RECLAIMING ILLINOIS STRIP COAL LAND WITH LEGUMES AND GRASSES

By A. F. GRANDT and A. L. LANG

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FOREWORD

MAKING AGRONOMIC SPECIES GROW where none grew before is an accomplishment worthy of man's efforts. The challenge presents itself on many thousands of acres of what was good corn belt land, where the "stripping" method of mining coal has replaced the original land surface with a new mass of varying soil materials.

Barren parallel ridges, left by stripping practices, temporarily disturb the social and economic aspects of a community. The disturbance can be overcome in whole or in part by making the new lands produce agronomic species or trees, or by developing chosen sites for recreational facilities.

This report was made possible by the cooperation of the Illinois Coal Strippers Association and the Illinois Agricultural Experiment Station. It complements a previous study, "Reclaiming Illinois Strip Coal Lands by Forest Planting," published as Bulletin 547 by the University of Illinois Agricultural Experiment Station in cooperation with the Central States Forest Experiment Station, Forest Service, U. S. Department of Agriculture.

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Fred C. Francis, formerly Assistant Professor of Animal Science, and R. R. Snapp, Professor of Animal Science (now deceased), selected the steers for the grazing experiments in 1948 and 1949. Byron Somers supplied the steers in 1950, and the Truax-Traer Coal Company supplied the sheep in 1951. The Central States Forest Experiment Station supplied maps of the strip-mined lands.

CONTENTS

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RECLAIMING ILLINOIS STRIP COAL LAND WITH LEGUMES AND GRASSES

By A. F. GRANDT and A. L. LANG[1]

OPEN-CUT or strip mining (mining coal by removing the entire overburden) was practiced in Illinois as early as 1866. In those days horses and slip scrapers were used, and only coal outcrops covered with soft, shallow overburden were removed (Fig. 1). Since the invention of the large revolving stripping shovel in 1911 (Fig. 2), the industry has expanded rather rapidly, with a corresponding increase in the acreage of strip-mined land.

The economics of the strip coal mining industry in Illinois has been ably presented by Graham.(6)* With regard to the reclamation of the mined land he concludes: "If spoil banks in general can be made productive, strip mining may well counteract the disfavor with which it is now regarded by many people. At the same time, society will gain from a more complete utilization of natural resources."

Probably the first extensive attempt at reclaiming strip-mined lands in Illinois was to plant trees. Schavilye(11) reports that in 1920 six acres in Vermilion county were planted with 9,000 trees consisting of black locust, red pine, jack pine, Scotch pine, tulip poplar, black walnut, white ash, and black ash. In 1937 a series of formal tree-planting studies on strip-mined lands in Ohio was initiated.(3) In 1945 and 1946 the Central States Forestry Experiment Station, Columbus, Ohio, made a survey of the strip-mined lands in the Central States Region, which was followed by forest planting experiments in 1947. The results of these studies in Illinois have been published in Illinois Agricultural Experiment Station Bulletin 547, "Reclaiming Illinois Strip Coal Lands by Forest Plantings."(9)

Experiment Station investigations on the use of grasses and legumes on strip-mined lands in Illinois began in 1947. As early as 1920, a few small plots on a graded strip-mine area in Vermilion county had been seeded with agronomic species.(14) However, the first recorded and sustained use of strip-mined lands for pasture production in Illinois began in 1938, when a mining company seeded about

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* This and similar numbers refer to the literature cited on page 64.

Horses and slip scrapers were used in the early days of strip mining. (Fig. 1)

A modern 1600-ton stripping shovel in action. It has a 35-cubic-yard bucket and a 7-cubic-yard loading shovel. The haulage truck shown in foreground has a 40-ton capacity. (Fig. 2)

300 acres in Fulton county. No doubt there have also been instances when volunteer sweet clover and grasses growing on strip-mined lands have been sporadically grazed by livestock.

Because the returns from a livestock grazing program are relatively quick, the use of grasses and legumes on strip-mined lands will undoubtedly attract more interest than other forms of reclamation.

Table 1. — Total Number of Acres Strip-Mined in Illinois Counties, January 1, 1952

County	Total acreage in county[a]	Acreage mined Jan. 1, 1952[b]	Percent of county mined
Adams	554 240	9.00	.002
Brown	196 480	6.00	.003
Bureau	555 520	1 086.00	.196
Crawford	282 880	4.00	.001
Edgar	401 920	51.00	.013
Fulton	559 360	14 068.00	2.530
Gallatin	209 920	9.00	.004
Greene	347 520	.25	.001
Grundy	276 480	4 914.00	1.796
Hancock	510 080	45.00	.009
Henry	528 640	2 608.00	.500
Jackson	385 920	2 452.00	.653
Jefferson	367 360	1.00	.001
Jersey	239 360	.50	.001
Kankakee	435 200	532.63	.124
Knox	465 920	4 435.00	.962
LaSalle	737 920	1 058.00	.143
Livingston	667 520	40.75	.006
Madison	467 840	7.00	.001
Marshall	252 800	1.00	.001
McDonough	372 480	6.00	.002
Mercer	355 840	1.75	.001
Morgan	361 600	4.00	.001
Peoria	399 360	52.00	.013
Perry	283 520	7 460.00	2.585
Pike	530 560	.50	.001
Randolph	380 120	1 572.00	.414
Saline	245 760	2 150.15	.870
Schuyler	277 760	259.75	.095
Scott	160 640	1.00	.001
Shelby	494 080	1.00	.001
St. Clair	428 800	2 439.53	.575
Vermilion	574 720	2 386.50	.421
Will	540 800	3 153.56	.590
Williamson	274 560	3 824.40	1.331
Total		54 640.27	

[a] Acreage from 1954 census.
[b] Figures supplied by the Illinois Coal Strippers Association.

EXTENT AND CHARACTERISTICS OF STRIP COAL LANDS

Coal is reported as having been strip-mined in 35 counties in Illinois. According to the Illinois Coal Strippers Association, the total area of strip-mined land, as of January 1, 1952, was 54,640 acres. The acreage in each county is shown in Table 1. Fulton county ranks first in acreage of strip-mined land, and Perry county second.

Major operations are now being carried on in 15 counties. These counties may be divided into the following sections: *southern,* St. Clair, Randolph, Perry, Jackson, Williamson, and Saline counties; *western,* Knox, Fulton, and Peoria; *northwestern,* Henry and Bureau; *northeastern,* Will, Grundy, and Kankakee; *eastern,* Vermilion.

How Strata Overlying the Coal Affect the Soil Material of Strip-Mined Lands

After strip-mining operations, the soil material is a heterogeneous mass whose physical and chemical properties are dominated by the character of the geologic strata overlying the coal. The mining areas in Illinois are widely scattered, and the overlying strata are highly variable in thickness and character (Figs. 3 and 4). These strata may include the surface soil, loess, glacial till, sands, shales, slates, limestone, and sandstone rock.

Of these, the topsoil, loess, glacial till, sands, and soft shales are the most important, because they are the principal sources of particles 2 mm. and less in size. In general, the higher the percentage of these particles, the greater the opportunities for successful reclamation. In Illinois, the relatively large deposits of loess (a silty, generally calcareous soil material) are very favorable to the revegetation of the strip-mined areas. About 70 percent of the upland areas of the state are covered by this material.[12] The loess cap is thickest near the Mississippi and Illinois rivers.

The glacial till is variable in texture and mineral content, and is thickest in the northeastern and eastern sections of the state. The sand layers are generally low in plant nutrients, especially potassium and phosphorus.

Most of the shales are soft and weather rapidly when exposed. These soft shales were found to be high in available phosphorus and potassium. The pH or reaction of the shales is highly variable, ranging from a high of 8.5 to a low of 2.2. Some shales contain very fine grains of pyrite and other sulfur-bearing materials, which upon weathering oxidize and cause the soil material to become highly acid (Fig. 5). The soft shale layers are generally high in clay, with over 50 percent of the material being finer than .002 mm. in diameter.

Overburden in western Illinois (right) carries a relatively high proportion of soil, loess, and glacial till over calcareous shale. (Fig. 3)

Overburden in southern Illinois (below) generally contains a larger proportion of rock than that in western Illinois. (Fig. 4)

The dark spots on these strip-mined lands in Saline county are highly acid. A pH as low as 2.2 has been found. (Fig. 5)

Where the shales predominate, their high clay content causes a poor physical condition on the surface of the soil material.

Differences in character and thickness of the rock (limestone and sandstone) and slate were also found. The percentage of rock and slate, which are slow-weathering materials, greatly affects revegetation. The higher the ratio of rock to soil-sized particles (those smaller than 2 mm. in diameter), the greater the effect on soil moisture, aeration, drainage, and tillability on graded areas.

The methods of mining with the several types of equipment also affect the resultant mined area. Power shovels usually deposit the overburden in long, more or less parallel ridges. Slope measurements made at a number of locations on newly mined ridges ranged between 40 and 65 percent. As the ridges weather and settle, the slopes tend to become less.

Draglines often deposit the material in conical piles or sharply serrated ridges that are steep and subject to severe erosion (Fig. 6). In western Illinois the rotary shovel is used with other stripping equip-

Draglines often deposit the material in conical piles or sharply serrated ridges that are steep and subject to severe erosion. (Fig. 6)

Spoil ridges made by the rotary-wheel shovel are irregular arcs, with short, steep slopes. (Fig. 7)

ment. With this method, the upper rock-free strata are placed on the tops of the lower rock and shale strata. The ridges are irregular arcs, with short, steep slopes (Fig. 7).

Basic Classification of Mined Land

The potential productivity of soil material left after mining operations is largely determined by the acidity and the texture. A method of classifying strip-mined lands on the basis of these two characteristics has been worked out by Limstrom as a result of the reconnaissance survey conducted by the Central States Forest Experiment Station in 1946.[8] Taken together, acidity and texture determine the basic spoil types. The system of classification proposed by Limstrom[9] is given below.

The acidity of strip-mined land, expressed in the range of pH values of the surface material, is classified as follows:

Class number and description	*pH value*	*Extent on area*
1. Toxic	Less than 4.0	More than 75 percent
2. Marginal	Less than 4.0	50 to 75 percent
3. Acid	4.0 to 6.9	50 to 75 percent
4. Calcareous	7.0 or more[a]	More than 50 percent
5. Mixed	(Too varied to be classified as any of the above)	

On the basis of texture, strip-mined lands are divided into three broad groups:

Group	*Description of texture*
A	Chiefly sand, sandstone, or sandy shales
B	Chiefly loamy materials and silty shales
C	Chiefly clay and clay shales

The acidity class and the texture group are then combined to describe the basic spoil types, as for example:

Spoil type	*Description*
4-A	Calcareous sands
1-C	Toxic clays

([a] For practical purposes any soils testing 7.0 (neutral) are included in the calcareous group.)

Chemical Analyses of Strip-Mine Materials

The soil material of 15 counties was thoroughly sampled and tested for this study. There were 51,420 acres mined in these 15 counties.

Acidity classes. Over 2,000 soil samples were tested for soil reaction or pH. The percentage of samples falling into each acidity class

Table 2. — Analysis by Acidity Class of Soil Samples Taken in Fifteen Major Strip-Mining Counties in Illinois

County	Acres mined Jan. 1, 1951	Number of soil tests	Acidity Class			
			Toxic, pH 4.0 or less	Acid		Calcareous, pH 7.0 and above
				pH 4.1 to 5.4	pH 5.5 to 6.9	
			pct.	*pct.*	*pct.*	*pct.*
Bureau	912	90	0	1	11	88
Fulton	13 262	360	1	1	7	91
Grundy	4 806	147	17	1	15	67
Henry	2 608	38	0	0	7	93
Jackson	2 289	82	12	24	36	28
Kankakee	327	20	0	0	5	95
Knox	3 938	526	2	1	9	88
Perry	7 094	185	7	4	16	73
Randolph	1 470	54	4	2	11	83
Saline	2 102	94	33	36	27	4
Schuyler	256	12	8	8	25	59
St. Clair	2 244	185	0	3	36	61
Vermilion	2 277	29	7	3	14	76
Will	3 109	52	4	0	2	94
Williamson	3 669	161	9	16	34	41
Total or average	50 363	2 035	5.4	5.5	16.2	72.9

as of January 1, 1951, is given in Table 2. The acid class was divided because many agronomic species grow satisfactorily with a pH of 5.5 and above. Nearly 90 percent of all the samples had a pH above 5.5, and only 5 percent had a pH below 4.0. According to Limstrom's method of classification, the strip-mine soil material is calcareous in 12 of the counties, and acid in the other three.

The generally high calcium content of these soils is indicated not only by the pH levels but also by effervescence tests.

Nature of the toxic class. In Illinois the toxic condition (a pH of less than 4.0) is due to a concentration of sulfur. This sulfur usually results from the weathering of sulfurous shale layers or coal scrapings. Toxic acid spots are wet-looking and very compact and hard.

Enough material from two of the sulfurous shales was brought into the greenhouse that the neutralization of the acidity could be studied. One was a blue-gray shale from southern Illinois, probably Coppers Creek shale. It is quite high in clay; of the material that is finer than 2 mm., over 50 percent is less than .002 mm. in size. Thus, the material is sticky and plastic when wet. After weathering, the reaction or pH is about 2.6. This shale contained about 5 percent organic matter, based on the carbon content.

Table 3. — Effect of Liming on Two Highly Acid Shales

Kind of shale and series number	Tons of limestone per acre	pH before liming	pH after liming	Legume growth after liming
Blue shale				
Series I	0	2.6	2.8	None
	5	2.6	3.1	None
	10	2.6	3.8	None
	20	2.7	5.7	Fair
	40	2.7	7.0	Good
Series II	0	2.7	2.9	None
	5	2.6	3.2	None
	10	2.6	3.7	None
	20	2.55	6.2	Fair
	40	2.6	7.2	Good
Yellow shale				
Series I	0	2.25	2.4	None
	5	2.25	2.6	None
	10	2.3	3.0	None
	20	2.3	3.7	None
	40	2.3	5.2	Fair
Series II	0	2.3	2.5	Series
	5	2.3	3.0	relimed
	10	2.3	2.8	
	20	2.25	3.2	
	40	2.3	3.5	
Series II with more limestone added	0	2.3	2.5	None
	45	3.0	6.3	Good
	50	2.8	6.0	Fair
	60	3.2	7.3	Good
	70	3.5	7.2	Good

The other shale was a yellow shale from western Illinois, known as the Canton shale. About 64 percent of the particles were less than .002 mm. in size, putting them into the clay classification. After weathering, the pH was about 2.3. Available phosphorus and potassium content was very high, and organic-matter content was very low, with about 1.25 percent recorded.

