are typical (Waldrip 1957). Two distinct growing periods are separated by a hot, dry period of high evapotranspiration which severely limits forage production from late June until mid-August (Figure 6).

Soils range from clays to sandy loams. The wide range of soil profiles is responsible for large differences in soil drainage and moisture-holding capacities. Range sites vary from Clay Loam to Deep Sand and from Shallow Ridge to Bottomlands. Thus, the study area is characterized by wide variability in both precipitation and soils that contribute to variability in forage production.

For purposes of the case study, a Clay Loam range site was used and probabilities of annual rainfall were determined to be 20, 50, and 30 percent for favorable, normal, and unfavorable conditions, respectively, based on data from 1951-80 for weather stations at Crystal City, La Pryor, and Cotulla (National Oceanic and Atmospheric Administration 1951-80).

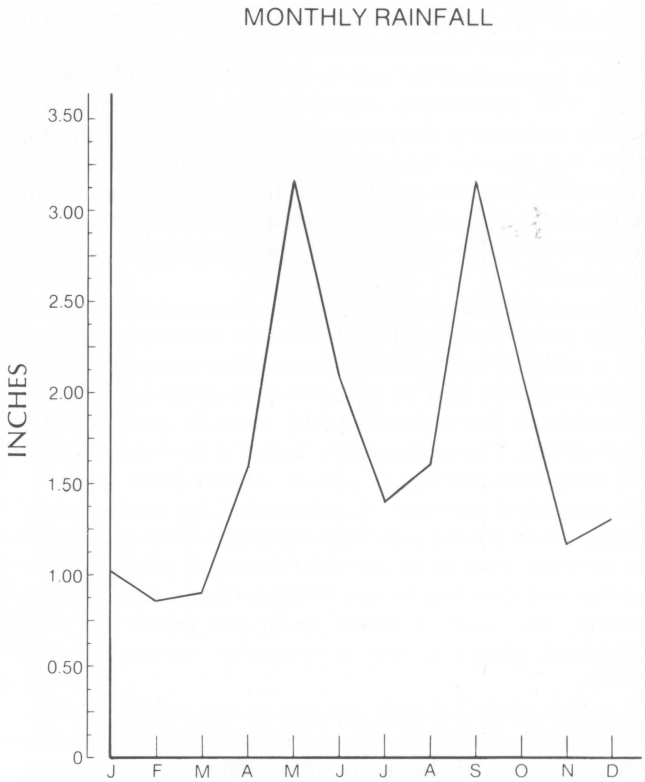


Figure 6. Average monthly rainfall for Laredo, Texas based on 79 years of records. Source: Waldrip, W.J. 1957. Farming and ranching risk as influenced by rainfall. Tex. Agr. Exp. Sta. MP 241. 35 pp.

METHODS

Estimated Production and Stocking Rates

The procedures previously described were used to estimate forage production and stocking rates for the four range condition classes and three precipitation levels for a Clay Loam range site in the 19-31 PE zone of the South Texas Plains (Figure 7). Recommended initial stocking rate for the site in excellent range condition is 15 to 18 acres per animal unit. The mid-range of the stocking rate, 16.5 acres per animal unit, was utilized for this study and assumed to represent a normal year.

The 16.5 acres per animal unit stocking rate from the range site description was converted to 2,761 pounds per acre of air-dry production in a normal year using the procedure described herein (9,490 x 4 ÷ 16.5 x 1.2). Favorable year production was then estimated as 3,450 pounds per acre (125 percent of normal) and unfavorable as 1,739 pounds per acre (63 percent of normal). Favorable and unfavorable stocking rates were then determined by dividing the production per acre calculated for each precipitation level by 1.2 and then dividing 37,960 by the quotient.

