SPATIAL VARIATION IN SPOIL AND VEGETATIVE CHARACTERISTICS OF PASTURES ON RECLAIMED SURFACE MINED LAND

by

C.D. Teutsch, M. Collins and D.C. Ditsch

Abstract. Kentucky has large areas of reclaimed surface mined land that could provide grazing for livestock. Research is needed to determine optimal stocking densities and to evaluate the sustainability of such grazing systems for this region. A long-term grazing study was initiated in 1997 on 151 ha of reclaimed land near Chavies, KY to determine spatial and temporal variation with stocking densities of 0, 0.28, 0.42, or 0.83 beef cow-calf units ha^{-1}. Global Positioning System and GIS technologies were used to establish pasture boundaries, locate permanent sampling markers at a density of 1 per 0.4 ha, and interpolate maps of physical, spoil, and vegetative pasture characteristics. Herbage and spoil samples were collected around the permanent markers in May of 1997. Stepwise regression was used to determine factors affecting the vegetative characteristics of the site. Biomass density ranged from 0 to 2500 kg ha^{-1} with a mean of 570 kg ha^{-1}. Factors affecting biomass included legume and weed proportions in the sward, grazing activity, soil potassium, elevation, and potential acidity, cumulatively accounting for 32% of the variation. Ground cover ranged from 10 to 100% with an average of 74%. Soil pH, potassium, and grass in the sward accounted for 14% of the variation in ground cover. Legumes made up 0 to 61% of the sward with a mean of 13% over the pasture areas. Variables affecting the amount of legume in the sward included biomass density, slope, elevation, pH, and stocking density, together accounting for 21% of the variation. Spatial variation in the physical, spoil, and vegetative characteristics of the pastures was large. Overall, regression accounted for a limited amount of the variation in the vegetative characteristics of the site indicating that other important variables exist.

Key Words: spatial variation, reclamation, grazing, pastures.

Introduction

In the Appalachian region, where agricultural production is limited by a lack of suitable land, surface mined land reclaimed to forage species represents a significant potential resource for livestock production. Kentucky alone has more than 130,000 ha reclaimed to hay and pasture species (Personal communication, Kentucky Department of Surface Mining Reclamation and Enforcement, 1991). Research from other regions suggests that reclaimed land can support sustained grazing by livestock (Hofmann and Ries, 1988; Schuman et al., 1985).

Spatial variation in topography and spoil composition of reclaimed mined land are large and should be considered in managing these sites. Global positioning systems (GPS) and geographic information systems (GIS) allow accurate measurement and mapping of landscape-scale sites and could lead to a better understanding of relationships among topographic, edaphic and biotic ecosystem components. The long-term objectives of this research were to document spatial and temporal variation in pasture vegetation and spoil characteristics under three stocking density treatments. Information gained in this research will be used to establish guidelines for producers managing beef cattle on reclaimed mined land pastures in southeastern Kentucky.

Materials and Methods

The experimental site is located on reclaimed surface mined land near Chavies, KY (37° 20'22.41" N, 83°18'18.97" W). The 151 ha mountain-top-removal site was divided into two replicates of pastures of 12, 24, and 36 ha and adjacent ungrazed areas (Fig. 1). Each pasture was grazed by 10 cow-calf pairs blocked according to cow weight and calf birth date and randomly assigned to treatment x replicate combinations resulting in stocking densities of 0.28, 0.41, and 0.82 cow-calf ha^{-1} (Table 1). Limited producer experience had established the middle

[1]Paper presented at the National Meeting of the American Society for Surface Mining and Reclamation, Scottsdale, AZ, August 13-19, 1999.

[2]Chris D. Teutsch, Michael Collins, and David C. Ditsch are Graduate Research Assistant, Professor, and Associate Professor, respectively, Department of Agronomy, University of Kentucky, Lexington, KY 40546.

Proceedings America Society of Mining and Reclamation, 1999 pp 352-365
DOI: 10.21000/JASMR99010352

https://doi.org/10.21000/JASMR99010352

stocking density of 0.41 cow-calf ha^{-1} as a typical stocking density on reclaimed pastureland in the Appalachian region of S.E. Kentucky. The lower and higher stocking densities of 0.28 and 0.82 cow-calf ha^{-1} provided a range in which the optimal density was most likely contained.

The site used in this study was revegetated between 1991 and 1993 by hydroseeding. The reclamation mixture included orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.), redtop (*Agrostis alba* L.), red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), birdsfoot trefoil (*Lotus corniculatus* L.), sericea lespedeza [*Lespedeza cuneata* (Dunmont) G. Don], and annual lespedeza [*Kummerowia striata* (Thunb.) Schindler]. The majority of the experimental pasture areas were grazed prior to the initiation of this study.

Table 1. Pasture size and stocking densities.