Known quantities of these shales were placed in pots in the greenhouse, and limestone was added at various rates. At first five pots in duplicate were treated at the rates of 0, 5, 10, 20, and 40 tons of limestone per acre. The pots were watered regularly, so that the acidity could be neutralized. The results are presented in Table 3. Forty tons of limestone per acre brought the pH up to 7.0 on the blue shale, but not on the yellow shale. Therefore, more limestone was added to four pots of the second series. Sixty tons of limestone was needed to bring the pH of the yellow shale up to and above neutral.

Soil reaction, or pH, and legume growth resulting from the addition of varying amounts of limestone to blue acid shale (top row of pots) and yellow acid shale (lower row). (Fig. 8)

Table 4. — Soil Test Analysis of Strip-Mine Soils by County

County	Number of samples	Average pH[a]	Available phosphorus average[b]	Available potassium average[c]	Available boron average
			lb.	*lb.*	*lb.*
Bureau	90	7.4	152	217	..
Fulton	360	7.5	142	153	8[d]
Grundy	147	6.2	120	183	..
Henry	38	7.3	174	288	..
Jackson	55	6.3	117	173	..
Kankakee	20	7.6	144	170	..
Knox	526	7.3	155	176	12[d]
Perry	146	6.9	127	187	..
Randolph	34	7.3	82	138	..
St. Clair	185	7.1	116	133	..
Saline	54	4.5	90	169	..
Schuyler	12	6.8	171	224	..
Vermilion	22	6.7	58	201	..
Will	32	7.6	56	170	..
Williamson	88	6.3	115	143	..
Total	1 801	...	...	...	..

[a] A pH of 7 is neutral. See Table 2 for range in pH values.
[b] An analysis of 92 pounds per acre is high.
[c] An analysis of 150 to 200 pounds per acre is high.
[d] An analysis of 6 pounds per acre is high. Six samples in Fulton county and two samples in Knox county were analyzed.

After the shale material had been limed, inoculated alfalfa, red clover, and birdsfoot trefoil were seeded in the pots. Fig. 8 shows the growth of legumes as the result of the limestone treatment.

From this study it appears that toxic areas, if graded, can be neutralized and used to grow legumes. However, because of the high clay content and poor physical condition and the extremely large amount of limestone required, reclaiming these toxic areas seems impractical. A more logical approach might be to bury any sulfurous materials in the mining operation.

Other elements. Of the more than 2,000 samples tested for acidity, over 1,800 were tested for available phosphorus and available potassium; and eight samples were tested for available boron.[1] As can be seen from Table 4, most of the samples tested very high in available phosphorus and high in potassium. Judging from the few boron tests made, strip-mine soils are also high in this material. Another indication of an adequate boron content is the excellent growth of legumes on strip-mine soils and the good seed set, especially of alfalfa.

[1] Determinations were made under the directon of A. U. Thor, at the University of Illinois soil testing laboratory.

Effects of grading. To study the effect of grading on pH and on the availability of phosphorus and potassium, 238 soil samples from 15 graded areas and 261 samples from 14 ungraded areas were tested. The effect on pH was variable, with the pH being appreciably raised in some areas and appreciably lowered in others. The over-all average change was a lowering of 0.08 of a unit.

With but one exception, grading raised the amount of available phosphorus. The average increase was about 40 pounds. Available potassium was increased, on the average, by about the same amount. In only three locations was the available potassium lowered by grading.

Mechanical Analyses

As already mentioned, the chances of reclaiming strip-mined lands increase with the percentage of particles 2 mm. or less in diameter, provided the chemical composition is not deleterious. Also, the percentages of the various separates — sands, silt, and clay — are important in determining the physical properties of the strip-mine soil material. Therefore, for help both in understanding these physical properties and in classifying or naming the soil material, the mechanical analysis of material finer than 2 mm. in diameter was determined for a limited number of samples. The hydrometer method was used.[1] The results obtained are listed in Table 5. Twenty-seven of the thirty-nine samples tested were silty clay loams, silty clays, or clay loams. This indicates that in general the strip-mine soil materials in Illinois are clays in texture.

Temperature and Moisture Relationships

Temperature and moisture contents of strip-mine soils were measured during July and August, 1948, on various slope exposures and under varying amounts of vegetative cover.

No excessively high temperatures were noted. The highest temperature recorded was 105° F. on a tight, plastic glacial till and shale material in Will county. The maximum range in temperature during a 24-hour period was 44 degrees and was recorded at the 2-inch level on a slope with a southern exposure. Temperature fluctuates less at a 6-inch depth than at a 2-inch depth.

Temperatures averaged about 10 to 12 degrees higher on bare slopes having southern or western exposures than on slopes with northern or eastern exposures. Grasses, especially bluegrass, become well established faster on northern and eastern exposures than on southern and western exposures.

Table 5. — Mechanical Analysis of Strip-Mine Soil Materials Finer Than 2 mm.

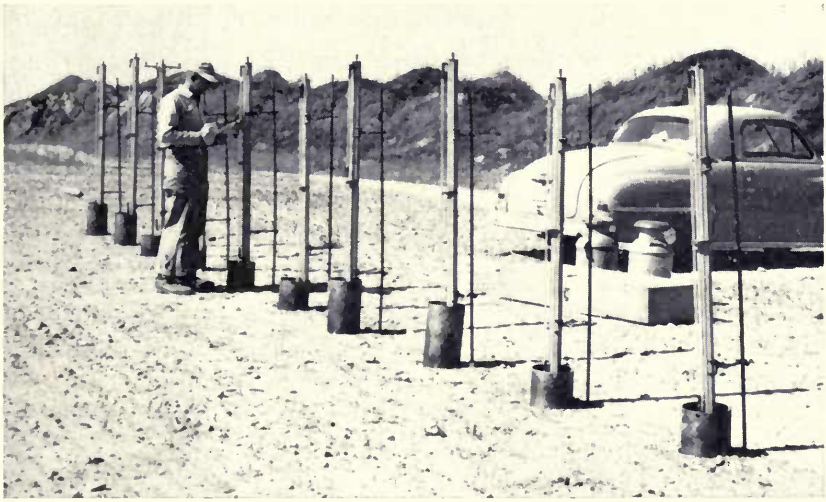
Company	County	Soil separates			Textural class
		Sand 2-.05 mm.	Silt .05-.002 mm.	Clay .002 mm.	
		pct.	*pct.*	*pct.*	
Delta Collieries	Williamson	21.6	48.7	29.7	Clay loam
		15.5	53.3	31.2	Silty clay loam
		15.3	55.1	29.6	Silty clay loam
Truax-Traer, Elkville	Jackson	14.4	46.7	38.9	Silty clay loam
		18.0	42.0	40.0	Silty clay
		18.2	49.0	32.9	Silty clay loam
		16.8	50.4	32.8	Silty clay loam
		15.0	51.2	33.8	Silty clay loam
U. E. Fidelity	Perry	31.2	42.9	25.9	Loam
		28.2	42.0	29.8	Clay loam
Pyramid	Perry	16.0	55.0	29.0	Silty clay loam
		14.5	55.2	30.3	Silty clay loam
		16.1	57.2	26.7	Silt loam
B. Somers	Fulton	28.8	50.2	21.0	Silt loam
		20.1	54.1	25.8	Silt loam
		15.8	59.8	24.4	Silt loam
		40.2	39.8	20.0	Loam
U. E. Cuba Mine	Fulton	20.6	40.5	38.9	Silty clay loam
		16.7	42.1	41.2	Silty clay
		10.1	49.0	40.9	Silty clay
		10.4	48.3	41.3	Silty clay
T. T. Fiatt	Fulton	11.4	60.3	28.3	Silty clay loam
		15.8	46.6	37.6	Silty clay loam
M. E. Sheffield	Bureau	17.1	40.2	42.7	Silty clay
		25.3	36.0	38.7	Clay loam
		16.1	44.1	39.8	Silty clay loam
		16.7	39.7	43.6	Clays
		19.5	41.1	39.4	Silty clay loam
		19.6	41.3	39.1	Silty clay loam
Northern Illinois, strike-off plot area	Grundy	40.9	36.0	23.1	Loams
		40.3	39.6	20.1	Loams
		56.8	24.8	18.4	Sandy loam[a]
Northern Illinois, Pit 12	Kankakee	13.7	32.8	53.5	Clays
		25.1	41.7	33.2	Clay loam
		41.6	28.3	30.1	Clay loam
		12.2	48.8	39.0	Silty clay loam[a]
Harmattan	Vermilion	39.0	33.8	27.2	Clay loam (reddish)
		40.8	34.0	25.2	Loam (reddish)
		2.7	45.2	52.1	Silty clay (blue-gray)

[a] From Will county.

Green vegetation tends to equalize soil temperatures. During periods of rising temperatures, soil temperatures were 7 to 10 degrees lower under alfalfa cover than on bare slopes.

Permeability of Strip-Mined Soils

Infiltration rate, or rate at which water passes downward through the soil material, was determined on undisturbed ridges, strike-off tops, and areas graded to be accessible with farm equipment (Fig. 9). On each of these three kinds of topography measurements were made on bare areas and on areas well-vegetated with legumes. The investigations were carried out on two major spoil types: calcareous clays (4-C); and calcareous loams and silty shales (4-B).



The permeability of a graded strip-mine area is being determined by the cylinder method. (Fig. 9)

The data obtained are presented in Table 6. As is indicated by the standard deviations, there was wide variation in the infiltration. This was especially true of the ridges, both bare and vegetated. There was little difference in infiltration rate between level and strike-off tops, but the undisturbed ridges had a significantly higher rate. Vegetation increased the infiltration on all three types of topography.

Seven degrees of permeability will express the most significant variations of the infiltration of most farm soils.[15] The ranges of permeability, and representative soil types falling within each range are given at the top of page 21.

Table 6. — Infiltration Rates[a] on Four Spoil Types Under Three Different Physical Conditions (Level, Strike-off, and Ridges), and Two Types of Cover (Bare and Grass-Legume Vegetation)

	Spoil type	Bare			Vegetated		
		Level	Strike-off	Ridges	Level	Strike-off	Ridges
		inches per hour					
4-C	Calcareous silty clay (Fulton county)	.89 ± .09	.75 ± .18	9.29* ± 10.10	1.49 ± .64	1.83 ± .65	13.57 ± 10.33
4-B	Calcareous silty shale (Fulton and Knox counties)	.70 ± .25	.58 ± .38	1.95 ± .84	.91 ± .48	1.02 ± .48	13.35 ± 5.92
4-C	Calcareous silty clay, rocky (Perry county)	1.39 ± .39	1.01 ± .43	6.83 ± 5.26	1.43 ± .51	1.44 ± .22	31.38 ± 24.00
4-B	Calcareous loam, loessal (St. Clair county)	.42 ± .40	1.20 ± .36	2.78 ± 3.30	1.71 ± .03	1.36 ± 1.01	53.27 ± 19.04
	Average	.85	.89	5.21	1.39	1.41	27.89

[a] Each figure with its standard deviation is a mean of 10 determinations except(*), for which 20 determinations were used.

Description of rate of permeability	*Infiltration in inches per hour*	*Soil group*
Very slow	Less than .05	Cisne-Wynoose silt loam
Slow	.05 to .20	Swygert silt loam
Moderately slow	.20 to .80	Herrick silt loam
Moderate	.80 to 2.50	Flanagan and Muscatine silt loam
Moderately rapid	2.50 to 5.00	Joy-Port Byron silt loam
Rapid	5.00 to 10.00	O'Neill sandy loam
Very rapid	More than 10.00	Hagener loamy sand

On the basis of this guide, the graded areas, both bare and vegetated, have moderate permeability; the bare ridges, rapid permeability; and the vegetated ridges, very rapid.

Microbiological Presence and Activity

Fungi, bacteria, and other microorganisms are very important in soil formation and development. They have three distinct functions: the decomposition of organic matter and plant residues; the nitrification or accumulation of nitrates in the soil as a result of the decomposition of organic matter; and nitrogen fixation by symbiotic and nonsymbiotic bacteria.

Microorganisms have been presumed to be very low or completely lacking in recently mined soils. This has been partially borne out by limited research on the numbers of bacteria and fungi found in bare soil and under vegetation.[10] In this study the bare soils were found low in fungi. Alfalfa and bromegrass vegetation increased fungal numbers four to eight times.

Work by other investigators, however, shows that bare soils low in organic matter and similar to strip-mine soils in pH and in potassium and phosphorus content contain relatively high numbers of azotobacter. Undoubtedly these microorganisms contribute moderate amounts of nitrogen to these soils, thus hastening the accumulation of organic matter and soil formation.

Legumes that have been inoculated with specific cultures of bacteria can fix atmospheric nitrogen in a symbiotic relationship and supply it to plants in the form of nitrogenous products. Thus, when legumes are seeded on strip-mine soils, nodule bacteria are added to the soil and increased in a very short time. As vegetation or organic matter accumulates, bacteria and fungi are increased, and organic matter begins to decompose. Thus soil development through bacteriological processes is begun on these new soil materials.