The same procedure was used to estimate the production and stocking rates for the mid-range of good and fair condition classes for each precipitation level. A stocking rate of at least 25 acres per animal unit for poor condition is recommended in the range site description. Since no range was given from which to

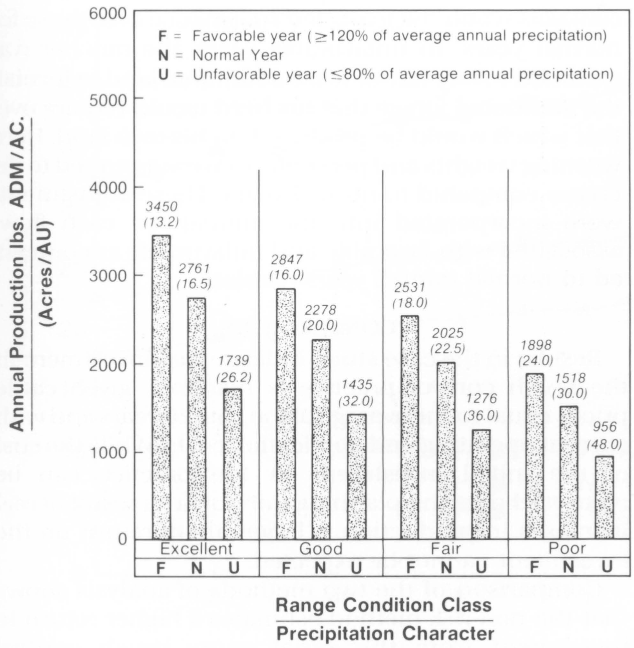


Figure 7. Estimated forage production and stocking rates for a Clay Loam range site in the 19-31 PE zone of the South Texas Plains for three precipitation regimes.

calculate a mid-range stocking rate, 25 to 35 acres per animal unit was assigned based on judgment of the authors and 30 acres per animal unit served as the mid-range for calculations.

The resulting 12 levels of production/stocking rates were reviewed by the panel of SCS range conservationists who agreed that they were reasonable estimates except for two levels, fair and poor condition in unfavorable years.

Correcting Stocking Rate for Woody Plant Utility Value

A typical Clay Loam site in mid-fair condition from a location approximately 8 miles west of La Pryor was used to show the procedure for determining woody plant utility value. The unfavorable year stocking rate calculated for the site was 36 acres per animal unit (Table 1 and Figure 7).

A transect approximately 300 paces long was used to traverse the site. There were two species encountered on the transect, pricklypear and honey mesquite, for which variable utility factors may be assigned. Honey mesquite should receive a utility factor of 0.7 when there is a high potential for bean production, or a 0.3 utility factor when there is a low potential for bean production.

An average of the percent within the browse line recorded for each honey mesquite plant can be used as a guide to assign utility factors, since the greater the percent within the browse line the smaller, less mature the plant and vice versa. For example, an average of 0 to 25 percent within the browse line may be assigned a 0.7 utility factor; 26 to 75 percent a 0.5 utility factor; and 76 to 100 percent a 0.3 factor. Honey mesquite in the example had an average of 95 percent within the browse line, indicating mostly small plants with limited potential for bean production. Therefore, a utility factor of 0.3 was assigned.

Pricklypear cactus may also be assigned a utility factor from 0.3 to 0.7, depending on use of the species by cattle on a specific ranch. For example, if there is a history of burning prickly pear for cattle feeding and obvious heavy use of the species, a 0.7 factor may be assigned. Additional factors may be assigned based on an on-site judgment of the utility of the species.

The utility value for the site of 8.13 (Table 1) was entered on the curve (Figure 5) and yielded a stocking rate correction factor of 0.896. The product of this factor and the calculated stocking rate (36 acres per animal unit) gives the corrected stocking rate (32 acres per animal unit) for the site. Therefore, the contribution of browse to carrying capacity of the sire in an unfavorable year is estimated as a reduction of 4 acres per animal unit from the uncorrected estimate. The procedure accounts for differential value of species, the amount present, and their accessibility. Thus, the same site could have greatly different utility value depending on the value of the species present, accessibility, stage of maturity, and stature of the plants.

As noted earlier, the conceptual curve that produces stocking rate correction factors from utility values is based on the judgment of range professionals in the area as to the influence of brush on range carrying capacity in times of stress. The curve will obviously need to be adjusted over time as research and observations indicate a more reliable level of woody plant contribution and better define the shape of the curve.

According to researchers (Cook 1972; Dietz 1972; Hanley 1982), consumption of browse depends on the nature of the herb/shrub complex. Differences in utility values among woody plant leaves are due not only to nutrient contents, but to secondary compounds and the nature of the cuticle of leaves. These substances may act as animal deterrents and decrease palatability and intake. There are also limitations in the ability of cattle to digest browse because of the limited digestibility of lignin and the need to reduce the forage into small particles before it can continue through the digestive system.

