TOPOGRAPHIC FACTORS AFFECTING UTILIZATION OF BLACK GRAMA IN SOUTHWESTERN ARIZONA

by

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A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN RANGE MANAGEMENT

In the Graduate College

THE UNIVERSITY OF ARIZONA

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ACKNOWLEDGMENTS

I wish to thank Dr. Ervin Schmutz, Dr. Phil Ogden, and Dr. Lamar Smith for their help and guidance and for serving on my committee. None were ever too busy to help.

I also wish to thank my wife Martha for all her support and help.

My sincere thanks to Steve and Jane Dobrott and Pete Carney for supplying a place for myself and my horse to stay during the study and to Pete Phelps for allowing me to do the study on his ranch.

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ABSTRACT

The study was conducted on the Santa Margarita Ranch in the Altar Valley of southwestern Arizona. The purpose was to determine what relationships topographic factors, such as distance-to-water, slope, exposure, and their interactions, had to do with the percentage utilization of black grama (Bouteloua eriopoda).

Sample points were distributed throughout two pastures in a restricted random fashion and the various factors and the percentage use of black grama were measured at each point. Utilization was evaluated with grazed-class photo guides.

Factors significantly correlated with use were distance-to-water, distance-up-primary-slope, percentage-maximum-slope-between-the-site-and-water, distance-to-water times percentage-maximum-slope, distance-up-primary-slope times percentage-maximum-slope, and distance-to-water times distance-up-primary-slope.

Use on the study area was best predicted by $\text{Log}_{10}Y = 1.916 - 0.0356X_5 - 0.000261X_1 + 0.000005X_1X_5$ where Y is percentage use of black grama, X_1 is distance-to-water, and X_5 is percentage-maximum-slope.

Under the conditions of the study, percentage use of black grama approached zero when the percentage-maximum-slope

exceeded 50%, no matter what the distance-to-water, or when the distance-to-water exceeded 3500 m, no matter what the slope.

INTRODUCTION

Lack of uniform utilization of range resources has been a problem in the United States since the first introduction of stock. At best, grazing use on any range unit is highly variable, often varying from 0 to 100%. Uniform use of any range unit increases the economic efficiency of range cattle operations and aids in the protection and improvement of the range resource. An understanding of what factors affect utilization patterns will help managers devise management techniques to promote more uniform livestock utilization.

The objectives of this study were:

1. Determine the significance of and quantify the relationship of various topographic factors to the utilization of black grama (Bouteloua eriopoda)[1] by cattle. Factors included were primary-distance-up-slope, distance-along-secondary-slope-to-the-nearest-major-access on or to that slope, percentage-slope-at-site, percentage-maximum-slope-between-site-and-water, and exposure.
2. Determine the relative importance of the dominant factors and how they interact.

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1. Scientific terminology follows Kearney and Peebles (1960) except as noted.

The study area was located on the Santa Margarita Ranch in the Altar Valley of southwestern Arizona and was confined to the Los Moras and the 7X pastures.

LITERATURE REVIEW

Little work has been done on the relationships between topography and distance-to-water and the percentage utilization of forage by cattle. Cook (1966) found that the factors most highly correlated with use were percentage-slope-at-site, percentage-slope-adjacent-to-water, percentage-slope-from-site-to-water, distance-to-water-below, percentage-maximum-slope-between-site-and-water, percentage-palatable-plants-on-site, percentage-slope-from-site-to-site, and thickness-of-brush-around-site. He also concluded that a high degree of correlation existed between many of the factors and that no one factor was a reliable index for predicting use.

Talbot (1926); Glendening (1944); Valentine (1947); Cook (1966); Herbel, Ares, and Nelson (1967); and Martin and Ward (1970) all have reported that utilization decreases with increases in distance-to-water, although Herbel et al. (1967) and Martin and Ward (1970) have recognized that perhaps distance-to-water is not important in small pastures. Cook (1967) recognized the importance of distance-to-water in determining use, as he reported that water development is by far the best means for improving the uniformity of range utilization. Glendening (1944), Mueggler (1965), and Cook (1967) all found that use decreases with increasing distance-up-slope and/or slope-steepness. The relationship Mueggler (1965) found is illustrated in Fig. 1. He described the relationship for his study with the equation $Y = 107.6 + 1.00X_1 - 95.37e^{-0.001X_2}$ where Y is relative use, X_1 is slope-steepness, X_2 is distance-up-slope, and e is the natural log. The relationship Glendening (1944) found between use of mountain muhly, distance-to-water, distance-up-slope, and slope-steepness is shown in Fig. 2. Klemmedson (1964) implied that exposure can affect utilization. He found differences in vegetation distribution associated with differences in aspect were partly due to exposure and partly due to exposure-induced use patterns. Glendening (1944) found that in the northern Arizona pine-bunchgrass range exposure was insignificant in affecting use.

Factors not considered which might have contributed variation not accounted for by my study are variation in soil and vegetation types, roughness of terrain, distribution and thickness of brush, climate and season, availability of shelter, size of range unit, class and type of cattle, soil fertility differences, and distribution of salt. Smith and Lang (1958), Holt and Wilson (1961), Cook and Jeffries (1963) Hooper et al. (1969), and Bryant (1971) have all reported that soil fertility and fertilization can affect utilization. Also, Klett, Holingsworth, and Schuster (1971) and Bryant (1971) noted increased utilization on the

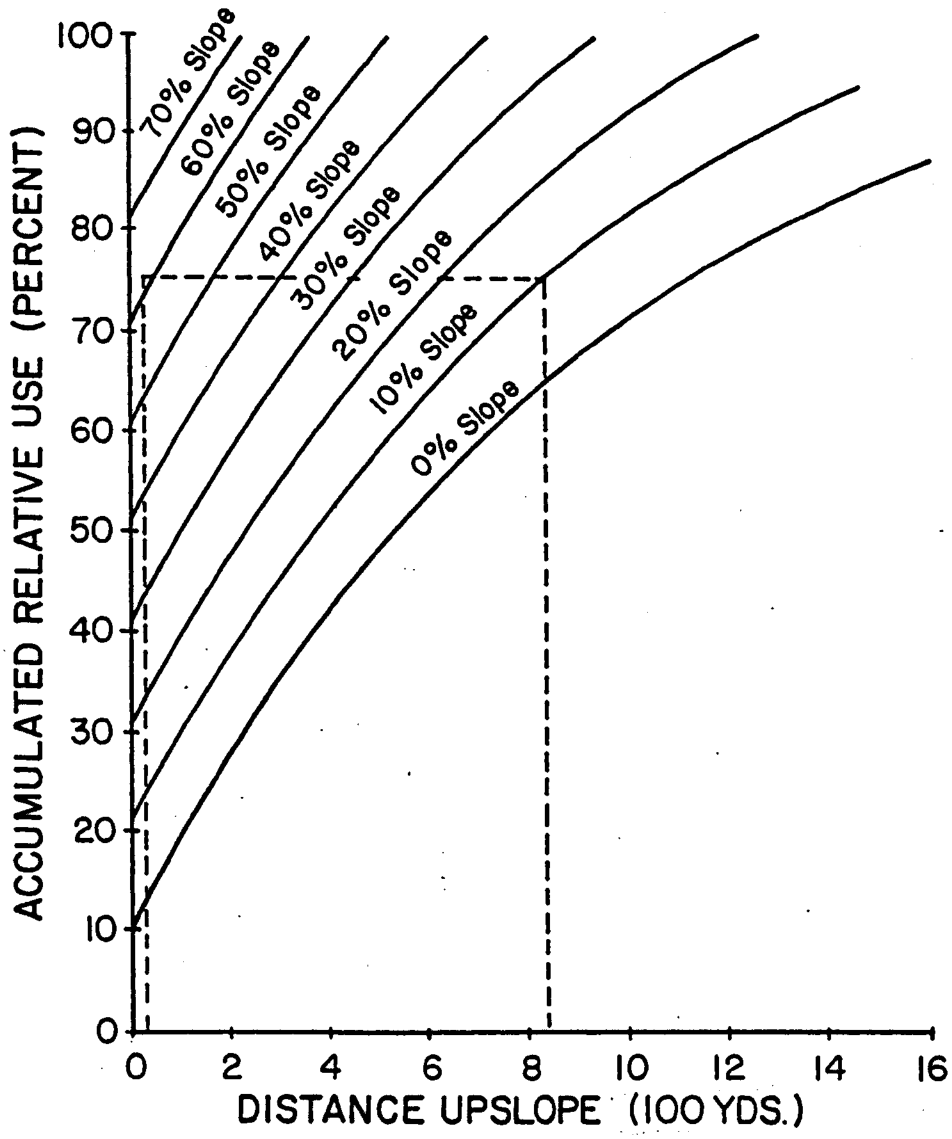

Fig. 1. Influence of slope steepness and distance upslope on relative cow use -- From Mueggler (1965). For example, where access is only from the bottom, 75% of cattle use on a 10% slope will occur within 810 yards of the foot of the slope; whereas, 75% of the cattle use on a 60% slope will occur within 35 yards of the bottom.