Table 7. — Agronomic Species Seeded on Experimental Plots

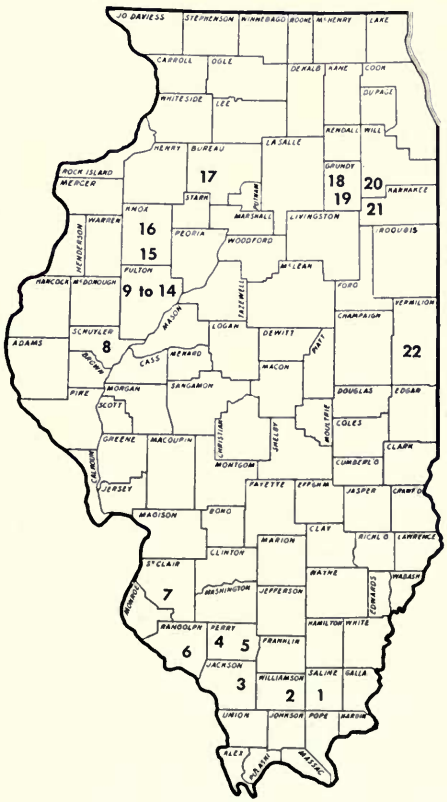
Grasses		Legumes	
Common name	Botanical name	Common name	Botanical name
Kentucky bluegrass	*Poa pratensis*	Alfalfa	*Medicago sativa*
Canada bluegrass	*Poa compressa*	Yellow sweet clover	*Melilotus officinalis*
Big bluegrass	*Poa ampla*	White sweet clover	*Melilotus alba*
Canby bluegrass	*Poa Canbyi*	Evergreen sweet clover	*Melilotus alba*
Redtop	*Agrostis alba*	Hubam sweet clover	*Melilotus alba* var. *annua*
Timothy	*Phleum pratense*	Spanish sweet clover	*Melilotus suaveolus*
Reed canary grass	*Phalaris arundinacea*	Mammoth red clover	*Trifolium pratense perenne.*
Orchard grass	*Dactylis glomerata*	Kenland red clover	*Trifolium pratense*
Bromegrass	*Bromus inermis*	Cumberland red clover	*Trifolium pratense*
Mountain brome	*Bromus marginatus*	Midland red clover	*Trifolium pratense*
Meadow fescue	*Festuca elatior*	Alsike clover	*Trifolium hybridum*
Alta fescue	*Festuca arundinacea*	Crimson clover	*Trifolium incarnatum*
Chewings fescue	*Festuca rubra*	Subterranean clover	*Trifolium subterraneum*
Creeping fescue	*Festuca rubra*	White Dutch clover	*Trifolium repens*
Ryegrass	*Lolium perenne*	Ladino clover	*Trifolium repens* var. *latum*
Bermuda grass	*Cynodon dactylon*	Hop clover	*Trifolium procumbens*
Dallas grass	*Paspalum dilatatum*	Alyce clover	*Trifolium alyce*
Crested wheatgrass	*Agropyron cristatum*	Persian clover	*Trifolium reseysinatum*
Slender wheatgrass	*Agropyron tenerm*	Button clover	*Medicago oebicularis*
Western wheatgrass	*Agropyron Smithii*	Lappacea	*Trifolium lappaceaum*
Blue grama	*Bouteloua gracilis*	Common lespedeza	*Lespedeza striata*
Side-oat grama	*Bouteloua curtipendula*	Korean lespedeza	*Lespedeza stipulacea*
Big bluestem	*Andropogon furcatus*	Kobe lespedeza	*Lespedeza striata*
Little bluestem	*Andropogon scoparius*	Sericea lespedeza	*Lespedeza sericea*
Buffalo grass	*Buchloe dactyloides*	Bicolor lespedeza	*Lespedeza tricolor*
Indian grass	*Sorghastrum nutans*	Birdsfoot trefoil	*Lotus corniculatus*
Tall oatgrass	*Arrhenatherum elatius*	Big broadleaf trefoil	*Lotus uliginosus*
Canadian wild rye	*Elymus canadensis*	Yellow trefoil	*Medicago lupulina*
Michael's grass	.....	Kudzu	*Pueraria chunbergiana*
Rhodes grass	*Chloris Gayana*	Lupines	*Lupinus* spp.
Switch grass	*Panicum virgatum*	Crown vetch	*Vicia* spp.
Meadow foxtail	*Alopecurus pratensis*	Hairy vetch	*Vicia villosa*
Millets	*Setaria* spp.	Sanfoin	*Onobrychis viciifolia*
Sudan	*Sorghum vulgare*	Austrian winter pea	*Pisum sativum*
Sweet sudan	*Sorghum vulgare*	Wagner pea	*Lathyrus sylvestris*
Love grass	*Eragrostis curvula*	Singletary pea	*Lathyrus* spp.
"M" pasture mix	.....		
Fields pasture mix	.....		
.....	*Calamagrostis epigeios*		

Other crops			
Wheat	*Triticum aestivum*	Corn	*Zea mays*
Oats	*Avena sativa*	Soybeans	*Glycine soja*
Rye	*Secale cereale*	Japanese rose	*Rosa multiflora*

TRIALS WITH AGRONOMIC SPECIES

From the foregoing discussion it is seen that strip-mine soils in Illinois are relatively high in unweathered minerals containing phosphorus, potassium, calcium, and magnesium. Organic matter and nitrogen are extremely low or entirely lacking, and often the soil material lacks good tilth and structure. There is a conglomerate mixture of rocks, gravel, and particles under 2 mm. in diameter. This then was the seedbed upon whch various experiments with agronomic species were established.

Strip-mined lands are generally left in the rough — a series of hills and valleys. Under this condition, permanent pastures would be the only long-time land use possible with agronomic species. Accordingly most of the experiments have been with forage crops, of which more than 70 have been seeded (Table 7). In addition, some cultivated crops have been seeded. Naturally it was not expected that all these

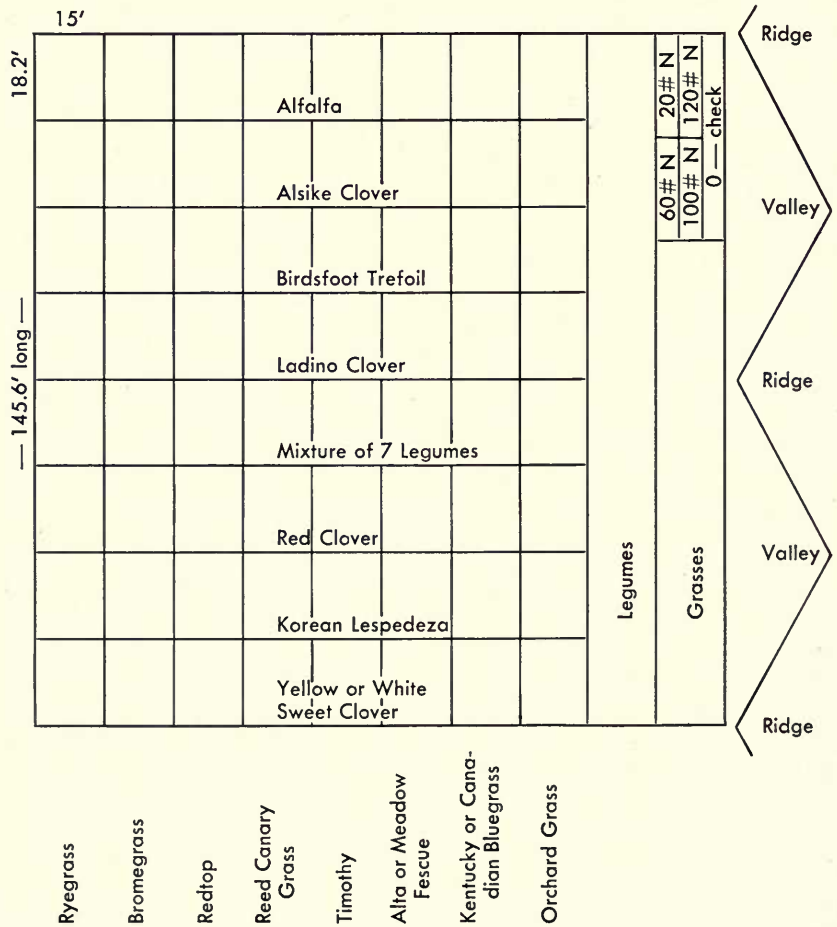


Location of experimental plots. Species adaptation on newly mined areas was studied at plots 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, and 22. Species adaptation in established stands was studied at plots 1, 2, 6, 9, 10, 15, and 19. Studies on strike-off ridges were conducted at plots 7 and 14; studies on leveled areas at plots 7, 15, and 19. Different rates and times of seeding were studied on plots 13 and 14. Fertility treatments were made on plots 1, 4, 7, 11, 15, and 19. Mixtures were tried on plots 5, 8, 13, 14, 17, 21, and 22. (Fig. 10)

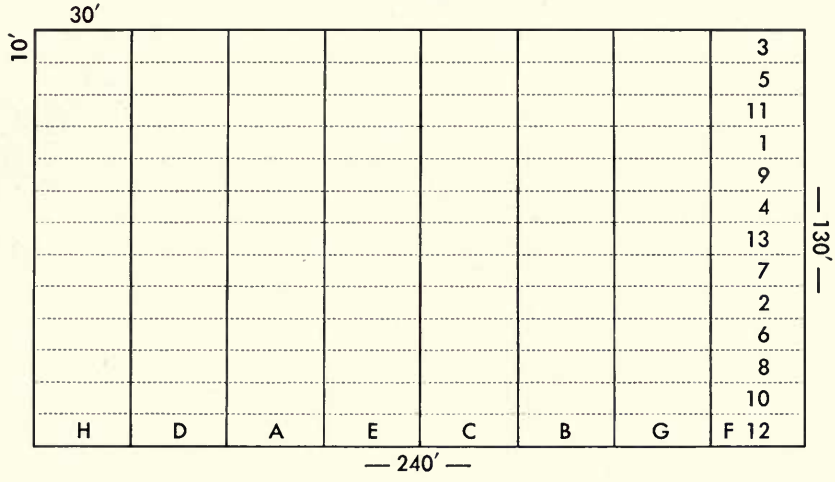
species would be adapted. However, it was desirable to observe the comparative aggressiveness and persistence of the various species.

The species were seeded alone and in association on newly mined ridges; into established stands of vegetation such as sweet clover, weeds, etc.; on strike-off ridges; and on more or less level areas. Different rates and times of seeding were tried. Also, some experiments were made with different fertility treatments, and mixtures of several different species were tried (Fig. 10).

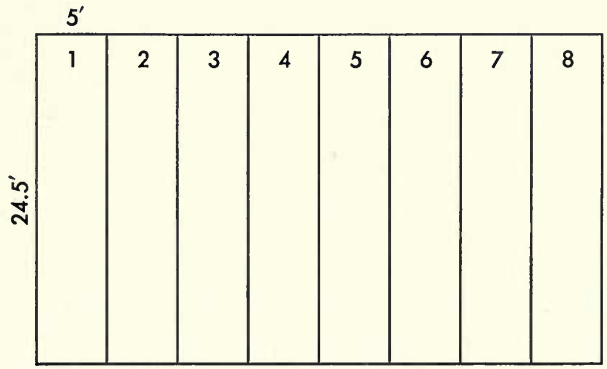
A seedbed, as generally prepared on farmland, was never prepared on the experimental plots. The seed was always broadcast and covered by natural means.



Plot design used for studying species adaptation on undisturbed areas, and different times and rates of seeding. (Fig. 11A)



Fertilizer application (750 lb./A)	*Species seeded*	*Pounds per plot*	*Rate per acre*
A — 8-8-8	1 — Kentucky bluegrass	1.1	15
B — 8-8-8 plus trace elements	2 — Bromegrass	1.1	15
C — 8-0-0 plus trace elements	3 — Redtop	1.0	14
D — 8-0-0	4 — Timothy	0.85	12
E — 8-8-0	5 — Orchard grass	1.1	15
F — 8-0-8	6 — Alta fescue	1.1	15
G — 0-8-8	7 — Ryegrass	1.1	15
H — 0-0-0	8 — Sweet clover	1.1	15
	9 — Alfalfa	1.1	15
	10 — Red clover	0.85	12
	11 — Ladino	0.33	5
	12 — Lespedeza	1.4	20
	13 — Birdsfoot trefoil	0.45	6



Treatment

1 — No nitrogen
2 — 20 lb. N
3 — 40 lb. N
4 — 60 lb. N
5 — 80 lb. N
6 — 100 lb. N
7 — 120 lb. N
8 — 500 lb. 8-8-8

Top diagram shows design for the experiments with different fertilizers; lower diagram shows the type of plot used on leveled and strike-off ridges. (Figs. 11B and 11C)

Description of Experimental Plots

Fig. 11A shows the plot design used both for studying species adaptation alone and in association on undisturbed spoil banks and for studying different times and rates of seeding. In the 64 association plots, eight grasses were seeded up and down the slopes to cover two complete spoil banks wherever possible. The grass plots were 145.2 by 15 feet, making 1/20 acre in area. Eight legumes were seeded across the grass plots. The legume plots ran approximately parallel to the ridges and valleys and were 18.2 feet by 120 feet, making 1/20-acre plots. The species seeded were randomized and all plots were duplicated.

All the species used were also seeded alone up and down the slope in 1/20-acre plots. Some of the grass plots were treated with various amounts of nitrogen fertilizer as shown in Fig. 11A. Each nitrogen-treated plot was 5 feet by 21.5 feet, or about 1/400 acre. Since the legumes were inoculated when they were seeded, they were not treated with a nitrogen fertilizer.

The plots used for seeding species into established vegetation and for trying mixtures of several species were essentially the same as those described above, except that the plots were 30 feet wide instead of 15 feet.

The plot design used for the fertility treatment experiment is shown in Fig. 11B. The fertilizers were applied up and down the slopes in plots 130 feet by 30 feet, or .09 acre in area. The rate of 750 pounds of 8-8-8 means that 60 pounds of nitrogen, 60 pounds of phosphoric acid (P_2O_5), and 60 pounds of potash (K_2O) were applied per acre. Straight materials were used and mixed in the proper amounts. When ammonium nitrate was used, 16.6 pounds of a 32.5-percent material was applied. Sometimes ammonium sulfate was used, with 27 pounds of 20-percent material being applied. Twelve pounds of a 45-percent phosphate and 9 pounds of a 60-percent potash were applied per plot to supply the proper amounts of phosphorus and potassium.

Trace elements were applied at the rate of 100 pounds per acre of a mixture containing zinc, copper, manganese, boron, iron, calcium, sodium, iodine, cobalt, magnesium, and ten other minor mineral elements.

