COO-2758-7

MASTER

STRIP MINE RECLAMATION: CRITERIA AND METHODS FOR MEASUREMENT OF REVEGETATION SUCCESS

Progress Report

for Period April 1, 1980 - March 31, 1981

James E. Carrel, Clair L. Kucera

Christian J. Johannsen, and Robert W. Blanchar

University of Missouri-Columbia

Columbia, Missouri 65211

December, 1980

Prepared for

The U.S. Department of Energy

Under Contract No. DE-AC02-76EV02758.A006

DISCLAIMER

TABLE OF CONTENTS

2. LEGAL NOTICE

3. ABSTRACT

During this contract period we continued our research aimed at finding suitable methods and criteria for determining the success of revegetation in Midwestern prime ag lands strip mined for coal. Particularly important to our experimental design was the concept of reference areas, which were nearby fields from which the performance standards for reclaimed areas were derived.

We tested direct and remote sensing techniques for measuring plant ground cover, production, and species composition. We worked for the first time in 15 mine sites permitted under interim permanent surface mine regulations and in 4 adjoining reference sites. We also continued our studies at 9 prelaw sites. All sites were either in Missouri or Illinois.

Data gathered by us in the 1980 growing season showed that 13 unmanaged or young mineland pastures generally had lower average ground cover and production than 2 reference pastures. In contrast, yields at approximately 40% of 11 recently reclaimed mine sites planted with winter wheat, soybeans, or milo were statistically similar to 3 reference values. Digital computer image analysis of color infrared aerial photographs, when compared to ground level measurements, was a fast, accurate, and inexpensive way to determine plant ground cover and areas. But the remote sensing approach was inferior to standard surface methods for detailing plant species abundance and composition.

4. SCOPE OF INVESTIGATIONS AND SIGNIFICANT RESULTS

4.1. Objectives

As proposed in 1978, we plan to do the following things:

1. To establish objective methods to measure and criteria to judge the diversity, effectiveness, and permanence of vegetation in reclaimed surface coal mines and in reference areas as required under Public Law 95-87.
2. To determine the cost-effectiveness, generality, and utility of our methods and criteria.
3. To transfer our information to interested parties, particularly mine operators and governmental regulators.

This report summarizes our progress during 1980 toward meeting these objectives.

4.2. Research Program

4.2.1. Introduction

Our research approach is to study strip mine and reference sites prepared and managed by midwestern mine operators under the approval of state and federal land reclamation officials. We intend to follow reclamation activities pertinent to our chosen sites for several consecutive years, going from pre-mining planning to post-mining termination. Thus, we are not responsible for the actual grading, seeding, or cropping of any area. Instead, we exploit the agricultural systems created by mine operators who are attempting to comply with various strip mine regulations. This fact is important because it means that all of our data are derived from large, legally permitted plots rather than from small, experimental plots of the sort commonly used by agronomists.

4.2.2. Site Descriptions

Our study sites are located at 4 active surface coal mines, 3 in Missouri and 1 in Illinois (Figure 1). Most of the acreage in these regions is classified as pastureland or cropland. Hence, after being stripped the land must usually be returned to high agricultural capability. However, since the permanent state surface mining rules and regulations were not approved by the federal Office of Surface Mining until late in 1980, only now are mine operators drafting final reclamation plans for areas permitted between 1978 and 1980. Thus, at all 4 mines we are still encountering a transitional situation.

During the 1980 contract period we worked to varying degrees at 4 active coal mines (Table 1). We sampled vegetation in mine and reference sites only at the first three coal mines. Because of limitations imposed by our budget and manpower, we were unable to conduct aerial and field studies at the Empire Coal Mine in southwestern Missouri. We plan to work at all four in the coming contract year.

Different crops prevailed at the three mines we studied in 1980 (Table 2). Forages were planted in all Missouri sites, whereas row crops were planted in Illinois sites. At the Prairie Hill Coal Mine we studied nine mine sites pre-dating Public Law 95-87 to collect our fourth and final consecutive year's data on plant growth. All ten Prairie Hill sites are slated to be re-mined or reclaimed to current standards in the near future. In 1981 four new sites seeded with forages should be available for our research. Hence, these pre-law sites will provide valuable benchmark information to evaluate future revegetation practices at this mine.

4.2.3. Climatological Data

Precipitation and air temperature at the three strip mines we studied

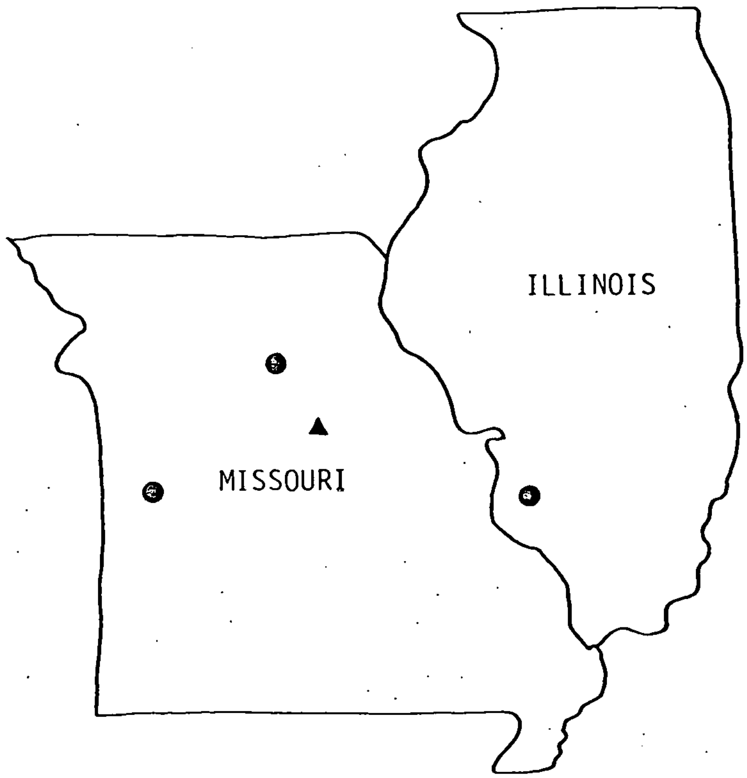

Figure 1. Location of 3 surface coal mines (●) and our laboratory (▲).
Reference sites were near the strip mines.

Table 1. Description of strip mines studied in 1980.

Mine	Operator	Location	Soils	Coal seam Average thickness of seam (ft.)- Stripping depth (ft.)
Prairie Hill Coal Mine	Associated Electric Cooperative, Inc.	Randolph Co., MO R16W, T55N	Gara-Mexico silt loams	Bevier 4 ft.-120 ft.
River King Coal Mine	Peabody Coal Company	Randolph Co., IL R6W, T4S	Eva-Darmstadt-Stoy silt loams	Herrin No. 6 6 ft.-120 ft.
Power Coal Mine	Peabody Coal Company	Henry Co., MO R27W, T39N R28W, T40N	Hartwell-Deepwater-Roseland silt loam and Norris-Rockland-Gasconade shaly loam	Tebo, Weir-Pittsburg 3.5 ft.-65 ft.
Empire Coal Mine	Pittsburg and Midway Coal Company	Barton Co., MO R15W, T53N	Parsons-Barden silt loam	Rowe 1.5 ft.-65 ft.

Table 2. Description of study sites.

Name	Number of sites		Age relative to PL 95-87	Crop
	Mine	Reference		
Prairie Hill	9	1	Pre-law	Fescue-alfalfa-orchard grass mixture
River King	7	1	Post-law	Winter wheat
	1	1	Post-law	Soybeans
	3	1	Post-law	Milo
Power	4	1	Post-law	Winter wheat nurse crop and fescue-alfalfa mixture
Total	24	5		

were estimated from monthly climatological data provided by four nearby weather stations. The 30 year means were used to assess departures in 1980 from normal climatic conditions.

An extreme drought prevailed this summer in Missouri, but it was less severe in Illinois. As is shown in Figure 2, mean air temperatures at the four stations were slightly below average from March to May, but they greatly exceeded the average from June to September. Rainfall values were below normal from April until August or September, especially in Missouri.

To quantify the deficit in energy available for plant growth at our sites, we calculated a water balance from the data in Figure 2. These results indicate that crops probably were greatly stressed at the Power and Prairie Hill mines, but less so at River King (Table 3). Evapotranspiration deficits estimated by us should be regarded as provisional figures because the validity of applying this methodology to poorly structured mine spoils has not been tested.

4.2.4. Direct and Remote Sensing Methods

Manual and automated methods for measuring plant growth were evaluated at 29 sites listed in Table 2. We timed our efforts so that data collection using both techniques preceded full-scale cropping of fields by 1 or 2 weeks. Forages and winter wheat were examined in early July, whereas soybeans and milo were studied in September 1980.

Method 1: Direct, manual measurements

Twenty-five permanent 0.5 m^2 plots were staked out at random distances along parallel transects spaced at regular intervals across each site. We visited each plot, estimated visually the percent ground covered by plants within

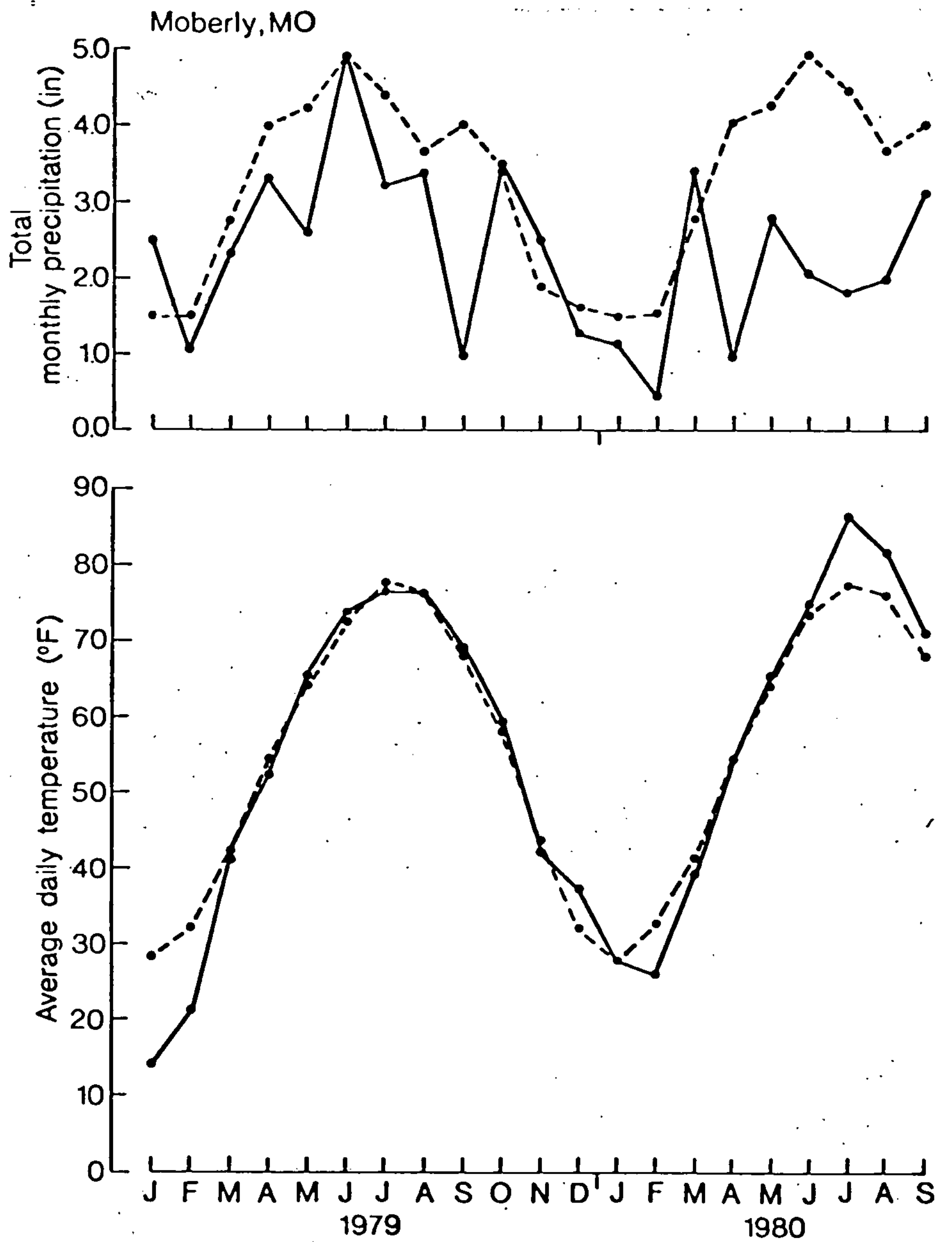

Figure 2a. Climatological data for Moberly, MO showing actual 1979-1980 values (———) and 30 year mean (- - -).

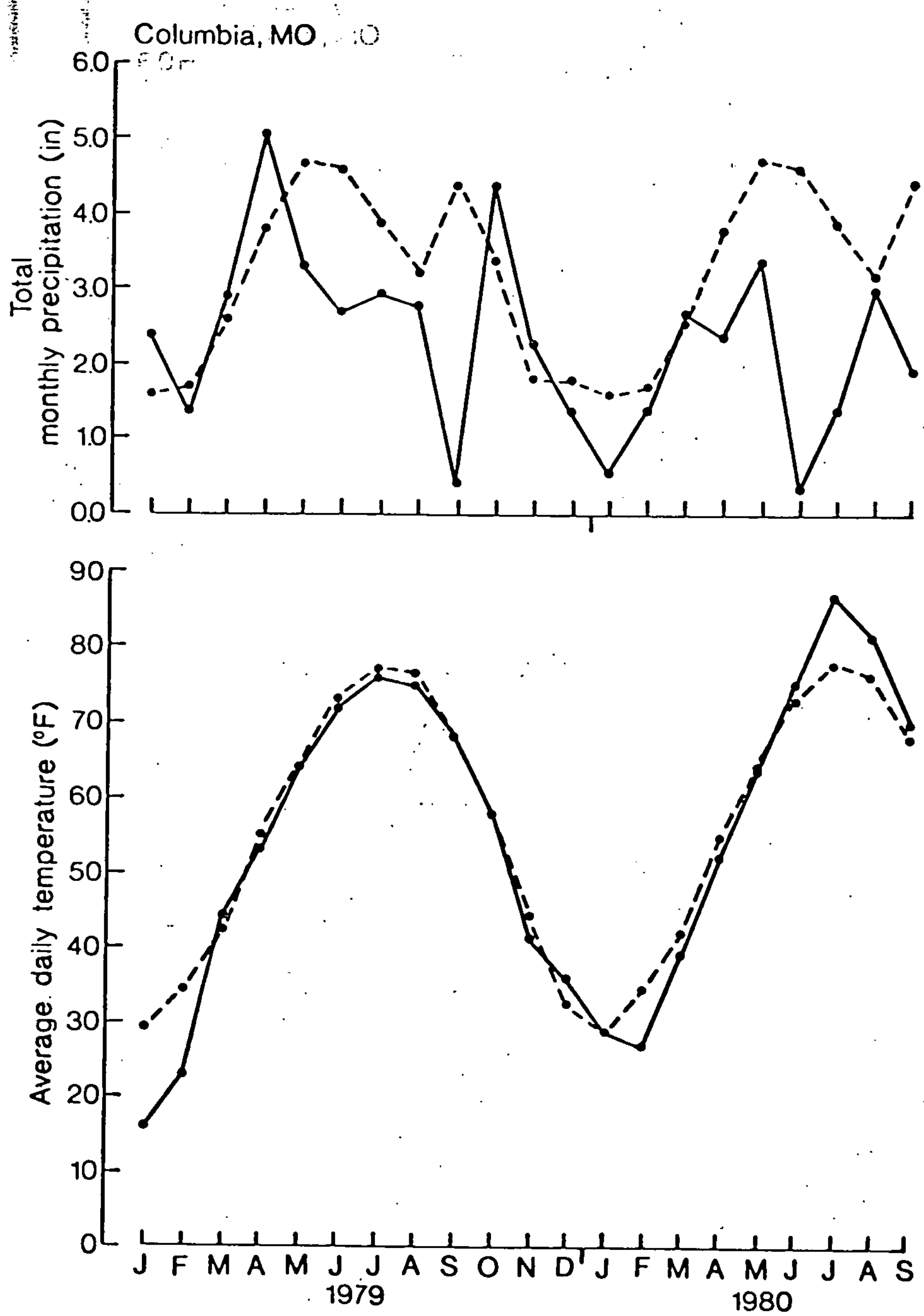

Figure 2b. Climatological data for Columbia, MO showing actual 1979-1980 values (———) and 30 year mean (- - -).