Treatment	Pasture area (ha)	Stocking density (cow-calf ha^{-1})
Heavy	12 ha	0.83
Moderate	24 ha	0.41
Light	36 ha	0.28

The site was mapped and pasture boundaries established using GPS/GIS (Fig. 1). Sampling points (334) were systematically located using GPS resulting in a sampling density of 1 point per 0.4 ha (Fig. 1). Soil and vegetation samples were collected during May of 1997. Yield and botanical composition were determined from clipped samples. Two 0.09 m^2 samples were clipped to a 2.5 cm stubble height at two randomly chosen points within a 5 m radius of each permanently established sampling point. Clipped samples were separated into grass, legume, weed and dead material and dried at 60^{O} C for 3 to 4 d. Percent ground covered by living vegetation was visually estimated within the same area. Grazing activity was determined visually by estimating the percentage of tillers showing signs of being severed during grazing. The following scale was used to rate grazing activity: 1=none, 2=light (<20% of tillers defoliated), 3=light + (20-40% of tillers defoliated), 4=moderate (40-60% of tillers defoliated), 5= moderate + (60-80% of tillers defoliated), and 6=heavy (>80% of tillers defoliated). Predominant forage and weed species were recorded for the 5 m radius surrounding each sample point.

Five soil cores with a 5 cm diameter were taken at a 10 cm depth in May of 1997 within a 5 m radius of each permanently established sampling point and were analyzed for P, K, Mg, Ca, Zn, Pb, Bo, Cd, Mo, Ni, Cr, Cu, organic matter, water holding capacity, buffer pH, water pH, potential acidity and soil texture (Donohue, 1992). Surface maps for elevation, slope, and aspect were created from approximately 11,000 additional GPS points using ArcView GIS software (ESRI, Redlands, CA). Aspect and slope values for permanent sampling points were derived from the interpolated surfaces. Maps of yield, legume and grass percentage, ground cover, grazing activity, soil phosphorus, potassium, pH, potential acidity, and water holding capacity were also created from the data collected at the permanent sampling points using ArcView. The spatial relationship was analyzed using Proc Mixed Models (SAS Institute, 1996). General linear model (GLM) was used to assess pasture differences in topology, and to determine if differences existed between the stocking density treatments in terms of spoil and vegetative characteristics. Stepwise regression was used to determine relationships among the topographic, soil, and plant variables. Independent variables were included in stepwise regression equation if they were significant at $P \leq 0.05$ and they accounted for two percent or more of the variation in the dependent variable.

Results and Discussion

Site Physical Characteristics

Elevations within the pastures ranged from 275 to 375 m with an overall mean of 342 m (Fig 2). Stocking density treatments were different with respect to elevation ($P<0.05$). Pasture slopes ranged from

Table 2. Spoil characteristics for stocking density treatments in May, 1997.

Stocking Density	pH	Pot. Acidity	Phosphorus	Potassium	Calcium	Magnesium	WHC
--cow-calf ha^{-1}--		----kg ha^{-1}----	--kg ha^{-1}--	--kg ha^{-1}--	--kg ha^{-1}--	--kg ha^{-1}--	---g kg^{-1}---
None	5.52b†	4917a	44abc	227b	2016bc	654ab	176a
Heavy	5.86ab	2815b	30b	237b	2034bc	739a	168a
Moderate	6.06a	1326bc	47a	328a	2611a	726a	176a
Light	5.58b	3412a	40c	225b	1909c	604b	161b

†Means within a column followed by the same letter are not significantly different (P=0.05).

nearly flat on plateaus and benches to 65° grade on the out-slopes (data not shown). The average slope for all pastures was 8°. Slope did not differ between stocking density treatments. All aspects were represented within the pastures. There was no difference in average aspect between stocking density treatments (P=0.05) (data not shown).

Spoil Characteristics

Soil pH of the pasture areas ranged from 3.5 to 9.9 with an overall mean of 5.8 (Fig. 3). The mean pH for the stocking density treatments ranged between 5.5 and 6.0 and was significantly different between the ungrazed areas and the moderate stocking density and the moderate stocking density and the light stocking density (Table 2). The potential acidity of the pasture areas ranged from zero to approximately 40 Mg ha^{-1} averaging 2.1 Mg ha^{-1} (data not shown). The stocking density treatments differed in respect to potential acidity. The highest potential acidity was found in the ungrazed areas and light stocking density, while the moderate stocking density had the lowest (Table 2). Linear regression showed that pH and potential acidity were highly correlated (r^2=0.89), indicating that the acid forming spoil components located in the upper portions of the spoil profile are being oxidized.

Phosphorus content of the spoil over the pasture areas ranged from 5 to over 200 kg ha^{-1} with a mean of 39 kg ha^{-1} (Fig. 4). The stocking density treatments had a mean phosphorus content ranging from 30 to 47 kg ha^{-1}. The moderate stocking density had higher soil phosphorus than either the low or high densities. Even though differences were detected, all of the treatments were in the in the medium soil fertility range (31-67 kg ha^{-1}) with respect to phosphorus. Spoil potassium content ranged from 31 to 1041 kg ha^{-1} with a mean of 255 kg ha^{-1} over the pasture areas (Fig. 5). Mean potassium content of the stocking density treatments were 227, 237, 328, and 225 kg ha^{-1} for the ungrazed, heavy, moderate, and light stocking densities respectively (Table 2). All of the stocking density treatments were in the medium to high soil fertility range in terms of potassium. The calcium content of the pasture areas ranged between 20 and 8380 kg ha^{-1} with mean of 2185 kg ha^{-1} (data not shown). The mean calcium content of the stocking density treatments ranged from 1909 to 2611 kg ha^{-1} (Table 2). The moderate stocking density had more calcium than the other treatments (Table 2). Spoil magnesium ranged from 100 to 1480 kg ha^{-1} with mean of 660 kg ha^{-1} (data not shown). The stocking density treatments had mean magnesium contents ranging from 604 to 739 kg ha^{-1} with the heavy and moderate treatments containing higher amounts of magnesium (Table 2).