The type of plot used on leveled and strike-off ridges is shown in Fig. 11C. These plots are 1/400 and 1/200 acre in size.

The first plots were established in the spring of 1947. Because of the cold, wet spring, however, it wasn't until 1948 that extensive trials could be begun. By 1952 more than 2,500 plots of all kinds had been

established. Most of the plots were on spoil type 4-B (calcareous loams and silty shales) and on spoil type 4-C (calcareous clays), the two dominant spoil type classes in Illinois.

Several Grasses and Legumes Well Adapted

Legume species that have proved well adapted include alfalfa, birdsfoot trefoil, red clover, sweet clover, lespedeza, and Kudzu. Of the grasses, tall fescue, orchard grass, and bromegrass have become established most rapidly, while Kentucky bluegrass, timothy, redtop, and reed canary grass have become established more slowly. The different species are discussed in detail on pages 31 to 47.

Early, Heavy Seeding Most Satisfactory

Seedings were tried both in spring and fall on newly mined ridges. In general, spring seedings were most satisfactory. Probably the best time to seed in Illinois is late February through March. Seeding as late as April 15 has resulted in poor growth and survival. Freezing and thawing help to cover early seedings. Later seedings often root on top of the soil or in crevices later filled by rains.

Fall seeding is not recommended for northern Illinois. In other areas, most species should be seeded no later than September 15 if fall seeding is done.

The rate of seeding on strip-mined soils should be about 20 percent greater than normal. This is necessary to insure quick establishment of a solid stand of forage. Good stands have been obtained by seeding a mixture at the rate of 17 pounds per acre.

Seeding Into Established Stands Often Unsuccessful

Different grass and legume species were seeded into existing stands of clover, weeds, and other vegetation on older spoil banks. The object was to see if more desirable mixtures could be established in this way. Most of the areas were not graded.

Generally the sweet clover and weeds were so rank that other species could not compete with them. Dense stands of sweet clover kept out all other legumes, while grasses seemed to come in only on slopes with eastern or northern exposures. Sweet clover, alfalfa, orchard grass, redtop, and timothy made the best growth of the species seeded into weedy areas.

The results obtained by seeding species into existing vegetation show that far better pastures are obtained by seeding fresh spoils than older spoils.

Grasses and Legumes Differ in Response to Fertilizers

Grasses responded very well to nitrogen fertilizer, but gave very little or no further response when other fertilizers were applied.

Legumes showed no response, either in stand or yield, to applications of a complete fertilizer (8-8-8) at the rate of 750 pounds an acre, plus 100 pounds of a mixture containing minor elements. Good prolific stands of legumes have been obtained without any added fertilizer. Therefore, it is assumed that the legumes are getting adequate nutrients from the soil material.

Good Results on Graded Areas

The pros and cons of grading strip-mined lands have been much debated. Two measures of the effects of grading — mechanical analysis and permeability — have already been discussed (pages 17 and 19). The ultimate measure, however, must be the growth made by forage plants.

Results of the experiments on leveled areas indicate that, where physical and chemical composition of the soil material has been favorable, grading has had several beneficial effects. A better seedbed can be prepared, less seed is required per acre, thicker stands have been obtained, weeds can be controlled more easily, and the excess forage material can be harvested as hay as well as pasture.

It has been noted that the top 2 or 3 feet of ungraded peaks have not been well covered with forage. Striking off to a width of 12 to 16 feet will do much to improve the stand of forage, both by flattening the tops and by shortening the length of slope.

Grass-Legume Mixtures Are Recommended

Permanent pastures are rarely made up of only one kind of plant. Better pastures usually result when a mixture of different grasses and legumes is seeded than when one species is seeded alone. These are some of the important reasons for using grass-legume mixtures:[5]

1. Legumes in the mixture, when properly inoculated, fix nitrogen and make it available to grasses. This is especially important on strip-mined soils, since they are low in nitrogen.

2. Mixtures usually give more complete coverage.

3. Production is more uniform throughout the season.

4. A mixture of grasses and legumes provides a more nearly balanced ration for livestock than either alone.

5. Mixtures of grasses and legumes often are more productive than either alone.

6. Grass-legume mixtures reduce the danger of freezing and heaving of legumes.

7. Grass-legume mixtures lessen the danger of bloat.

The choice of species depends largely upon the adaptability of the various plants to the strip-mined soil conditions. Palatability should also be considered. When planning a pasture program, it is well to seed different mixtures to provide grazing in the spring and fall, as well as in the summer. Some mixtures that have been successful are:

Species	*lb./A.*
Alfalfa	6
Red clover	3
Alsike	2
Ladino	1
Bromegrass	5
Orchard grass	3
Total	20

Species	*lb./A.*
Alfalfa	5
Lespedeza	5
Sweet clover	3
Orchard grass	3
Tall fescue	3
Total	19

Species	*lb./A.*
Birdsfoot trefoil	8
Red clover	2 to 4
Bromegrass or orchard grass	6
Total	16 to 18

Species	*lb./A.*
Alfalfa	10
Bromegrass	5
Kentucky bluegrass	3
Total	18

To establish a good grass cover on a strip-mine area takes at least two years and often longer. However, as the nitrogen content increases with the growing of legumes, the grasses become more prolific and may crowd out some legumes. An established strip-mine pasture was found to be 70 percent grasses, 20 percent legumes, and 10 percent weeds. As the legumes decrease, it is possible to reseed them without extra soil preparation. Livestock hoof tracks provide enough exposed soil material on the ridges for the legumes to "catch." Success has been obtained by seeding alfalfa, sweet clover, Ladino, and alsike clover in predominantly grass mixtures.

Three-year average yields of forage mixtures produced on strip-mined lands in Illinois from 1948 to 1951 are presented in Table 8. Alfalfa-grass and birdsfoot trefoil-grass gave the highest yields during this period (Fig. 12). These yields, 3.4 tons an acre for alfalfa-grasses and 3.3 tons an acre for birdsfoot trefoil-grasses, compare very favorably with yields obtained on treated farm lands. Burlison[2] reports that on Illinois farm lands yields of 2.8 tons of dry forage per acre may be expected from fertilized alfalfa-bromegrass; 2.5 tons from fertilized timothy-red clover; and 2.3 tons from fertilized lespedeza-grass.

Alfalfa and bromegrass plants grown in a mixed seeding on experimental plot in Fulton county. These two species are well adapted to mined lands and are valuable forages for livestock in central and northern Illinois.
(Fig. 12)

Table 8. — Yields of Forage Mixtures Produced on Strip-Mined Lands in Illinois, 1949-1951

Mixture	Year	Yield per acre	
		lb.	*tons*
Alfalfa and grasses	1949	7 624	3.8
	1950	7 067	3.5
	1951	5 425	2.7
	Average	6 705	3.4
Birdsfoot trefoil and grasses	1949	6 912	3.5
	1950	6 811	3.4
	1951	6 169	3.1
	Average	6 631	3.3
Mixed legumes and grasses	1949	3 477	1.7
	1950	4 702	2.4
	1951	4 948	2.5
	Average	4 376	2.2
Lespedeza and grasses	1949	4 086	2.0
	1950	3 350	1.7
	1951	4 186	2.1
	Average	3 874	1.9
Ladino and grasses	1950	5 968	3.0
	1951	5 611	2.8
	Average	5 790	2.9
Red clover and grasses	1949	4 195	2.1

LEGUME SPECIES ADAPTED TO STRIP-MINE SOILS

Over 35 different legume species or varieties were planted in the species adaptation trials. These trials were conducted over a wide area, with a range in latitude of about 300 miles. Some of the species well adapted in the southern sections were not so well adapted in the northern areas.

Alfalfa, Queen of the Legumes

Alfalfa is one of the best adapted species over all the strip-mine areas in Illinois. It is a potentially long-lived, deep-rooted perennial legume, requiring a fertile, sweet, well-drained soil. It takes advantage of the high calcium, phosphorus, potassium, and boron content of strip-mine soils and produces high-yielding, nutritious forage. The composition of alfalfa forage during seven months of the year is shown in Table 9.

Wilt-resistant, winter-hardy strains such as Ranger and Buffalo should be seeded on permanent strip-mine pastures. Southern strains are not winter-hardy in western and northern Illinois. Nonwilt-

Table 9. — Chemical Composition of Alfalfa During Seven Months of the Year

Location	Year	Month	No. of samples	N[a]	Protein	P[a]	K[a]	Ca[a]	Mg[a]	Mn[a]
				pct.	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*
Strip mine....	1948	May	3	3.11	19.4	.19	1.62	2.91	.54	.0090
Strip mine....	1949	May	6	3.17	19.8	.22	1.88	1.85	.58	.0028
Univ. of Ill.[b]..	1948	May	3	2.56	16.0	.13	1.34	2.00	.49	.0065
Strip mine....	1948	June	3	3.25	20.3	.23	1.35	2.07	.45	.0066
Strip mine....	1949	June	7	2.59	16.2	.19	1.67	1.27	.38	.0030
Univ. of Ill....	1948	June	3	3.06	19.1	.14	1.59	1.33	.47	.0070
Strip mine....	1948	July	6	2.97	18.6	.20	1.53	1.74	.59	.0064
Strip mine....	1949	July	6	2.70	16.9	.19	1.86	1.10	.39	.0023
Univ. of Ill....	1948	July	2	3.02	18.9	.20	1.44	1.78	.52	.....
Strip mine....	1948	Aug.	5	2.65	16.6	.19	1.46	1.73	.49	.0068
Strip mine....	1949	Aug.	2	3.40	21.3	.30	2.05	1.21	.36	.0014
Univ. of Ill....	1948	Aug.	3	3.35	20.9	.21	2.17	1.31	.40	.0070
Strip mine....	1948	Sept.	3	3.48	21.8	.28	1.78	1.77	.39	.0025
Strip mine....	1949	Sept.	4	3.39	21.2	.25	1.99	1.26	.31	.0021
Univ. of Ill....	1948	Sept.	1	2.81	17.6	.20	.81	1.46	.56	.....
Strip mine....	1948	Oct.	3	3.30	20.6	.22	1.81	1.67	.41	.0098
Strip mine....	1949	Oct.	5	3.99	24.9	.30	2.57	1.18	.35	.0015
Strip mine....	1949	Nov.	4	3.62	22.6	.24	2.01	1.30	.37	.0030
Univ. of Ill....	1948	Nov.	3	2.83	17.7	.17	1.35	1.24	.40	.0249
Strip mine....	1948	Aver.	...	2.99	18.7	.21	1.56	1.87	.49	.0066
Strip mine....	1949	Aver.	...	2.80	17.5	.21	1.71	1.35	.38	.0022
Univ. of Ill....	1948	Aver.	...	2.75	17.2	.18	1.25	1.75	.49	.0100

[a] N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; Mn = manganese.

[b] Figures for the University of Illinois location were obtained from H. J. Snider. The average figures were published in "Chemical Composition of Hay and Forage Crops," Ill. Agr. Exp. Sta. Bul. 518. 1946.

resistant strains, such as Kansas Common and Grimm, have died out in less than four years. Ranger and Buffalo seeded at the same time were still growing vigorously in 1952 (Fig. 13).

When alfalfa is seeded alone, the seeding rate is 12 to 15 pounds an acre. In mixture seedings, 5 to 10 pounds of alfalfa seed are recommended. A mixture of alfalfa and either bromegrass, tall fescue, or orchard grass makes excellent pasture on strip-mined areas.

Alfalfa is especially good for summer pastures. It provides succulent nutritious pasture during dry periods when the production of other forage species is normally limited. However, whenever alfalfa is pastured, precautions must be taken against bloat.[5]

On graded or leveled areas, alfalfa may be grown for hay. Alfalfa on strip-mined soils has given excellent hay yields the year after seed-

ing. Yields from pure stands in 1949 and 1950 averaged over 3.5 tons of hay per acre. One 1-acre plot which was predominantly alfalfa yielded over 6 tons of hay in 1950.

Seed production should also be considered on graded strip-mined areas. Although very little alfalfa seed is normally produced under Illinois climatic conditions, yields of alfalfa seed harvested on August 1, 1950, from three different strip-mined locations, ranged from 145 to 390 pounds an acre. The following year average seed yields for adapted varieties were near 60 pounds an acre. No first growth of hay was removed in either year. The much lower production in 1951 than in 1950 was probably largely due to the extremely wet season.

Spraying to kill harmful insects is advocated in the seed-producing program.

A vigorous plant of Ranger alfalfa grown on strip-mined soils. (Fig. 13)

Birdsfoot Trefoil — A Very Promising Legume

Birdsfoot trefoil is a long-lived, perennial legume that grows from 12 to 30 inches high, branches profusely, and forms a dense mat of vegetation when grown alone. It resembles alfalfa except that the stems are weak and tend to lodge. Birdsfoot trefoil will persist for many years even when closely grazed and tends to spread when grazed.

The Empire strain of birdsfoot trefoil is one of the most promising legumes to use for permanent strip-mined pastures. Most seedings made on Illinois farm soils are very slow in becoming established, largely because of competition from other ground cover. On newly mined strip-mine soils, however, the competition from other species is practically nil, and excellent stands have been obtained even though the seedlings are rather weak the first year.

For satisfactory results, seed must be inoculated with the *Lotus* strain of inoculant. About 6 to 8 pounds of seed per acre have given good stands. It is recommended that birdsfoot trefoil be seeded as the only legume along with one or two grasses or with 3 to 5 pounds of red clover plus the grasses.

Birdsfoot trefoil-grass mixtures were cut for forage (three or four cuttings a season) during the 1949, 1950, and 1951 seasons. During the first year, birdsfoot trefoil was the dominant species. Even in 1951, the fourth year after seeding, birdsfoot trefoil had withstood the competition from grasses better than the rest of the common legumes. The yields obtained for the three years with no supplementary treatments are as follows:

Year	*Yield per acre*	
	pounds	*tons*
1949	6 912	3.5
1950	6 811	3.4
1951	6 169	3.1

These yields are considered excellent. The chemical analyses of birdsfoot trefoil at various dates or cuttings during the year are presented in Table 10.