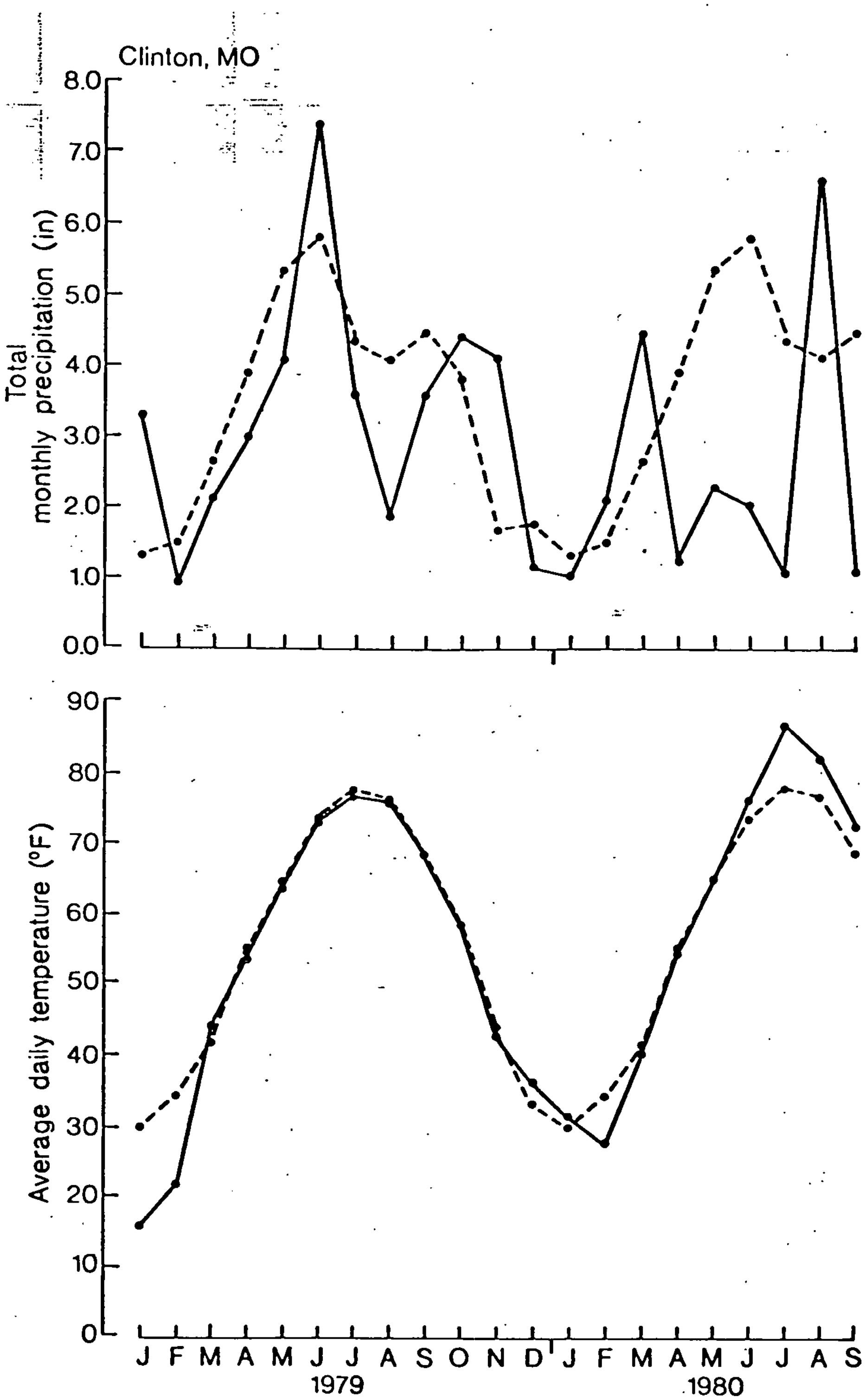

Figure 2c. Climatological data for Clinton, MO showing actual 1979-1980 values (———) and 30 year mean (- - -).

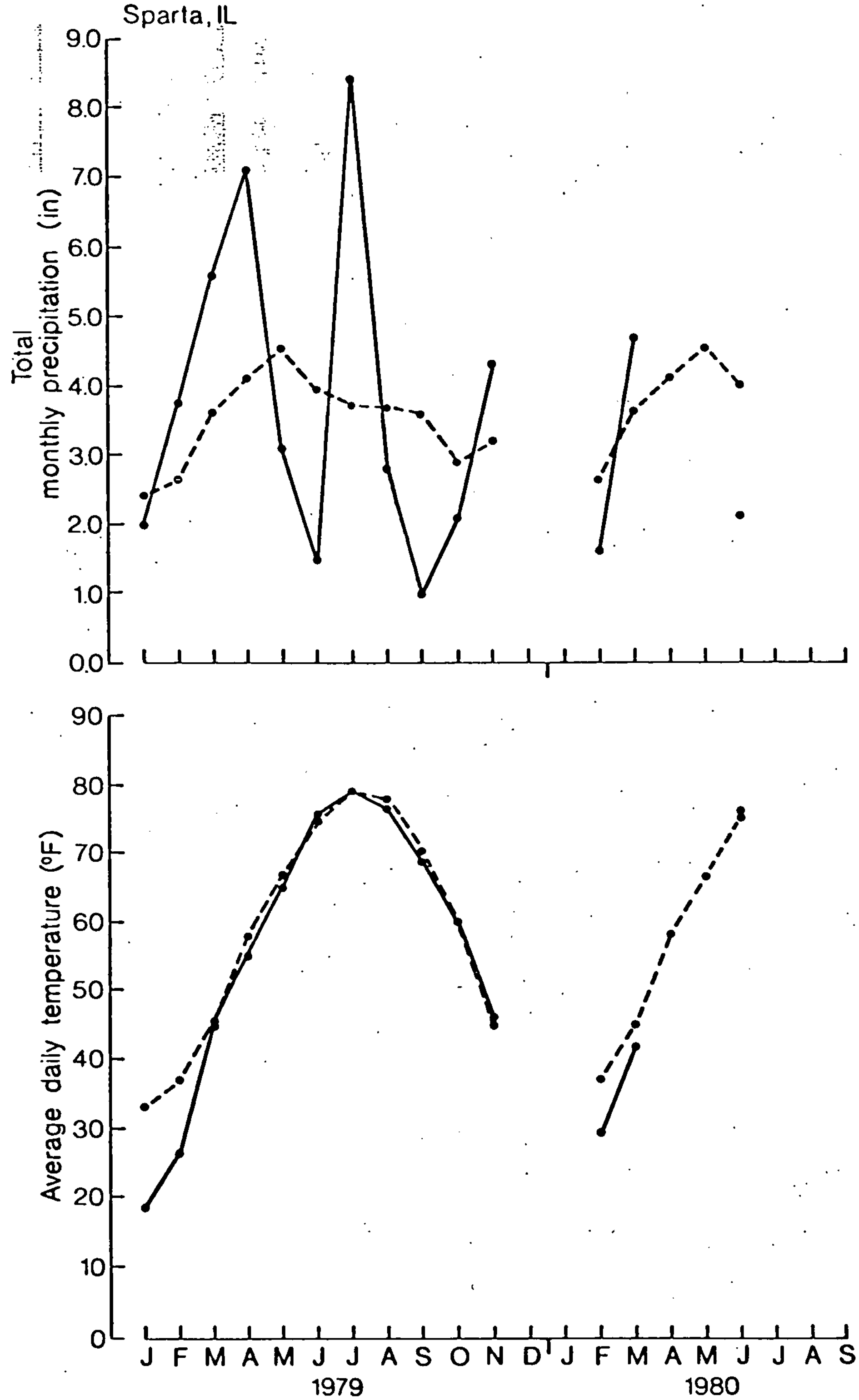

Figure 2d. Climatological data for Sparta, IL showing 1979-1980 values (———) and 30 year mean (- - -). Some data points were omitted.

Table 3. Actual evapotranspiration and moisture deficit estimates for three mine soils based on available climatological data.

Weather Station	Water balance parameters (inches)* 30 year mean Actual evapotranspiration	Deficit	1980** Actual evapotranspiration	Deficit
Moberly, MO (near Prairie Hill Mine)	27.24	2.25	17.90	14.64
Columbia, MO (near laboratory)	25.60	4.27	16.86	15.73
Clinton, MO (near Power Mine)	28.51	1.62	19.51	13.94
Sparta, IL (near River King Mine)	27.48	4.56	22.48	10.94

* Calculated using the water balance method of Thornthwaite and Mather (1957). Soil moisture holding capacity was estimated at 2.76 in assuming a 30 cm rooting depth and 0.234 in/in available water holding capacity for silt loam soils (Longwell et al. 1963).

** November and December climatological data estimated from 30-year means.

Thornthwaite, C.W., and J.R. Mather. 1957. Instructions and tables for computing potential evapotranspiration and the water balance. Drexel Inst. Technol., Lab. Climatol., Publ. Climatol. 10 (3): 181-311.

Longwell, T.J., W.L. Parks, and M.E. Springer. 1963. Moisture characteristics of Tennessee soils. Tenn. Ag. Exp. Sta. Bul. 367:1-46.

it, and then harvested all standing material by clipping it at ground level. Plant samples were separated to species, bagged in the field, and brought back to the laboratory where they were dried and weighed. Grains were harvested by threshing and moisture content was measured. Data for percent vegetative cover, species composition, and species abundance were calculated for each plot and for each study site. Yields for total above-ground biomass and grains were also determined. The area of each study site was measured from a recent aerial photograph using a hand-operated planimeter.

Method 2: Remote, computer measurements

Vertical aerial photographs of a mine or reference site were subjected to digital computer image analysis. Color infrared (CIR) photographs at a scale of approximately 1:12,000 were taken in an airplane flown over all study sites in either early July or in September when ground level measurements were being made. Computer interpretations of CIR imagery involved a rapid, multi-step process which is shown in Figure 3. In brief, the photograph was converted to a two-dimensional, black-and-white video image consisting of nearly 250,000 tiny picture points or cells. The grey value of each picture cell was measured on a digital scale ranging from 0 for absolute white to 256 for pitch black. Boundaries delineating a mine or reference site were drawn in the digital video image using a sonic pen. Thereafter all points outside the area of interest were disregarded. Spatial and contrast information was stored on magnetic disk and tape. Classification of cover into various categories was achieved interactively by slicing the spectrum of grey values into two or more subgroups and then by displaying the resultant, simplified digital image for visual verification with the more complex, analog CIR photographic inputs. A variety of new computer programs developed expressly for our research improved these procedures. Once a classification scheme was established, a spatial rendition of the picture cells was printed or plotted to scale on paper (Figure 4). A summary of the computer boundary values for each grey level slice and the absolute and relative areas of each cover class were also generated.

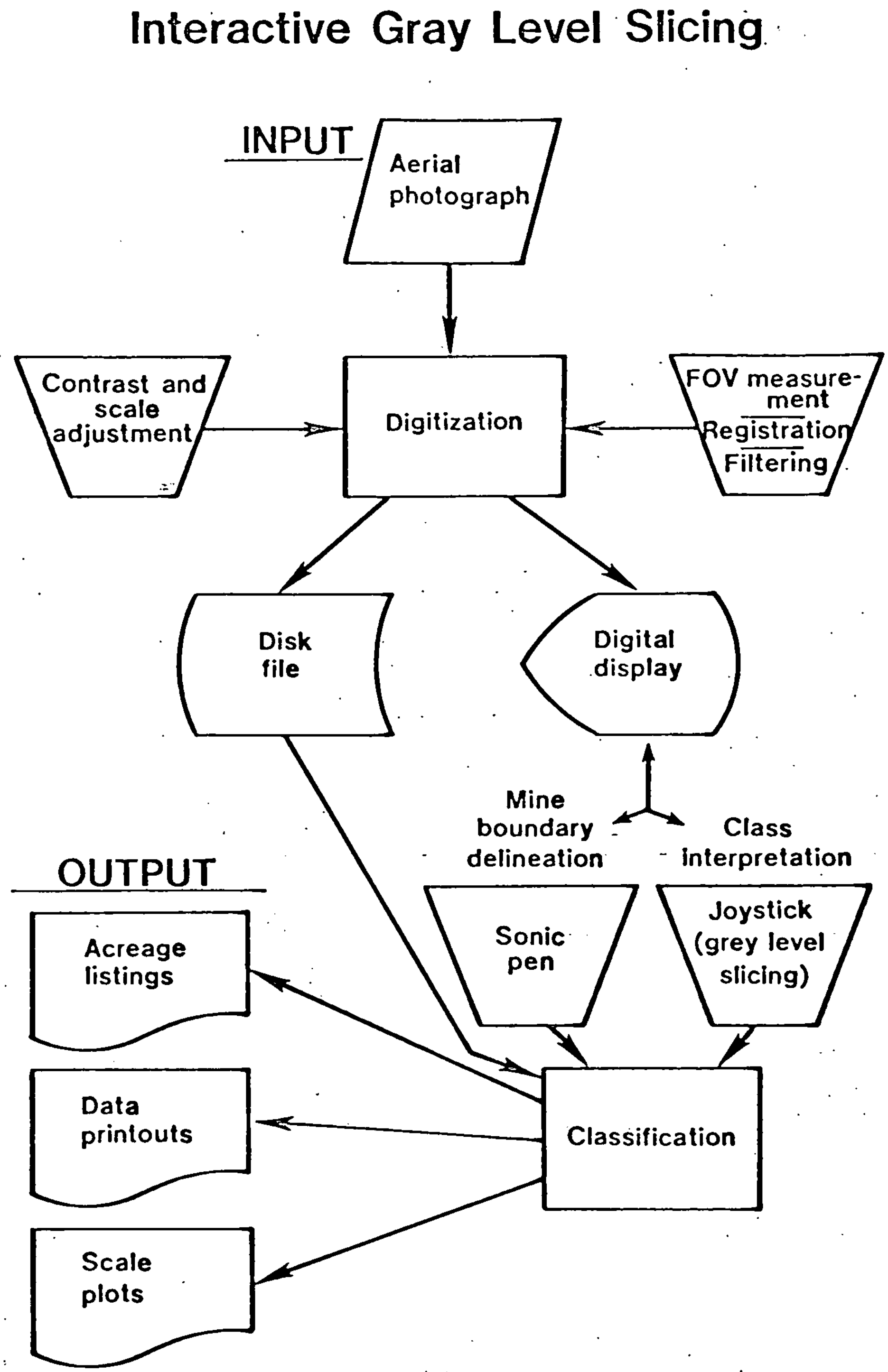

Figure 3. Flow diagram for interactive gray level slicing routine used in computerized image analysis.