Fig. 2. Effect of steepness and distance from bottom of slope on per cent grazing use of mountain muhly -- Example: To find the per cent utilization at a point 1/2 mile from the bottom of a 30 per cent slope, follow the line marked "1/2 mile" to point "A" where it crosses the line marked "30%." A vertical line drawn from "A" to the base of the chart shows the utilization to be about 9 per cent. From Glendening (1944).

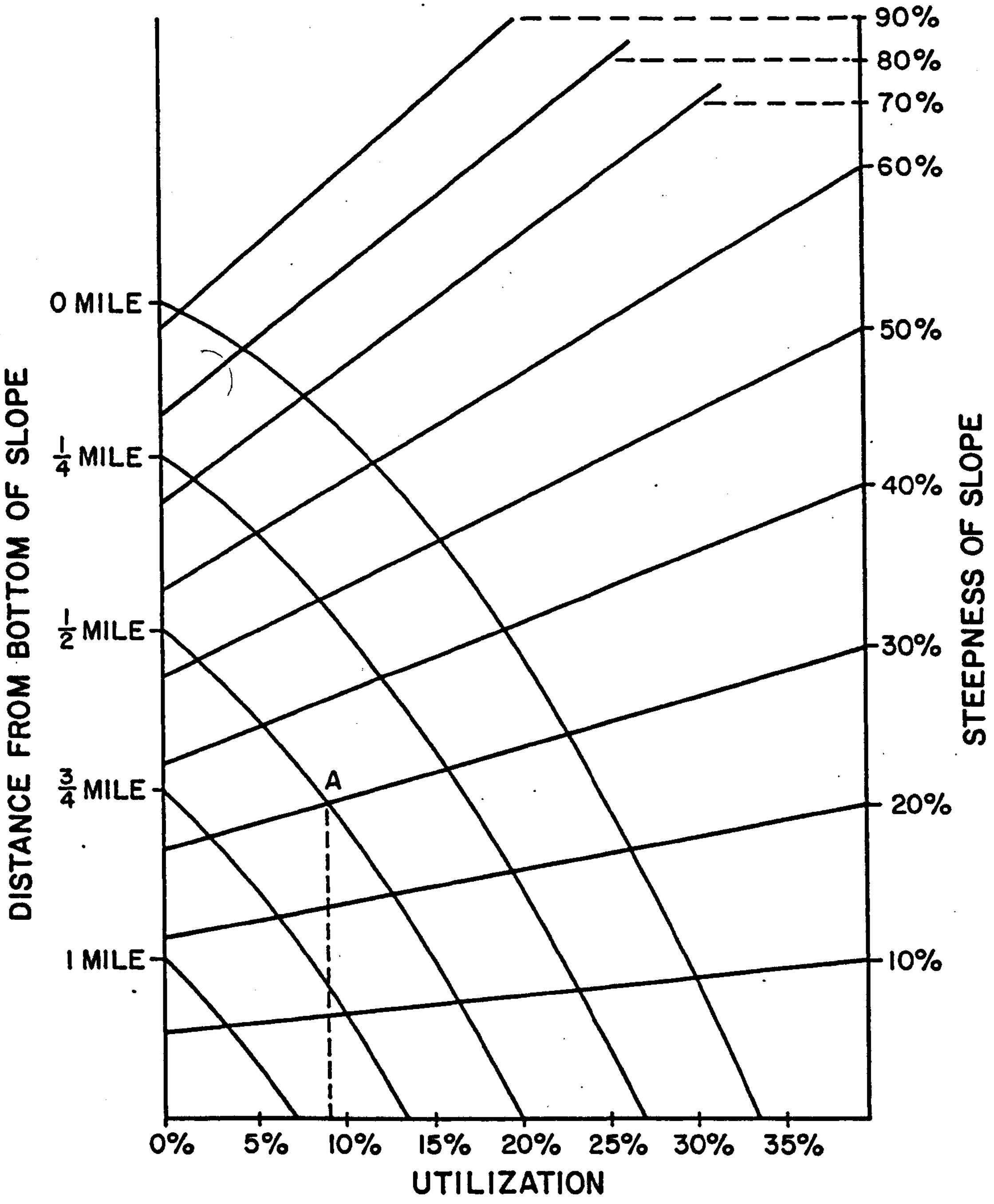

Fig. 2. Effect of steepness and distance from bottom of slope on per cent grazing use of mountain muhly.

regrowth of forage that had been burned. Vandermark, Schmutz, and Ogden (1971) found that differences in soil as related to differences in fertility can cause varying degrees of use. Ares (1953), Cook (1967), and Martin and Ward (1973) reported that the distribution of salt can affect use patterns.

Hickey and Garcia (1964) and Herbel et al. (1967) found that differences in breed and class of livestock can also affect utilization patterns. Hickey and Garcia (1964) determined that rough terrain was most evenly used by yearling heifers and that open range was most uniformly utilized by mixed classes of cattle. Talbot (1926), Glendening (1944), Williams (1954), and Cook (1966) have reported that thick brush or trees and rocky or rough terrain can also affect how a range unit will be utilized.

DESCRIPTION OF STUDY AREA

The study area consisted of two adjacent pastures where vegetation was primarily desert grassland. There were also some mesquite-shrub and oak-woodland areas present. The pasture to the west was named the Los Moras and the pasture to the east was named the 7X. Each pasture was approximately six sections in size.

The Los Moras pasture consisted of a variety of topography from rolling flats in the east to small steep mountains in the west with intergrading foothills between. Altitudes varied from about 1160 to 1525 m (3800 to 5000 ft). There were four water sources present, located 1 to 2 miles apart. Distances from water existed to a maximum of about 1.5 miles.

The vegetation in the Los Moras for the most part consisted of four associations. In the eastern or bottom-land section of the pasture, the vegetation was dominated by broom snakeweed (*Gutierrezia* sp.) and rothrock grama (*Bouteloua rothrockii*) with some black grama, cane beard-grass [*Bothrichloa barbinodis* (Lag.) Herter] sand and spike dropseed (*Sporobulus cryptandrus* and *S. contractus*), annual and perennial threeawns (*Aristida* sp.), and other species. This area has been for the most part bulldozed free of velvet mesquite (*Prosopis julifora* var. *velutina*).

Along drainages vegetation was dominated by dense velvet mesquite and catclaw (Acacia greggii) with an understory of broom snakeweed and rothrock grama. Black grama was usually not present.

On the more southerly facing slopes of the foothills and the mountains, the vegetation was primarily black grama, hairy grama (Bouteloua hirsuta), and sprucetop grama (Bouteloua chondrosioides) with some curly-mesquite (Hilaria belangeri), rothrock grama, velvet mesquite, ocotillo (Fouquieria splendens), calliandra (Calliandra eriophylla), and broom snakeweed present.

The vegetation on the more northerly facing slopes consisted primarily of sideoats grama (Bouteloua curtipendula) with some velvet mesquite, emory oak (Quercus emoryi), beargrass (Nolina texana), desertspoon (Dasylirion wheeleri), plains lovegrass (Eragrostis intermedia), and black grama.

The soils for the pasture can be divided into two associations; the Whitehouse-Bernardino-Caralampi-Hathaway association and the Rock Outcrop-Lampshire-Cellar association. The Rock Outcrop association was found in the upper mountain sections and the Whitehouse association was found in the bottomlands, foothills, and lower slopes of the mountains. The parent materials for the Rock Outcrop association are schist and some granitic bedrock. Parent material for the Whitehouse association is alluvium of mainly schists and some granite.

The pasture was lightly stocked with Hereford cows and calves. Hereford bulls were put in the pasture for several of the late spring months and then removed. The pasture is grazed year-long.

The 7X pasture is relatively flat topography of long rolling ridges. Altitudes varied from 1100 to 1175 m (3600 to 3850 ft). There were two water sources present which were approximately 1 mile apart. Maximum distances from water existed to just over 2 miles.

The vegetation consisted of two associations. The north half of the pasture had been bulldozed clear of most mesquite and was dominated by hairy grama with considerable amounts of broom snakeweed, black grama, Arizona cottontop [_Digitaria californica_ (Benth.) Henrard], cane beardgrass plains bristlegrass (_Setaria leucopila_), and lehmann lovegrass (_Eragrostis lehmanniana_). Small amounts of blue grama (_Bouteloua gracilis_), small velvet mesquite, gregg catclaw, and calliandra were also present.

The southern half of the pasture was a mesquite bosque with an understory of broom snakeweed, Arizona cottontop, plains bristlegrass, annual and perennial threeawns, and small amounts of hairy and black grama.

The soils for the pasture are a Whitehouse-Bernardino-Caralampi association. The parent material for these soils is alluvium consisting of mostly schists and some granite.

This pasture was also lightly stocked yearlong with Hereford cows and calves. Bulls were put in during the late spring months and then removed.