An added consideration is that available browse may be more limited than visual estimates would indicate. Several studies have revealed that in brush canopies of up to 50 percent, shrub production can account for as little as 2-9 percent of total available production (Rector 1983; Kibet 1984). Browse generally constitutes less than 25 percent of the diets of cattle under conditions in which herbage is not severely limiting intake of the animal (Kirby and Stuth 1982a, 1982b). Thus, the conceptual curve assumes a 25 percent maximum contribution from the woody plant component to animal nutrition and as the percentage of browse in cattle diets increases, the ability of cattle to utilize it decreases.

Economic Evaluation

A brush control practice commonly used in South Texas was evaluated with both the non-risk and the risk

TABLE 1. WOODY PLANT UTILITY VALUE ON A CLAY LOAM RANGE SITE IN THE 19-31 PE ZONE OF THE SOUTH TEXAS PLAINS NEAR LA PRYOR, TEXAS

Woody Species	Canopy Cover (percent)	Utility Factor	Accessibility Factor	Utility Value
Guajillo	2.5	1.0	0.840	2.10
Desert yaupon	0.5	0.3	1.000	0.15
Guayacan	4.0	0.3	0.500	0.60
Blackbrush acacia	15.0	0.3	0.565	2.54
Pricklypear	9.5	0.5[1]	0.458	2.18
Coyotillo	1.0	0.0	0.400	0.00
Wolfberry	1.0	0.7	0.250	0.18
Tasajillo	1.5	0.0	0.300	0.00
Creosotebush	3.5	0.0	0.571	0.00
Honey mesquite	2.0	0.3[2]	0.640	0.38
	40.5			8.13

[1]Pricklypear utility factor based on a judgment of intermediate use by range cattle.
[2]Honey mesquite utility factor based on average percent in browse of 0.95 (95 percent).

techniques on the Clay Loam site described previously (page 8). Three levels of production were estimated and stocking rate adjusted based on woody plant utility value in unfavorable years (See Appendix D for procedures for calculating cash flows under risk). The practice selected was aerial spray application of 2,4,5-T + picloram (1:1) at 1 pound active ingredient per acre. The response curves for a normal year were generated by SCS personnel. Final response curves used for no treatment and treated are presented in Figures 8 and 9.

Expected cash flows were calculated for both no treatment and treated cases using both the risk and non-risk procedures. Expected cash flows, accumulated cash flow, net present value of the cash flow, and the internal rates of return associated with the investment in the treatment are reported in Table 2. Under the non-risk procedure, the expected cash flow is calculated based on projected range productivity assuming that normal rainfall occurs each year in the planning period. Under the risk procedure, expected cash flows are computed by weighting the cash flows that would be obtained under favorable, normal, and unfavorable conditions by their estimated probability of occurrence (Appendix D).

Variable costs of a cow-calf operation are based on Texas Agricultural Extension Service 1982 budgets for the South Texas region. Calf selling prices are assumed to be $70 per hundred weight, the average price over the past 20 years in constant 1982 dollars. The cost of the treatment is based on current prices paid to contractors who provide a comparable service (McBryde et al. 1984).

Since herd size (annual stocking rate) would be based on expected forage production under normal rainfall conditions, it was assumed that in favorable years, the rancher would lease out grazing rights or buy stocker cattle to utilize at least part of the forage which would be produced in excess of what his herd could utilize. Also, herd weaning weights and weaning percentages would be expected to increase over those for normal years. In unfavorable years, the rancher was assumed to buy hay or lease additional land to furnish the additional forage that his herd would require over that which would be produced on his own land. Herd weaning weights and percentages were assumed to decrease compared to normal years. These adjustments were incorporated into the annual net cash flows associated with favorable and unfavorable as contrasted to normal rainfall years (Table 3).

CONCLUSIONS

Results in the case study indicate that investment in the brush control practice is marginal, given cattle prices equal to the average of the past 20 years and with current operating and application costs. While the cost of the initial investment in the practice can be recovered over the planning horizon as a result of real increases in production, a large rate of return on the investment cannot be expected.

Comparison of the two methods of analysis shows that the non-risk method estimates a higher return to investment from the aerial spray brush control treatment than the risk method. The non-risk procedure estimates the internal rate of return to be approximately two percentage points larger than the risk procedure estimate.