Clover (Trifolium) Species Excellent in Mixtures

The clover or *Trifolium* species used include medium red, mammoth, alsike, Ladino, common white, crimson, hop, and other less common species. With the exception of Ladino and common white clover these clovers are short-lived perennials. They are shallow- to medium-rooted.

Table 10. — Yield and Composition of Birdsfoot Trefoil on Different Sampling Dates During the 1949 Season

Sampling date	Yield per acre of dry matter	Protein	Calcium	Phosphorus
	lb.	*pct.*	*pct.*	*pct.*
May 5[a]	2 040	19.2	.82	.20
May 24	2 530	16.0	.88	.24
June 7[a]	3 078	16.1	1.44	.19
July 18	2 055	14.7	.95	.24
August 18	264	16.2	.97	.22
September 21	794	15.8	1.36	.23
October 18	.....	24.7	.96	.26
Total or average	5 643	17.5	1.05	.23

[a] Not used to figure total yield.

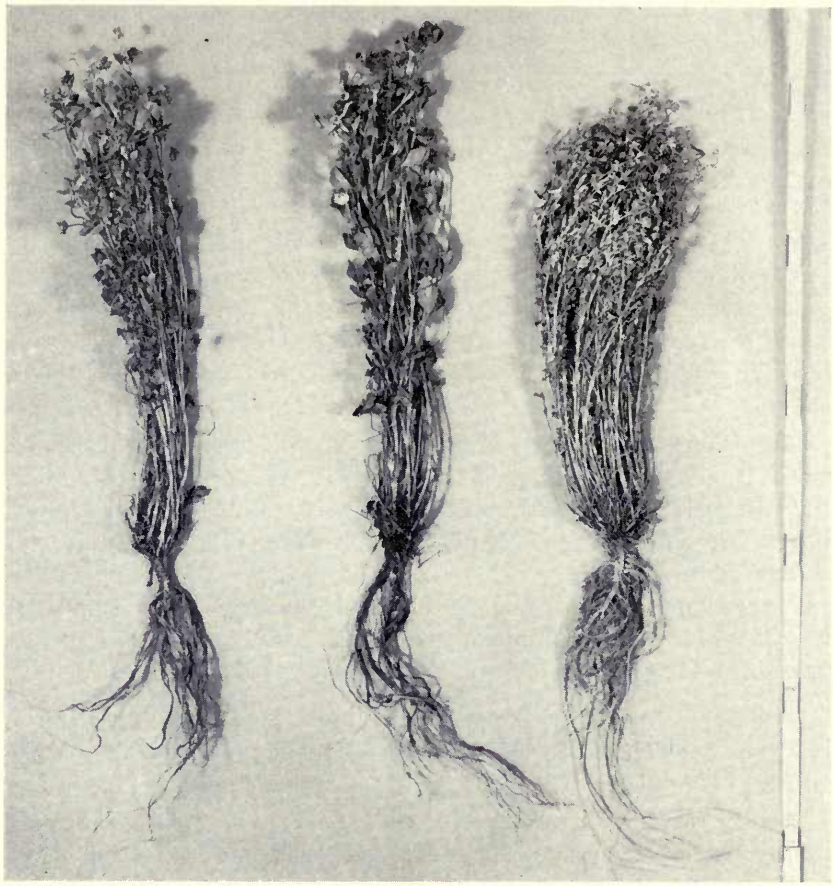
Red clover is a short-lived perennial with medium-deep branching roots. It gives excellent stands and growth on strip-mine soils the first two years but dies out rather rapidly. As a pasture plant it appears to be more palatable than alfalfa, but has a lower carrying capacity.

Red clover does best when seeded fairly early in the spring. When it is seeded alone, the seeding rate should be about 10 to 12 pounds an acre; in mixtures, smaller amounts are used. It is a good legume species to use with birdsfoot trefoil in a mixture (Fig. 14).

Mammoth red clover is coarser and taller than red clover, and is generally thought to be shorter-lived. Its growth on strip-mine soils is about the same.

Alsike clover is a shallow-rooted, rather leafy perennial, living from three to five years. The stems are weak and the plants lodge badly. It grows longer and blooms later than red clover. Although it resists cold better than red clover, it does not resist drouth so well. It will grow fairly well on moderately acid, poorly drained soils. When used in mixtures on strip-mine soils, it has given excellent results. It persists well in the valleys and low, moist areas on western and northern Illinois strip-mined lands.

Ladino clover is a giant-type perennial white clover that is larger, more vigorous, and more productive than common white clover. It is long-lived under favorable conditions but it does winterkill occasionally and a severe drouth also injures the stand. Ladino is more adapted to the older, more compact strip-mine soils than to the loose, recently mined soils. It does best in the valleys and on northern and eastern slopes. When it is seeded in mixtures, 1 pound of seed an acre produces a good stand.



Alsike, red clover, and birdsfoot trefoil plants (left to right) taken from plots in Fulton county, 1949. (Fig. 14)

Ladino forage is high in protein and minerals (Table 11). It is very palatable to all classes of livestock and produces relatively large gains. Since it is very succulent, however, it will cause bloat. This danger can be reduced by the same measures used to prevent bloat from alfalfa and other legumes on unstripped lands.[5]

White Dutch clover is a winter-hardy, short-lived perennial, similar to Ladino in its adaptation to strip-mined soils. When once established, it sets an abundance of seed. The plants disappear during drouths, but reappear from self-seeding afterwards.

Crimson clover, hop clover, and the rest of the *Trifolium* species tried in the adaptation tests have given very poor results.

Table 11. — Chemical Composition of Ladino Clover During Six Months of the Year

Location	Year	Month	No. of samples	N	Protein	P	K	Ca	Mg
				pct.	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*
Strip mine.....	1949	May	4	3.69	23.1	.27	2.34	1.82	.68
Univ. of Ill.[a].....	1948	May	2	4.44	27.8	.31	2.09	1.68	.47
Strip mine.....	1949	June	4	3.03	18.9	.23	2.05	1.60	.60
Univ. of Ill.....	1948	June	2	3.56	22.3	.27	1.95	1.45	.45
Strip mine.....	1948	July	2	2.79	17.4	.25	1.60	1.74	.59
Strip mine.....	1949	July	3	2.93	18.3	.24	2.17	1.47	.54
Univ. of Ill.....	1948	July	2	3.44	21.5	.26	1.90	1.56	.57
Strip mine.....	1948	Aug.	4	2.80	17.5	.21	1.29	1.57	.56
Strip mine.....	1949	Aug.	1	3.68	23.0	.31	2.28	.95	.50
Univ. of Ill.....	1948	Aug.	2	3.17	19.8	.24	1.88	1.41	.51
Strip mine.....	1948	Sept.	3	2.48	15.5	.22	1.12	1.30	.56
Strip mine.....	1949	Sept.	4	3.34	20.9	.24	2.22	1.07	.52
Univ. of Ill.....	1948	Sept.	2	3.67	22.9	.27	1.93	1.55	.50
Strip mine.....	1948	Oct.	4	3.21	20.1	.24	1.83	1.53	.48
Strip mine.....	1949	Oct.	3	3.95	24.7	.24	2.51	1.22	.47
Univ. of Ill.....	1948	Oct.	1	3.72	23.2	.23	2.10	1.40	.48
Strip mine.....	1948	Aver.	...	2.85	17.8	.23	1.46	1.42	.49
Strip mine.....	1949	Aver.	...	3.27	20.4	.24	2.18	1.46	.57
Univ. of Ill.....1946-48		Aver.	...	3.56	22.2	.31	2.24	1.61	.48

[a] Figures for the University of Illinois location were obtained from H. J. Snider.

Sweet Clover Makes Prolific Growth

Sweet clover has produced rank, volunteer growth on most strip-mine soils in Illinois. It is a widely adapted biennial legume with a high calcium requirement. In its early stages, it closely resembles alfalfa.

The following strains of sweet clover were seeded: common white (*Melilotus alba*); common yellow (*M. officinalis*); Evergreen, a strain of white sweet clover which blooms about two weeks later than the common white; and Hubam, an annual form of white sweet clover. The seeding rate was 12 to 15 pounds an acre.

All strains have generally given good results. However, in recent years the sweet clover weevil has seriously damaged both new seedings and old stands. Also, a root rot caused by *Phytophtora cactorium* killed or severely damaged second-year stands on several strip-mine areas in 1948 and 1949.

When seeded on mined areas in mixtures, sweet clover soon becomes the dominant legume unless damaged by weevil or rot. Grasses

will grow well with it when seeded at the same time. Sweet clover pastures have had outstanding carrying capacity. On strip-mined lands the first year's growth may be pastured lightly as early as July. Heavy grazing the first year usually results in severe winter damage. The second year's growth starts early and can be pastured rather heavily through June.

Sweet clover is not very palatable to livestock. In fact, one of the reasons that it soon crowds out other legumes is that animals will eat the other species first. Beef cattle will not gain as much on sweet clover as on other pastures.[5]

Lespedezas — Hot Weather Legumes

Korean, Early Korean, Kobe, Common, and Sericea lespedezas were seeded. The first four of these are spring-seeded annuals, generally growing from 6 to 18 inches tall. Sericea, a perennial, grows taller, has larger stems, and is more woody. Korean and Early Korean have proved best adapted to strip-mine soils.

All lespedezas are hot-weather plants, making very slow early growth. They provide late-summer and fall pastures. Pure stands of Korean are not ready for grazing until after July 1. Although lespedezas are drouth-resistant, deficient moisture does lessen their growth.

Lespedeza is highly recommended for strip-mined areas in southern Illinois. It produces good cover and yields the first year. Volunteer lespedeza has completely covered the ridges in many of these areas.

Satisfactory stands have been hard to obtain in western and northern Illinois, even with Early Korean strains. The plants are short, often appearing very yellow and chlorotic. These chlorotic plants, when examined, have been found to be poorly nodulated. Close grazing and early freezing often cause lespedeza to disappear from the mixtures in these areas. Reseeding is then necessary.

The three-year average yield from seven different locations in southern Illinois was 3,894 pounds or 1.9 tons of dry forage per acre. The amount of grazing depends upon soil productivity, seasonal conditions, particularly rainfall, and pasture management. Lespedeza seems less likely than most other legumes to cause bloat. It is a good fall and early-winter pasture for beef cattle.

Lespedeza bicolor, a shrub-type plant which provides feed for quail and other birds, was seeded. A Georgia strain produced a good stand and growth in southern Illinois.

Kudzu made excellent growth in a southern Illinois strip-mined area, covering the ridges almost completely in 3 years. (Fig. 15)

A close-up of the Kudzu shown in Fig. 15. The rather heavy bloom is unusual, as Kudzu does not ordinarily bloom and set seed this far north. (Fig. 16)

Kudzu — Vine Type Growth

Kudzu, a viney, rapid-growing, long-lived perennial that has been used in the southern part of the United States for pasture and erosion control, has given good results in the southern Illinois strip-mined section. Acclimated root crowns from a midwestern source proved adaptable to southern Illinois, but winterkilling was severe in western Illinois. When good survival is obtained, this species will cover the ridges rather completely in three to five years (Figs. 15 and 16). As pasturage, Kudzu has high feeding value.

PASTURE GRASSES ON STRIP-MINE SOILS

In general, grasses become established on strip-mine soils more slowly than legumes. Undoubtedly the main reason is the lack of nitrogen in the raw soil material. As the legumes grow and add nitrogen to the soil the grasses gradually become more competitive.

Orchard grass and tall fescues have produced good stands after two full growing seasons. Bromegrass and Kentucky bluegrass take a little longer.

The effect of alfalfa, sweet clover, and birdsfoot trefoil on the composition of orchard grass, Alta fescue, and bromegrass is presented in Table 12. This series of analyses shows that the grasses have a high protein content where grown in association with legumes. The grasses seem to get more nitrogen from sweet clover than from alfalfa or birdsfoot trefoil, although the differences are probably not significant. The grasses were in the bloom stage when sampled.

Table 12. — Chemical Composition of Orchard Grass, Alta Fescue and Bromegrass Growing in Alfalfa, Sweet Clover, and Birdsfoot Trefoil, June 2, 1950

Crop	N	Protein	P	K	Ca	Mg
	pct.	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*
In alfalfa						
Orchard grass	1.54	9.6	.26	2.46	.33	.16
Alta fescue	1.52	9.5	.27	2.48	.30	.18
Bromegrass	1.70	10.6	.25	2.48	.34	.19
In sweet clover						
Orchard grass	1.60	10.0	.23	2.47	.34	.18
Alta fescue	1.59	9.9	.30	2.20	.36	.17
Bromegrass	1.78	11.1	.22	1.75	.36	.11
In birdsfoot trefoil						
Orchard grass	1.66	10.4	.22	2.80	.31	.18
Alta fescue	1.57	9.8	.33	2.40	.28	.21
Bromegrass	1.42	8.9	.25	2.10	.32	.11

Bromegrass — A High-Producing, Palatable Forage

Bromegrass (smooth brome) is a long-lived, perennial, sod-forming grass with heavy roots of coarse stolons. A palatable, leafy grass, it matures rather late and remains green during the summer. It is very resistant to drouth and cold. In Illinois the southern strains of bromegrass mature earlier, are more aggressive, and yield somewhat better than the northern strains.[5] Bromegrass is generally thought of as requiring very fertile soils and being a heavy feeder on nitrogen.

This vigorous bromegrass plant grew on strip-mined land in western Illinois. (Fig. 17)

Bromegrass has done very well on strip-mine soils when seeded with a legume mixture in the spring. It grows slowly during the first year and does not reach full growth until at least the third year after seeding. Even when seeded alone, bromegrass has produced a good stand on the mined lands but the plants are yellowish and short. Good results have been obtained from August seedings into established vegetation.

On soil material that is high in fertility but heavy in texture, bromegrass has given as good results as any of the grass species. As the nitrogen content of the mined lands is built up through the use of legumes the grass grows vigorously (Fig. 17). The composition of bromegrass on different sampling dates during the year is presented in Table 13.