METHODS

Field Sampling Design and Technique

Location of Sample Points

The first step was to obtain an aerial photograph of the Los Moras pasture. The photograph was covered with an acetate overlay and the boundaries of the pasture were outlined. The pasture was then divided into blocks on the map, which were 2 cm square and which represented areas about 0.5 miles square in the pasture.

Sample points in the Los Moras pasture were then selected by making a list of random number pairs, either member of the pair being from 0 to 20. The points were then located on the photograph by measuring the first number of a pair in the north direction from the southeast corner of the selected block and the second number in the west direction from the same corner. The point where lines, perpendicular to the block's boundaries, drawn through these points intersected is where the sample point was located. Points that fell out of the pasture were disregarded and the next set of numbers was used. Five sample points were placed in each block, giving a total of 185 possible points.

During the study, seven blocks in the northwest corner of the pasture were excluded (see Fig. 3). This was done because of the sparseness of black grama and the very rough and rocky terrain. The sample points were taken from these blocks and were placed five in a block in the group of blocks covering the mountain topography surrounding the southwest water. This was done to keep the number of samples taken from the mountain topography high enough to be representative of any existing trends. The location of the sample points in the Los Moras pasture can be seen in Fig. 3.

Sample points in the 7X pasture were located in the field by the use of a range finder. One point was located next to the central water. The other points were located by measuring 500 meters from the previous point along two straight lines. These lines ran in an east-west direction along the top of a low rolling ridge. The points were continued along these lines at 500-meter intervals until the boundary fence of the pasture was reached. The purpose of sampling this pasture was to obtain more data representative of flat land topography at equal and greater distances from water than were available in the Los Moras pasture. The location of the sample points in the 7X pasture can be seen in Fig. 4.

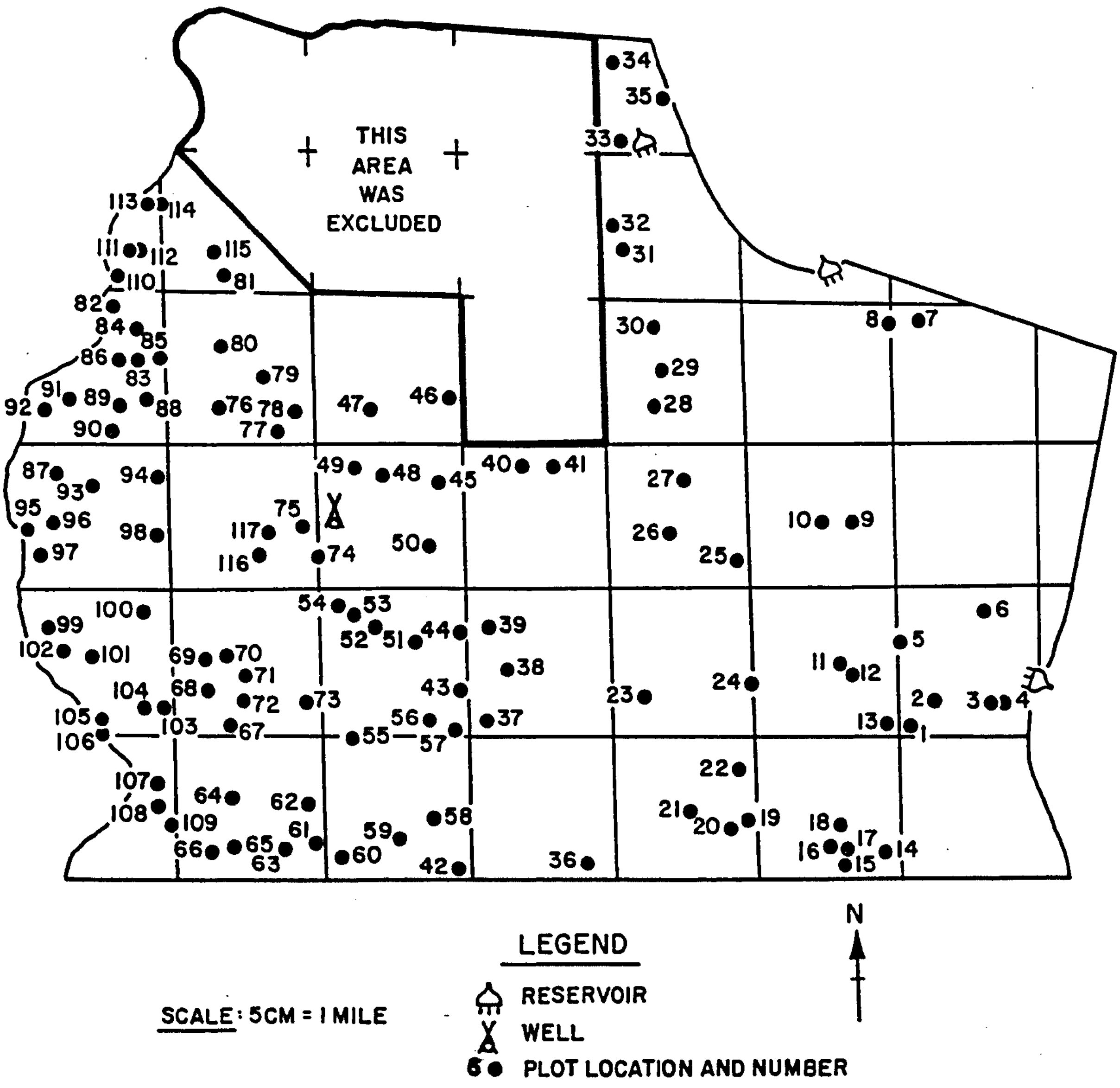

Fig. 3. Location of sample points and water sources within boundaries of the Los Moras Pasture -- Sample points lacking black grama are not shown.

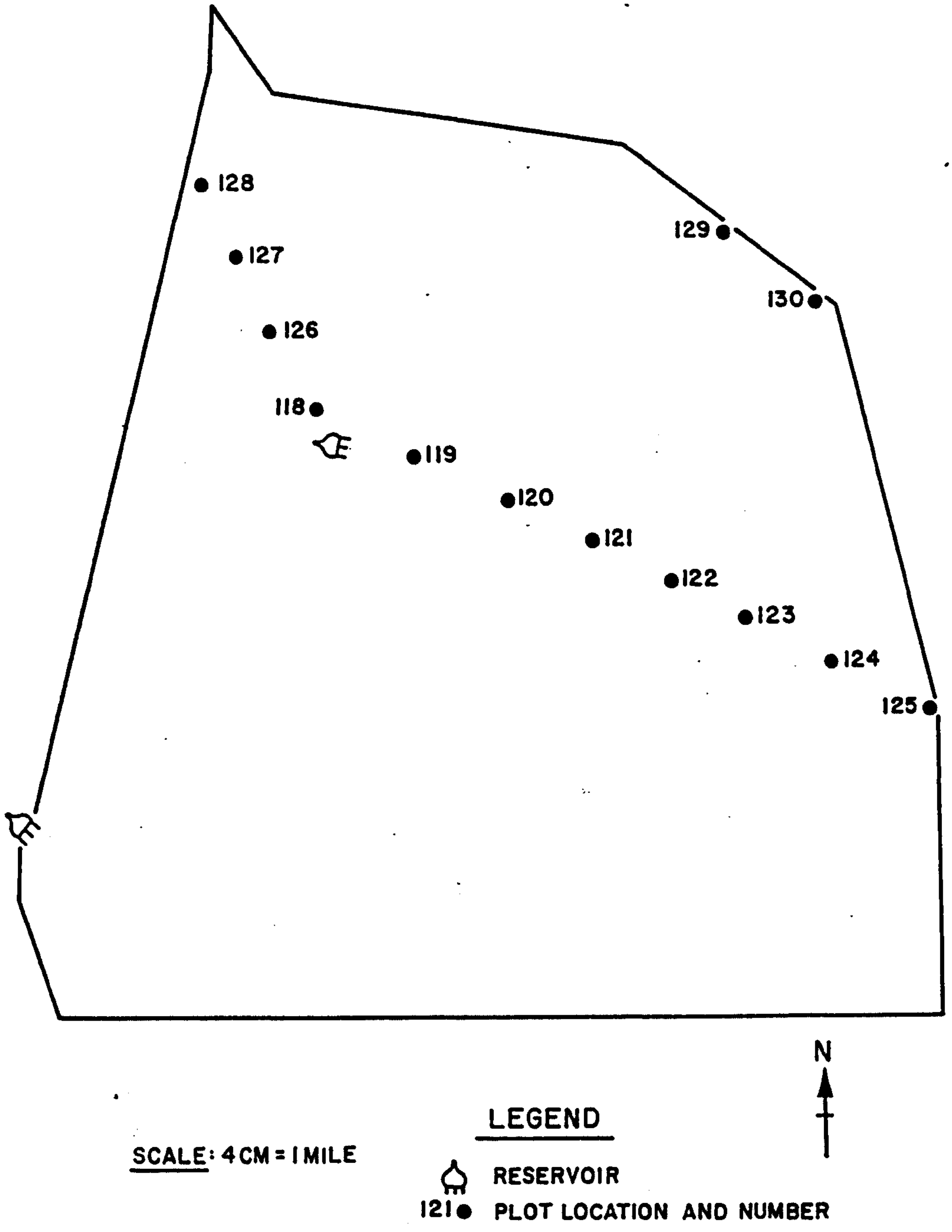

Fig. 4. Location of sample points and water sources within the boundaries of the 7X Pasture.