One reason the non-risk method estimates a higher return to investment is that the distribution of rainfall and annual productivity levels over the range of favorable, normal, and unfavorable conditions is asymmetrical. That is, there is a larger probability of unfavorable rainfall years occurring than favorable years. Also, annual cash flows receive greater penalty during unfavorable years than they are enhanced for favorable years. Thus, differences in the estimates obtained using the two methods would tend to be greater as the asymmetry of the distribution of annual cash flows increased over the range of annual production levels.

The risk method of evaluating range improvement investments provides additional information the producer should find useful. This information (Table 3) is shown as the variation in annual cash flows that could be expected over the planning period from a given range improvement practice. Information on the yearly cash flows and the probability associated with favorable, normal, and the unfavorable cash flow events can be used by producers to better assess the relative merit of alternative practices. Although the aerial spray results in slightly higher expected yearly cash flows, it also results in relatively larger differences in cash flows between normal and unfavorable years compared to no treatment (Table 3).

Based on the example used in the case study, internal rate of return differences in the aerial spray practice between risk and non-risk analyses are small. This could indicate that rational action would be the same regardless of the analysis used. However, margins of difference between risk and non-risk methods will often be greater as the procedure is applied to a variety of conditions in actual applications. In any event, the

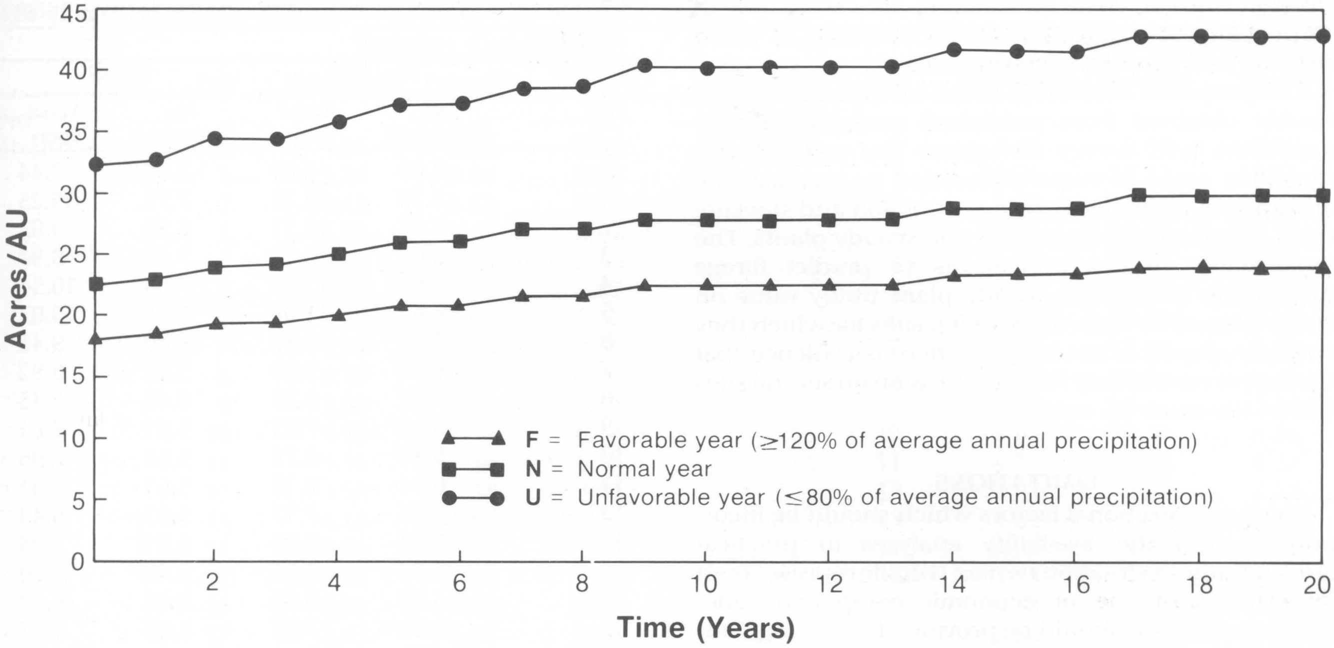


Figure 8. Response curves based on three precipitation levels for an untreated Clay Loam site in the 19-31 PE zone of the South Texas Plains.

