QUANTIFYING TOPOGRAPHIC DIFFERENCES BETWEEN PREMINING AND RECLAIMED LANDSCAPES AT A LARGE SURFACE COAL MINE[1]

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Abstract: Premining and reclaimed landscapes on 2,300 acres were compared quantitatively at a surface coal mine in western North Dakota. Weighted average slopes were determined by calculating acres in each slope class (0% to 3%, 3% to 6%, 6% to 9%, 9% to 15%, and >15%) and dividing by the total number of acres. Weighted average slopes were 3.8% and 3.0% for all premining and reclaimed lands respectively. Weighted average slopes were 2.7% and 2.1% for premining and reclaimed croplands respectively. Reclaimed native rangeland slopes are 5.5% compared to 7.0% premining. The acreage of native rangeland with >9% slopes decreased more than 50% during reclamation. For all mined lands there is 25% more reclaimed land with 0% to 3% slopes and 25% less reclaimed land with >6% slopes than before mining. Topographic changes caused by surface mining and reclamation enhance soil conservation, moisture retention, and agricultural productivity. A cross-sectional profile had 26.8 and 15.5 premining and reclaimed land up-down gradient changes per mile respectively, indicating reclaimed land is less diverse than it was prior to mining. Slope class map units average 3.5 and 4.4 acres respectively on premining and reclaimed lands, further indicating reduced diversity. Landscape improvements conflict with regulatory diversity requirements to determine reclamation success.

Additional Key Words: reclamation, topography, surface mining

Introduction

Surface coal mining affects thousands of acres annually across the United States. Reclamation success is directly related to characteristics of the reclaimed landscape. This paper quantifies differences between premining and reclaimed landscapes at a large surface coal mine in the Northern Great Plains.

Topography is an important variable in the stability and productivity of agricultural lands. Steeply sloping and convex hillslopes are more prone to runoff and erosion than gently sloping and concave hillslopes. Researchers have made recommendations for reconstructing landscapes following surface mining. The Surface Mining Control and Reclamation Act requires that mined land be returned to "approximate original contour" or AOC. Brenner and Steiner (1987) and Gregory et al. (1987) state that grading spoils to AOC requirements may actually be detrimental to a reclaimed landscape; they suggest landscape improvements be made during spoils grading. Vogel (1987) recommends slopes of about 2%, stating that constructing broad flat areas should be avoided, as differential settlement could result in poor drainage. Bauer et al. (1976) recommend mine spoils be graded to slopes less than 5%. Stiller et al. (1980) recommend reducing slope lengths on reclaimed lands. Richardson and Wollenhaupt (1983), Law (1984) and Schaefer et al. (1979) stress the importance of slope shape, and favor creation of concave slopes in reclaimed landscapes.

Research has been conducted to quantify landscape characteristics and their effect on erosion and agricultural production. Lentz et al. (1993) modeled a relationship between certain landscape parameters and ephemeral gully erosion on unmined cropland. Halvorson and Doll (1991) developed a topographic slope factor to quantify the topographic effects of landscape on surface water runoff and runon. This factor correlated

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closely with wheat yields in western North Dakota. Schroeder and Carter (1992) found this slope factor equally useful on reclaimed lands.

Little work has been conducted to quantifiably compare premining and reclaimed landscapes. Gregory et al. (1987) addressed the current subjectivity associated with evaluating reclaimed landscapes by suggesting several quantitative measures, including frequency distribution of slopes.

Probably the greatest stumbling block associated with quantifying a comparison between premining and reclaimed landscapes is that landforms do not lend themselves to normal randomized sampling techniques and statistical comparisons of sampled landscape parameters. An evaluation of entire land tracts provides the best comparison between premining and reclaimed landscapes.

Location and Mining Operations

The Freedom Mine, located about 90 miles northwest of Bismarck, N.D., is owned and operated by The Coteau Properties Company, a subsidiary of the North American Coal Corporation. Lignite coal mining began in 1983, and current production is about 15.6 million st/yr. From 400 - 700 acres are mined and reclaimed annually. About 3,000 acres have been reclaimed to date.

The undisturbed landscape is characterized by mostly gently rolling and well-drained croplands used for dryland wheat production. About 25% of the mine is composed of steeply sloping mixed grass native rangeland used for livestock grazing. Most areas used for grazing have slopes too steep and soils too shallow to support grain production.

Earth moving for mining is accomplished through the use of tractor-scrapers, bulldozers, a truck-shovel fleet, and two 110-cu-yd class draglines. Spoils are regraded immediately behind active pits, and topsoil and subsoil are respread and seeded immediately after regrading. Reclaimed lands are currently being used for hay and grain production and livestock grazing.

Comparison of Premining and Reclaimed Landscapes

About 2,300 acres of reclaimed land were evaluated and compared with the same lands prior to mining. Slopes were compared by class: 0% to 3%, 3% to 6%, 6% to 9%, 9% to 15%, and >15%. The acreage of each slope class was measured for premining and reclaimed croplands, rangelands, and all lands (croplands, rangeland, and small tracts of industrial and shelterbelt land uses).