Average values of water holding capacity for the stocking density treatments were 176, 168, 176, and 161 g kg^{-1} for the ungrazed, heavy, moderate, and light stocking density treatments respectively (Table 2). Estimates of the water holding capacity for the stocking density treatments, were higher than those of typical undisturbed silt loam soil. This would indicate that more water should be available for plant use on the reclaimed spoils in this study, however field observations indicate that the opposite is true. In general, spoils tend to be more drought prone than undisturbed soils. The increased estimates of water holding capacity for the stocking density treatments may have been due to the sample preparation procedure. While the very coarse fragments of the soil samples were removed, a significant amount of particles greater than 2 mm remained. The sample was then ground thereby reducing the particle size of the remaining sample. This may have in turn increased the estimates of water holding capacity for the spoil samples. Another important factor that may affect the droughtiness of reclaimed mined land pastures is the ratio of coarse fragments to those less than 2 mm. In general reclaimed mined spoils contain a larger proportion of coarse fragments thereby decreasing the amount of total soil volume capable of retaining water for plant growth. The end result is less total water for plant growth leading to the observation of earlier drought stress.

Vegetative Characteristics

Within the study area, herbage biomass ranged from zero on washes and hot-spots to nearly 2500 kg ha^{-1} in areas with a dense cover of sericea lespedeza (Fig 6). Sericea lespedeza is well adapted to the low pH, droughty conditions prevalent in surface mine spoil (Windham et al., 1988) and this species often dominates on ungrazed reclamation sites in Kentucky. The mean biomass present in May, 1997 for the ungrazed, heavy, moderate, and light stocking density treatments was 1030, 421, 566, and 600 kg ha^{-1} respectively (Table 3). As expected, the ungrazed areas had the highest biomass, while the heavy stocking density had the lowest (Table 3). Stepwise regression indicated biomass production was influenced by a number of factors including legume proportion in the sward, grazing activity, soil potassium, and elevation (Table 4). As legumes in the sward increased, biomass also increased. Reclaimed spoils tend to be low in nitrogen and therefore symbiotic nitrogen fixation by legumes plays an important role in herbage growth and production. Grazing activity of the cattle had a negative effect on the measured biomass production. Pasture elevation had a negative effect on biomass production and was most likely related to the grazing intensity. The cattle tended to spend more time grazing at the higher elevations where the flat plateaus were located thereby reducing the measurable biomass at these elevations. Soil potassium was positively associated with biomass production. Approximately 33% of the variation in biomass production could be explained by the above mentioned factors.

The legume proportion in the sward over the pasture areas ranged from 0 to 61% with a mean of 13% (Fig 7). Grasses over the pasture areas ranged from none in the areas dominated by sericea lespedeza to almost 100% in some of the more heavily grazed areas (Fig. 8). Legumes made up a smaller proportion

Table 3. Vegetative characteristics of stocking density treatments in May, 1997.

Stocking Density	Biomass	Grass	Legume	Weed	Dead	Ground Cover
--Cow-Calf ha^{-1}--	--kg ha^{-1}--	-------%--------	-------%-------	-------%-------	-------%------	-------%-------
None	1030a	53a	12a	4abcd	30a	81a
Heavy	421c	41b	6b	1b	52b	72b
Moderate	566b	38bc	13a	5c	44c	76ac
Light	600b	33c	16a	3d	48bc	74bc

†Means within a column followed by the same letter are not significantly different (P=0.05).

Table 4. Results of stepwise regression analysis for biomass, legumes, grass, and ground cover.

Variable	Regression Equation[†]	r^2
Biomass	BM= 2180 + LG(10.5) - GZ(101) + K(0.835) - EV(4.78) + WD(9.36) - PA(26.0)	0.33
Legume in sward	Legume %= -70.8 + BM(0.0105) - SP(0.138) + EV(0.161) + pH(2.76) + SD(0.126)	0.21
Grass in sward	Grass %=38.1 + GZ(4.47) + K(0.0617) - GC(0.414)	0.19
Ground cover	%GC= 59.7 + pH(2.70) - GR(0.130) + K(0.281)	0.14

[†]BM=biomass, LG=legume proportion, GZ=grazing intensity, K=potassium, EV=elevation, WD=weed proportion, PA=potential acidity, SP=slope, SD=stocking density, GC=ground cover, and GR=grass proportion.