Definition of Factors

The factors which were tested for a relationship with the percentage utilization of black grama were distance-to-water, distance-up-primary-slope, distance-along-secondary-slope-from-site-to-the-nearest-access, percentage-slope-at-site, percentage-maximum-slope-between-site-and-water, exposure, pasture differences, the percentage composition of black grama, and the various interactions of these factors.

Distance-from-water was used to test for an association between how the cattle move away from water and forage use. Distance-up-primary-slope was included to test for a relationship between use and how far cattle move up from the bottom of slopes of over 10%. The distance from the base of a slope to a point where travel was deviated from a ridge, draw, or trail was considered the primary-slope-distance. The distance to the sample site along a slope from the point of deviation from a ridge, trail, or draw was considered the distance-along-secondary-slope-to-the-nearest-access. This was included to test for a correlation between movement off off a major access on or near a slope to a sample site on that slope. The variable percentage-slope-at-site was used to measure associations that steepness at a sample point might have with utilization of black grama. Maximum-slope-between-site-and-water was used to determine any relationship existing between use at a sample point and the maximum steepness of over 100 ft that had to be crossed in order to reach that point. Exposure was included to test for a relationship between the degree of solar insolation on a sample site and utilization at that site. Percentage-composition was included to determine a possible correlation between use and the relative amount of black grama present at the sample point. It also was intended to test for differences in use related to differences in species associated with black grama.

Measurement of Independent Variables

Values for the independent variables were determined both in the field and on the photograph. Distance-to-water, distance-up-primary-slope, and some values for percentage-maximum-slope-between-site-and-water were measured on the photograph. Distance-to-water was measured by the use of a map wheel and was the nearest distance from a sample point to water along well-used trails. For points not near a trail, the most direct route to the nearest trail was measured and added to the remaining distance along the trail to the nearest water. Primary-distance-up-slope was also measured with the use of a map wheel and was the length along the distance-to-water measurement that had to be traveled up a slope of over 10%. Differences in elevation between the water and the sample point were used to correct the distance-to-water and the primary-distance-up-slope measurements for any slope existing along these measurements. Percentage-maximum-slope-between-site-and-water measurements that were difficult to measure in the field were estimated by comparing the slope to be used to slopes on the photograph whose slopes were known.

All other values for the remaining independent variables were measured in the field at the actual location of the sample points. Slope-at-the-sample-site and water maximum-slope-between-site-and-water were measured with a clinometer. Those that were considered maximum-slopes-between-site-and-water were continuous for at least 100 feet. Elevation was measured with an altimeter and the direction in which slopes were facing was measured with the use of a compass. Three other possible measurements were taken at each point for distance-along-secondary-slope-to-the-nearest-major-access. The distances were determined for the distance from the sample point to the nearest ridge top, to the nearest draw bottom, and to the nearest well-used trail along the slope if a trail existed. These distances were measured with a range finder. Notes were taken as to which of these three were considered the major access to the secondary slope. Percentage-composition of black grama was estimated ocularly and was given class values between 0 and 100 per cent in increments of 10. The purpose of the introduction of the composition variable was to allow for the correction of the data for the effect of composition if it demonstrated a significant correlation with use.

Sampling Percentage Use of Black Grama

Actual sampling was started May 17, 1976, and completed June 21, 1976. Sample points were located by matching landmarks in the field to those on the photograph. At each sample point percentage utilization of black grama was measured by use of a grazed-class method using grazed-class photo guides (Schmutz, Holt, and Michaels, 1963; Schmutz, 1971). If black grama was not present within the area of the sample point or if sample points fell in areas of heavy mesquite, brush, and/or rocks they were disregarded.

One hundred plants were sampled at each point, which Schmutz et al. (1963) found to give a coefficient of variation of the mean of 5% for black grama. Plants to be sampled were located by walking a paced grid of four parallel lines approximately one meter apart. At each step along the line, the nearest plant to the toe was sampled. The length of the lines depended on how many steps were necessary to sample 25 plants. The grids were oriented so that the parallel lines were running directly up and down slope on sloped areas and north-south on flat areas.

Black grama was chosen as the sample species as it had the greatest abundance and widest distribution on the study area. After sampling was completed, a total of 130 sample points had been measured for utilization.

Statistical Analyses

Multiple Regression Analyses

Sample points were randomized in a restricted manner. This was done by dividing the pasture into blocks as described before. This was to allow for some degree of random randomization and at the same time obtain a sample representative of the variety of topography found in the pasture.

To analyze the data a stepwise multiple regression analysis initially was completed. The dependent variable (Y) was percentage utilization of black grama and the independent variables (X_o) were distance-to-water, distance-up-primary-slope, percentage-slope-at-site, percentage-maximum-slope-between-site-and-water, distance-along-secondary-slope-from-nearest-major-access-to-site, percentage-composition of black grama, and exposure.

At the time of analysis, two new independent variables were introduced into the program. The first was a pasture variable and the second was an exposure variable. The pasture variable was introduced to account and correct for any possible differences between data collected from the Los Moras and that collected from the 7X. Such differences might have been caused by differences in stocking rates or grazing intensity, soils, average age of stock, and so on.

The exposure variable was introduced to allow flat topography to be expressed in the model and to check if there was any substantial relationship between exposure and the percentage use of black grama before attempting to quantify the relationship. The variable could be expressed in five possible ways; north, south, east, west, or flat.

Five basic regression analyses were run on the data. The first allowed the variables and variable interactions to fall out in order of their importance or decreasing effect on reducing the variation in the sums of squares. This was an initial determination of which variables and variable interactions demonstrated a significant correlation with use. Several follow up analyses were run rearranging the order in which variables fell out. These were to ensure that decisions on the significance of factors were correct no matter what order factors were introduced.

The second analysis was run only with the variables of distance-to-water, distance-up-primary-slope, percentage-maximum-slope-between-site-and-water, pasture, and corresponding interactions. In this run pasture was forced out first to be certain of its non-significance and to correct for variation it might have introduced.

The third analysis was run in the same manner except that percentage-maximum-slope-between-site-and-water was replaced with percentage-slope-at-site. The second and third runs were then compared to see which accounted for the most variation.

The fourth run included $\log_{10}$ Y as the dependent variable with distance-to-water and percentage-maximum-slope-betwen-site-and-water as the independent variables. None of the interactions of these factors were considered in this run. The purpose of this run was to provide the information necessary to apply a path coefficient analysis on the association the two variables had with use.

The fifth and final analysis was run with distance-to-water, percentage-maximum-slope-between-site-and-water, and their interactions in order to supply the constant and coefficients necessary to construct a prediction model.

Path Coefficient Analysis

A path coefficient analysis (Li, 1956; Liang and Riedl, 1964) was then run on the data, using partial regression coefficients and linear correlation coefficients obtained from the fourth regression analysis. A path coefficient is a standardized partial regression coefficient. It measures the direct influence of an independent variable on a dependent variable. It also allows correlation coefficients to be separated into direct and indirect influences. It also gives a means to determine the proportions of variability in the dependent variable accounted for by the direct or combined influences of the dependent variables.

RESULTS AND DISCUSSION

Factors Related to Use

Percentage-maximum-slope-between-site-and-water, distance-to-water, and distance-up-primary-slope were all significantly correlated with the percentage utilization of black grama at the 95 per cent level of significance (Table 1).

The interactions of distance-to-water times percentage-maximum-slope-between-site-and-water (X_1X_5), distance-up-primary-slope times percentage-maximum-slope-between-site-and-water (X_2X_5), and distance-to-water times distance-up-primary-slope (X_1X_2) were also significantly correlated to the use of black grama at the 95 per cent level.

It should be noted that the percentage-slope-at-site factor and its interactions with distance-up-primary-slope, distance-to-water, and percentage-maximum-slope-between-site-and-water showed a marginally insignificant association with use at the 95 per cent level when variables were allowed to fall out in order of their decreasing effect on reducing variation in the sums of squares. Not until the percentage-slope-at-site and its interactions mentioned were forced out of the regression analysis before percentage-maximum-slope-between-site-and-water and its mentioned

Table 1. Pertinent statistics produced by the multiple regression analysis of the data collected on the Santa Margarita Ranch, Altar Valley, Arizona.