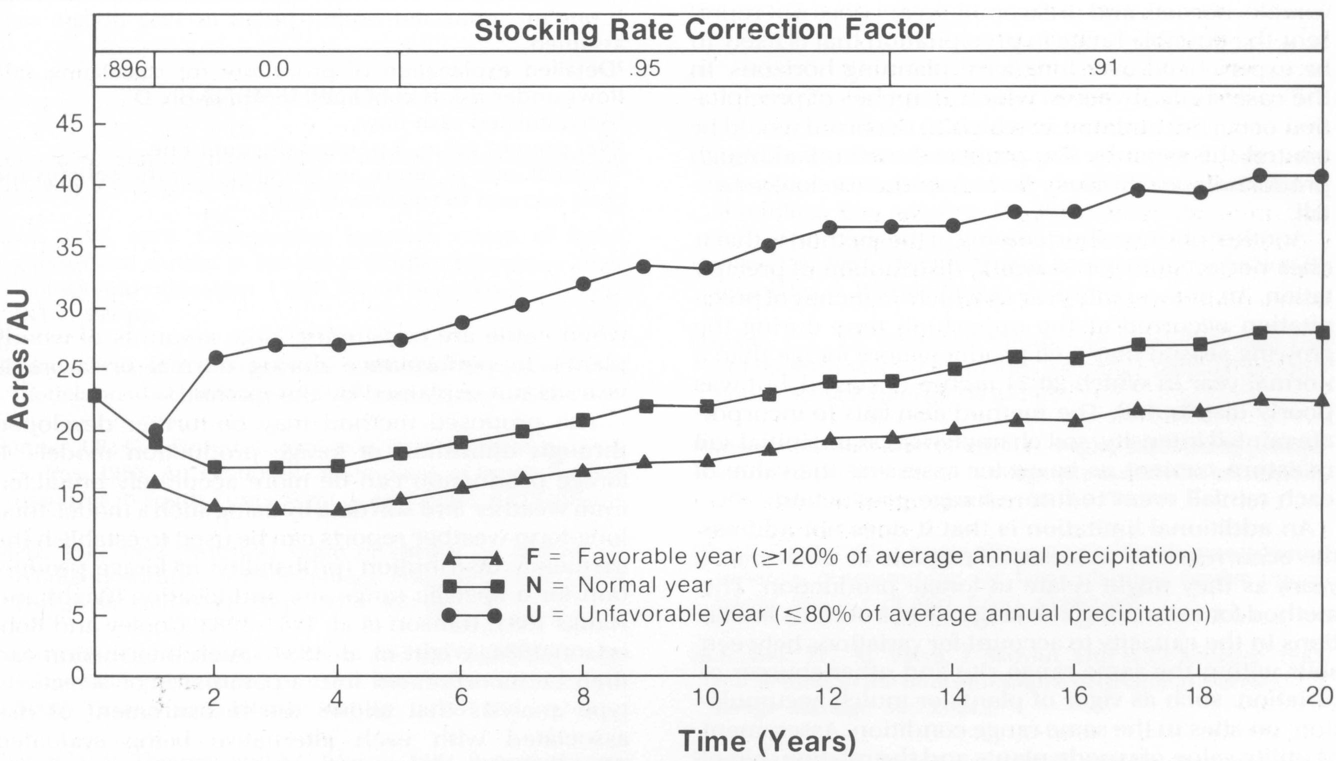


Figure 9. Response curves based on three precipitation levels for a Clay Loam site in the 19-31 PE zone of the South Texas Plains treated in year 1 with an aerially applied herbicide application. (Treatment is assumed to be 1 pound per acre active ingredient 2,4,5-T + picloram (1:1) or a herbicide with the equivalent effectiveness on the woody plants and at the some cost per acre.)

method should yield information for evaluation of improvement practice alternatives that is more realistic and useful to decisionmakers.

The proposed method is based on data that can be readily obtained from published materials and by expedient field survey techniqes. The method also identifies areas of research needed to increase the accuracy of estimated forage production and stocking rates as influenced by rainfall and woody plants. The applicability of the procedures to predict forage production and assess woody plant utility value on range sites other than the specific sites for which they were developed is not known. There is evidence that these procedures may have application on several sites within the same PE zone.