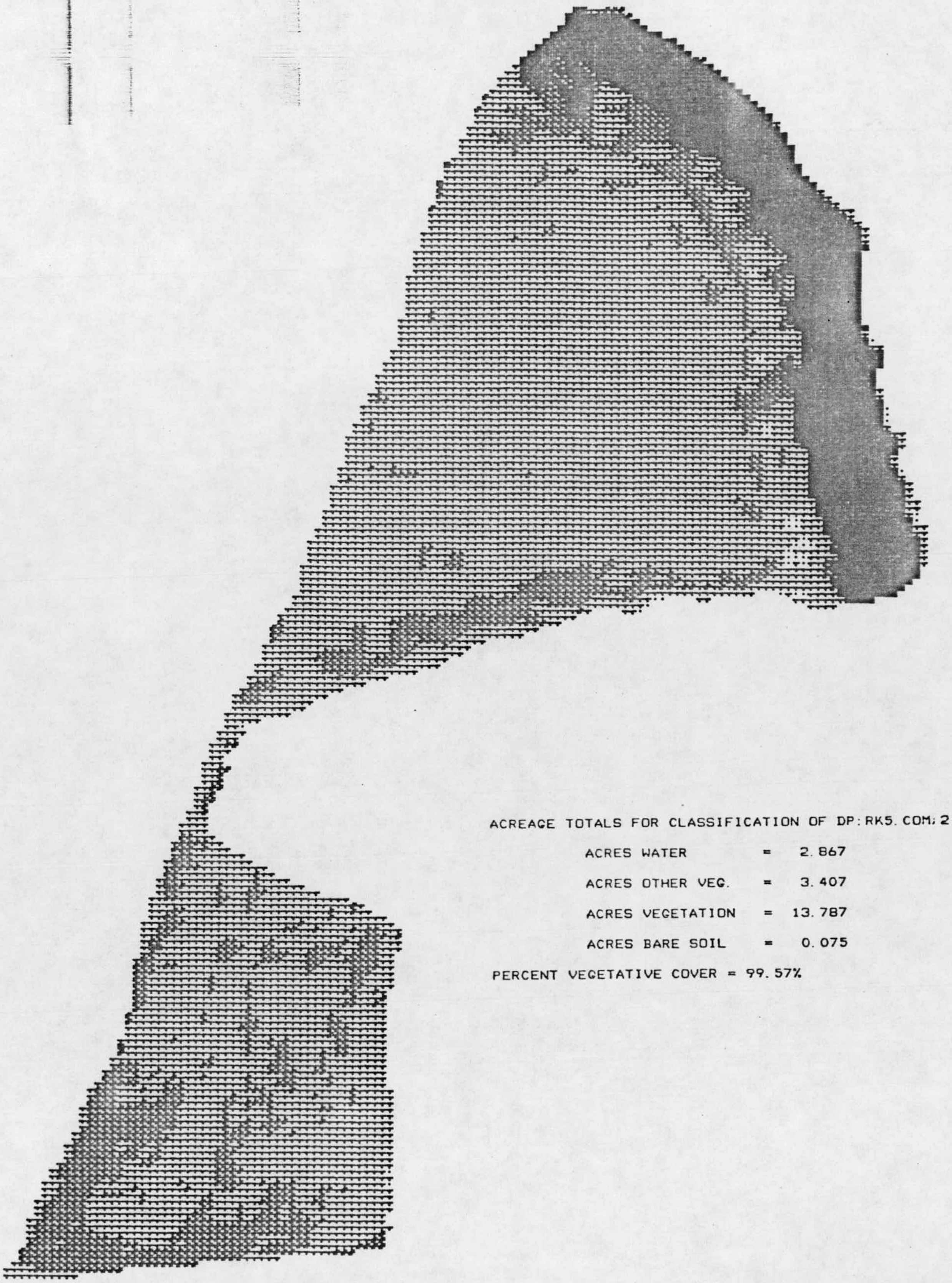

Figure 4.Scale plot automatically produced by digital computer. The area of 4 cover classes and ground covered by vegetation are printed.

4.3. Results and Discussion

Data on the size of sites, plant ground cover, plant productivity, and plant species composition for 1980 are here presented. Other information, such as species similarity indices, will be completed in the first quarter of 1981.

4.3.1. Area Determinations

Total area of 22 sites was measured both by the digital computer and by a manual planimeter. Computer results were based on a single scan of summer or fall CIR aerial photographs. Manual measurements of the same aerial photographs were repeated 5 times and an average was calculated.

Area data, as summarized in Table 4 and Figure 5, show that there was excellent agreement between the two methods (r^2 = 0.995). Computer values tended to be slightly larger (10 a, 4 ha) than planimetric ones, but this systematic discrepancy increased very slowly as sites became larger. Based on controls, we knew that the error resided primarily with the planimeter and not with the computer. When standards of known area were used to calibrate each system, the computer error was insignificant (≈5%) (Game et al., 1981), whereas the planimeter generally underestimated the real size by a small amount. A second source of discrepancies was the independent delineation of site boundaries. Operators drew the perimeter of each location on two separate occaisions, first with the sonic pen on the GRC computer display and later in another building with a planimeter wand drawn over the original CIR aerial photograph.

We could, if we wished, interconvert a computer measurement (Y) and a planimetric one (X) by using the equation $Y = 3.66 + 1.05X$. But considering that the computer outputs for size were automatic and highly accurate (95%), there appeared to be no reason in the future to rely on planimetric methods

Table 4

Comparison of Computer Digital Methods for Determining Area

Site	Planimeter estimate (n=5) Total area $\overline{X}$±SE (hectares)	Planimeter estimate (n=5) Total area $\overline{X}$±SE (acres)	Computer estimate (n=1) Total area $\overline{X}$±SE (acres)
C1	56.510 ± 0.074	139.636 ± 0.183	145.885
C2	50.198 ± 0.174	124.039 ± 0.430	130.514
C3	38.537 ± 0.168	95.225 ± 0.415	105.879
C4	25.266 ± 0.111	62.432 ± 0.274	72.688
C5	14.782 ± 0.089	36.526 ± 0.220	34.586
C6	4.496 ± 0.016	11.110 ± 0.040	15.284
B1	29.748 ± 0.155	73.507 ± 0.383	82.938
B2	22.861 ± 0.082	56.490 ± 0.203	65.631
B3	14.975 ± 0.039	37.003 ± 0.096	42.576
R3	4.937 ± 0.030	12.199 ± 0.074	14.179
RK1	7.315 ± 0.015	18.075 ± 0.037	20.600
RK2	18.919 ± 0.232	46.749 ± 0.573	56.386
RK3	16.532 ± 0.047	40.851 ± 0.116	42.159
RK4	14.570 ± 0.087	36.002 ± 0.215	37.319
RK5	5.084 ± 0.104	12.563 ± 0.257	20.136
RK6	25.931 ± 0.075	64.076 ± 0.185	77.618
RK7	8.920 ± 0.039	22.040 ± 0.096	31.418
RK8	21.019 ± 0.080	51.938 ± 0.198	65.125
RK9	2.936 ± 0.013	7.255 ± 0.032	8.804
RK10	12.751 ± 0.065	31.508 ± 0.161	40.205
RK11	2.889 ± 0.013	7.139 ± 0.032	9.417
RK13	2.858 ± 0.049	7.062 ± 0.121	6.775

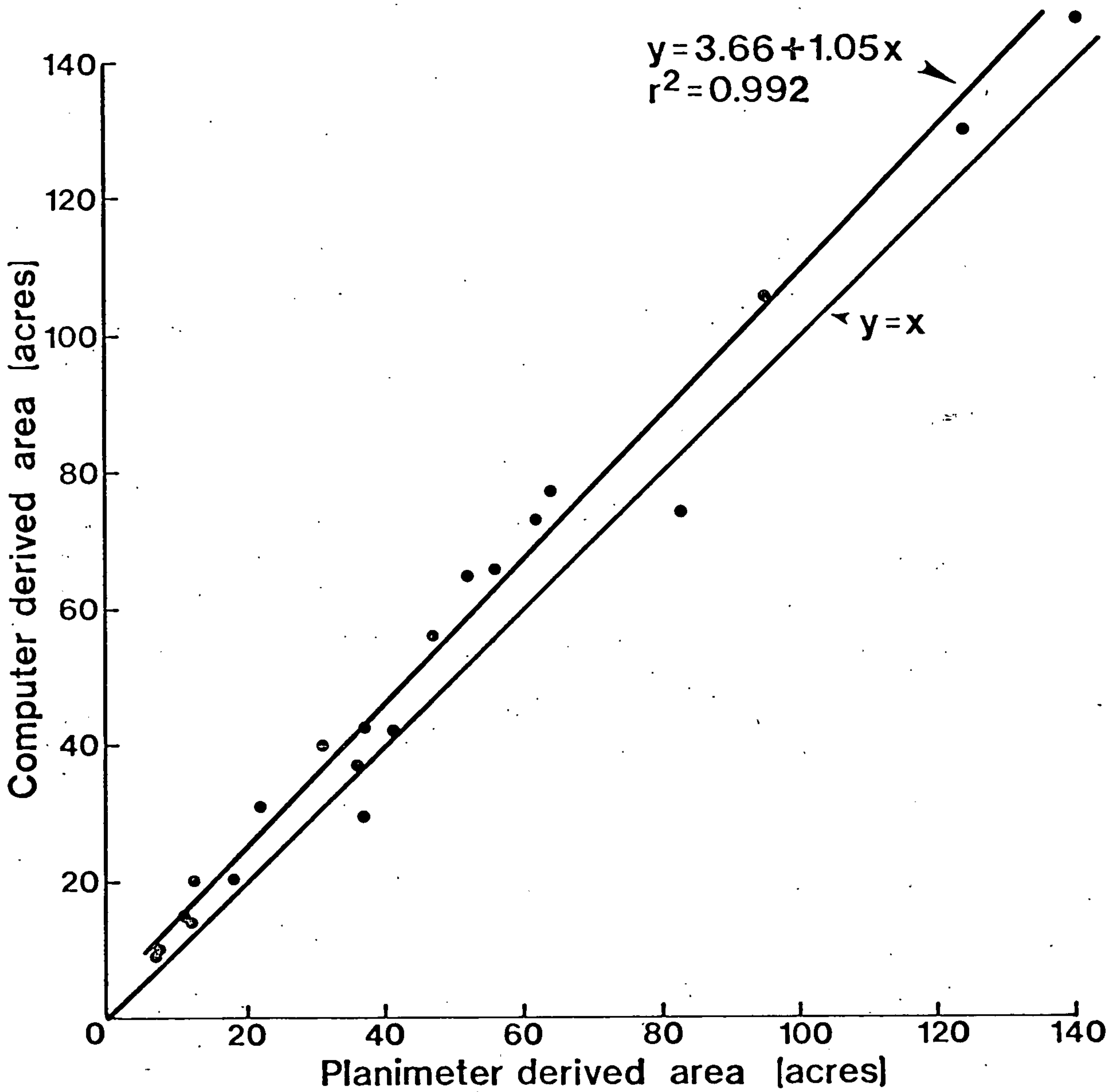

Figure 5. Comparison of manual and automatic techniques for measuring area of study sites. Ideal (Y = X) and best fit regression lines are shown.

for precise area measurements.

In our 1979 progress report, COO-2758-6, there was an error in Table 1 and Figure 5 due to miscalculation of scale factors for the planimetric area of all sites. When corrected, the regression equation and correlation coefficient were $Y = 2.69 + 0.98X$, $r^2 = 0.986$, $p < 0.001$.

4.3.2. Pastureland Studies

Mine and reference sites seeded with forages at Prairie Hill and Power Coal Mines were studied. Data on plant ground cover, productivity, and species composition are presented.

4.3.2.1. Ground cover of pasturelands

Vegetative cover was measured at 15 sites using 2 techniques (Table 5). Visual estimates were made at ground level in 25 sample plots per site, whereas digital image analysis of CIR aerial photographs taken either in summer or fall 1980 censused 10 entire sites. Photographs for the remaining 5 sites, all of which were at the Power Coal Mine, were not analyzed because the 4 mine areas were mowed and the herbage left on the ground for mulch during the interval between field sampling and aerial reconnaissance.

As we found in 1979, there was excellent agreement between remote and direct measurements of ground cover (Figure 6). Seven of 10 values for Prairie Hill sites had a similarity greater than 90%. Statistical analysis confirmed that the 2 parameters were significantly correlated with each other ($r^2 = 0.648$, $p < 0.01$). Thus, at most sites computer estimates of ground cover equalled at least 90% of the mean for visually determined values with a statistical confidence greater than 90%.