of the total sward at the high stocking density (Table 3). Grasses predominated at the heaviest stocking densities (Table 3). Factors affecting legumes in the sward included biomass production, slope, elevation, pH, and stocking density (Table 4). The positive association of legumes and biomass was mostly likely due to dinitrogen fixation of the legume component. More sloping areas tended to have lower proportions legumes. This may be due to poorer initial establishment of legumes on steeper areas. Elevation was positively associated with legume proportion. The higher elevations consisted of flatter areas in the pastures which have better water infiltration, which may have resulted in better initial establishment of the legumes. Soil pH was positively associated with legumes in sward, which was likely due to the fact that most legumes grow best at higher pH's (6.5-7.0). Factors affecting grass in the sward included grazing activity, soil potassium, and ground cover (Table 4). As grazing activity increased, the grass component increased, probably due to the superior ability of grasses to sustain higher levels of continuous grazing in contrast to most legumes, which require a rest period between grazing events. Grass proportion in the sward was positively correlated with soil potassium. As the ground cover increased, grass in the sward tended to decrease, most likely being replaced with increased legumes. The increased legumes in the sward resulted in increased biomass and concurrently increased ground cover. Another possible explanation for the negative relationship between grass proportion and ground cover is that areas with very high ground cover were generally dominated by sericea lespedeza, which resulted in decreased grazing, leading to higher ground cover and less grass in the sward. Sericea lespedeza becomes very unpalatable once it exceeds a height of about 25 cm and would therefore deter grazing from areas dominated by this species.

Ground cover over the pasture areas ranged from 10 to 100% with a mean of 74% (Fig. 9). The ungrazed areas had the highest ground cover, the heavy and light stocking densities had a lower ground cover (Table 3). Factors affecting pasture ground cover included spoil pH, grass in the sward and soil potassium. The pH positively impacted ground cover by increasing the legume in the sward and concurrently the total biomass. The grass component of the sward was negatively associated with ground cover since increasing the grass proportion was negatively related to legumes in the sward. In addition, areas with heavy concentrations of sericea lespedeza most likely deterred grazing. These factors most likely resulted in increased ground cover and therefore the negative association with the grass component of the sward.

Conclusions

Reclaimed mine land pastures varied widely in physical characteristics such as elevation, slope, and aspect. Spoil characteristics of the pastures also differed widely among and within stocking density treatments. The vegetative variables measured in this study varied both among and within stocking density treatments. The stepwise regression analysis used to evaluate the factors affecting the vegetative pasture characteristics accounted for a limited amount of the variation. This indicates that other important variables are affecting plant components of this complex grassland ecosystem and these variables remain to be identified. Based on field observations and the data collected thus far, increased attention is being placed on elucidating the water relations of the reclaimed pasture areas used in this study. The availability of GPS and GIS technologies is aiding in the understanding of relationships and changes taking place over time within this complex ecosystem. This grazing study will be continued for at least four additional grazing seasons providing information on the temporal effects of grazing on reclaimed mined land pastures.

Literature Cited

Donohue, S.J (ed.). 1992. Soil and media diagnostic procedures for the southern region of the United States. Southern cooperative extension bulletin No. 374. Va. Agric. Exp. Stn., Blacksburg.

Hofmann, L. and R.E. Ries. 1988. Vegetation and animal production from reclaimed mined pastures. Agron. J. 80:40-44.
https://doi.org/10.2134/agronj1988.00021962008000010009x

PC SAS. 1989-1996. SAS Institute Inc., Cary, NC, USA.

Schuman, G.E., D.T. Booth, J.W. Waggoner, and F. Rauzi. 1985. The effect of grazing reclaimed mined lands on forage production and composition. *In* Proc. 2nd Int. Rangeland Congr., Adelaide, Australia. May 1984. Soc. for Range Manage., Denver, CO.

Windham, W.R., S.L. Fales, and C.S. Hoveland. 1988. Analysis for tannin concentration in sericea lespedeza by near infrared reflectance spectroscopy. Crop Sci. 28:705-708.
https://doi.org/10.2135/cropsci1988.0011183X002800040031x