Table 13. — Chemical Composition of Bromegrass During Eleven Months of the Year

Month and location	N	Protein	P	K	Ca	Mg	Si[a]
January							
Southern Ill.	.98	6.1	.25	.50	.46	.10	3.44
Western Ill.	.60	3.8	.15	.40	.34	.12	4.56
February							
Southern Ill.	1.52	9.5	.17	.38	.61	.19	....
Western Ill.	.64	4.0	.14	.13	.40	.26	....
March							
Southern Ill.	2.00	12.5	.32	.63	.46	.26	....
Western Ill.	1.10	6.9	.24	.23	.40	.29	....
April							
Southern Ill.	2.82	17.6	.39	2.35	.26	.32	....
Western Ill.	2.60	16.3	.21	2.75	.45	.29	2.40
May							
Southern Ill.	1.80	11.3	.21	2.31	.33	.10	1.35
Western Ill.	2.06	12.9	.24	2.77	.32	.12	1.52
June							
Southern Ill.	1.46	9.1	.30	2.18	.37	.08	....
Western Ill.	1.59	9.9	.20	1.94	.36	.17	1.35
July-August							
Southern Ill.	....	....	...	....	...	...	....
Western Ill.	1.54	9.6	.21	1.63	.50	.29	2.32
September							
Southern Ill.	....	....	...	....	...	...	....
Western Ill.	2.28	14.3	.26	2.04	.71	.39	3.03
October							
Southern Ill.	1.89	11.8	.34	2.20	.40	.19	....
Western Ill.	1.66	10.4	.18	1.60	.99	.50	4.15
November							
Southern Ill.	1.81	11.3	.29	1.20	.59	.21	....
Western Ill.	1.36	8.2	.15	1.22	.59	.26	3.93

[a] Si = silicon.

Orchard Grass Quickly Established

Orchard grass is a long-lived, perennial, tall-growing bunch grass. In Illinois it is highly resistant to heat but is easily injured by cold.

It establishes itself rather rapidly on strip-mined lands and is therefore very useful in a pasture mixture. Spring seedings have been most successful in all sections. Some winterkilling was noted in western and northern Illinois after the rather severe winter of 1950.

Since orchard grass begins growth early in the spring, it can be grazed early. The young growth is succulent and palatable to cattle

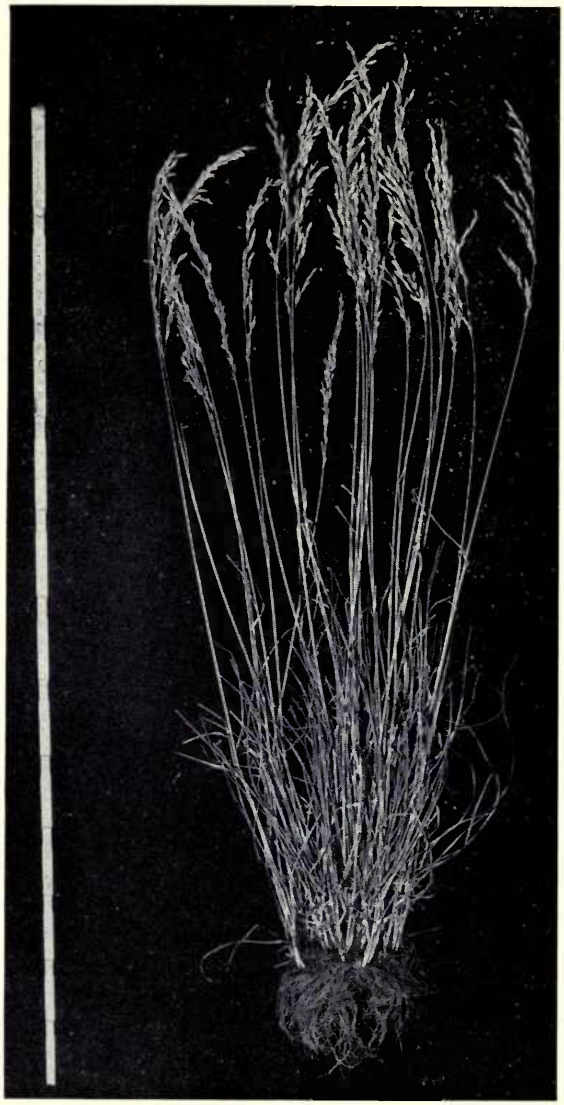
Table 14. — Chemical Composition of Orchard Grass During Eleven Months of the Year

Month and location	N	Protein	P	K	Ca	Mg	Si
January							
Southern Ill.	1.72	10.8	.25	.75	.58	.21	....
Western Ill.	.86	5.4	.15	.62	.93	.38	....
February							
Southern Ill.	1.90	11.9	.21	.55	.63	.35	....
Western Ill.	1.04	6.5	.18	.65	.67	.68	....
March							
Southern Ill.	1.80	11.3	.31	1.00	.53	.31	....
Western Ill.	1.18	7.4	.17	.47	.61	.50	....
April							
Southern Ill.	2.18	13.7	.30	2.90	.63	.43	....
Western Ill.	3.00	18.7	.24	3.20	.32	.29	....
May (early)							
Southern Ill. (May 2)	1.98	12.4	.25	2.85	.20	.21	1.89
Western Ill. (May 9)	2.29	14.3	.25	2.96	.25	.26	1.39
May (late)							
Southern Ill. (May 22)	1.46	9.1	.25	2.40	.31	.20	2.22
Western Ill. (May 29)	1.66	10.4	.25	2.50	.30	.19	2.22
June							
Southern Ill.	1.59	9.9	.32	2.40	.45	.31	2.79
Western Ill.	1.48	9.3	.24	2.30	.46	.27	2.36
July-August							
Southern Ill.	1.75	10.9	.29	2.27	.75	.40	2.36
Western Ill.	2.09	13.1	.28	2.93	.55	.43	2.46
September							
Southern Ill.	2.13	13.3	.26	2.10	.55	.38	4.35
Western Ill.	1.68	10.5	.26	2.14	.58	.47	3.31
October							
Southern Ill.	1.79	11.2	.39	2.20	.83	.39	3.79
Western Ill.	2.23	13.9	.32	2.40	.55	.38	3.11
November							
Southern Ill.	1.69	10.6	.24	1.25	.58	.31	....
Western Ill.	1.14	7.1	.05	1.30	.72	.37	4.69

and sheep. If the grass is not grazed closely, a seed stalk is produced early and the plant becomes coarse, fibrous, and unpalatable. The composition of orchard grass on different sampling dates during the year is presented in Table 14.

Tall Fescue — A Fast-Growing Grass

Meadow, Alta, and Kentucky 31 fescues were seeded. Alta and Kentucky 31 are characterized by rapid growth, leafiness, and spread.[5] The leaves are shiny, dark green, and usually stiff and coarse. The



Alta fescue plant grown on plot in southern Illinois. This grass furnishes good winter pasture in that part of the state. (Fig. 18)

foliage tends to become tough and unpalatable with age. Tall fescues are resistant to cold, heat, and drouth.

Meadow fescue was slower to become established than Alta and Kentucky 31, which established themselves rather rapidly on strip-

Table 15. — Chemical Composition of Alta Fescue During Eleven Months of the Year

Month and location	N	Protein	P	K	Ca	Mg	Si
January							
Southern Ill.	1.60	10.0	.25	1.22	.42	.18	3.33
Western Ill.	1.46	9.1	.12	1.22	.56	.27	2.04
February							
Southern Ill.	1.62	10.1	.20	.95	.50	.20	3.77
Western Ill.	1.44	9.0	.12	.58	.46	.49	....
March							
Southern Ill.	1.56	9.8	.22	1.08	.26	.32	....
Western Ill.	1.34	8.4	.15	.43	.53	.42	....
April							
Southern Ill. (green)	2.60	16.3	.30	3.00	.15	.28	1.97
Western Ill. (very dry)	.84	5.3	.10	.55	.25	.46	....
May							
Southern Ill.	2.20	13.8	.23	2.60	.41	.47	1.50
Western Ill.	1.89	11.8	.23	2.78	.40	.33	2.42
June							
Southern Ill.	1.33	8.3	.29	2.28	.32	.18	4.65
Western Ill.	1.53	9.3	.23	2.17	.28	.21	1.96
July-August							
Southern Ill.	1.62	10.1	.27	1.87	.32	.60	4.20
Western Ill.	2.10	13.1	.30	2.22	.29	.62	2.48
September							
Southern Ill.	2.62	16.4	.18	2.90	.20	.40	1.91
Western Ill.	2.01	12.6	.22	2.19	.23	.56	2.73
October							
Southern Ill.	2.16	13.5	.20	3.15	.20	.44	1.90
Western Ill.	2.07	12.9	.20	2.30	.20	.50	3.20
November							
Southern Ill.	1.82	11.4	.20	3.05	.20	.28	1.53
Western Ill.	1.66	10.4	.20	1.95	.23	.58	3.03
December							
Southern Ill.	1.76	11.0	.25	2.80	.15	.30	3.00
Western Ill.	1.48	9.3	.15	1.50	.20	.46	3.14

mined soils in southern Illinois (Fig. 18), more slowly in western and northern Illinois. Early spring seedings have been most successful.

Alta and Kentucky 31 make a good winter pasture for southern Illinois, as some of the basal leaves remain green throughout the winter in that area. These green leaves account for the rather high protein content of the forage in winter (Table 15).

Fescues are probably less useful in western Illinois than bromegrass and Kentucky bluegrass.

Kentucky Bluegrass Requires Fertile Soil

Of the four species of the genus *Poa* that were seeded, Kentucky bluegrass (*Poa pratensis*) is the most common. It is nutritive, withstands close grazing, forms a sod, provides good early pasture, and is extremely persistent and aggressive. It matures relatively early — in late May or early June — but then it becomes semidormant. Drouth and hot weather accentuate the semidormancy.[5]

Bluegrass is slow to develop a good stand, especially on the southerly and westerly exposed slopes of the ridges. This is probably due to the greater drouthiness and higher temperatures on these ridges. Even though Kentucky bluegrass establishes itself slowly, it is well adapted to the western and northern Illinois strip-mined sections and should be used.

The other species of the genus *Poa* seeded were Canada bluegrass (*Poa compressa*), big bluegrass (*Poa ampla*), and Canby bluegrass (*Poa Canbyi*). These species are not as common or as well adapted as Kentucky bluegrass.

Timothy — A Very Palatable Grass

Timothy is one of the best known hay grasses in the United States. It does especially well in a cool, humid climate and is well suited to clay and silt loam soils.[5] It is very palatable; all classes of grazing animals relish it. It is not as persistent in a mixture as other grasses. On strip-mine soils early fall seedings have given best results.

Redtop — Highly Resistant to Drouth

Redtop is adapted to all of Illinois. It has given good results on the strip-mined lands, being especially valuable for the rougher sites where soil fertility is rather low. Fall and spring seedings have been equally successful. Redtop is slower in becoming established than orchard grass or the tall fescues, but it is aggressive and fits well into mixtures. It is not considered as palatable as the other grasses discussed.

Ryegrass — Good Nurse Crop

Ryegrass is a short-lived perennial that forms a turf more quickly than any other grass commonly grown in Illinois. It is easily winterkilled however; and it does not withstand hot, dry weather. Consequently it disappears from mixtures in a relatively short time.

Its use on strip-mined lands appears to be very limited. It may be used to provide some grass pasture the first year and to act as a nurse crop for pasture seedings.

Tall Oatgrass — Best in Mixtures

Tall oatgrass is a tall-growing, long-lived, deep-rooted, very drouth-resistant perennial grass. It grows under about the same conditions of moisture and temperature as orchard grass except that it is not adapted to shade. It does not withstand continuous close grazing as well as other species. On strip-mined lands, it becomes established quite rapidly but has not formed a good dense stand. It is readily eaten by livestock. Because of shattering and difficulties in harvesting seed, its use is limited.

Grasses of Secondary Importance

Reed canary grass is best known as a grass for moist or wet land. It is also drouth-resistant. It has grown well on the ridges as well as in the valleys of most strip-mine areas. The leaves stay green all through the grazing season even though the plant matures seed. The pasturage is generally coarse and apparently not relished by livestock except during the early growth period.

Meadow foxtail does well on strip-mined land when seeded in the spring on easterly and northerly exposed slopes. It is considered a wet-land pasture crop, relished by livestock.

Wheatgrasses. Three species, crested wheatgrass, slender wheatgrass, and western wheatgrass, were used in the species adaptation trials. Western and crested wheatgrass have given fair results. The plants seem to persist even on the rather poor sites. It is not known how they would survive under grazing conditions.

Other cultivated grasses of secondary importance that have been seeded include Bermuda grass, Dallis grass, rescue grass, Rhodes grass, live grass, blue grama, side-oat grama, and Michels grass. Some plants of all these species except Rhodes grass came through the winter in good condition and also made good summer growth. However, most of these species will probably never be used extensively on Illinois strip-mined areas since the more common grasses are more available and are often more desirable.

Native grasses. The native grasses seeded include Indian grass, big bluestem, little bluestem, switch grass, and Canadian or nodding wild rye. They are very slow in becoming established, but once they are established, are very productive. They are valuable as summer pasture since they make 60 percent of their growth during this season. Established stands can best be maintained by pasturing during the summer and keeping the livestock off during the rest of the year.[5]

CHEMICAL ANALYSIS OF PLANTS GROWN ON STRIP-MINE SOILS

Forage Species

Samples of the various forage species were collected from the several spoil types at different locations and at various times of the year, and their chemical composition was determined. Most species were sampled at the bloom stage. Four hundred twenty-five legumes and 216 grass samples were analyzed during a 3-year period, 1948-1950 (Table 16).

Because of the large number of samples and the spread over 3 years' time, the values shown in Table 16 are considered reliable. However, it is well to keep in mind the factors that may cause variations in the chemical composition of forage. Composition may vary with species, stage of growth, climatic conditions, productivity, and mineral content of the soil. Internal or external injuries by insects, diseases, rodents, animals, or weather may also affect the composition of vegetation.

Furthermore, as brought out by Fuelleman,[4] comparable samples of the same species cut on any given date may vary considerably in percentages of nutrients. This does not imply errors in analysis or sampling, or differences due to soil heterogeneity. Rather, it is reasonable to assume that the forage itself may be undergoing changes brought about by the synthesis or desynthesis of material.