Table 5

Comparison of Vegetative Cover Calculations from Aerial Photographs and Direct Estimates for Sites Seeded with Forages

Mine	Site	Vegetative Cover (%)	
		Computer analysis	Visual analysis ($\bar{X} \pm$ SE, n=25)
Prairie Hill	C1	52.24	53.56 ± 8.97
	C2	59.05	54.44 ± 8.19
	C3	89.01	85.68 ± 5.38
	C4	68.31	68.40 ± 6.76
	C5	83.39	54.28 ± 6.65
	C6	86.42	88.88 ± 4.34
	B1	55.64	36.96 ± 8.75
	B2	94.20	90.24 ± 4.21
	B3	94.44	69.44 ± 5.24
	R3*	94.65	99.24 ± 0.41
Power	D1	NA	45.44 ± 5.33
	D2	NA	60.44 ± 4.32
	D3	NA	59.92 ± 3.75
	D4	NA	75.52 ± 4.24
	D5*	NA	98.24 ± 0.52

*Reference Site

NA - Not available because sites were mowed just before aerial photographs were taken

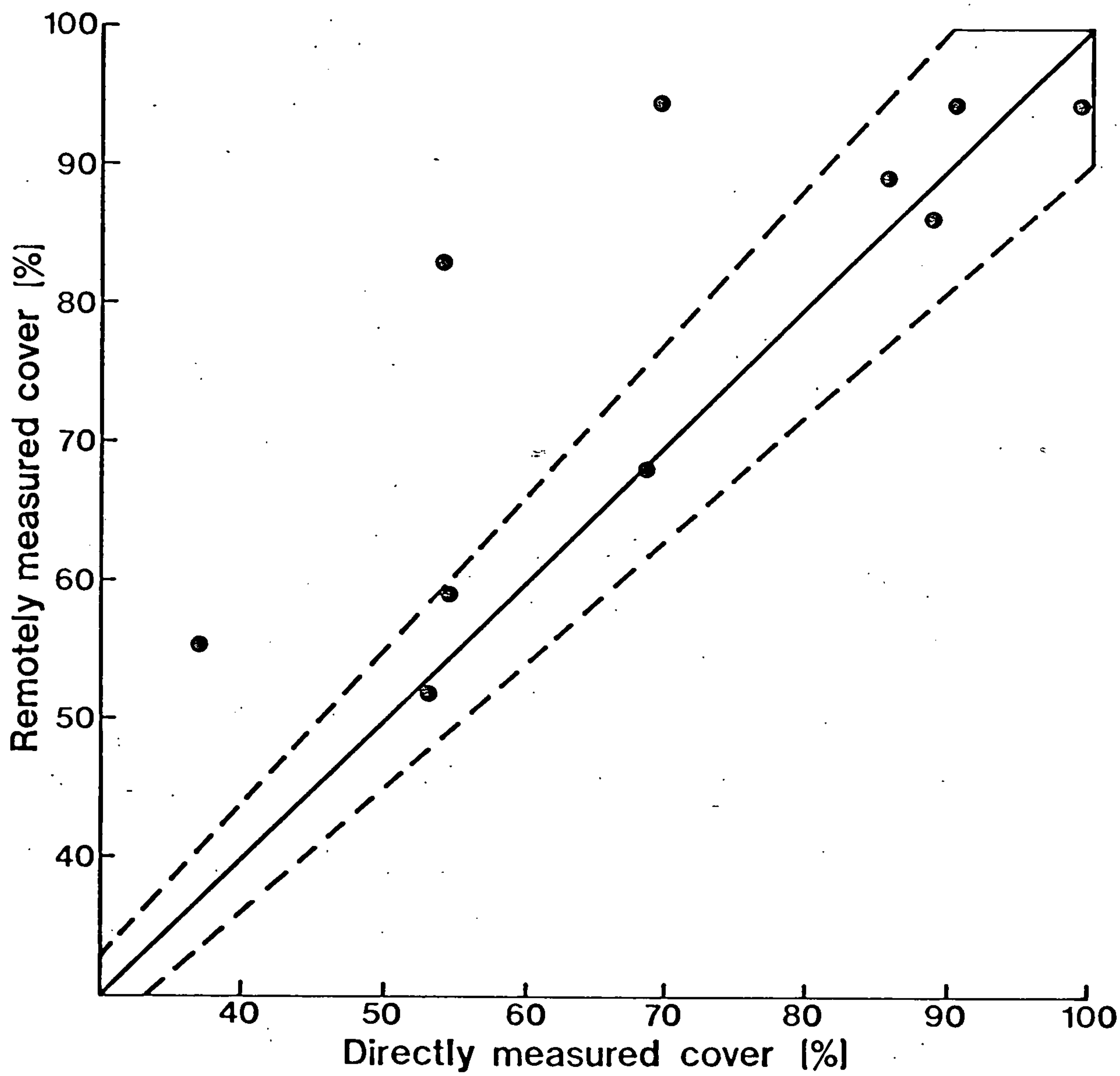

Figure 6. Comparison of visual and computer measurements of vegetative cover in pastureland study sites. The 90% similarity zone is depicted.

Ground cover at most mine sites in Prairie Hill and Power Coal Mines was significantly less (Student's t-test, $p < 0.05$) than in nearby established reference pastures. Since this condition has prevailed for 2 consecutive years at Prairie Hill, the comparison may be legitimate. However, it certainly is not scientifically justified to make much of the differences at Power Mine because reclaimed fields were but 8 months old and dominated by annual nurse crops, not by perennial forages.

Regardless of method used for acquiring data, ground cover at 7 of the 10 Prairie Hill sites did not change by more than 5% between 1979 and 1980. Since all of these sites were at least 3 years old, perhaps a sort of short-term stability had been achieved. If this was true, it suggests that the effectiveness of forages in the mine sites is not increasing and that alternative management methods might be necessary to achieve complete revegetation.

4.3.2.2. Production of pasturelands

Plant production at 13 mine and 2 reference sites seeded with forages ranged in 1980 from 112.2 to 692.1 g/m^2 (Table 6). If nurse crops in new sites at Power Coal Mine were excluded from further consideration, the range of yields dropped to 17.8 - 470.7 g/m^2.

As in 1979, all sites were dominated by forages and other seeded species. Weeds and woody species comprised less than 15% of the entire yield at all sites irrespective of age.

Yields in 7 mine sites at Prairie Hill were not significantly lower than 90% of the reference pasture (R3) harvest both in 1979 and 1980 (Table 7). Production declined at most locations, including the reference site, in 1980 probably because of the severe summer drought (Table 3).

Table 6

Average Yield of Dried Plant Biomass (g/m^2) in Strip Mine and Reference Pasturelands During 1980

Summer (June & July) Harvest

Prairie Hill Mine

	Mine									Reference
Site	C6	C5	C4	C3	B3	B2	C2	B1	C1	R3
Age (yr)	3	3.25	3.75	5	7	7	7	8	9	13
Grasses	155.8	71.6	97.9	134.7	76.8	170.9	104.6	41.7	110.7	301.8
Legumes	128.1	173.8	154.1	148.9	59.1	288.0	60.1	64.1	86.6	0.3
Weeds	2.5	15.5	4.7	2.6	22.2	11.8	12.3	6.4	1.0	7.1
Total	286.5	260.9	256.7	286.2	158.1	470.7	177.0	112.2	198.3	309.2

Power Mine

	Mine				Reference
Site	D1	D2	D3	D4	D5
Age (yr)	.8	.8	.8	.8	> 5
Grasses	13.0	4.4	7.6	6.4	181.3
Legumes	0.5	0.2	1.9	0.8	5.7
Nurse Crops	183.0	307.6	287.8	633.1	0
Weeds	4.3	13.7	24.5	51.8	15.1
Total	200.8	325.9	321.8	692.1	202.1

Table 7

Statistical Comparison** of Total Production in Mine Pastures Relative to the Reference Pasture at Prairie Hill Mine in 1979 and 1980

Summer 1979

Rank Order

	Less than Reference		Equal to Reference							
Site	B1	C2	B3	C4	C5	C1	C3	B2	R3*	C6
Yield (g/m²)	106.85	223.13	274.24	297.46	304.90	309.08	327.04	368.13	376.84	442.97

Summer 1980

Rank Order

	Less than Reference		Equal to Reference							
Site	B1	B3	C2	C1	C4	C5	R3*	C3	C6	B2
Yield (g/m²)	112.18	158.05	176.92	198.26	256.65	267.71	278.23	286.21	286.50	470.68

* R3= reference site for which 90% of total yield was used as the standard for comparison with other sites.

** ANOVA test modified with Dunnett's procedure was used to separate means. Level of signifigance was set at p=0.05.

Rank order of pasture sites at Prairie Hill according to production in 1980 remained similar to what it was in 1979 (Tables 6 and 7). The influences of spoil amendments, recovery time, and weather on forage yields are discussed in detail in a forthcoming paper (Rapp et al. 1981).

Data from Prairie Hill also suggested for a second year that plant ground cover may be a good predictor of pastureland production. There again was a strong regression between percent ground cover and dried biomass harvested a 10 sites studied in 1980 (Figure 7). The regression coefficient was slightly lower this year than in 1979 because yields declined more than cover values during the 1980 drought. But the weakness of the correlation coefficient ($r^2 = 0.506$, $p < 0.05$) meant that the confidence interval for expected yields calculated from our data might be too large to meet certain performance standards.

Standing biomass at the 4 Power Mine sites was equal to or higher than at the matching reference pasture.(Table 6). But this comparison is not valid because all mine sites were dominated by annual grasses sown as nurse crops on these new areas. None of the young fields had virtually any established stands of perennial grasses and legumes. In fact, mulching of the areas by mowing the nurse crops in July did not enable the seedlings to withstand the extreme drought, so all 4 reclaimed sites had to be disked and reseeded in the fall 1980.

4.3.2.3. Species composition of pasturelands

The taxonomic identity, frequency, and abundance of all plant species were calculated for each of 25 replicate clip quadrats within 13 mine and 2 reference sites sampled during June and July 1980. The attempt to discriminate

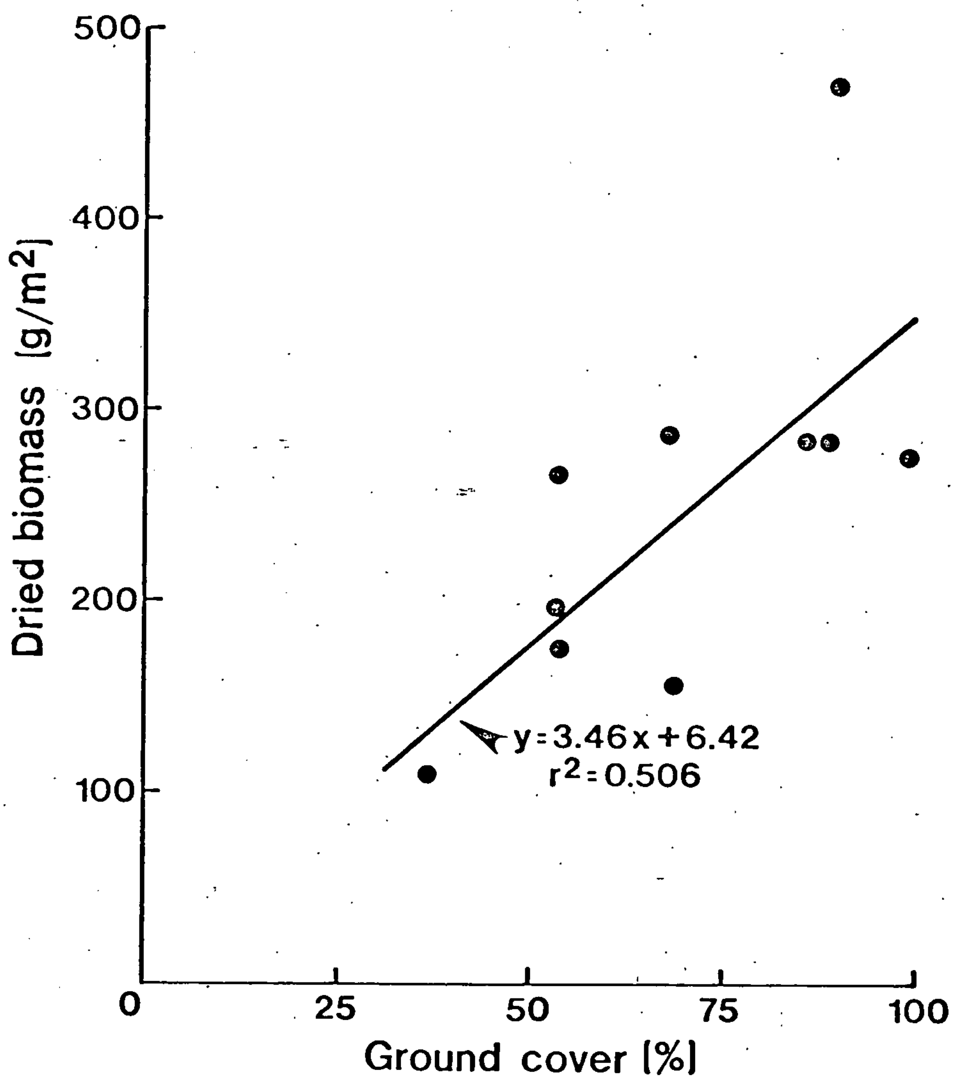

Figure 7. Relationship between ground cover and standing crop in pastureland study sites. Best fit regression line for 1980 data is shown.

different types of herbaceous species, which we started in December 1979, proved to be costly, non-generalizable, and nonpredictive (Lake 1980), so it was quickly discontinued by March 1980. Hence, this report contains only the results of ground level studies.

All sites at both strip mines were dominated by 9 species of grasses and legumes seeded as a pasture mix or as pasture plus nurse crops. Seeded grasses were Festuca elatior, Dactylis glomerata, Poa pratensis, Panicum virgatum, Triticum aestivum, and Lolium multiflorum. Seeded legumes were Medicago sativa, Lespedeza stipulacea, and Trifolium hybridum.

All sites, regardless of age, locality, or treatment, usually had more weedy species than the 7 or so seeded ones (Table 8). Reference sites and top-soiled mine sites tended to have more weedy species and a higher density of herbaceous species than mine sites covered with raw spoil. This pattern was identical to that found in 1979 at Prairie Hill despite fluctuations in acutual numbers of species. Complex species diversity and similarity computations were not completed for this report. The calculations will be finished in January 1981. Species lists for all sites are included as appendix tables.

4.3.3. Cropland Studies

Mine and reference sites seeded with winter wheat, soybeans, and milo were studied at River King Coal Mine. Data on ground cover, productivity, and species composition are presented.

4.3.3.1. Ground cover of croplands

Vegetative cover was measured at 14 sites using both visual and computer techniques (Table 9). One exception was the winter wheat reference field.

Table 8

Plant Species Diversity in Pasturelands in Summer 1980

Mine	Site	S	ΔS	$\overline{S}/m^2$
Prairie Hill	C1	12	0	2.0
	C2	19	+8	2.6
	C3*	22	0	3.9
	C4	21	+7	3.4
	C5	18	-5	4.3
	C6	18	+3	4.5
	B1	12	-8	1.6
	B2*	19	-11	3.4
	B3*	31	-7	5.1
	R3**	43	+6	9.2
Power	D1*	22	NA	6.3
	D2*	20	NA	5.9
	D3*	30	NA	11.9
	D4*	31	NA	10.4
	D5**	40	NA	9.4

S = Number of plant species or species richness.