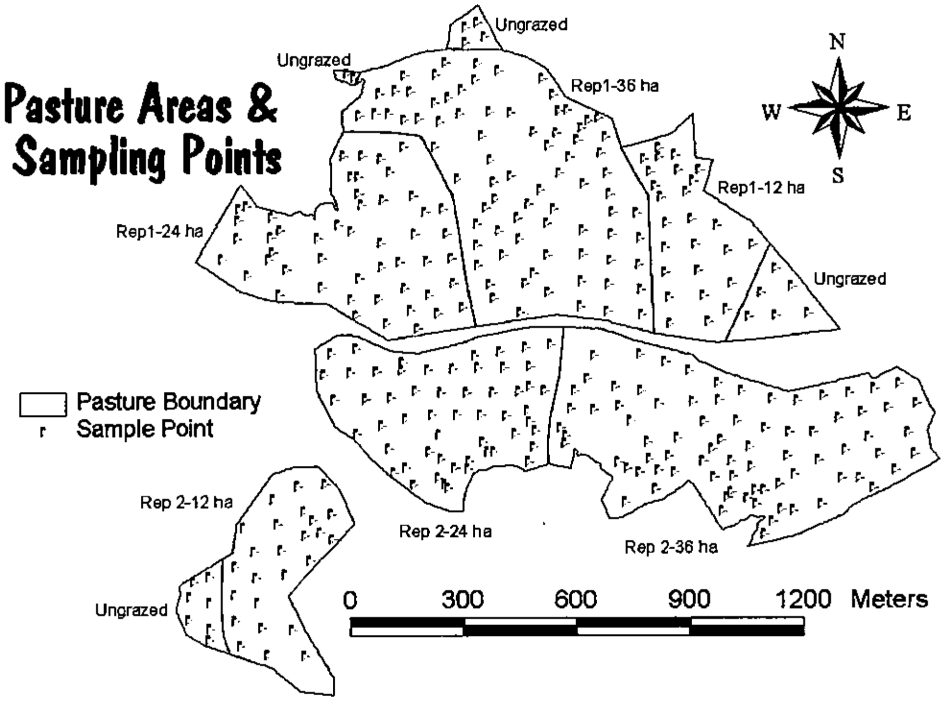

Figure 1. Pasture boundaries, permanent sampling points, and water sources.

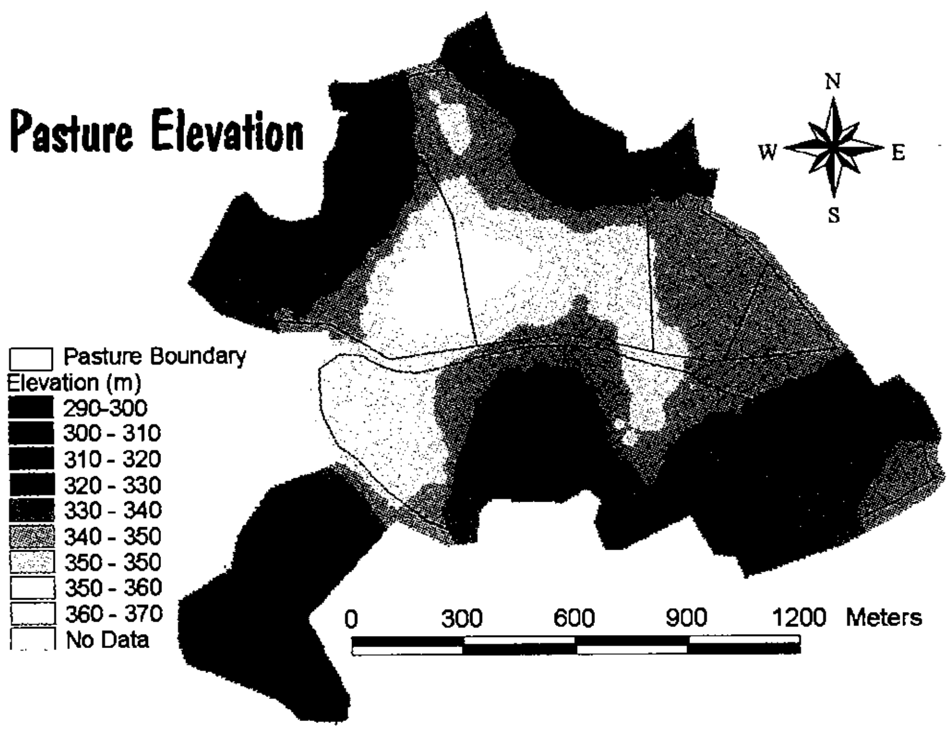

Figure 2. Interpolated surface for elevation.