Factor	F-Value[a]	Significance[a]	Multiple[a] R^2	Correlation coefficient (r)[a] for factor and percentage use
X_5 Percentage-maximum-slope-between-site-and-water	181.948	0.000	0.587	-0.766[c]
X_1 Distance-to-water	31.748	0.000	0.670	-0.641
X_1X_5	53.338	0.000	0.768	-0.683
X_2 Distance-up-primary-slope	6.389	0.013	0.779	-0.645
X_2X_5	11.232	0.001	0.798	-0.564
X_1X_2	4.188	0.043	0.904	-0.531
X_3 Percentage-slope-at-site	3.141	0.079	0.809	-0.696
X_3X_5	3.385	0.068	0.814	-0.636
X_6 Exposure	2.40	0.126	0.818	-0.501
X_7 Distance-along-secondary-slope-to-major-access	1.970	0.161	0.821	-0.323
X_4 Percentage composition of black grama	1.941	0.166	0.821	-0.053
X_1X_3	1.687	0.197	0.824	-0.638
X_{14} Pasture	1.310	0.255	0.826	-0.155
X_4X_6	0.788	0.377	0.827	0.090
X_2X_3	0.763	0.384	0.828	-0.598
X_5X_6	0.723	0.397	0.820	-0.448
X_3X_6	0.654	0.420	0.830	-0.432
X_1X_4	0.391	0.533	0.831	-0.327
X_4X_5	0.379	0.539	0.832	-0.620
X_3X_4	0.158	0.692	0.832	-0.586
X_2X_6	0.129	0.720	0.832	-0.428
X_1X_6[b]	0.069	0.793	0.832	-0.286

Table 1.--Continued

[a]The values presented for the factors are those obtained from the first multiple regression analysis which allowed the factors to fall out in order of decreasing effect on reducing the variation in the sums of squares. Single factors had to fall out before their respective interactions could be considered.

[b]Interactions with less significance than those presented were deleted.

[c]Correlation coefficients (r) greater than .174 or less than -.174 were significant at the 95 per cent level.

interactions were they found to be significant. This can be accounted for by the high correlation of r = 0.932 between percentage-slope-at-site and the percentage-maximum-slope factor and the high correlation of the analogous interactions of these two variables. This high correlation was due to the fact that in 62 of 130 of the sample cases the two factors had the same value, as they were actually the same. Also in the large number of the remaining cases the two factors had nearly equal values. Because of this, much of the variability attributable to percentage-slope-at-site and its important interactions were probably expressed through percentage-maximum-slope-between-site-and-water and its interaction. It must also be mentioned though that the percentage-maximum-slope factor and its interactions analogous to those of the percentage-slope-at-site factor (where they were analyzed as individual groups) accounted for a higher amount of variation (multiple R^2 = 0.805) than did the percentage-slope-at-site factor and its interactions (multiple R^2 = 0.769).

The range of mountains on the study area were relatively narrow, running north and south, with the east and west slopes rising rather steeply and continuously along their width to the crest. It is my opinion that in mountains of greater width and more variety of slope rise and descent, percentage-maximum-slope-between-site-and-water and percentage slope-at-site would tend to be separated out to a greater extent. The mean for percentage-slope-at-site must be either equal to or less than that for the percentage-maximum-slope factor; therefore, with the two factors being separated further apart, the mean for the percentage-maximum-slope variable would have to increase over that for percentage-slope-at-site. Under these circumstances it would seem that percentage-maximum-slope-between-site-and-water and its interactions would probably show a higher correlation with use at the expense of percentage-slope-at-site.

Tested at the 95 per cent level of significance, the variables for percentage-slope-at-site, exposure, distance-along-secondary-slope-to-the-nearest-major-access, percentage composition of black grama, and pasture, and all the remaining interactions demonstrated an insignificant relationship with use (Table 1).

Because both pasture and composition were insignificant, the planned correction of the data for these factors was not necessary. The pasture variable was rechecked by forcing it out of the analysis first and was still found to have an insignificant correlation with use. Notes were taken on the general vegetation type at each sample point and no apparent association between the vegetation type and use appeared.

It should be noted here that although no significant association was found between the utilization of black grama and exposure under yearlong use some significant seasonal exposure effect might still exist. With one season cattle might tend to concentrate their use on basically the same exposures. With a change in season a new exposure might be exploited. If these differences balanced out fairly well throughout the year, then any effects present would be masked when sampling for yearlong use. This is assuming that black grama is used throughout the year. If it is used only during one particular season, then it would be safe to assume that no significant relationship exists between exposure and the utilization of black grama. Also it must be noted that although there is no significant effect of exposure on yearlong use of black grama there might be such an effect on other species of forage.

Prediction Model

The predition model calculated for the study area is $Log_{10}Y = 1.916 - 0.0356X_5 - 0.000261X_1 + 0.000005X_1X_5$ where Y is the percentage utilization of black grama, X_5 is the percentage-maximum-slope-between-site-and-water, X_1 is distance-to-water, and X_1X_5 is their interaction. The model was chosen on the basis of simplicity with the greatest amount of variability accounted for possible. The model accounted for 80% (multiple $R^2 = .802$) of the variation found in $Log_{10}Y$. The total variation accounted for by all the variables tested was approximately 85%.

Percentage-maximum-slope-between-site-and-water and distance-to-water were chosen for the model because of their high combined multiple R^2 values and because of their highly significant correlations with use. The interaction of these two variables was included to account and correct for any joint association with use the two factors might have had.

Of those variables found to be significantly correlated with use, several were not used in the prediction model. Percentage-slope-at-site and percentage-maximum-slope-between-site-and-water were nearly equivalent factors. Percentage-maximum-slope-between-site-and-water was chosen over percentage-slope-at-site as the maximum slope factor's correlation with use had higher significance. When the regression analysis was run only on distance-up-primary-slope, distance-to-water, and percentage-maximum-slope-between-site-and-water, the relationship between distance-up-primary-slope and use was found to be insignificant. For this reason it was dropped from the model. Also the interactions of distance-up-primary-slope times percentage-maximum-slope-between-site-and-water, distance-to-water times distance-up-primary-slope, distance-to-water times percentage-slope-at-site, and distance-up-primary-slope times percentage-slope-at-site were dropped. This was done because of the small or marginal contributions to the multiple R^2 by these interactions, because of the dropping of the percentage-slope-at-site and distance-up-primary-slope factors, and for reasons of simplicity.

It must be pointed out that the prediction model can be applied to the study area only. It must also be pointed out that the prediction equation is specific for black grama and for Hereford cows and calves. It is not certain that the relationship between X_1, X_5, and X_1X_5 and the percentage use of black grama would remain the same if stocking rates were altered. If the relationship did remain the same, then the plot of the relationship would simply move straight up and down with increasing and decreasing grazing intensity. The only factor that would change in the equation would be the constant. I suspect this to be the case.

Different breeds and types or classes of cattle might also create a different relationship. Herbel et al. (1967) found differences in grazing patterns between those created by Hereford vs. Santa Gertrudis breeds of cattle. Hickey and Garcia (1964) reported that they found differences in the amount of use of rough terrain by different classes of cattle. It is also generally known that Brahman and Brahman crossbreeds will utilize rougher terrain than European breeds.

Another point which might change the relationship is if another indicator species is used to determine use.

Individual Effects of the Factors in the Prediction Model

The graphs of the relationships the three factors used in the model had with the percentage utilization of black grama were plotted for each of the factors against Y and $Log_{10}Y$. The best fit was then used to illustrate the relationships. For distance-to-water the correlation coefficient was - 0.641 (r) for the linear fit as compared to - 0.584 (r) for the curvilinear fit; therefore, the linear model was decided to best fit the relationship (Fig. 5). The negative correlations indicate that as distance to water increases percentage utilization of black grama decreases. The linear fit indicates that for each unit of distance moved away from water use decreases by a proportional unit. The scattering of the data toward the bottom of the graph seems to indicate that as cattle move further from water the relationships of other factors with use become more important.

For percentage-maximum-slope-between-site-and-water the correlation coefficient was - 0.766 (r) for the linear fit as compared to - 0.847 (r) for the curvilinear fit (Fig. 6). As can be seen the curvilinear model best fits the relationship. The negative correlation coefficients and the slope of the curve both indicate that as percentage-maximum-slope-between-site-and-water increases percentage use of black grama decreases. The curvilinear fit indicates