ΔS = Change in number of plant species between 1979 and 1980.

$\overline{S}/m^2$ = Mean number of plant species per square meter or species density.

* = Topsoiled

** = Unmined reference site

Table 9

Comparison of Cover Calculations from Aerial Photographs and Direct Estimates

Crop	Site	Vegetative Cover (%)	
		Computer analysis (n=1)	Visual analysis ($\overline{X}$ ± SE, n=25)
Wheat	RK1	98.75	49.88 ± 0.31
	RK2	99.78	53.20 ± 2.56
	RK3	92.43	50.00 ± 0.00
	RK4	97.13	50.00 ± 0.00
	RK5	99.57	50.00 ± 0.00
	RK6	99.78	47.40 ± 1.48
	RK7	99.54	51.64 ± 1.60
	RK-*	NA	50.00 ± 0.00
Soybeans	RK9	86.00	22.52 ± 1.20
	RK10*	99.88	14.20 ± 2.49
Milo	RK4	86.39	48.33 ± 4.06
	RK8	96.38	43.40 ± 4.85
	RK11	91.76	84.28 ± 3.40
	RK13	96.56	93.56 ± 2.12

* Reference sites

This site was not subjected to computer analysis because just before the CIR aerial photographs were taken, it was graded as part of pre-mining preparation.

Unlike in pasturelands, there was no significant correlation ($r^2 = 0.001$, $p > 0.5$) between remote and direct measurements of ground cover in various croplands (Figure 8). Ground level estimates ranged from 14 to 93%, whereas computer estimates for the same areas varied only from 85 to 100% canopy cover. This differnece was not surprizing once the nature of row crops was considered. Bare soil between rows of soybeans, wheat, and milo usually was conspicuous to any trained observer standing in a field or on a platform just above the canopy layer. But these gaps were not resolvable in 1:12,000 scale CIR aerial photographs either when viewed by eye or when enhanced by the computer system. We found the row size varied from field to field, ranging from 6 inches (15 cm) at mine sites to 30 inches (75 cm) at soybean and milo reference sites. A second factor that affected surface observations more than remote ones was the variant structure of crop plants themselves. For example, soybeans had defoliated by time of harvest, so the fields looked relatively barren to the inspectors but the fallen leaves rendered a false image in the CIR so aerial photographs showed a well covered condition.

Although cover estimates made at small plots in croplands might be of questionable value, we reasoned that computer measurements of cover could enable one to detect problem spots of significant size. Weedy crops, bare soil, and ponds having an area greater than 1 - 5 square yards (1 - 4 m^2) were evident in the CIR aerial photographs and appropriately classified during computerized inventories (Table 10). Scale plots, as shown for reclaimed site RK5 in Figure 4, permanently documented the spatial condition of each field.

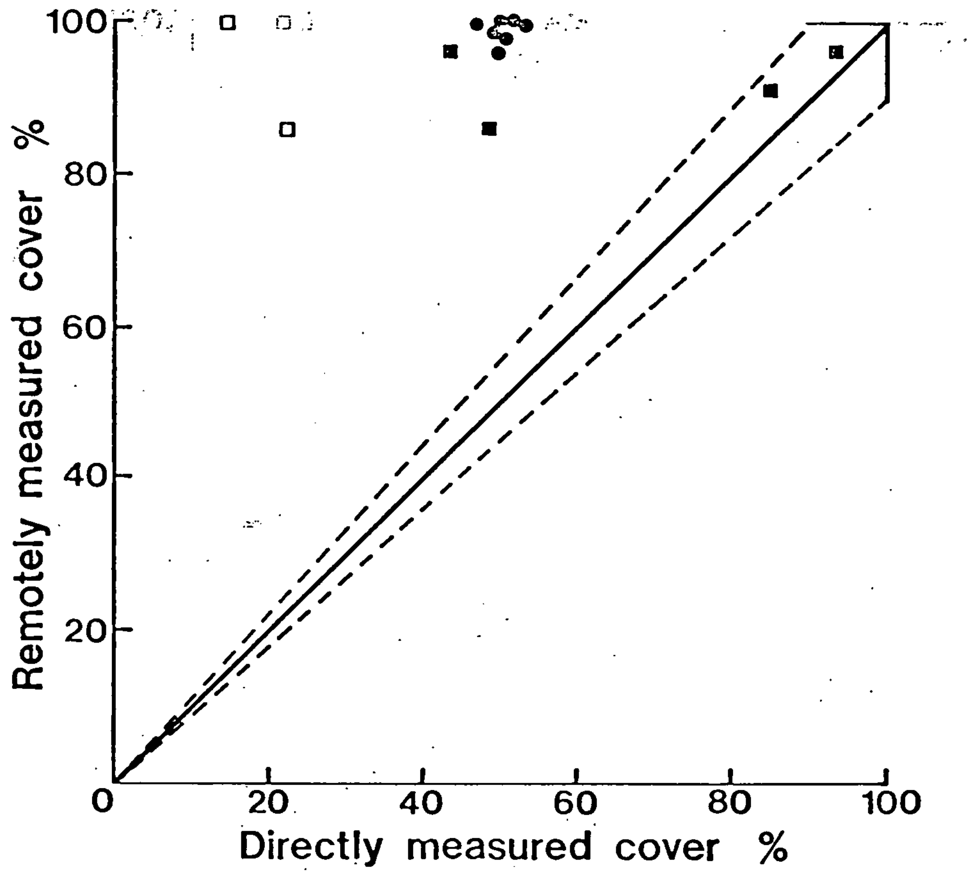

Figure 8. Comparison of visual and computer measurements of vegetative cover in cropland study sites. The crops were winter wheat (●), soybeans (□), and milo (■). The 90% similarity zone is depicted.

Table 10

Computer Classification of Cropland Study Sites at River King Mine in 1980

Crop	Site	Area				
		Clean Crops	Weedy Crops	Bare Soil	Water	Total
Wheat	RK1	19.870	0.473	0.257	0	20.600
	RK2	53.328	2.933	0.125	0	56.386
	RK3	37.122	1.846	3.191	0	42.159
	RK4	36.247	0	1.072	0	37.319
	RK5	13.787	3.407	0.075	2.867	20.136
	RK6	73.343	4.106	0.169	0	77.618
	RK7	31.275	0	0.143	0	31.418
	RKX*	NA	NA	NA	NA	NA
Soybeans	RK9	7.571	0	1.233	0	8.804
	RK10*	34.158	5.998	0.049	0	40.205
Milo	RK4	31.905	0	5.028	0	36.933
	RK8	62.768	0	2.357	0	65.125
	RK11	8.575	0	0.770	0.072	9.417
	RK13*	6.542	0	0.233	0	6.775

* Reference areas

NA = Not Available

4.3.3.2 Production of croplands

Yields of winter wheat, soybeans, and milo were calculated both for total standing biomass and for grain (Table 11). All grain yields were standardized at 13% moisture using the equation

$$Y = \frac{(\text{mass})\ (100 - X)}{(\text{area})\ 87}$$

wherein X = percentage moisture measured by us. To derive typical agronomic yields as bushels per acre (bu / a) (Y') from metric values, we used the following grain densities (Z):

wheat	60 bu/a
soybeans	56 bu/a
milo	60 bu/a

in the equation

$$Y' = Y \frac{(g)}{(m^2)} \frac{(1\ lb)}{(454\ g)} \frac{(10{,}000\ m^2)}{(2.5\ a)} \frac{(1\ bu)}{(Z\ lb)} = \frac{8.81\ Y}{Z}$$

As an additional index, estimates of typical 1980 crop yields at farms in southwest Illinois crop reporting district were obtained from Dr. L. V. Boone.

Average production of winter wheat at 7 mine sites ranged from 27.04 to 51.28 bu/a. Yields at 6 of these fields were significantly less than 90% of the reference value, 51.78 bu/a (Table 12). The value for 1 mine site and the reference field were comparable to each other and to the southwest Illinois wheat estimate for 1980, which was placed at 47 bu/a.

The single reclaimed soybean site at River King produced 24.09 bu/a. This figure was significantly less than 90% of the soybean reference yield, which averaged 30.12 bu/a (Table 12). However, the mine site value equalled

Table 11

Production of Croplands at River King Mine in 1980

Crop	Site	Standing Biomass (g/m²) Crop ($\overline{X}$±SE)	Standing Biomass (g/m²) Crop & Weeds ($\overline{X}$±SE)	Grain (bu/a) ($\overline{X}$±SE)
Wheat	RK1	972.34 ± 49.04	972.34 ± 49.04	51.28 ± 2.46
	RK2	731.67 ± 60.12	754.18 ± 50.01	37.12 ± 3.86
	RK3	679.62 ± 21.66	679.62 ± 21.66	39.56 ± 1.17
	RK4	624.68 ± 22.35	628.36 ± 21.90	30.77 ± 1.55
	RK5	619.92 ± 45.74	619.92 ± 45.74	36.09 ± 2.26
	RK6	460.36 ± 28.74	469.63 ± 27.10	27.04 ± 1.77
	RK7	690.10 ± 51.75	698.40 ± 49.08	36.97 ± 3.39
	RKX*	927.28 ± 32.05	927.28 ± 32.05	57.54 ± 1.98
Soybeans	RK9	351.55 ± 17.62	352.03 ± 17.49	24.09 ± 1.57
	RK10*	462.63 ± 21.37	479.44 ± 17.10	33.47 ± 2.19
Milo	RK4	706.76 ± 76.05	707.34 ± 75.96	39.92 ± 6.35
	RK8	779.14 ± 72.96	780.10 ± 72.92	48.10 ± 5.30
	RK11	1132.24 ± 69.48	1133.47 ± 69.75	65.84 ± 5.08
	RK13*	1123.11 ± 71.17	1123.11 ± 71.17	42.76 ± 3.92

* Reference areas

Table 12

Statistical Comparison** of Total Production in Mine Croplands Relative to Reference Croplands at River King Mine in 1980

Winter Wheat

	Rank Order							
	Less than Reference						Equal to Reference	
Site	RK6	RK4	RK5	RK7	RK2	RK3	RK1	RKX*
Yield (bu/a)	27.04	30.77	36.09	36.97	37.12	39.56	51.28	51.78

Soybeans

	Rank Order	
	Less than Reference	Equal to Reference
Site	RK9	RK10*
Yield (bu/a)	24.09	30.12

Milo

	Rank Order				
	Less than Reference	Equal to or Greater than Reference			
Site		RK13*	RK4	RK8	RK11
Yield (bu/a)		38.91	39.92	48.10	65.84

* Reference sites for which 90% of total yield was used as the standard for comparison with other sites.

** ANOVA test modified with Dunnett's procedure or Student's t-test was used. Level of signifigance was set at p=0.05.

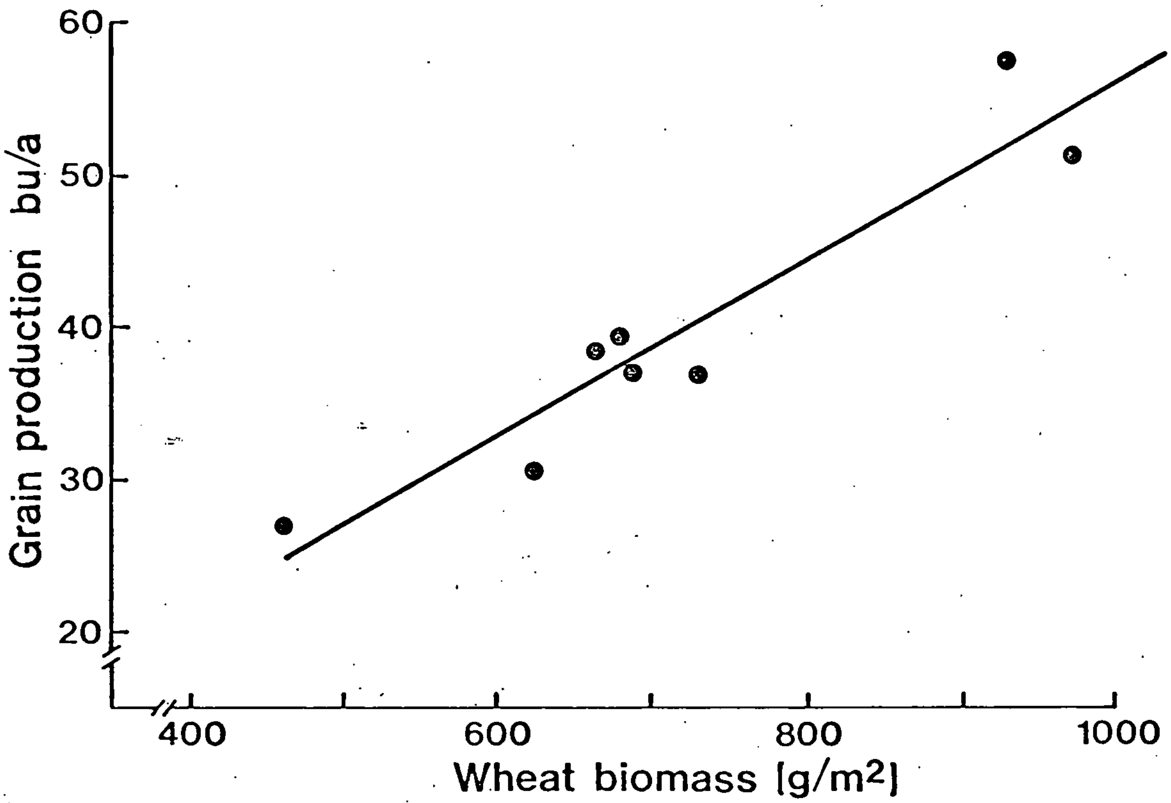

Figure 9. Relationship between standing crop of winter wheat and grain harvested at study sites in 1980. Best fit regression line is shown.

the estimate for soybeans in southwest Illinois, which was set at 25 bu/a.

Milo production at 3 reclaimed mine sites ranged from 39.92 to 65.84 bu/a. Yields at all 3 areas were statistically equal to or greater than 90% of the reference field, which averaged 38.91 bu/a (Table 12). Values for mine sites were were similar to the estimate for milo in southwest Illinois, which was bu/a.

Hence, the performance of row crops in reclaimed fields in southwest Illinois was mixed. Four or 5 of 11 mine sites met either of 2 production standards for this region in 1980. Most winter wheat yields were below expected values, whereas all soybean and milo yields were equal to or greater than the reference figures. In many cases poor wheat harvests may have been due to planting at the improper time since seeding was often done more to stabilized the top-soil than to insure healthy growth.

Grain yields for winter wheat were highly correlated with aboveground biomass (Figure 9). Data points for soybeans and milo, although insufficient for individual crop analysis, did follow the same positive trend as was shown by wheat. These results suggest that biomass might be a robust predictor of grain production given species, varietal, and other constraints.