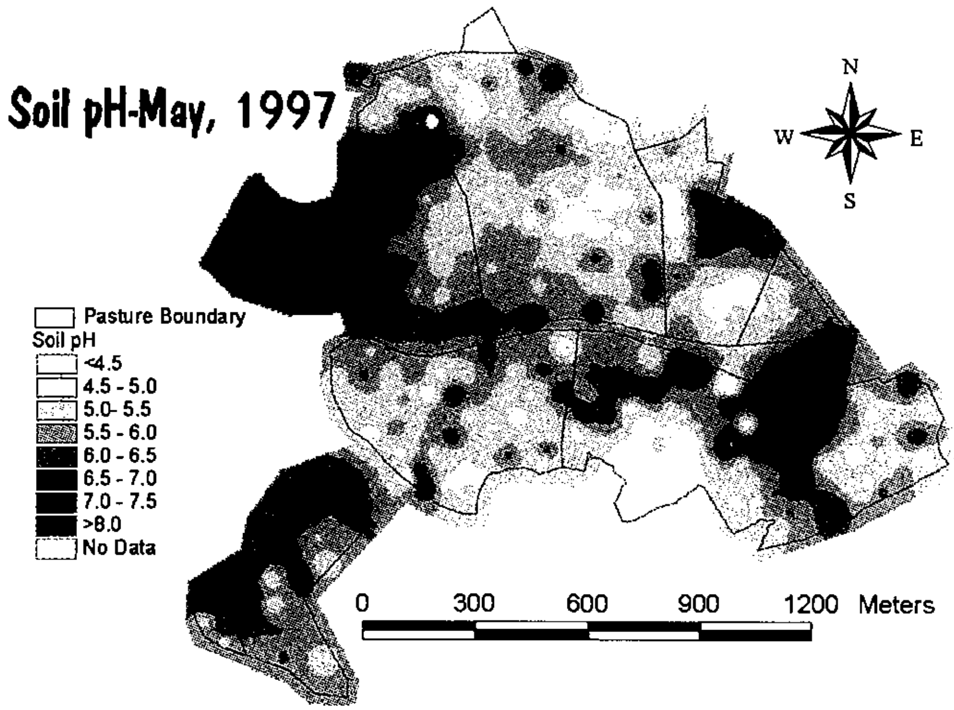

Figure 3. Interpolated surface for pH.

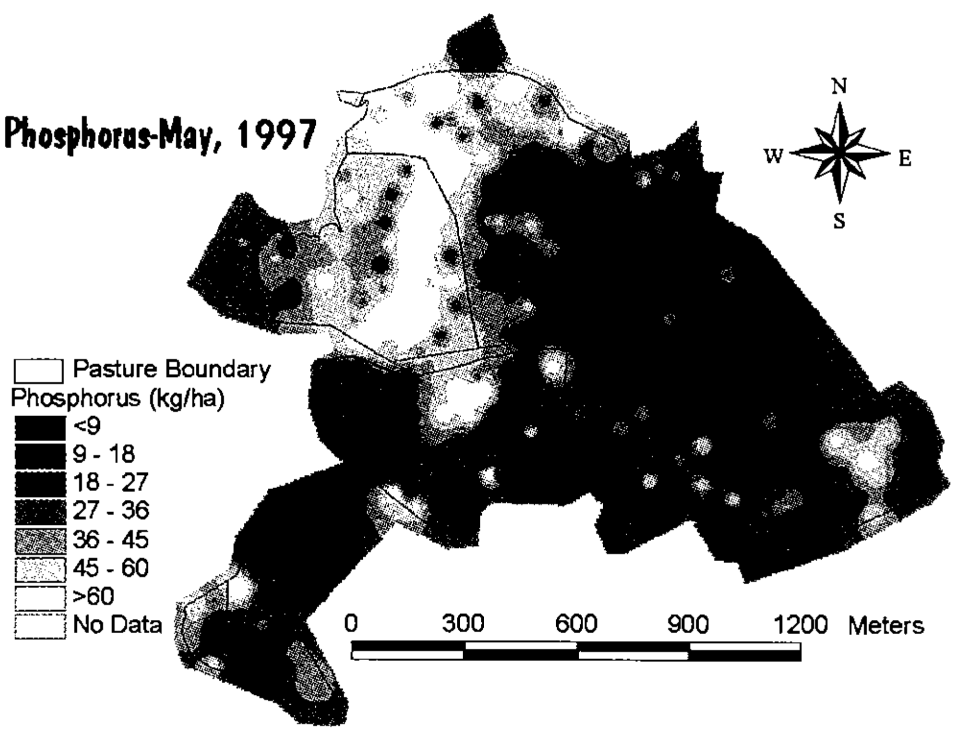

Figure 4. Interpolated surface for soil phosphorus.

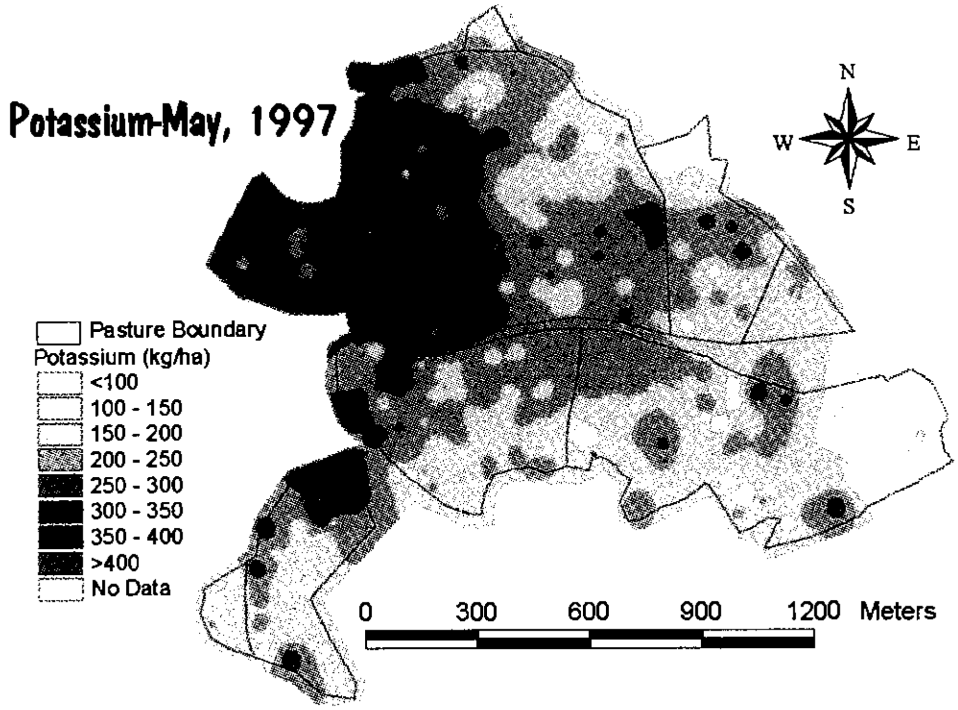

Figure 5. Interpolated surface for soil potassium.