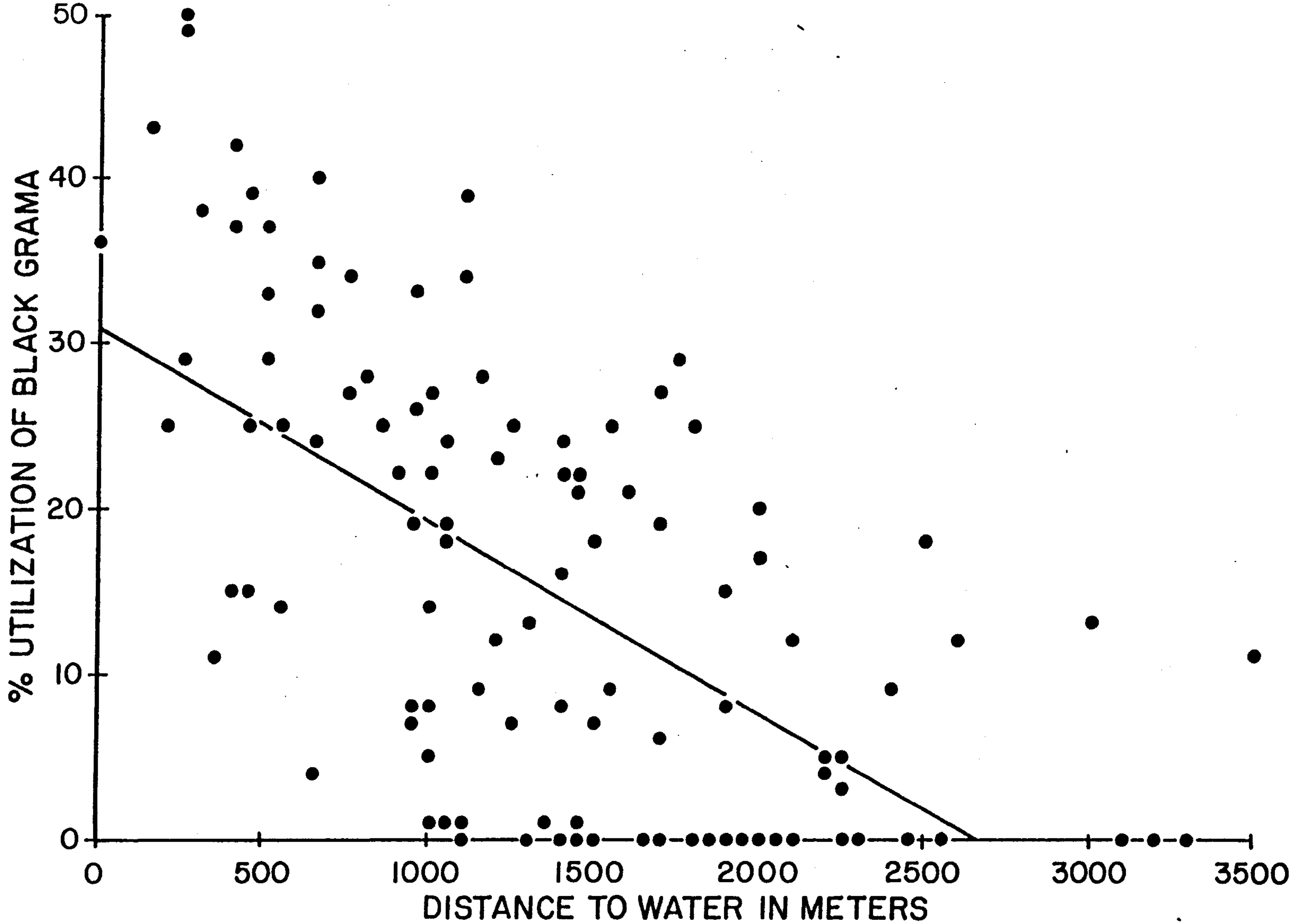

Fig. 5. The association between distance-to-water and the percentage utilization of black grama by cattle on the Santa Margarita Ranch, Altar Valley, Arizona.

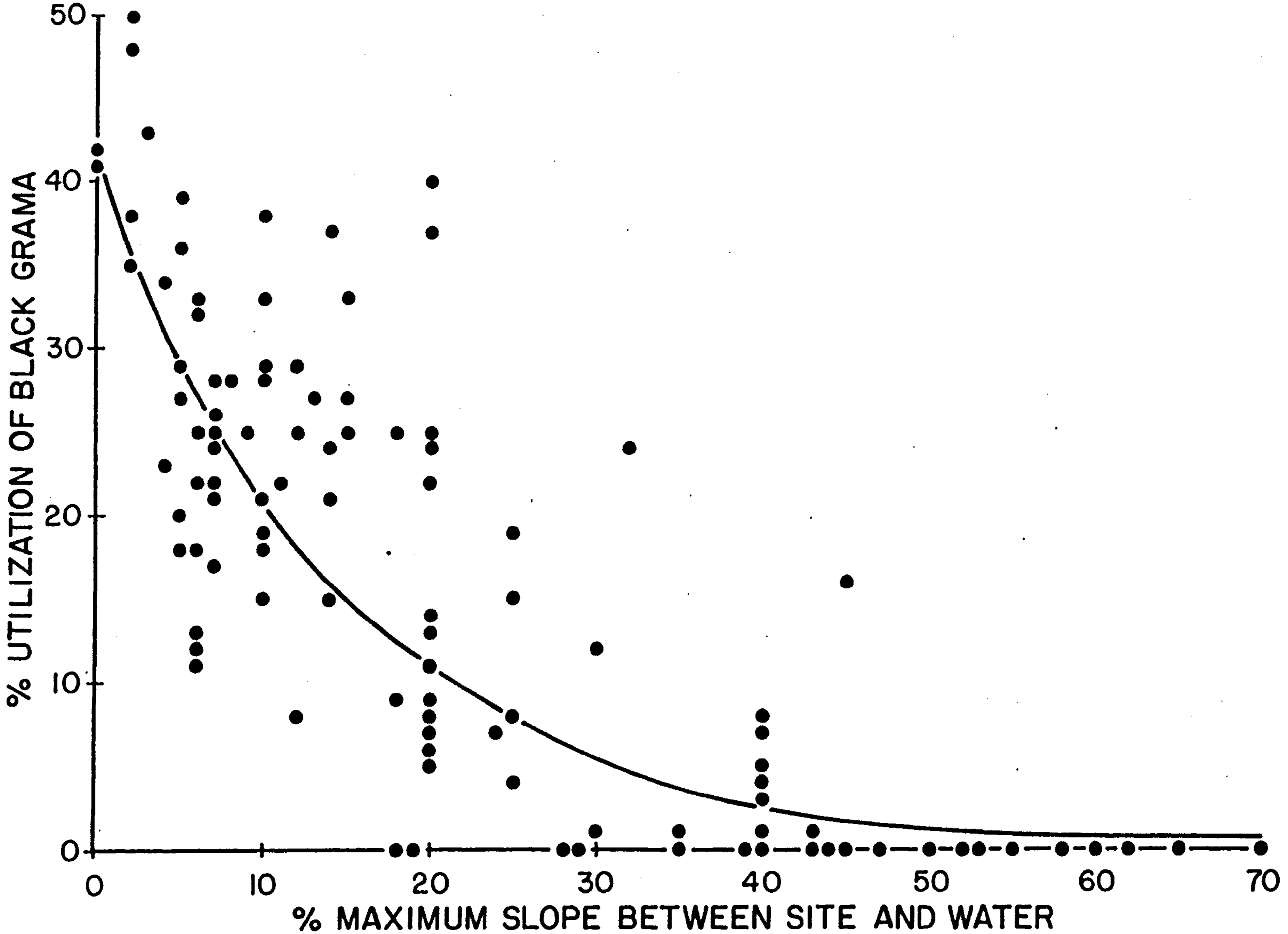

Fig. 6. The association between percentage-maximum-slope-between-site-and-water and the percentage utilization of black grama by cattle on the Santa Margarita Ranch, Altar Valley, Arizona.

that as percentage-maximum-slope is increasing the amount of influence each unit of slope has on use is decreasing. The plot also indicates that when the percentage-maximum-slope-between-site-and-water is about 50% the percentage utilization of black grama approaches zero.

The interaction of distance-to-water times percentage-maximum-slope-between-site-and-water best fits a curvilinear relationship (Fig. 7). The negative slope of the curve indicates that as the value of the interaction increases the importance of its influence on use decreases.

Path Coefficient Analysis

How the relationship of distance-to-water and percentage-maximum-slope-between-site-and-water with percentage utilization of black grama is broken into its various pathways is illustrated in Fig. 8. The correlation coefficient for the Log_{10} of the percentage use of black grama and percentage-maximum-slope, r = 0.875, consists of two components. The relative contributions of these to the relationship can be shown as follows:

Direct path, percentage-maximum-slope, $P_{X_5} - Y$	= -.781
Indirect path via distance-to-water, $r_{X_1X_5}P_{X_1} - Y$	= -.093
TOTAL	= -.875