4.3.3.3. Species composition of croplands

The taxonomic identity, frequency, and abundance of all plant species were calculated for each pf 25 replicate clip quadrats within 7 mine and 3 reference sites. At 4 mine sites plants other than wheat were labelled as weeds and not systematically described.

All croplands studied by us in 1980 were dominated by the singly seeded species (Table 13). Species richness ranged from 1 to 7, but in most quadrats only the crop species was found.

Table 13

Plant Species Diversity in Croplands in 1980

Mine	Crop	Site	S	$\overline{S}/m^2$
River King	Wheat	RK1	1	1
		RK2	≥ 2	NA
		RK3	1	1
		RK4	≥ 2	NA
		RK5	1	1
		RK6	≥ 2	NA
		RK7	≥ 2	NA
		RKX*	1	1
	Soybeans	RK9	2	1.2
		RK10*	7	1.4
	Milo	RK4	3	1.2
		RK8	5	1.6
		RK11	7	1.4
		RK13*	1	1

S = Number of plant species or species richness.

$\overline{S}/m^2$ = Mean number of plant species per square meter or species density.

NA = Not available.

* = Unmined reference site.

These results contrast greatly with those from Power Mine where more than 10 weedy annuals were found commonly in all 4 newly seeded pastures (Table 8). The absence of weeds at River King was attributed predominantly to the action of herbicides applied to the crops and not to any intrinsic site factor.

Although weedy spots were detected during analysis of CIR aerial photographs (Table 10), we did not always obtain similar results from our clip quadrat samples. For example, RK1, RK3, and RK5 each had at least ½ a (.2 ha) of weedy crops but their species richness values all were 1. This discrepancy was possible because a limited number of small samples were taken in a stratified random fashion for species enumeration rather than a botanic survey of an entire mine. The error, should it occur, was probably insignificant when biomass was considered as an importance index since crop species overwhelmingly dominated every site (Table 11).

4.3.4. Cost and Time Measurements

Both the times and costs required to perform assorted tasks in the field and laboratory were itemized and recorded (Table 14). The expense of a complete study of one 30 a (12 ha) site, as based of our experience during 2 growing seasons, ranged from a low of $889 to a high of $1,365.

We found that our remote sensing approaches for vegetation measurements were faster and cheaper than ground level methods (Table 14). However, remotely sensed data did not afford much information about species composition and abundance. Thus, we conclude that a combination of both approaches should be used to gain accurate and timely information about revegetation success in strip mines.

Table 14

COMPARATIVE COST ANALYSIS FOR DOCUMENTATION OF REVEGETATION SUCCESS IN A 30 ACRE STRIP MINE IN MISSOURI

		$/site	$/acre
1. Ground level measurements			
a. Labor			
Field sampling	40 hr. X $10/hr.	$400	$13.33
Lab sampling	5 hr. X $10/hr.	50	1.67
Data analysis	8 hr. X $10/hr.	80	2.67
Report Writing	4 hr. X $10/hr.	40	1.33
Subtotal	57 hr. X $10/hr.	$570	$19.00
b. Supplies			
Bags, paper, pens, stakes, markers		$ 25	$ .33
c. Travel			
120-1,000 miles X $.20/mile		$ 25-200	$ .80-6.87
d. Computer time			
Data reduction, plotting		$ 5	$ .17
TOTAL:	LOW	$624	$20.80
	HIGH	$800	$26.87
2. Remote aerial measurements			
a. Labor			
Photo mission setup	1 hr. X $10/hr.	$ 10	$ .33
Photo interpretation & computer analysis	4 hr. X $10/hr.	40	1.33
Plot preparation	1 hr. X $10/hr.	10	.33
Report writing	4 hr. X $10/hr.	40	1.33
Subtotal	10 hr. X $10/hr.	$100	$ 3.32
b. Supplies			
Computer tapes, paper filters		$ 15	$ .50
c. Aerial Photographs-Procurement of 9X9 in Color infrared transparencies 1:12,000 scale		$100-400	$ 3.33-13.33
d. Computer time			
Digital image analysis and data display	1 hr. X $50/hr.	$ 50	$ 1.67
TOTAL:	LOW	$265	$ 8.82
	HIGH	$565	$18.82

4.4. Technology Transfer

We presented the results of our research to the scientific community by publishing several papers in the open literature. A number of other articles will be forthcoming in 1981 and 1982. Most of these are listed in our bibliography, Section 7.

We also gave 8 seminars or poster papers at the following scientific meetings:

XIII Argonne Universities Association - Argonne National Laboratory Annual Biology Symposium on "Biological Aspects of Ecosystem Restoration", Argonne, IL. April 21-22, 1980.

Annual Meeting, American Institute of Biological Sciences and the Ecological Society of America, Tucson, AZ. August 3-7, 1980.

Annual Symposium of the American Council for Reclamation Research, St. Louis, MO. September 18, 1980.

Conference on "Remote Sensing for Resource Management" sponsored by the Soil Conservation Society and other societies, Kansas City, MO. October 28-30, 1980. (C.J. Johannsen was a co-organizer of this meeting)

For more in-depth discussions, we met informally on many occaisions with mine operators, state and federal regulatory officials, and various agronomists and engineers.

Currently we are involved in a series of "hands-on" workshops dealing with "Remote Sensing for Strip Mine Reclamation". The program. which originates out of the University of Missouri-Rolla campus, uses tapes of our digital computer data. The workshops are being conducted in 1980-1981 by 3 UMR faculty and 2 reclamation experts from Peabody Coal Company.

5. COMPLIANCE WITH THE CONTRACT

To our knowledge, we have fully complied with the letter and the spirit of the contract.

6. EFFORT OF SCIENTIFIC PERSONNEL

The principal investigator (PI) devoted at least 50% of his time during the academic year and 50% during 4 summer and fall months to this project. During the remainder of the contract period, from December, 1980 to March, 1981, the PI expects to spend 50% of his effort on the project.

All other scientific personnel have complied with the effort description in the original proposal.

7. BIBLIOGRAPHY

7.1 Carrel, J.E., K. Wieder, V. Leftwich, S. Weems, C.L. Kucera, L. Bouchard, and M. Game. 1979. Strip Mine Reclamation: Production and Decomposition of Plant Litter. In: Ecology and Coal Resource Development (M.K. Wali, ed.) Pergammon. Vol. 2:670-676.

7.2 Johannsen, C.J., T.W. Barney, A. Dale Coble, J.E. Carrel, S. Weems, W. McFarland, and D.J. Barr. 1979. Characterization of Vegetation and Drainage in Strip Mined Land Utilizing Remote Sensing Techniques. U.S. EPA Tech. Bull. EPA-600/7-79-194.

7.3 Wieder, R.K., and J.E. Carrel. 1979. Radioactive Carbon-14 as an Indicator of Energy Flow in Litter Decomposition Studies. Oecologia 44:31-33.

7.4 Carrel, J.E., C.J. Johannsen, T.W. Barney, A.D. Coble, S. Weems, and W. McFarland. 1979. Remote sensing techniques measure revegetation success in strip mines. Abst. 159, 145th Natl. Meeting, A.A.A.S. (A. Herschman, ed.), 119.

7.5 Johannsen, C.J., R.G. Hanson, W. McFarland, J.E. Carrel, R.W. Blanchar, A.D. Coble, M. Tucker, C.C. Ainsworth, T.W. Barney, R.B. Lake, J. Rapp, and S. Weems. 1980. Characterization of chemical, physical, and vegetative properties of strip mine spoils and overburden as related to remote sensing. U.S. EPA Tech. Bull. (In press).

7.6 Carrel, J.E., J.K. Rapp, S.R. Weems, C.L. Kucera, R. Lake, W. McFarland, G. Reese, and T.W. Barney. 1980. Documenting revegetation success in Midwestern strip mines: Comparison of direct and remote sensing methods. Bull. Ecol. Soc. Amer. 61:81.

7.7 Rapp, J.K., J.E. Carrel, C.L. Kucera, S.R. Weems, and G.A. Reese. 1980. Plant biomass production in Missouri surface coal mines. Bull. Ecol. Soc. Amer. 61:124.

7.8 Game, M., J.E. Carrel, and T. Hotrabhavananda. 1981. Patch dynamics of plant succession in abandoned surface coal mines: a case history approach. J. Ecol. (In review, submitted August, 1980).

7.9 Lake, R.B. 1980. Computer processing techniques for the evaluation of strip mine revegetation. Unpublished M.S., Electrical Engineering thesis, University of Missouri-Columbia, 65211.

7.10 Kafagi, M. 1980. Studies of below ground ecosystems in Missouri strip mines. Unpublished Ph.D. thesis, University of Missouri-Columbia, 65211.

7.11 Carrel, J.E. et al. Plant biomass production in mineland ecosystems. Reclam. Rev. (A review in preparation for 1981).

7.12 Carrel, J.E. et al. 1981. Remote sensing of vegetation in strip mines. User's Guide to Remote Sensing Activities in Missouri. T.W. Barney (ed.) (In press).

7.13. Rapp, J.K., J.E. Carrel, C.L. Kucera, S.R. Weems, and G.A. Reese. Plant biomass production in some Missouri strip mines reclaimed with forages. Reclam. Rev. (In preparation for submission in December 1980).

7.14 J.E. Carrel. Recovery of abandoned strip mines: time heals most wounds. Missouri Conservationist. (In preparation).

7.15. J.E. Carrel. Space age techniques measure success of revegetation in strip mines. Missouri Conservationist. (In preparation).

7. APPENDIX

Table A. Vegetative species composition, frequency, biomass, and rank of species in Power Mine, site D1.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Triticum aestivum Wheat	1.00	4573.68	91.14	1
Lolium multiflorum Italian Rye Grass	0.04	196.53	3.92	2
Festuca elatior Meadow Fescue	0.92	128.08	2.55	3
Bromus japonicus Japanese Chess	0.68	70.92	1.41	4
Ukn. grass A -----	0.12	17.26	0.34	5
Medicago sativa Alfalfa	0.92	11.27	0.22	6
Ambrosia artemisiifolia Common Ragweed	0.92	5.39	0.11	7
A. trifida Horse Weed	0.56	4.63	0.09	8
A. bidentata Ragweed	0.28	2.89	0.06	9
Lepidium virginicum Pepper Grass	0.08	1.64	0.03	10
Arenaria serpyllifolia Sandwort	0.04	1.10	0.02	11
Dactylis glomerata Orchard Grass	0.08	0.94	0.02	12
Ukn. dicot B -----	0.16	0.90	0.02	13
Geranium carolinianum Cranesbill	0.08	0.74	0.01	14
Trifolium repens White Clover	0.12	0.48	0.01	15
Ukn. dicot A -----	0.04	0.42	0.01	16
Chenopodium album Lamb's Quarters	0.08	0.40	0.01	17
Ukn. dicot D -----	0.04	0.26	0.01	18.5
Viola Kitaibeliana Field Pansy	0.04	0.26	0.01	18.5
Hordeum pusillum Little Barley	0.04	0.22	0.01	20
Veronica arvensis Corn Speedwell	0.04	0.16	0.00	21
Ukn. dicot C -----	0.04	0.14	0.00	22

Table B. Vegetative species composition, frequency, biomass, and rank of species in Power Mine, site D2.

Species Common Name	Frequency	Biomass ($g/25\ m^2$)	% of Total Biomass	Rank (Based on biomass)
Triticum aestivum Wheat	1.00	7719.59	94.43	1
Bromus japonicus Japanese Chess	0.76	318.51	3.89	2
Festuca elatior Meadow Fescue	0.96	63.69	0.78	3
Lolium multiflorum Italian Rye Grass	0.12	55.48	0.68	4
Aegilops cylindrica Goat Grass	0.08	3.60	0.04	5
Ambrosia trifida Horse Weed	0.12	3.56	0.04	6
Medicago sativa Alfalfa	0.92	3.18	0.04	7
A. artemisiifolia Common Ragweed	0.68	2.84	0.03	8
Lactuca Scariola Prickly Lettuce	0.04	1.24	0.02	9
A. bidentata Ragweed	0.28	0.97	0.01	10
Trifolium repens White Clover	0.40	0.75	0.01	11
Polygonum pensylvanicum Pinkweed	0.04	0.66	0.01	12
Ukn. dicot A -----	0.08	0.21	0.00	13
Ukn. dicot B -----	0.08	0.15	0.00	14
Viola Kitaibeliana Field Pansy	0.04	0.10	0.00	15
Chenopodium album Lamb's Quarters	0.12	0.04	0.00	16.5
Ukn. dicot D -----	0.04	0.04	0.00	16.5
Oxalis stricta Yellow Wood Sorrel	0.08	0.02	0.00	19
Ukn. dicot C -----	0.04	0.02	0.00	19
Cerastium vulgatum Common Mouse-ear Chickweed	0.04	0.02	0.00	19

Table C.7. Vegetative species composition, frequency, biomass, and rank of species in Power Mine, site D3.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Triticum aestivum Wheat	1.00	7194.40	89.44	1
Alopecurus carolinianus Foxtail	0.96	288.26	3.58	2
Festuca elatior Meadow Fescue	1.00	185.50	2.31	3
Bromus japonicus Japanese Chess	0.80	125.34	1.56	4
Lepidium virginicum Pepper Grass	0.72	74.42	0.93	5
Medicago sativa Alfalfa	0.72	45.81	0.57	6
Veronica peregrina Neckweed	0.68	41.83	0.52	7
Cardamine parviflora Small-flowered Bitter Cress	0.72	29.46	0.37	8
Ambrosia artemisiifolia Common Ragweed	0.96	17.64	0.22	9
Polygonum pensylvanicum Pinkweed	0.76	9.58	0.12	10
Myosotis virginica Scorpion Grass	0.20	8.55	0.11	11
Myosurus minimus Mousetail	0.36	7.30	0.09	12
Chenopodium album Lamb's Quarters	0.48	4.20	0.05	13
Dactylis glomerata Orchard Grass	0.28	3.88	0.05	14
Poa chapmaniana Chapman Blue Grass	0.48	2.85	0.04	15
A. trifida Horse Weed	0.12	1.02	0.01	16
P. pratensis Kentucky Blue Grass	0.08	0.86	0.01	17
Ukn. grass B -----	0.20	0.80	0.01	18
Trifolium repens White Clover	0.24	0.69	0.01	19
Lespedeza stipulacea Korean Clover	0.16	0.28	0.00	20.5
Agrostis hiemalis Hair Grass	0.04	0.28	0.00	20.5

Table C, continued.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Ukn. dicot A -----	0.20	0.22	0.00	22
Draba brachycarpa Whitlow Grass	0.08	0.18	0.00	23
Lactuca Scariola Prickly Lettuce	0.12	0.14	0.00	24.5
Hordeum pusillum Little Barley	0.04	0.14	0.00	24.5
Oxalis stricta Yellow Wood Sorrel	0.28	0.12	0.00	26
A. bidentata Ragweed	0.08	0.11	0.00	27
Galium Aparine Cleavers	0.04	0.10	0.00	28
Ukn. grass A -----	0.04	0.02	0.00	29
Viola Kitaibeliana Field Pansy	0.04	0.01	0.00	30