LIMITATIONS

There are additional factors which should be incorporated into the feasibility analyses in practical applications. In situations where wildlife represents an important aesthetic or economic component, adequate accounting should be provided for this segment of range resources. Also, individual producer debt/equity positions and income tax liabilities can affect the realized yearly cash flows and should be incorporated in practical applications.

There are other limitations in the capacity of the proposed method to yield more accurate estimates. One such limitation is that selection of the criteria for favorable, normal, and unfavorable years does not represent the possible range in precipitation that is likely to be experienced over long-term planning horizons. In the case study, a year in which 16 inches of precipitation occurred and one in which 10 occurred would be treated the same by the proposed method, although production would likely be less under the lower rainfall.

Another obvious shortcoming of the method is that it does not account for seasonal distribution of precipitation. An unfavorable year in which 15 inches of precipitation occurred at the opportune time during the growing season may well produce more forage than a normal year in which 20-24 inches occurred, but was poorly distributed. The method also fails to incorporate rainfall intensity, soil characteristics, and initial soil moisture content as bases for assessing the value of each rainfall event to future forage production.

An additional limitation is that it does not address the occurrence of successive favorable or unfavorable years as they might relate to forage production. The method for estimating stocking rate has obvious limitations in the capacity to account for variations between soils within the same range site and other sources of variation, such as vigor of plants or mulch accumulation, on sites in the same range condition. Assessment of utility value of woody plants and the relationship of utility value to stocking rates during stress conditions is highly subjective and will require verification by research. Moreover, the relationship of animal performance and variable cost (weaning weights, conception rates, and supplemental feed) during unfavorable years when cattle are consuming large amounts of woody plants, to performance during normal or favorable years is not explained by the method.

The proposed method may be further developed through utilization of forage production models. If forage production can be more accurately predicted from weather and soil data by using such a model, then long-term weather reports can be used to establish the frequency distribution (probability) of forage production for a specific range site and location (Wight and Hanks 1981; Hanson et al. 1982, 1983; Cooley and Robertson 1984; Wight et al. 1984). Such information can then be incorporated into a parametric or sensitivity type analysis that allows the measurement of risk associated with each alternative being evaluated (Hazell 1971).

TABLE 2. EXPECTED YEARLY CASH FLOWS[1] PER ACRE

Year	No Risk		Risk[2]	
	No Treatment	Aerial Spray	No Treatment	Aerial Spray
0	8.09	8.09	7.44	7.44
1	8.38	-19.15	7.73	-19.25
2	7.17	10.11	6.55	9.07
3	8.02	10.11	7.40	8.94
4	7.63	11.71	7.04	10.54
5	6.62	11.06	6.05	10.07
6	7.37	10.35	6.80	9.42
7	6.36	9.80	5.82	8.92
8	7.01	9.29	6.46	8.45
9	6.14	7.81	5.61	7.01
10	6.14	8.76	5.61	7.96
11	6.14	8.38	5.61	7.61
12	6.14	7.17	5.61	6.43
13	6.74	8.02	6.61	7.28
14	5.93	7.63	5.42	7.00
15	5.93	6.62	5.42	6.02
16	6.53	7.37	6.02	6.77
17	5.73	6.36	5.27	5.78
18	5.73	7.01	5.27	6.44
19	5.73	6.14	5.27	5.55
20	5.73	6.14	5.27	5.55
ACC[3]	131.17	140.69	120.44	125.56
NPV[4]	84.10	83.34	77.23	73.58
IRR(%)[5]		4.5		2.6

[1]Constant input and output prices in 1982 dollars were assumed.

[2]Detailed explanation of procedure for calculating cash flows under risk is contained in Appendix D.

[3]Accumulated cash flow.

[4]Net present value, 5 percent discount rate.

[5]Internal rates of return are calculated for the benefits and costs accrued to treatments only.