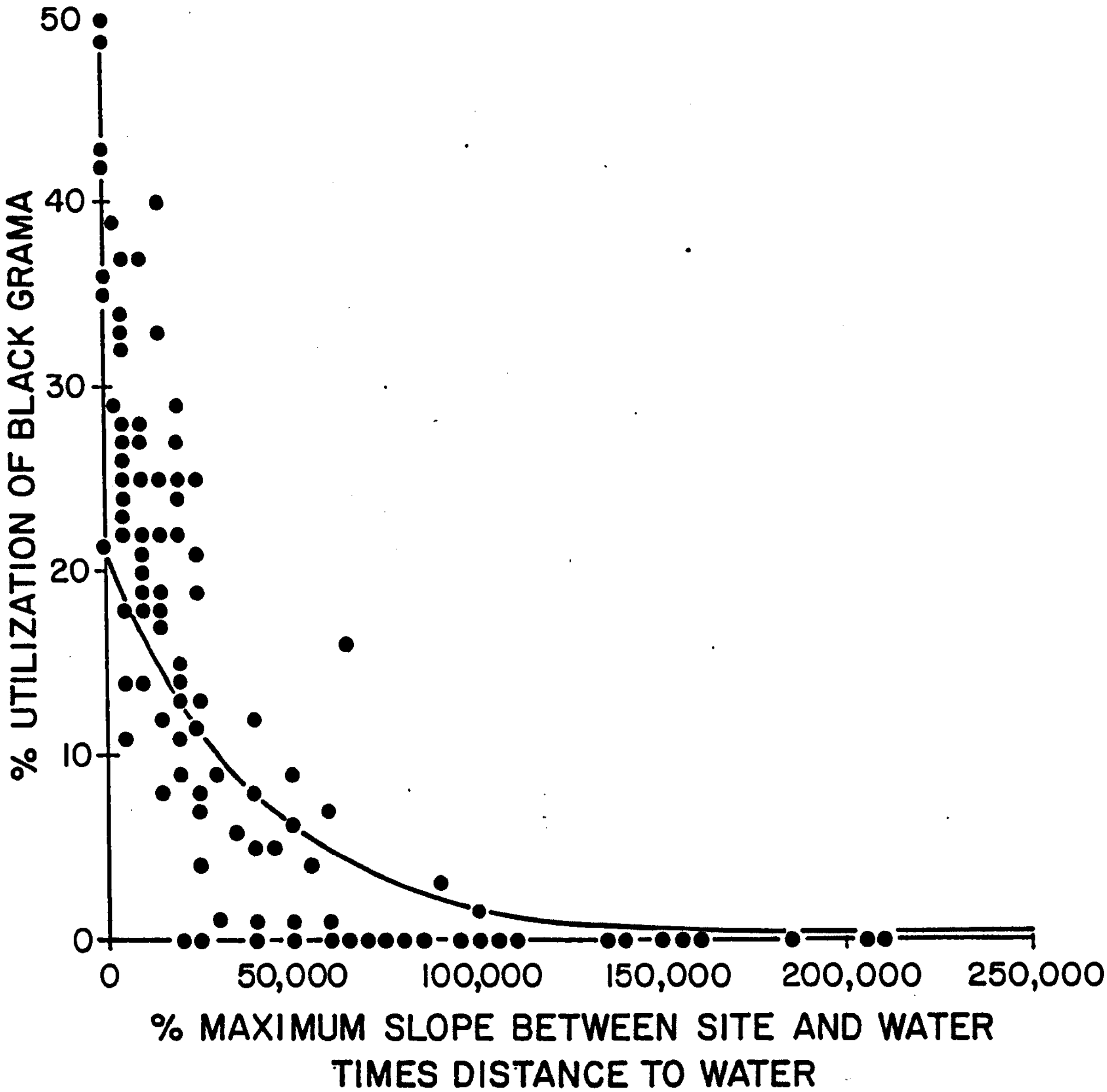

Fig. 7. The association between the interaction of percentage-maximum-slope-between-site-and-water and distance-to-water with the percentage utilization of black grama.

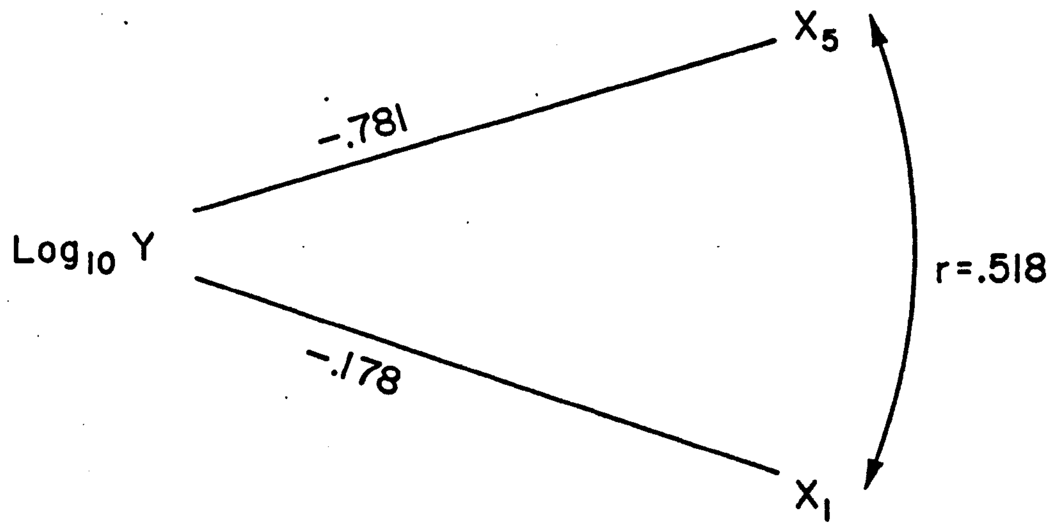

Fig. 8. A diagram of the pathways of the direct influences of distance-to-water, X_1, and the percentage-maximum-slope-between-site-and-water, X_5, on the $\log_{10}Y$ of the percentage utilization of black grama.

It can be seen that the direct path accounts for the most of the correlation of the percentage use of black grama and percentage-maximum-slope. The indirect path via distance-to-water makes a very small contribution.

The correlation coefficient of the percentage utilization of black grama with distance-to-water, r = -.584, also consists of two components, the relative contributions being as follows:

Direct path, distance-two-water, $P_{X_1} - Y$	= -.178
Indirect path via percentage-maximum-slope, $r_{X_1X_5}P_{X_5} - Y$	= -.406
TOTAL	= -.584

Here it is apparent that both the direct and indirect paths give important contributions to the relationship.

The path coefficients model can then be used to calculate the relative amounts the three factors of the prediction model contribute to their association with use. When the path coefficients of the direct paths are squared they show that percentage-maximum-slope-between-site-and-water accounts for 61% ($-.781^2$), distance-to-water accounts for 3% ($-.178^2$), and the interactions of these variables accounts for 14% [2(-0.178)(-0.781)(0.518)] of the variability accounted for by the prediction model (Fig. 8).

Although the path coefficient analysis reveals the direct and indirect influence of distance-to-water and percentage-maximum-slope-between-site-and-water on the percentage use of black grama, it does not indicate how changes in one factor affect the other. Figure 9 shows that as distance-to-water increases the association between black grama and the percentage-maximum-slope becomes less important. The convergence of the lines between 40 and 50% maximum slope indicates that it is somewhere in this range that the percentage utilization of black grama becomes zero no matter what the distance-to-water is within the range of 0 to around 3000 m. The scattering of the intercepts on the X axis can be explained by the fact that as values for distance-to-water and percentage-maximum-slope start to reach their upper levels a lack of data causes the prediction equation to become less precise in predicting use.

Figure 10 shows that as percentage-maximum-slope-between-site-and-water increases the association between the percentage use of black grama and distance-to-water also becomes less important. Here the convergence of the lines indicates that somewhere around 3500 m to water, use becomes zero no matter what the percentage-maximum-slope-between-site-and-water is within the range of 40 to 50% maximum slope. The scattering of the X intercepts on this plot can be explained in the same manner as for Fig. 9.