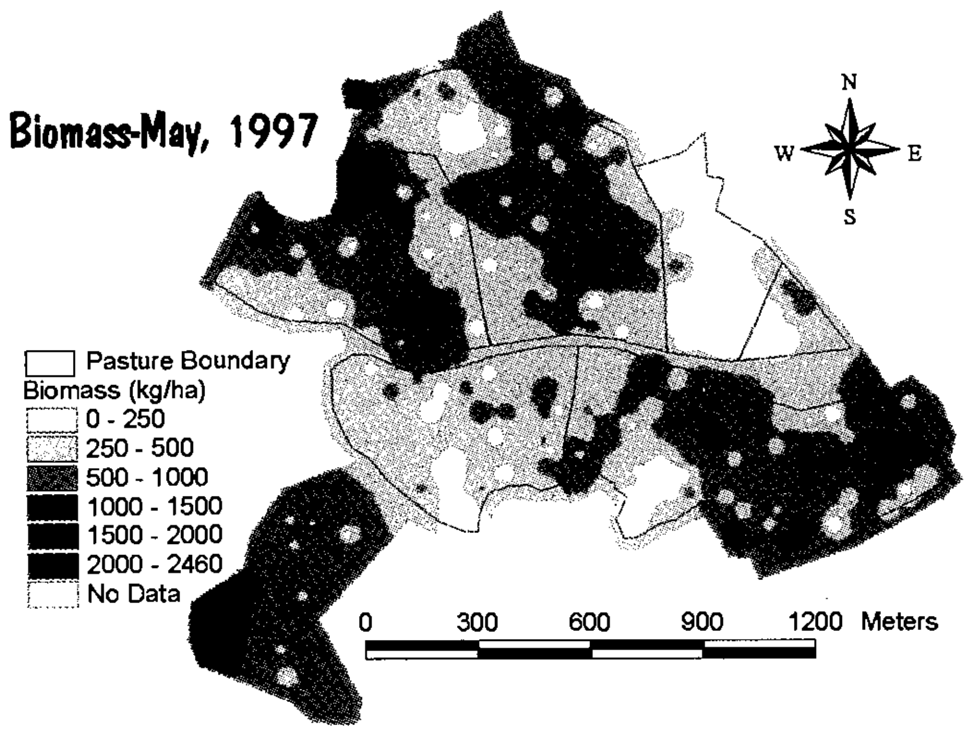

Figure 6. Interpolated surface for pasture biomass.

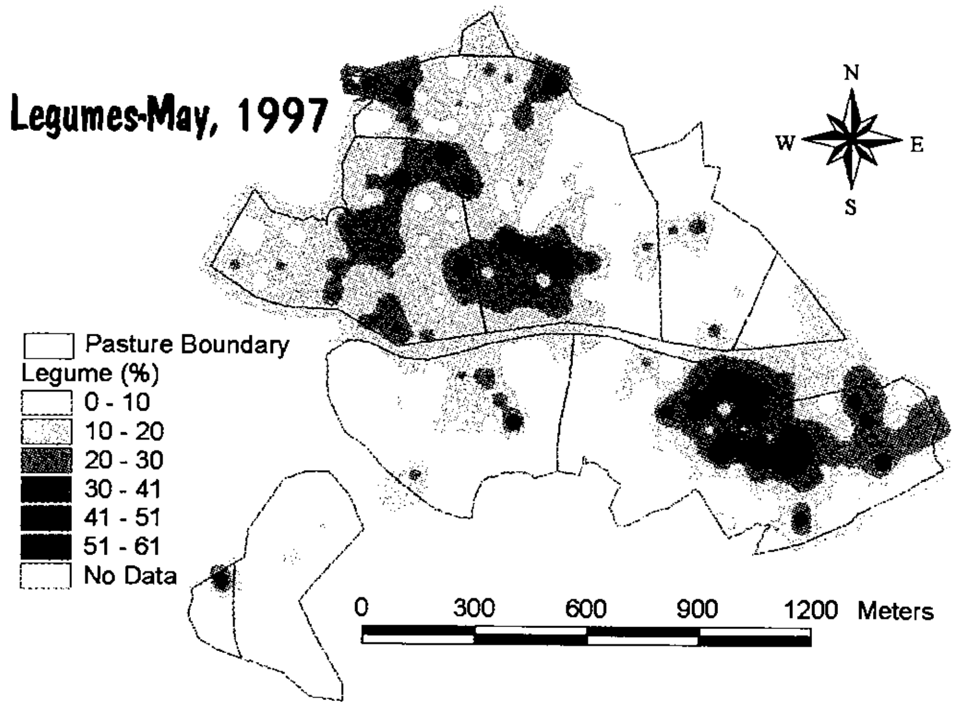

Figure 7. Interpolated surface for legume proportion.