TABLE 3. VARIATION IN YEARLY CASH FLOWS[1] PER ACRE

	Year	Weather Condition Unfavorable	Favorable	Normal		Year	Weather Condition Unfavorable	Favorable	Normal
No Treatment	0	4.91	9.60	8.09	Aerial Spray	0	4.91	9.60	8.09
	1	5.24	9.84	8.38		1	-19.76	-18.72	-19.15
	2	4.18	8.57	7.17		2	5.29	12.13	10.11
	3	5.03	9.42	8.02		3	4.88	12.13	10.11
	4	4.76	8.98	7.63		4	6.48	13.73	11.71
	5	3.84	7.92	6.62		5	6.52	12.92	11.06
	6	4.59	8.67	7.37		6	6.08	12.13	10.35
	7	3.70	7.66	6.36		7	5.74	11.49	9.80
	8	4.35	8.27	7.01		8	5.42	10.90	9.29
	9	3.58	7.34	6.14		9	4.13	9.35	7.81
	10	3.58	7.34	6.14		10	5.08	10.30	8.76
	11	3.58	7.34	6.14		11	4.84	9.84	8.38
	12	3.58	7.34	3.58		12	3.77	8.57	7.17
	13	4.18	7.94	6.74		13	4.62	9.42	8.02
	14	3.44	7.09	5.93		14	4.64	8.98	7.63
	15	3.44	7.09	5.93		15	3.75	7.92	6.62
	16	4.04	7.69	6.53		16	4.50	8.67	7.37
	17	3.43	6.86	3.43		17	3.60	7.62	6.36
	18	3.43	6.86	5.73		18	4.26	8.27	7.01
	19	3.43	6.86	5.73		19	3.38	7.34	6.14
	20	3.43	6.86	5.73		20	3.38	7.34	6.14

[1]Procedure for deriving yearly cash flows is detailed in Appendix D.

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APPENDIX A. SCIENTIFIC NAMES OF PLANTS MENTIONED IN TEXT AND TABLES

Common Name	Scientific Name
Blackbrush acacia	*Acacia rigidula*
Coyotillo	*Karwinskia humboldtiana*
Creosotebush	*Larrea tridentata*
Desert yaupon	*Schaefferia cuneifolia*
Guajillo	*Acacia berlandieri*
Guayacan	*Porlieria angustifolia*
Honey mesquite	*Prosopis glandulosa var. glandulosa*
Plateau oak	*Quercus fusiformis*
Pricklypear	*Opuntia spp.*
Tasajillo	*Opuntia leptocaulis*
Wolfberry	*Lycium berlandieri*

APPENDIX B. CONVERSION FACTORS FOR ENGLISH AND METRIC UNITS

To Convert Column 1 into Column 2, Multiply by:	Column 1	Column 2	To Convert Column 2 into Column 1, Multiply by:
0.621	kilometer	mile	1.609
1.094	meter	yard	0.914
0.394	centimeter	inch	2.54
0.386	kilometer^2	mile^2	2.590
247.1	kilometer^2	acre^2	0.00405
2.471	hectare	acre	0.405
2.205	kilogram	pound	0.454
0.035	gram	ounce	28.35
0.891	kilogram per hectare	pound per acre	1.12
(9/5)°C + 32	Celsius	Fahrenheit	(5/9) °F - 32

APPENDIX C. CALCULATIONS OF WOODY PLANT UTILITY VALUE

The method to calculate woody plant utility value of a range site requires the use of field data as well as a classification of woody plants according to animal preference. The field data required can be obtained by using a modification of the line interception method to estimate browse availability by woody species. Canopy interceptions of individual brush plants, overstory and understory, and spaces in which no brush canopy occurs (open) must be recorded along a randomly selected line. In addition, estimates of the proportion of the canopy of each individual woody plant under the browse line (percent in browse) and the proportion of that percent within the browse line that can be effectively browsed by cattle (penetration) must also be made. Percent canopy cover and an accessibility factor for each woody species are computed from the data as follows:

$$\%CC_{i.} = \frac{C_{i.}}{L} = \frac{\sum_{j=1}^{h} C_{ij}}{L}$$

where: $\% CC_{i.}$ is the percent canopy cover of species i,
$C_{i.}$ is the canopy cover of species i,
C_{ij} is the canopy of individual plant j of species i,
L is the length of the sampling line,
h is the number of plants within species i.

The length of the line (L) is equal to the open plus the total canopy cover minus the understory canopy.

The accessibility factor of each woody species is computed as a weighted average of the individual plant accessibilities of that species. Individual plant accessibility is defined as the product of percent browse and penetration. That is:

$$a_{ij} = INB_{ij} \times PEN_{ij}$$

and

$$A_{i.} = \sum_{j=1}^{h} INB_{ij} \times PEN_{ij} \times P_{ij}$$

where: a_{ij} is the accessibility of individual plant j of species i,
$A_{i.}$ is the accessibility factor for woody species i,
INB_{ij} is the percent in browse of individual plant j for species i,
PEN_{ij} is the penetration of individual plant j for species i,
$P_{ij} = \frac{C_{ij}}{C_{i.}}$ is the proportion which individual plant j contributes to the canopy cover of species i.