Table D4. Vegetative species composition, frequency, biomass, and rank of species in Power Mine, site D4.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Triticum aestivum Wheat	1.00	15,828.00	91.48	1
Bromus japonicus Japanese Chess	0.44	976.53	5.64	2
Festuca elatior Meadow Fescue	0.96	161.12	0.93	3
Lepidium virginicum Pepper Grass	0.48	143.64	0.83	4
Hordeum pusillum Little Barley	0.52	92.22	0.53	5
Alopecurus carolinianus Foxtail	0.40	20.89	0.12	6
Medicago sativa Alfalfa	1.00	19.29	0.11	7
Myosotis virginica Scorpion Grass	0.64	14.37	0.08	8
Ambrosia bidentata Ragweed	0.72	11.66	0.08	9
Veronica peregrina Neckweed	0.96	10.42	0.06	10
Geranium carolinianum Cranesbill	0.16	7.90	0.05	11
Solidago nemoralis Old-field Goldenrod	0.12	4.64	0.03	12
Cardamine parviflora Small-flowered Bitter Cress	0.48	4.01	0.02	13
Viola Kitaibeliana Field Pansy	0.28	1.46	0.01	14
Lactuca Scariola Prickly Lettuce	0.16	1.28	0.01	15
Plantago virginica Hoary Plantain	0.32	1.21	0.01	16
A. trifida Horse Weed	0.04	0.80	0.00	17
Polygonum pensylvanicum Pinkweed	0.16	0.58	0.00	18
Cerastium vulgatum Common Mouse-ear Chickweed	0.12	0.41	0.00	19
Oxalis stricta Yellow Wood Sorrel	0.52	0.38	0.00	20
A. artemisiifolia Common Ragweed	0.12	0.37	0.00	21

Table D, continued.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (based on biomass)
Ukn. dicot A -----	0.08	0.22	0.00	22
Rumex spp. Dock	0.04	0.20	0.00	23.5
Aster pilosus White Heath Aster	0.04	0.20	0.00	23.5
Silene antirrhina Sleepy Catchfly	0.12	0.18	0.00	25
Veronica arvensis Corn Speedwell	0.16	0.16	0.00	26
Gnaphalium obtusifolium Sweet Everlasting	0.08	0.10	0.00	27
Ukn. dicot C -----	0.04	0.08	0.00	28
Chenopodium album Lamb's Quarters	0.12	0.06	0.00	29
Specularia perfoliata Venus' Looking Glass	0.08	0.05	0.00	30
Ukn. dicot B -----	0.04	0.02	0.00	31

Table E. Vegetative species composition, frequency, biomass, and rank of species in Power Mine, reference site D5.

Species Common Name	Frequency	Biomass (g/25 m²)	% of Total Biomass	Rank (Based on biomass)
Festuca elatior Meadow Fescue	1.00	3896.90	77.46	1
Poa pratensis Kentucky Blue Grass	0.92	627.17	12.47	2
Galium Aparine Cleavers	0.16	154.67	3.07	3
Dianthus Armeria Deptford Pink	0.60	80.21	1.59	4
Lespedeza stipulacea Korean Clover	0.68	65.82	1.31	5
Trifolium repens White Clover	0.20	56.49	1.12	6
Robinia pseudoacacia Black Locust	0.08	35.80	0.71	7
Tridens flavus Purpletop	0.28	22.02	0.44	8
T. hybridum Alsike Clover	0.72	17.25	0.34	9
Erigeron annuus Daisy Fleabane	0.20	16.58	0.33	10
Rumex crispus Sour Dock	0.04	15.24	0.30	11
Solidago nemoralis Old-field Goldenrod	0.12	8.94	0.18	12
Dactylis glomerata Orchard Grass	0.04	8.46	0.17	13
Ukn. grass A -----	0.32	4.30	0.09	14
Andropogon virginicus Broom Sedge	0.24	3.56	0.07	15
Ukn. grass C -----	0.12	1.92	0.04	16
Vernonia Baldwini Ironweed	0.04	1.78	0.04	17
Ukn. grass B -----	0.16	1.68	0.03	18
Cerastium vulgatum Common Mouse-ear Chickweed	0.16	1.64	0.03	19
T. campestre Large Hop Clover	0.04	1.48	0.03	20
Carex spp. Sedge	0.20	1.15	0.02	21
Veronica arvensis Corn Speedwell	0.68	1.10	0.02	22.5

Table E. continued.

Species Common Name	Frequency	Biomass ($g/25\ m^2$)	% of Total Biomass	Rank (Based on biomass)
Thlaspi arvense Field Penny Cress	0.08	1.10	0.02	22.5
Oxalis stricta Yellow Wood Sorrel	0.52	1.08	0.02	24
Panicum spp. Panic Grass	0.32	0.87	0.02	25
Ukn. dicot A -----	0.28	0.75	0.01	26
Juncus tenuis Path Rush	0.20	0.62	0.01	27
Phleum pratense Timothy	0.04	0.58	0.01	28
Lactuca canadensis Wild Lettuce	0.12	0.55	0.01	29
Bromus japonicus Japanese Chess	0.12	0.40	0.01	30
Solanum carolinense Horse Nettle	0.20	0.24	0.00	31
Aegilops cylindrica Goat Grass	0.04	0.22	0.00	32
Plantago virginica Hoary Plantain	0.04	0.14	0.00	33
Quercus spp. Oak	0.04	0.12	0.00	34
L. Scariola Prickly Lettuce	0.04	0.10	0.00	35
Aster spp. Aster	0.04	0.04	0.00	36
Ambrosia artemisiifolia Common Ragweed	0.12	0.03	0.00	37
Myosotis virginica Scorpion Grass	0.04	0.02	0.00	39
Ukn. dicot B -----	0.08	0.02	0.00	39
Daucus carota	0.04	0.02	0.00	39

Table F. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site C1.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Festuca elatior Meadow Fescue	0.68	2010.22	40.54	1
Medicago sativa Alfalfa	0.32	1668.40	33.65	2
Bromus inermis Smooth Brome	0.20	757.90	15.28	3
Melilotus officinalis Yellow Sweet Clover	0.32	496.98	10.02	4
Monarda fistulosa Wild Bergamot	0.04	14.42	0.29	5
Lactuca Scariola Prickly Lettuce	0.12	4.02	0.08	6
Ambrosia artemisiifolia Common Ragweed	0.12	3.90	0.08	7
Polygonum pensylvanicum Pinkweed	0.08	1.98	0.04	8
Ukn. dicot -----	0.04	0.26	0.01	9
Lespedeza stipulacea Korean Clover	0.04	0.18	0.00	10
Lepidium virginicum Pepper Grass	0.04	0.16	0.00	11
Aster pilosus White Heath Aster	0.04	0.10	0.00	12

Table G. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site C2.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Festuca elatior Meadow Fescue	0.68	2595.08	58.67	1
Medicago sativa Alfalfa	0.44	1372.56	31.03	2
Andropogon virginicum Broom Sedge	0.16	133.68	3.02	3
Melilotus officinalis Yellow Sweet Clover	0.12	128.86	2.91	4
Polygonum pensylvanicum Pinkweed	0.28	88.12	1.99	5
Solidago nemoralis Old-field Goldenrod	0.08	37.82	0.86	6
Bidens polylepis Tickseed Sunflower	0.08	22.60	0.51	7
Poa pratensis Kentucky Blue Grass	0.08	19.16	0.43	8
Vernonia Baldwini Ironweed	0.04	12.86	0.29	9
Echinochloa crus-galli Barnyard Grass	0.08	6.34	0.14	10
Aster pilosus White Heath Aster	0.04	2.38	0.05	11
Panicum lanuginosum Panic Grass	0.08	1.80	0.04	12
Carex spp. Sedge	0.04	0.96	0.02	13
Lactuca Scariola Prickly Lettuce	0.12	0.26	0.01	14
Verbena stricta Vervain	0.08	0.18	0.00	15
Ambrosia artemisiifolia Common Ragweed	0.08	0.12	0.00	16
Ukn. dicot A -----	0.08	0.10	0.00	17
Ukn. dicot B -----	0.04	0.07	0.00	18
Setaria spp. Foxtail Grass	0.04	0.04	0.00	19

Table H. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site C3.

Species Common Name	Frequency	Biomass ($g/25\ m^2$)	% of Total Biomass	Rank (Based on biomass)
Medicago sativa Alfalfa	0.60	2842.20	39.72	1
Festuca elatior Meadow Fescue	0.92	2795.16	39.06	2
Melilotus officinalis Yellow Sweet Clover	0.40	822.96	11.50	3
Panicum virgatum Switch Grass	0.44	528.54	7.39	4
Trifolium repens White Clover	0.04	36.10	0.50	5
Poa pratensis Kentucky Blue Grass	0.04	29.18	0.41	6
Lespedeza stipulacea Korean Clover	0.24	21.58	0.30	7
Cassia fasciculata Partridge Pea	0.08	20.08	0.28	8
Dactylis glomerata Orchard Grass	0.32	15.44	0.22	9
Aster pilosus White Heath Aster	0.12	14.84	0.21	10
Monarda fistulosa Wild Bergamot	0.08	11.60	0.16	11
Bromus japonicus Japanese Chess	0.04	8.38	0.12	12
Erigeron annuus Daisy Fleabane	0.04	3.26	0.05	13
Lactuca Scariola Prickly Lettuce	0.12	2.76	0.04	14
Kochia scoparia Firebush	0.04	0.92	0.01	15
Ukn. grass A -----	0.08	0.82	0.01	16
Chenopodium album Lamb's Quarters	0.08	0.57	0.01	17
Polygonum pensylvanicum Pinkweed	0.08	0.54	0.01	18
Solidago nemoralis Old-field Goldenrod	0.04	0.12	0.00	19.5
Ukn. dicot A -----	0.04	0.12	0.00	19.5
Cerastium nutans Nodding Chickweed	0.04	0.02	0.00	21.5
Draba brachycarpa Whitlow Grass	0.04	0.02	0.00	21.5

Table I. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site C4.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Medicago sativa Alfalfa	0.72	2579.12	40.20	1
Festuca elatior Meadow Fescue	0.88	2418.94	37.70	2
Melilotus officinalis Yellow Sweet Clover	0.68	1273.44	19.85	3
Robinia pseudoacacia Black Locust	0.04	38.60	0.60	4
Aster pilosus White Heath Aster	0.04	29.50	0.46	5
Kochia scoparia Firebush	0.28	17.50	0.27	6
Tridens flavus Purpletop	0.04	14.18	0.22	7
Chenopodium album Lamb's Quarters	0.04	9.28	0.14	8
Panicum virgatum Switch Grass	0.04	8.54	0.13	9
Poa pratensis Kentucky Blue Grass	0.04	8.24	0.13	10
Dactylis glomerata Orchard Grass	0.08	7.92	0.12	11
Lactuca Scariola Prickly Lettuce	0.16	3.50	0.05	12
Phleum pratense Timothy	0.04	3.04	0.05	13
Solidago nemoralis Old-field Goldenrod	0.04	1.12	0.02	14
Ambrosia bidentata Ragweed	0.04	1.08	0.02	15
Hordeum jubatum Squirreltail	0.04	0.70	0.01	16
Ukn. dicot A -----	0.08	0.52	0.01	17
A. artemisiifolia Common Ragweed	0.04	0.48	0.01	18
Draba brachycarpa Whitlow Grass	0.04	0.30	0.00	19
Bromus japonicus Japanese Chess	0.04	0.24	0.00	20
Lespedeza stipulacea Korean Clover	0.04	0.21	0.00	21

Table J. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site C5.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Medicago sativa Alfalfa	0.60	3039.23	46.63	1
Festuca elatior Meadow Fescue	0.76	1720.78	26.40	2
Melilotus officinalis Yellow Sweet Clover	0.68	1302.50	19.97	3
Kochia scoparia Firebush	0.28	247.34	3.79	4
Bromus japonicus Japanese Chess	0.32	62.06	0.95	5
Lactuca Scariola Prickly Lettuce	0.24	52.88	0.81	6
Poa pratensis Kentucky Blue Grass	0.12	32.56	0.50	7
Phleum pratense Timothy	0.20	30.12	0.46	8
Aster pilosus White Heath Aster	0.32	8.80	0.14	9
Chenopodium album Lamb's Quarters	0.12	6.26	0.10	10
Lepidium virginicum Pepper Grass	0.24	5.16	0.08	11
Dactylis glomerata Orchard Grass	0.16	3.80	0.06	12
Bromus inermis Smooth Brome	0.04	3.14	0.05	13
L. canadensis Wild Lettuce	0.04	1.72	0.03	14
Andropogon virginicum Broom Sedge	0.04	0.80	0.01	15
Draba brachycarpa Whitlow Grass	0.04	0.72	0.01	16
Echinochloa crus-galli Barnyard Grass	0.04	0.48	0.01	17
Plantago lanceolata English Plantain	0.04	0.28	0.00	18

Table K. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site C6.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Festuca elatior Meadow Fescue	0.96	3702.94	51.70	1
Medicago sativa Alfalfa	0.88	2523.68	35.23	2
Melilotus officinalis Yellow Sweet Clover	0.44	517.56	7.23	3
Dactylis glomerata Orchard Grass	0.40	165.82	2.32	4
Lespedeza stipulacea Korean Clover	0.56	163.80	2.29	5
Aster pilosus White Heath Aster	0.40	54.52	0.76	6
Poa pratensis Kentucky Blue Grass	0.20	16.58	0.23	7
Phleum pratense Timothy	0.20	10.26	0.14	8
Setaria glauca Yellow Foxtail	0.04	3.54	0.05	9
Chenopodium album Lamb's Quarters	0.08	1.16	0.02	10
Polygonum pensylvanicum Pinkweed	0.04	0.94	0.01	11
Carex spp. Sedge	0.04	0.52	0.01	12
Draba brachycarpa Whitlow Grass	0.08	0.50	0.01	13
Juncus tenuis Path Rush	0.04	0.24	0.00	14.5
Ukn. grass A -----	0.04	0.24	0.00	14.5
Ambrosia artemisiifolia Common Ragweed	0.04	0.16	0.00	16
Solidago nemoralis Old-field Goldenrod	0.04	0.10	0.00	17
Ukn. dicot A -----	0.04	0.01	0.00	18

Table L. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site B1.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Festuca elatior Meadow Fescue	0.44	1041.52	37.14	1
Medicago sativa Alfalfa	0.24	1031.98	36.80	2
Melilotus officinalis Yellow Sweet Clover	0.28	571.34	20.37	3
Rubus flagellaris Dewberry	0.04	122.84	4.38	4
Ambrosia bidentata Ragweed	0.08	9.28	0.33	5
Danthonia spicata Poverty Grass	0.20	7.76	0.28	6
Rumex acetosella Sheep Sorrel	0.04	5.08	0.18	7
Draba brachycarpa Whitlow Grass	0.08	4.92	0.18	8
Bromus japonicus Japanese Chess	0.08	4.10	0.15	9
Aster pilosus White Heath Aster	0.04	3.82	0.14	10
Festuca octoflora Six-weeks Fescue	0.04	1.00	0.04	11
Panicum lanuginosum Panic Grass	0.04	0.74	0.03	12

Table M. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site B2.