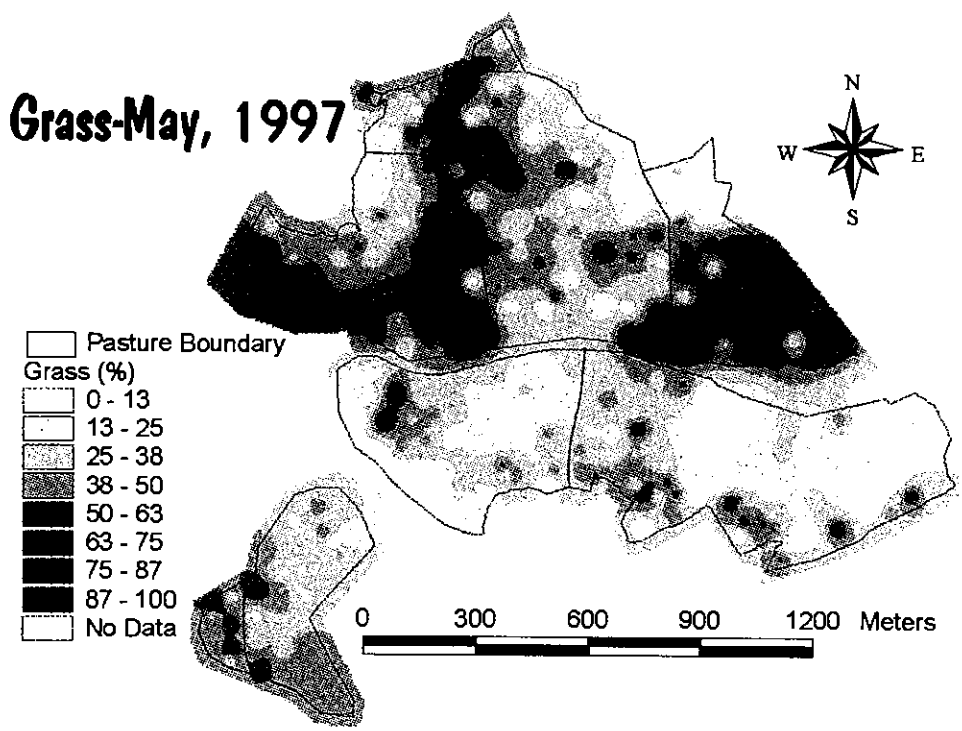

Figure 8. Interpolated surface for grass proportion.

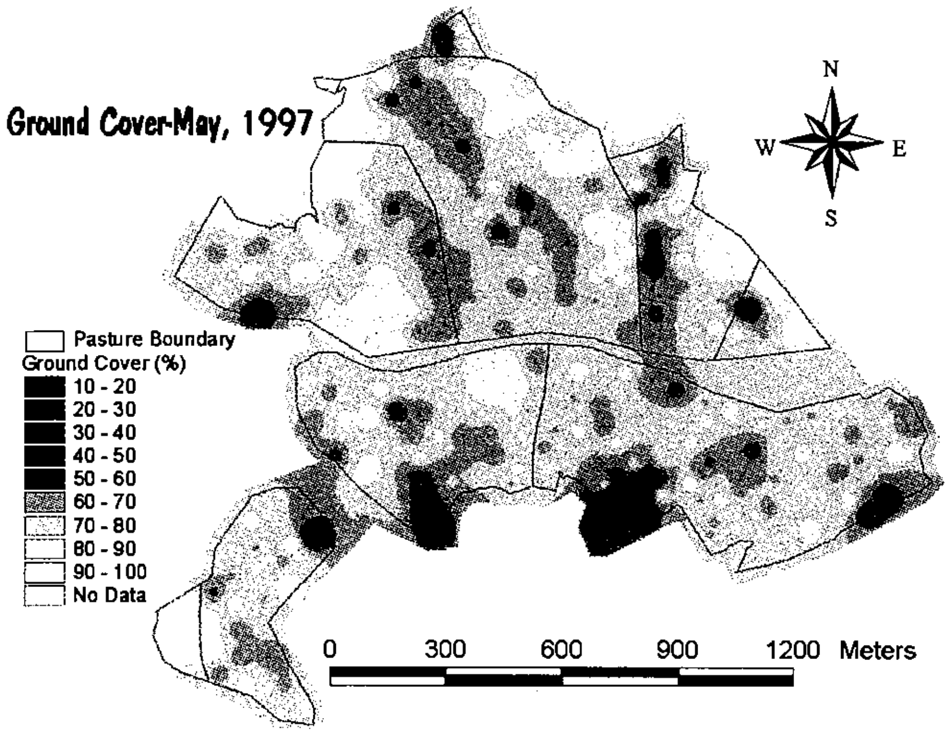

Figure 9. Interpolated surface for ground cover.