The utility value of each woody species ($UV_{i.}$) is computed by

$$UV_{i.} = \% CC_{i.} \times A_{i.} \times UF_{i.}$$

where $UF_{i.}$ is the utility factor of brush species i.

Total utility value of woody plants is calculated as the summation of all the utility values of the different brush species present on the range site as represented by the line interception and can be expressed as

$$UV_{..} = \sum_{i=1}^{n} UV_{i.}$$

where n is total number of woody species found on the site.

APPENDIX D. PROCEDURE FOR CALCULATING ANNUAL CASH FLOW PER ACRE FOR FAVORABLE, NORMAL, AND UNFAVORABLE HERBAGE PRODUCTION CONDITIONS AND A WEIGHTED AVERAGE (RISK INCLUDED) ANNUAL CASH FLOW PER ACRE

1. Calculate cash flow for each normal year (NYCF) as follows:
   a. from response curves, determine for each normal year (t)
   $N(Au/A/yr)_t = 1 \div N(A/Au/yr)_t$;
   b. for each year (t), starting with current year (0 on response curve), determine the change in (Δ)Au/A
   $(\Delta Au/A)_t = [N(Au/A/yr)_t - N(Au/A/yr)_{t+1}]$;
   c. for each year (t) determine
   $$(NYCF)_t = [N(Au/A/yr)_t \times (ANR/Au)] + [(\Delta Au/A)_t \times (IC/Au)] - (TC/A)_t .$$

   Where:

   ANR/Au = annual net returns to land, management, and livestock capital per animal unit. In this example calculated as $172 = [average weaning weight (500 lb x weaning percent (0.85) x average expected price per pound ($0.70)] - [annual operating and equipment ownership and investment costs ($125)].

   IC/Au = total investment cost per animal unit. In this example $500 was used.

   TC/A = treatment costs per acre, if any, In this example $21 per acre was used for year 1 for the spray treatment only.

2. Calculate cash flow for each favorable year (FYCF) as follows:
   a. from response curves, determine for each favorable year (t)
   $F(Au/A/yr)_t = 1 \div F(A/Au/yr)_t$;
   b. for each year (t) determine difference between favorable and normal year
   $(F\text{-}NAu/A)_t = F(Au/A/yr)_t - N(Au/A/yr)_t$;
   c. for each year (t) determine
   $(FYCF)_t = [(1\text{-}NAu/A)_t \times (FINR/Au)] + (NYCF)_t$.
   Where:

   FINR/Au = increased annual net returns per increased animal unit in favorable year. In this example $135 was used to account for increased weaning weights, increased calving percent, or other increases over normal year net returns.

3. Calculate cash flow for each unfavorable year (UYCF) as follows:
   a. from response curves, determine for each unfavorable year (t)
   $U(Au/A/yr)_t = 1 \div U(A/Au/yr)_t$;
   b. for each year (t) determine difference between normal and unfavorable year Au/A
   $(N\text{-}UAu/A)_t = N(Au/A/yr)_t - U(Au/A/yr)_t$;
   c. for each year (t) determine
   $(UYCF)_t = (NYCF)_t - [(N\text{-}UAu/A) \times (UDNR/Au)]$.
   Where:

   UDNR/Au = decreased annual net returns per decreased animal unit in unfavorable year. In this example $237.50 was used to account for decreased net returns due to decreased weaning weights, decreased calving percent, or increased feed costs compared to normal year net returns.

4. Calculate cash flow with risk included (RCF) for each year as follows:
   a. determine for each year (t)
   $(RCF)_t = [PN \times (NYCF)_t] + [PF \times (FYCF)_t] + [PU \times (UYCF)_t]$.
   Where:

   PN = probability of occurrence of normal year. In this example 0.5 was used.
   PF = probability of occurrence of a favorable year. In this example 0.2 was used.
   PU = probability of occurrence of an unfavorable year. In this example 0.3 was used.
   $PN + PF + PU = 1.0$.

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