In discussing the chemical analyses of forages, Fuelleman[4] states that they are valuable as an aid in interpreting pasture experimental results as well as an indication of apparent palatability. They serve as a basis for comparing the nutritive value of forages. The quantity of protein does not necessarily indicate its quality or digestibility; however, most high-protein forages are apparently more palatable and nutritious than those containing less protein. Similarly, the percentages of phosphorus and calcium are indicators of nutritive value, although they are not necessarily entirely digestible by the animal.

On the basis of chemical composition, the quality of the forage species grown on strip-mined lands is excellent. As shown by Table 16, the nitrogen and protein content is high. This is especially true of the grasses that must depend mainly on the legumes for their nitrogen. The grasses were sampled at the prebloom to early-bloom stage of growth.

The phosphorus content of strip-mine forage is very high when compared with that of forage grown under Illinois farm conditions.[13]

Table 16. — Average Chemical Composition of Forage Crops Grown on Strip-Mined Land, 1948-1951

Species	No. of samples	N	Protein	P	K	Ca	Mg	Mn	Si
		pct.	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*
Legumes									
Alfalfa	61	2.92	18.3	.21	1.69	1.68	.42	.0044	.057
Red clover	45	2.65	16.6	.19	1.75	1.55	.42	.0087	....
Ladino	38	3.38	21.1	.27	1.98	1.48	.45	.0016	....
Alsike	39	2.91	18.2	.24	2.10	1.30	.54	.0144	....
Birdsfoot trefoil	55	2.70	16.9	.21	1.84	1.41	.52	.0076	....
Lespedeza	40	2.17	13.6	.23	1.00	1.09	.26	.0085	....
Sweet clover, 1st year	33	3.24	20.3	.23	1.43	1.53	.59	.0066	....
Sweet clover, bloom, 2nd year	31	2.99	18.7	.23	1.77	1.44	.44	.0075	....
Mammoth red clover	11	2.80	17.5	.20	1.87	1.51	.53	.....	....
Crimson clover	2	2.73	17.1	.16	1.52	2.14	.36	.....	....
White clover	8	3.10	19.2	.24	.97	1.75	.55	.....	....
Hubam clover	13	2.98	18.6	.28	1.26	1.38	.56	.....	....
Yellow trefoil	15	2.98	18.6	.23	1.96	1.66	.54	.....	....
Kobe lespedeza	10	2.05	12.8	.21	.90	1.03	.26	.....	....
Sericea lespedeza	10	1.85	11.6	.17	.82	.93	.24	.....	....
Kudzu leaves	7	2.70	16.9	.33	2.03	1.49	.39	.....	....
Austrian winter pea	1	3.88	24.3	.25	2.12	1.30	.30	.0010	....
Button clover	1	2.16	13.5	.22	1.05	1.24	.56	.0175	....
Lappacea	1	1.42	8.9	.18	.85	1.82	.60	.0360	....
Winter vetch	1	4.20	26.2	.31	2.45	1.13	.29	.....	....
Sanfoin	2	2.42	14.1	.23	1.88	1.11	.30	.....	....
Crown vetch	1								
Grasses									
Kentucky bluegrass	18	1.68	10.5	.23	1.41	.34	.20	.0093	1.19
Orchard grass	34	1.67	10.4	.26	2.60	.42	.28	.0244	2.15
Alta fescue	26	1.59	9.9	.26	2.10	.41	.27	.0200	2.32
Bromegrass	24	1.71	10.7	.22	2.28	.44	.30	.0154	1.89
Timothy	17	1.60	10.0	.23	1.95	.35	.18	.0092	1.00
Redtop	21	1.26	7.9	.19	1.55	.42	.22	.0160	2.08
Tall oatgrass	7	1.29	8.1	.17	2.30	.27	.17	.0103	2.93
Reed canary grass	10	2.14	13.4	.19	2.37	.50	.26	.....	....
Chewing's fescue	2	2.06	6.6	.11	1.48	.36	.11	.....	....
Meadow foxtail	1	1.66	10.4	.18	2.40	.38	.18	.....	....
Switch grass	7	.88	5.5	.17	.58	.55	.29	.....	....
Indian grass	5	.66	4.1	.10	.76	.38	.18	.....	....
Little bluestem	4	.71	4.4	.17	.74	.33	.13	.....	....
Big bluestem	5	.69	4.3	.16	.77	.30	.12	.....	....
Canada wild rye	7	1.57	9.8	.19	1.21	.58	.18	.....	....
Michels grass	1	1.84	11.5	.24	....	.36	.15	.0065	1.19
Side-oat grama	4	1.01	6.3	.07	.85	.41	.15	.....	....
Rhodes grass	4	1.36	8.5	.18	1.05	.41	.13	.....	....
Ryegrass	9	1.69	10.6	.20	1.88	.53	.24	.....	....
Western wheatgrass	6	1.34	8.4	.19	1.31	.40	.20	.....	....
Love grass	4	1.22	7.6	.12	.83	.24	.11	.....	....

Some have theorized that the phosphorus in the soil is not readily available at the high pH levels shown by the soil tests. If this were so, forages grown on mined lands would make poor growth and would probably be low in phosphorus. That the reverse is true indicates a very close association between the very high available phosphorus content shown by soil tests and the high phosphorus content of the forages.

In calcium, potassium, and magnesium content, the strip-mine forages compare very favorably with forages grown on Illinois farms.

Herbaceous Species

To obtain information about the nature of plants that can be found growing on strip-mined land, a plant collection was started in 1950. This collection did not include trees, but was predominantly of herbaceous plants. A total of 158 different species was collected, mounted, and identified. Fifty-three of these had been seeded and were considered to be artificially introduced, while the other 105 species were considered as being naturally introduced.

Thirty-four different plant families were represented. Those repre-

Table 17. — Composition of Common Weeds Growing on Strip-Mine Areas and on Farmland

Plant species	Type of area	N	Protein	P	K	Ca	Mg
		pct.	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*
Ambrosia artemissifolia	Strip mine....	2.41	15.1	.24	1.45	1.67	.37
(Common ragweed)	Farmland[a]....	1.44	9.0	.31	1.63	1.21	.32
Ambrosia ferfidia	Strip mine....	2.06	12.9	.37	2.10	2.10	.66
(Giant ragweed)	Farmland....	1.58	9.9	.32	1.56	1.75	.49
Chenopodium album	Strip mine....	3.10	19.4	.16	3.25	1.45	.89
(Lambsquarter)	Farmland....	1.39	8.8	.17	2.77	.66	.46
Polygonum hydrodiper	Strip mine....	2.50	15.6	.23	1.48	.98	.68
(Common smartweed)	Farmland....	.93	5.8	...	1.90	.60	.73
Aster multifloras	Strip mine....	1.42	8.9	.16	1.34	.73	.11
(Frost weed or many-flowered aster)	Farmland....	.94	5.9	...	1.27	.78	.17
Pastinaca sativa	Strip mine....	2.10	13.1	.38	1.40	1.01	.53
(Wild parsnip)	Farmland....	2.02	12.6	.29	2.19	1.10	.43
Rumex spp.	Strip mine....	2.17	13.6	.26	2.63	.88	.37
(Dock)	Farmland....	3.21	20.1	.39	2.80	.90	.87
Salidago serotina	Strip mine....	1.38	8.6	.18	2.25	.91	.18
(Goldenrod)	Farmland....	1.04	6.5	.23	1.80	.82	.17
Latuca scariola	Strip mine....	1.97	12.3	.26	2.31	.89	.17
(Prickly lettuce)	Farmland....						
Andropogan virginicus	Strip mine....	1.02	6.4	.16	.70	.26	.06
(Broom sedge)	Farmland....	.41	2.6	.10	.40	.20	.10

[a] Figures for farmland are from unpublished data by H. J. Snider.

sented most often were the Composite family with 19 species, the Grass family with 14 naturally introduced and 32 artificially introduced species, the Pea family with 5 naturally introduced and 21 artificially introduced species, and the Buckwheat family with 5 species.

Weeds are considered good indicators of soil fertility. Ten weeds most commonly found on strip-mine soils were analyzed to determine their chemical composition. When sampled, the weeds were all in the seed stage with the leaves still green. The entire plant above ground was used for analysis. The results, as shown in Table 17, indicate that the weed plants are getting adequate amounts of nitrogen, phosphorus, potassium, calcium, and magnesium from the soil material. Especially surprising is the high nitrogen content compared to that of farmland weeds.

ANIMAL GAINS FROM GRAZING STRIP-MINED PASTURES

Knowing the gains made by livestock on strip-mine pasture lands is important in determining the value of these lands. Results of grazing experiments show that strip-mine pastures can profitably be used for livestock production.

For three years, 1948-1950, 2-year old steers were used for the grazing experiments, and in 1951 sheep (ewes and lambs) were used.

Beef Cattle Experiments in Western Illinois

In western Illinois a lot of 10 steers was grazed on strip-mined lands while the same number were run on a woodland bluegrass pasture as a check or control group. On the strip-mine pasture sward, grasses made up from 65 to 70 percent, legumes from 20 to 25 percent, and weeds from 5 to 10 percent of the species represented. From 6 to 12 percent of the area was bare. Kentucky bluegrass was the dominant species, with bromegrass, redtop, timothy, sweet clover, red clover, and alsike adding variety to the mixture.

The average length of time on pasture was 176 days. A summary of the results obtained during the three grazing seasons in terms of average daily gains is as follows:

	Average daily gain, lb.			*3-year average*
	1948	*1949*	*1950*	*daily gain, lb.*
Lot 1 (strip-mine pasture).....	1.19	.98	1.56	1.24
Lot 2 (control pasture).....	1.29	1.10	1.17	1.19

The difference in average daily gain made by the two lots over the 3-year period is not statistically significant. The fact that the strip-mine pastures have been equal to the control pasture is important.

Beef Cattle Experiments in Southern Illinois

The grazing project was carried on in southern Illinois for two years, 1948-1949. The forage on the strip-mine pasture was predominantly sweet clover, red clover, lespedeza, orchard grass, redtop, tall fescue, and Kentucky bluegrass. This pasture had been established more recently than the strip-mine pasture in western Illinois. The control pastures in southern Illinois were improved grass-legume pastures.

A summary of the results obtained during the two-year grazing season in terms of average daily gains is as follows:

	Average daily gain, lb.		*2-year average*
	1948	*1949*	*daily gain, lb.*
Lot 3 (strip-mine pasture).....	1.06	.84	.95
Lot 4 (improved grass-legume pasture)	1.23	1.11	1.17

Herds of Beef Cattle Do Well

In addition to the detailed information obtained from the beef cattle feeding experiments, it was possible to measure the gains made by several lots of cattle grazing on strip-mined lands. In 1950, one herd of 95 yearling steers on pasture for 210 days made an average daily gain of 1.47 pounds. Another herd of 128 steers and heifers made an average daily gain of 1.4 pounds.

During the 1951 grazing season, 271 head of steers grazed a 500-acre strip-mine pasture range. Three different groups of steers were in this herd. The first lot included 112 two-year-olds. They weighed an average of 858 pounds per head when turned on pasture April 26. On September 20 they weighed 1,021 pounds, having gained an average of 163 pounds during the 147 days, or 1.13 pounds a day. A total of 18,626 pounds of beef was produced during the 147-day grazing period. After September 20 the 112 steers were fed ground corn and protein supplement while continuing to graze the strip-mined pastures. (This lot is pictured on front cover.)

Another lot of 95 yearling steers weighed 524 pounds per head when turned on pasture April 26. They weighed 794 pounds per head when taken off the pasture on November 17 after a 204-day grazing season. They had gained 270 pounds each, for an average daily gain of 1.32 pounds per head. Total beef production was 25,656 pounds.

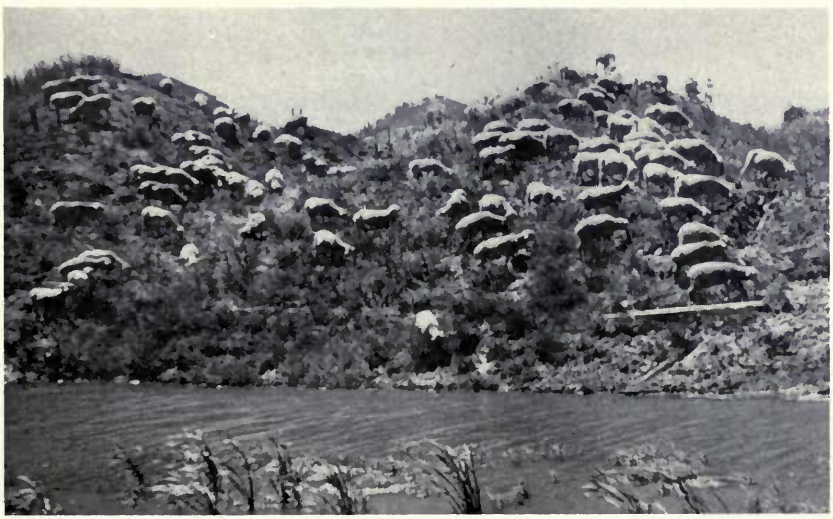
The third lot consisted of 64 yearlings purchased in August. They weighed 513 pounds per head and were in good flesh. On November 17, after a 103-day grazing period, they weighed 573 pounds. They had gained 60 pounds each for an average daily gain of .58 pound per head. They produced 3,860 pounds of beef in 103 days.

The entire herd of 271 head produced a total of 48,141 pounds of beef, or about 96 pounds per acre. In addition some credit must be given to the pasture during the time the 112 steers were on feed and still grazed the pasture. The pastures could have been stocked more heavily as a goodly amount of forage was not utilized. Therefore, it is concluded that at least 100 pounds of beef per acre could have been produced from the 500-acre pasture range.

Another herd of 219 yearling steers and heifers pastured on strip-mine lands made an average daily gain of 1.6 pounds during a 128-day grazing period. The forage was sweet clover, alfalfa, birdsfoot trefoil, bromegrass, and bluegrass. Fifteen of the top animals selected from this herd placed fourth in the "Short Feed Special Carlot Class" at the 1951 International Livestock Show in Chicago.