Species Common Name	Frequency	Biomass ($g/25\ m^2$)	% of Total Biomass	Rank (Based on biomass)
Medicago sativa Alfalfa	0.76	5964.54	50.69	1
Festuca elatior Meadow Fescue	0.96	3852.96	32.74	2
Melilotus officinalis Yellow Sweet Clover	0.48	1225.90	10.42	3
Bromus inermis Smooth Brome	0.20	267.38	2.27	4
Solidago nemoralis Old-field Goldenrod	0.08	200.84	1.71	5
Dactylis glomerata Orchard Grass	0.08	151.96	1.29	6
Potentilla simplex Cinquefoil	0.08	40.80	0.35	7
Panicum lanuginosum Panic Grass	0.08	34.28	0.29	8
Erigeron annuus Daisy Fleabane	0.04	10.34	0.09	9
Lespedeza stipulacea Korean Clover	0.20	5.32	0.05	10
Aster pilosus White Heath Aster	0.08	3.72	0.03	11
Trifolium repens White Clover	0.04	3.64	0.03	12
Danthonia spicata Poverty Grass	0.04	1.68	0.01	13
Polygonum pensylvanicum Pinkweed	0.04	1.00	0.01	14
Dianthus Armeria Deptford Pink	0.04	0.90	0.01	15
Solanum carolinense Horse Nettle	0.04	0.76	0.01	16
Robinia pseudoacacia Black Locust	0.04	0.52	0.00	17
Lactuca Scariola Prickly Lettuce	0.04	0.44	0.00	18
Ukn. dicot A. -----	0.04	0.10	0.00	19

Table N. Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, site B3.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Festuca elatior Meadow Fescue	0.96	1880.48	47.59	1
Medicago sativa Alfalfa	0.28	1217.64	30.82	2
Solidago nemoralis Old-field Goldenrod	0.24	317.08	8.02	3
Lespedeza stipulacea Korean Clover	0.64	190.54	4.82	4
Melilotus officinalis Yellow Sweet Clover	0.08	67.92	1.72	5
Ambrosia bidentata Ragweed	0.24	62.34	1.58	6
Panicum lanuginosum Panic Grass	0.40	38.50	0.97	7
Phleum pratense Timothy	0.24	36.52	0.92	8
Erigeron annuus Daisy Fleabane	0.20	33.86	0.86	9
Danthonia spicata Poverty Grass	0.16	27.00	0.68	10
Rubus flagellaris Dewberry	0.12	21.48	0.54	11
Carex spp. Sedge	0.20	16.08	0.41	12
Aster pilosus White Heath Aster	0.16	7.34	0.19	13
Lactuca Scariola Prickly Lettuce	0.08	7.06	0.19	14
Croton capitatus Hogwort	0.20	6.16	0.16	15
Plantago Rugelii Rugel Plantain	0.04	4.62	0.12	16
Potentilla simplex Cinquefoil	0.04	4.36	0.11	17
P. virginica Hoary Plantain	0.20	2.96	0.07	18
Poa pratensis Kentucky Blue Grass	0.04	2.66	0.07	19
Psoralea psoralioides Sampson's Snakeroot	0.12	1.92	0.05	20
Dactylis glomerata Orchard Grass	0.04	1.08	0.03	21

Table N, continued.

Species Common Name	Frequency	Biomass (g/25 m^2)	% of Total Biomass	Rank (Based on biomass)
Solanum carolinense Horse Nettle	0.04	0.80	0.02	22
Trifolium repens White Clover	0.04	0.64	0.02	23
Acalypha virginica Three-seeded Mercury	0.04	0.50	0.01	24
Cassis fasciculata Partridge Pea	0.04	0.48	0.01	25
Oxalis stricta Yellow Wood Sorrel	0.04	0.32	0.01	26
Bidens polylepis Tickseed Sunflower	0.04	0.28	0.01	27
Symphoricarpos orbiculatus Coral Berry	0.04	0.26	0.01	28
Draba brachycarpa Whitlow Grass	0.04	0.20	0.01	29
Bromus japonicus Japanese Chess	0.04	0.10	0.00	30
Agrostis hiemalis Hair Grass	0.04	0.01	0.00	31

Table 0 Vegetative species composition, frequency, biomass, and rank of species in Prairie Hill Mine, reference site R3.

Species Common Name	Frequency	Biomass ($g/25\ m^2$)	% of Total Biomass	Rank (Based on biomass)
Festuca elatior Meadow Fescue	1.00	3704.72	47.94	1
Dactylis glomerata Orchard Grass	1.00	3317.78	42.93	2
Poa pratensis Kentucky Blue Grass	1.00	419.36	5.43	3
Bromus inermis Smooth Brome	0.20	53.14	0.69	4
Phleum pratense Timothy	0.28	49.00	0.63	5
Plantago lanceolata English Plantain	0.52	39.22	0.51	6
Erigeron annuus Daisy Fleabane	0.24	23.50	0.30	7
Solidago nemoralis Old-field Goldenrod	0.32	22.86	0.30	8
Vernonia Baldwini Ironweed	0.12	18.46	0.24	9
Hypericum perforatum Common St. John's-wort	0.08	15.46	0.20	10
Ukn. grass A -----	0.24	14.91	0.19	11
Carex sp. C Sedge	0.04	13.26	0.17	12
Carex sp. A Sedge	0.56	8.64	0.11	13
Trifolium hybridum Alsike Clover	0.36	6.36	0.08	14
Juncus tenuis Path Rush	0.56	6.06	0.08	15
Carex sp. B Sedge	0.12	3.74	0.05	16
Eupatorium serotinum Late Boneset	0.08	1.98	0.03	17
Ukn. dicot A -----	0.24	1.49	0.02	18
Barbarea vulgaris Yellow Rocket	0.04	1.46	0.02	19
Solanum carolinense Horse Nettle	0.20	1.44	0.02	20
Oxalis stricta Yellow Wood Sorrel	0.20	1.12	0.01	21

Table O, continued.

Species Common Name	Frequency	Biomass (g/25 m²)	% of Total Biomass	Rank (Based on biomass)
Veronica arvensis Corn Speedwell	0.32	0.96	0.01	22
Ambrosia artemisiifolia Common Ragweed	0.28	0.75	0.01	23
Rumex acetosella Sheep Sorrel	0.04	0.68	0.01	24
P. Rugelii Rugel Plantain	0.04	0.50	0.01	25
Panicum spp. Panic Grass	0.04	0.28	0.00	26
Galium Aparine Cleavers	0.20	0.25	0.00	27
Lepidium virginicum Pepper Grass	0.08	0.21	0.00	28
Robinia pseudoacacia Black Locust	0.04	0.18	0.00	29
Lactuca canadensis Wild Lettuce	0.16	0.13	0.00	30
Ukn. grass B -----	0.04	0.08	0.00	31.5
T. repens White Clover	0.04	0.08	0.00	31.5
Veronica peregrina Neckweed	0.04	0.06	0.00	34
Capsella bursa-pastoris Shepherd's Purse	0.04	0.06	0.00	34
Lespedeza stipulacea Korean Clover	0.04	0.06	0.00	34
Aster pilosus White Heath Aster	0.08	0.05	0.00	36
Ukn. dicot C -----	0.04	0.04	0.00	37.5
Cerastium nutans Nodding Chickweed	0.04	0.04	0.00	37.5
Symphoricarpos orbiculatus Coral Berry	0.04	0.03	0.00	39.5
Acalypha virginica Three-seeded Mercury	0.08	0.03	0.00	39.5
Bromus spp. Brome Grass	0.04	0.02	0.00	41.5
Ukn. dicot B -----	0.04	0.02	0.00	41.5
Ukn. dicot D -----	0.04	0.01	0.00	43

Table P. Comparison of vegetative communities at Power Mine, sites D1-D4 and reference site D5.

	Species Rank in Mine				
Species	D1	D2	D3	D4	D5
Triticum aestivum	1	1	1	1	
Lolium multiflorum	2	4			
Festuca elatior	3	3	3	3	1
Bromus japonicus	4	2	4	2	30
Ukn. grass A *	5		29		14
Medicago sativa	6	7	6	7	
Ambrosia artemisiifolia	7	8	9	21	37
A. trifida	8	6	16	17	
A. bidentata	9	10	27	9	
Lepidium virginicum	10		5	4	
Arenaria serpyllifolia	11				
Dactylis glomerata	12		14		13
Ukn. dicot B *	13	14		31	39
Geranium carolinianum	14			11	
Trifolium repens	15	11	19		6
Ukn. dicot A *	16	13	22	22	26
Chenopodium album	17	16.5	13	29	
Ukn. dicot D *	18.5	16.5			
Viola Kitaibeliana	18.5	15			
Hordeum pusillum	20		24.5	5	
Veronica arvensis	21			26	22.5
Ukn. dicot C *	22	19		28	
Aegilops cylindrica		5			32
Lactuca Scariola		9	24.5	15	35
Polygonum pensylvanicum		12	10	18	
Oxalis stricta		19	26	20	24
Cerastium vulgatum		19		19	19
Alopecurus carolinianus			2	6	
Veronica peregrina			7	10	

* Due to age, size, or condition of specimen, unable to identify to species.

Table P, continued.

Species	Species Rank in Mine				
	D1	D2	D3	D4	D5
Cardamine parviflora			8	13	
Myosotis virginica			11	8	39
Myosurus minimus			12		
Poa chapmaniana			15		
P. pratensis			17		2
Ukn. grass B *			18		18
Lespedeza stipulacea			20.5		5
Agrostis hiemalis			20.5		
Draba brachycarpa			23		
Galium Aparine			28		3
Viola Kitaibeliana			30	14	
Solidago nemoralis				12	12
Plantago virginica				16	33
Rumex spp. *				23.5	11
Aster pilosus				23.5	36
Silene antirrhina				25	
Gnaphalium obtusifolium				27	
Specularia perfoliata				30	
Juncus tenuis					27
Solanum carolinense					31
Panicum spp. *					25
Ukn. grass C *					16
Lactuca canadensis					29
T. hybridum					9
Dianthus Armeria					4
Phleum pratense					28
Erigeron annuus					10
Tridens flavus					8
Andropogon virginicus					15

* Due to age, size, or condition of specimen, unable to identify to species.

Table P, continued.

	Species Rank by Mine				
Species	D1	D2	D3	D4	D5
Carex spp. *					21
Daucus carota					39
Thlaspi arvense					22.5
Quercus spp. *					34
Robinia pseudoacacia					7
Trifolium campestre					20
Vernonia Baldwini					17

* Due to age, size, or condition of specimen, unable to identify to species.

Table Q. Comparison of vegetative communities at Prairie Hill Mine, sites C1-C6, B1-B3, and reference site R3.

Species	Species Rank in Mine									
	C1	C2	C3	C4	C5	C6	B1	B2	B3	R3
Festuca elatior	1	1	2	2	2	1	1	2	1	1
Medicago sativa	2	2	1	1	1	2	2	1	2	
Bromus inermis	3				13			4		
Melilotus officinalis	4	4	3	3	3	3	3	3	5	3
Monarda fistulosa	5									
Lactuca Scariola	6	14	14	12	6			18	14	
Ambrosia artemisiifolia	7	16		18		16				23
Polygonum pensylvanicum	8	5	18			11		14		
Ukn. dicot A *	9	17	19.5	17		18		19		18
Lespedeza stipulacea	10		7	21		5		10	4	34
Lepidium virginicum	11				11					28
Aster pilosus	12	11	10	5	9	6	10	11	13	36
Andropogon virginicum		3			15					
Solidago nemoralis		6	19.5	14		17		5	3	8
Bidens polylepis		7							27	
Poa pratensis		8	6	10	7	7			13	3
Vernonia Baldwini		9								99
Echinochloa crus-galli		10			17					
Panicum lanuginosum		12					12	8	7	26
Carex spp. A *		13				12			12	13
Verbena stricta		15								

* Due to age, size, or condition of specimen, unable to identify to species.

COO-2758-7

Table Q, continued.

Species	Species Rank in Mine									
	C1	C2	C3	C4	C5	C6	B1	B2	B3	R3
Ukn. dicot B *		18								41.5
Setaria spp. *		19				9				
Panicum virgatum			4	9						
Trifolium repens			5					12	23	31.5
Cassia fasciculata			8						25	
Dactylis glomerata			9	11	12	4		6	21	2
Monarda fistulosa			11							
Bromus japonicus			12	20	5		9		30	41.5
Erigeron annuus			13					9	9	7
Kochia scoparia			15	6	4					
Ukn. grass A *			16			14.5				11
Chenopodium album			17	8	10	10				37.5
Cerastium nutans			21.5							
Draba brachycarpa			21.5	19	16	13	8		29	
Robinia pseudoacacia				4				17		29
Tridens flavus				7						
Phleum pratense				13	8	8			8	5
A. bidentata				15			5		6	
Hordeum jubatum				16						
Lactuca canadensis					14					30
Plantago lanceolata					18					6
Juncus tenuis						14.5				15

* Due to age, size, or condition of specimen, unable to identify to species.

COO-2758-7

Table Q, continued.

Species	Species Rank in Mine									
	C1	C2	C3	C4	C5	C6	B1	B2	B3	R3
Rumex acetosella							7			24
Rubus flagellaris							4		11	
Danthonia spicata							6	13	10	
Festuca octoflora							11			
Solanum carolinense								16	22	20
Potentilla simplex								7	17	
Dianthus Armeria								15		
Oxalis stricta									26	21
Plantago Rugelii									16	25
Acalypha virginica									24	39.5
Symphoricarpos orbiculatus									28	39.5
Croton capitatus									15	
P. virginica									18	
Psoralea psoralioides									20	
Agrostis hiemalis									31	
Hypericum perforatum										10
Carex spp. C *										12
Trifolium hybridum										14
Carex spp. B *										16
Eupatorium serotinum										17
Barbarea vulgaris										19

* Due to age, size, or condition of specimen, unable to identify to species.

COO-2758-7

Table Q, continued.

Species	Species Rank in Mine									
	C1	C2	C3	C4	C5	C6	B1	B2	B3	R3
Veronica arvensis										22
Galium Aparine										27
Ukn. grass B *										31.5
Veronica peregrina										34
Capsella bursa-pastoris										34
Ukn. dicot C *										37.5
Ukn. dicot D.*										43

* Due to age, size, or condition of specimen, unable to identify to species.

COO-2758-7