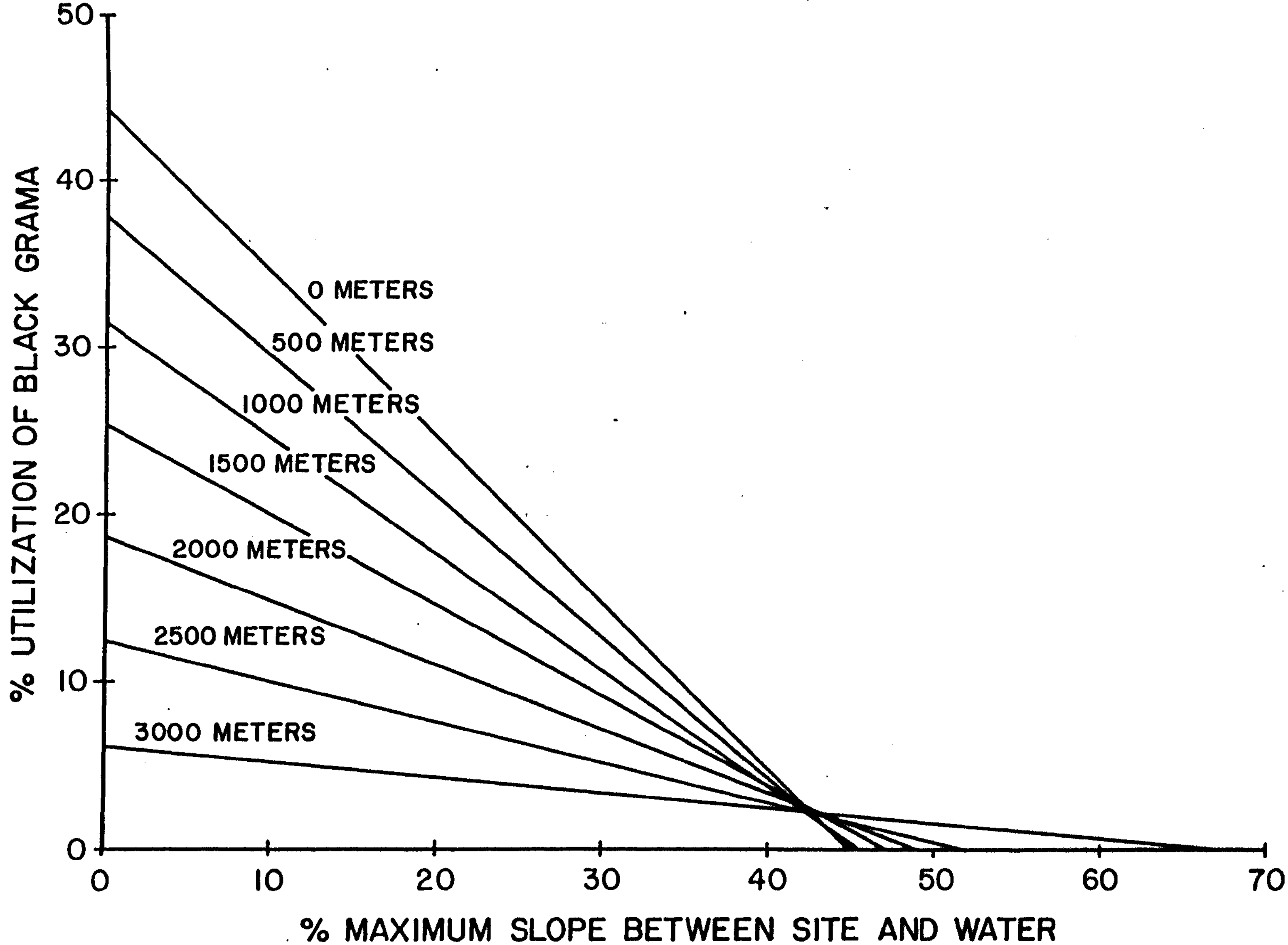

Fig. 9. Effect of changing distance-to-water on the relationship between percentage utilization of black grama and the percentage-maximum-slope-between-site-and-water.

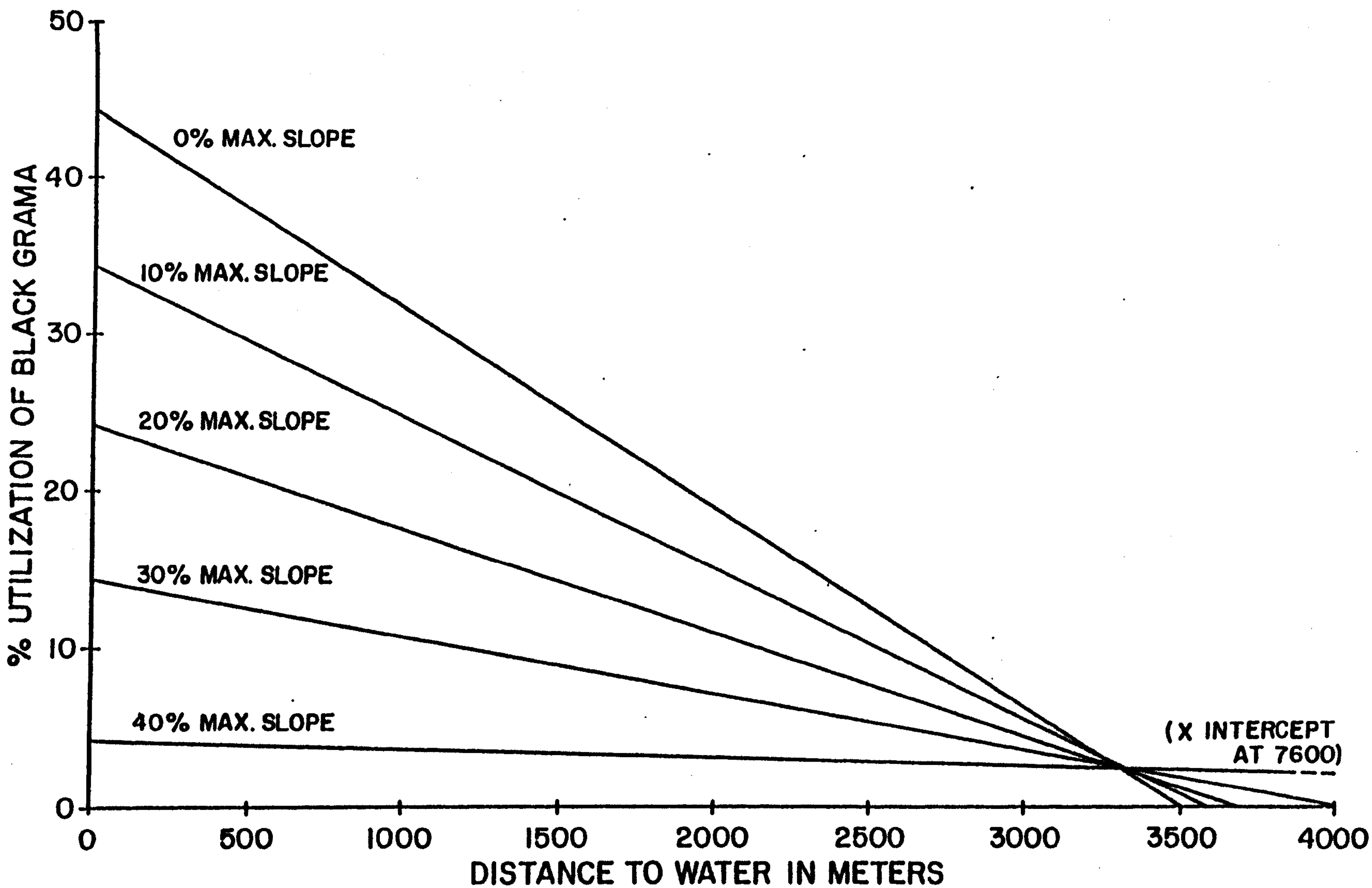

Fig. 10. Effect of changing percentage-maximum-slope on the relationship between percentage utilization of black grama and distance-to-water.

CONCLUSIONS

The factors and factor interactions which demonstrated a significant relationship at the 95 per cent level with the percentage utilization of black grama were percentage-maximum-slope-between-site-and-water, distance-to-water, distance-to-water times percentage maximum-slope-between-site-and-water, distance-up-primary-slope, distance-up-primary-slope times percentage-maximum-slope-between-site-and-water, and distance-to-water times distance-up-primary-slope (Table 1).

The factors and factor interactions which did not demonstrate a significant relationship at the 95 per cent level with the percentage utilization of black grama were percentage-slope-at-site, exposure, distance-along-secondary-slope-to-the-nearest-major-access, percentage composition of black grama at the site, pasture, and all the remaining interactions between the factors.

The percentage utilization of black grama for the study area can be predicted with the equation $\text{Log}_{10}Y = 1.916 - 0.0356X_5 - 0.000261X_1 + 0.000005X_1X_5$ where Y is the percentage utilization of black grama, X_1 is the distance-to-water, X_5 is the percentage-maximum-slope-between-site-and-water, and X_1X_5 is their interaction.

When the factors used to predict use were analyzed by the means of a path coefficient analysis it is found that the direct influence of percentage-maximum-slope-between-site-and-water, the direct influence of distance-to-water, and the indirect influence of distance-to-water through the percentage-maximum-slope-between-site-and-water were important.

The path coefficient analysis also revealed that percentage-maximum-slope-between-site-and-water accounted for 61%, distance-to-water accounted for 3%, and the interaction of these two factors accounted for 14% of the variability accounted for by the prediction equation.

As distance-to-water increased the relationship between the percentage-maximum-slope-between-site-and-water and the percentage utilization of black grama became less important. As percentage-slope-between-site-and-water increased, the relationship between distance-to-water and the percentage utilization of black grama also became less important.

When the percentage-maximum-slope-between-site-and-water was somewhere between 45 and 50%, the percentage utilization of black grama became zero no matter what the distance-to-water. Also, under the grazing intensity on the study area, the percentage utilization of black grama became zero when the distance-to-water was around 3500 m, no matter what the percentage-maximum-slope-between-site-and-water was under 40%.

There are several implications indicated by this study. To begin with, the model could be used on the study area to aid in the determination of a grazing capacity. A key area could be chosen which would receive use of about 50%. Then the model could be used to calculate what amount of use would occur at various points over the rest of the study area. This combined with production sampling could be used to determine how much usable forage was present and thereby the grazing capacity.

The model might also be used to aid in the prediction of the effects developments and improvements might have on use patterns and grazing capacities. The study also suggests that areas which can be reached only by crossing slopes over 45% to 50% will not be used by Hereford cows and calves. Thus, the combination of this study with similar future studies on other areas of desert grassland might be used to construct a model which could be used to aid in the planning of grazing use on and to promote more uniform use of southwestern Arizona ranges.

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