Experiments With Lambs and Ewes

In 1951 a flock of ewes and their lambs was turned onto a strip-mined pasture (Fig. 19). The pasture mixture was sweet clover, alfalfa, alsike, Ladino, bromegrass, Kentucky bluegrass, tall fescue, and timothy. The grazing season was rather short — 116 days. During that time the lambs made an average daily gain of .29 pound and the ewes an average daily gain of .07 pound. The gains made by the lambs varied from a low of .16 pound per day to a high of .37 pound a day.



This flock of ewes and lambs was used to study the value of forage produced on strip-mined lands. (Fig. 19)

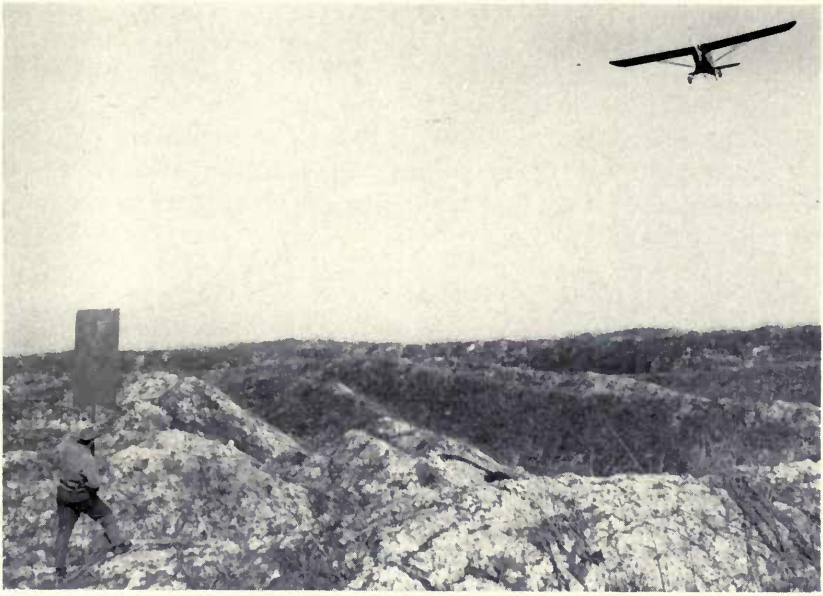
ECONOMIC CONSIDERATIONS

Methods and Costs of Establishing Forage Species

The mined areas have been seeded by hand, with a power seeder, and by airplane and helicopter (Figs. 20, 21, and 22). The length of time required to seed the areas by any method varies with the species seeded. The seed of some of the grasses is very lightweight and bulky, requiring more time to seed. Under good conditions it has taken 1 to 1½ hours to seed an acre by hand. Including all labor and supervisory

Hand seeding of strip-mined area. Under good conditions it takes 1 to 1½ hours to seed an acre by this method. (Fig. 20)

To seed a topped area with tractor seeder takes about 25 minutes. (Fig. 21)



The airplane has been used to seed mined areas in Illinois since 1946. The helicopter has been used for this purpose since 1949. (Fig. 22)

This illustrates a hazard of seeding by air on any but a perfectly calm day. Here, when a bromegrass-alfalfa mixture was seeded, the lighter weight bromegrass seeds drifted to the left side. (Fig. 23)

time, about 25 minutes an acre was needed to seed a prepared area by tractor seeder. In contrast, 75 to 125 acres an hour can be seeded from the air. Whatever method is used, complete and thorough application of a good seed mixture is of prime importance.

Total cost per acre varies greatly, depending on the kind of seed or mixture used, the seeding rate per acre, amount of labor, and type of equipment used. Costs ranged between $10 and $15 per acre during the 1951-52 season.

Preparation of Mined Areas

Several degrees of preparation are possible in developing a mined area for agricultural use. If the area is to be used for pasture, it must be accessible throughout. Some have found it expedient to provide access roadways only (Fig. 24). The making of roadways has varied greatly. Usually too few are made rather than too many.

Still others have prepared a strip-mined area by knocking off the tops of all ridges to a width of 12 to 16 feet with a bulldozer (Fig. 25). The advantages of this method are that the area is readily accessible for seeding either by hand or with tractor-mounted seeders, roadways are already made, management and control of livestock are easier, and the scenery or skyline is improved.

A strip-mined area developed for pasture. Ridge in foreground has been topped and can serve as an access road. (Fig. 24)

All ridges have been topped to a width of 12 to 16 feet with a bulldozer. The area is now easily accessible. (Fig. 25)

The highest degree of preparation is to grade the whole area so that farm equipment can be driven over it. This permits land to be used for other purposes than just pasturing.

Since trees grow faster on ungraded than on graded strip-mined lands,[9] it has been stated that grading strip-mined lands harms plant growth. Limited experiments with grasses and legumes on graded mined lands, however, have generally given good results (page 28). An acre of alfalfa-grasses on a leveled area in 1950 produced over 12,000 pounds of baled hay. Even small grain crops such as rye and wheat grew well when nitrogen was applied. This indicates that good production of agronomic species is possible on graded strip-mine areas, provided the physical texture of the soil material, soil reaction, and nutrient content are favorable. In several areas of Illinois the high percentage of loess and till material, the low percentage of rock, the favorable chemical composition of the soil material, and the present methods of mining appear to make grading feasible.

Several small areas in the mined lands of Fulton and Knox counties have a rather thick stratum of muck-type material in the overburden (Fig. 26). The organic-matter content of this material is very high, averaging between 7 and 8 percent. Where this material is present and the area is graded, the soil is very loose and friable and can immediately be used for tillable crops. Soybeans and wheat seeded on such areas have yielded 33 and 25 bushels per acre, respectively.

Grading has been rather extensively practiced in Illinois since 1950. According to the Illinois Coal Strippers Association, as of January 1, 1952, 939 acres of mined land had been graded so that

Strata of muck-type material are found in the overburden in several areas of the western Illinois strip-mining area. (Fig. 26)

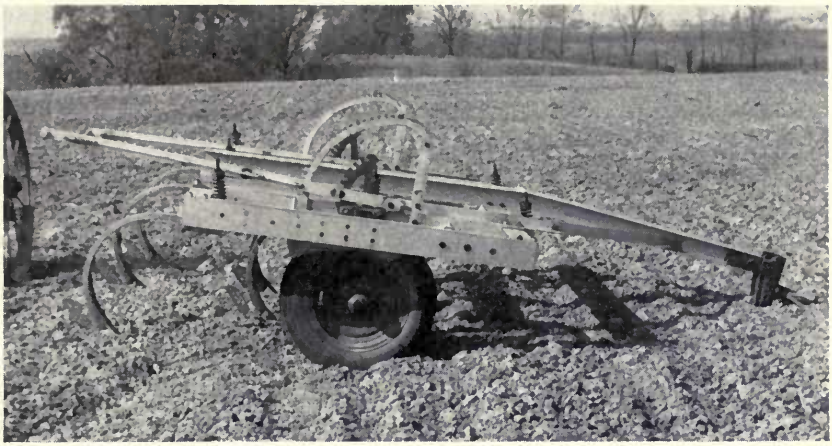
farm equipment could be driven over the whole area. One of the largest contiguous graded areas, comprising about 470 acres, is in western Illinois.

Problems connected with grading. Grading has created several problems that as yet are unsolved. Drainage is one of the most severe. Often slight depressions caused by unequal settling fill with water and drown out the growing crop. Either surface or internal drainage of these depressions is necessary for the area to be completely and satisfactorily reclaimed.

Rocks in the graded area present another problem. Sometimes it can be solved, at least partially, by picking up the rocks and hauling them away. Large rocks in the plow layer can damage such tillage equipment as disks and drills. The maximum amount of rocks that can be in the surface layer without making the grading job impractical is not known. More research is needed on this question, as well as on the types of tillage and seeding machines that will give the most satisfactory results (Figs. 27 and 28).

Returns Depend on Type of Utilization

The gross returns that can be expected from agronomic species on strip-mined lands are determined partly by the degree of preparation. If the areas are developed by providing roadways or by topping the ridges, permanent pasture is the only feasible use. Gross returns



A heavily built field cultivator is needed to work mined areas. (Fig. 27)

therefore depend upon the gains made by the animals grazing the area and upon the prices received for livestock and livestock products.

Graded or leveled areas, however, may be used for grain and hay production as well as for grazing. The potential returns from such areas would depend not only on the price of livestock but also on the yield and price of grain and hay.

For example, if each steer on a pasture gained an average of 1.25 pounds per day for 176 days, then 220 pounds of beef would be

A culti-packer type of seeder has been used on mined lands because it makes a firm, fine seedbed and covers the seed. (Fig. 28)

produced per steer. If it is assumed — and there is some basis for the assumption — that the carrying capacity of a good strip-mined pasture is ½ head or animal unit per acre per year, then each acre of the pasture has produced 110 pounds of beef per year. If the beef were sold at 28 cents per pound, the gross return would be $30.80 per acre. What returns could be expected from a leveled area growing alfalfa hay? Assuming a yield of 3.4 tons an acre (Table 8) and a value of $15 a ton, the gross returns would be $51 per acre.

One way of utilizing strip-mined land is to organize the mined and unmined land into farm units. The costs and problems of establishing a profitable farm unit can be greatly reduced by following a planned, long-range program. Two things need to be done in such a program: First the lands that do not contain minable coal and which make up a part of every mine property must be improved and maintained as soon as control is acquired; and, second, the mined land must be developed progressively each year and utilized as soon as it is ready to produce. Thus, the mined land and surrounding land can be incorporated into a well-organized farm unit capable of concentrated and continued use.

More mined acres are being used each year. Of the 54,000 acres strip-mined in Illinois as of January 1, 1952, approximately 35,000 acres or 64 percent had had some reclamation work. Twelve thousand acres had been reforested with 12,000,000 trees, and 2,500 acres had been covered by volunteer tree growth. Sixteen thousand acres had been seeded to grasses and legumes. Of these 16,000 acres, 11,000

Hampshire hogs grazing unleveled mined areas. Such land can be combined with unmined areas into a profitable farm unit. (Fig. 29)

acres were being actively used for pasture, hay production, small grains, or orchards. Thirty-five different farm units were utilizing the 11,000 acres.

Control of Undesirable Vegetation

Controlling volunteer trees, shrubs, and other undesirable vegetation is very important in maintaining a good pasture area. On common pasture lands this can be done by clipping with a mower. On ungraded strip-mine ridges, however, the use of a mower is impossible.

When the control of undesirable vegetation on strip-mine lands becomes a problem, the cause is often faulty management. If the area is not seeded and utilized before volunteer growth becomes established, the productive capacity of the pasture is reduced. To restore the productive capacity, the undesirable vegetation must be removed and controlled. The slow, expensive method of hand cutting often does not destroy the undesirable species permanently since many broad-leaved species will sprout vigorously and persistently. Such chemicals as a 2,4-D — 2,4,5-T mixture, can be used effectively to control the

Chemicals such as a 2,4-D — 2,4,5-T mixture are effective against volunteer woody growth and noxious weeds. The bark on dead trees begins to peel off within a year after treatment. (Fig. 30)

volunteer woody growth and noxious weeds (Fig. 30). The cost of control methods differs with each location but depends largely upon previous management.

Agricultural Uses of Strip-Mine Lake Water

The mining operation leaves excavations that will fill with water to form lakes. By using earthen dams and diverting drainage, lakes have been made that are over 2 miles long and 200 feet wide (Fig. 31). These lakes are used for recreational purposes such as swimming, boating, and fishing, and as wildlife habitats. In summer cattle, sheep, and other livestock use the water directly. In winter the water is pumped to the livestock headquarters. This eliminates the necessity for digging wells or making ponds to provide the water needed for large herds of livestock. The lakes are also an excellent source of water for irrigation purposes. Alfalfa and commercially grown gladiolas have been irrigated from such lakes.

Lakes made by strip-mining are used for recreation, for watering livestock, and for irrigation. (Fig. 31)

A study of the quality of strip-mine lake water in Illinois was made by C. D. Hoover in 1946.[7] He found that most of the water would be classified as hard. Over 85 percent of the samples analyzed had an alkaline reaction. The average pH value of the samples was 7.8 and the average alkalinity was 116 parts per million. Information from this study indicates that the quality of strip-mine lake waters is very satisfactory for livestock and irrigational purposes.

SUMMARY

Formal research on the reclamation of strip-mined lands in Illinois was begun in 1946. Characteristics of the soil material, species adaptation, and the utilization of strip-mined lands have been investigated.

Mined lands have been classified on the basis of acidity and texture of the soil material. Both the material in the overburden and the method of mining affect the land classification. Of more than 2,000 soil samples tested, 73 percent had a pH above 7.0 and 90 percent a pH above 5.5. The soil material was found to be very high in available phosphorus and high in available potassium. The texture is predominantly silty clay loam, silty clay, or clay loam. Permeability was found to be rapid on the ridges and moderate on the graded areas.

Grasses and legumes can be successfully established on most of the strip-mined lands in Illinois. Alfalfa, birdsfoot trefoil, sweet clover, lespedeza, bromegrass, orchard grass, Kentucky bluegrass, and tall fescues are the most desirable species that can be established. The forage produced is high in nitrogen, phosphorus, calcium, and potassium.

The three-year average daily gain of steers on strip-mined pastures in western Illinois was 1.24 pounds, compared to 1.10 pounds for the control steers that grazed on unmined lands. In southern Illinois steers grazing strip-mined areas made a two-year average daily gain of .95 pound, while steers on improved grass-legume pasture on unstripped land gained 1.17 pounds. During the 1951 season, 29 lambs made an average daily gain of 0.29 pound on strip-mine pasture.

Various methods of sowing and of preparing the mined land are possible. Seedings have been made by hand, with power seeders, and from the air. These methods have been used on undisturbed ridges, topped ridges, and more completely graded areas.

The most concentrated and continued use of mined land can be made by incorporating it with surrounding farmland into a well-organized livestock farm unit. Such use has proved profitable even in a period of lowering prices.

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