Because values represent the entire field or population of premining and reclaimed lands, no statistical analyses are applied. Differences between premining and reclaimed lands are absolute for all land considered here.

A weighted average slope for each type of land was determined by multiplying the midpoint of each slope class by the number of acres in that class, and dividing by the total number of acres evaluated. A 15% value was used for slopes greater than 15%.

Weighted average slopes decreased for all three categories of land (table 1). All categories of land have lower average slopes on reclaimed land compared to premining land. The greatest decrease was on reclaimed rangeland. These slope reductions represent landscape improvements positively affecting water runoff, erosional stability and ultimately agricultural productivity.

Table 1. Comparison of premining and reclaimed lands at the Freedom Mine.

	Slope class					
	0% to 3%	3% to 6%	6% to 9%	9% to 15%	>15%	Average weighted slope by percent
Total lands reclaimed (2,294.6 ac.):						
Premining acreage	1,244.1 (54%)	709.4 (31%)	181.7 (8%)	107.3 (5%)	52.1 (2%)	3.77
Reclaimed acreage	1,557.3 (68%)	479.5 (21%)	175.2 (8%)	71.9 (3%)	10.7 (0%)	2.99
Croplands reclaimed (1,447.6 ac.):						
Premining acreage	960.5 (66%)	434.0 (30%)	38.1 (3%)	15.0 (1%)	0.0 (0%)	2.66
Reclaimed acreage	1,185.2 (82%)	247.6 (17%)	13.9 (1%)	0.9 (0%)	0.0 (0%)	2.08
Native rangeland reclaimed (405.6 ac.):						
Premining acreage	98.0 (24%)	116.9 (29%)	91.0 (22%)	54.5 (13%)	45.2 (11%)	6.97
Reclaimed acreage	119.2 (29%)	119.3 (29%)	119.7 (29%)	40.3 (10%)	7.1 (2%)	5.48

Slope class acreage changes further demonstrate landscape improvements. For all mined lands there is an increase in the acreage with 0% to 3% slopes, from 1244 acres prior to mining to 1557 acres after mining and reclamation (fig. 1). This is a 25% increase in the amount of land with most favorable slopes. This change correlates with decreased amounts of land having steeper slopes. About half of all lands prior to mining had slopes greater than 3%, but after mining and reclamation only a third of all lands have slopes greater than 3%.

The same trend is evident for mined and reclaimed croplands, where shallow slopes are especially beneficial (fig. 2). The amount of cropland with 0% to 3% slopes increased 23%, from 960 acres premining to 1,185 acres following mining and reclamation. Again, there are subsequent decreases in acreage with steeper slopes. Following reclamation, the amount of cropland with slopes greater than 6% has decreased to less than a third of its premining acreage.

Both premining and reclaimed native rangeland have steeper slopes than croplands, although reclaimed rangelands also exhibit favorable landscape changes (fig. 3). Rangeland with 0% to 3% slopes increased 20%, from 98 acres premining to 119 acres following mining and reclamation. Changes in rangeland acreage with 6% to 9% slopes are very similar. The amount of rangeland with slopes greater than 9% decreased from 100 acres premining to 47 acres following mining and reclamation. This is more than a 50% decrease in the amount of rangeland with unfavorably steep slopes. Not reflected in described values are badland type rangelands, many of which were impassable with four-wheel drive trucks or farm tractors prior to mining, either because of their steep slopes or very rocky conditions. These have been eliminated entirely, further improving the quality of this land for livestock production. Many rangeland areas that were previously too steep or rocky for farm equipment can now be cut for hay. Although they may not qualify for use as cropland, their economic potential has increased tremendously over premine conditions.

Decreasing slopes increases soil moisture retention, decreases erosion, and enhances crop and forage productivity. It also provides more favorable conditions for livestock grazing. These positive landscape changes are accompanied by a decrease in landscape diversity caused by mining and reclamation.

Topographic diversity has a profound effect on vegetative diversity, for which standards must be met to achieve bond release on reclaimed rangelands. High vegetative diversity standards may be difficult to attain if rangelands are reduced in slope and improved for productivity. Thus productivity and diversity standards for successful reclamation may be in conflict.

Several vegetative diversity indices are available. However, there are no such diversity indices currently in use for evaluating and comparing landscapes. Premining and reclaimed landscapes can be compared graphically and quantitatively through the use of topographic maps and cross-sectional profiles (figs. 4-5-6). A cross-sectional profile approximately 7,500 feet long was developed along the same northwest-southeast line through premining and reclaimed rangeland. Reduced slopes, combined with fewer changes in slope and up-down gradient, results in a reclaimed landscape less diverse than before mining. The number of hilltops and valley bottoms per length of profile line relate directly to the total number of up-down gradient changes and can be used as a quantitative measure of landscape diversity. For the 7,500 feet long profile described here, there were 38 hilltops and valley bottoms (gradient changes) prior to mining, and 22 following mining and reclamation. This equates to 26.8 gradient changes per linear mile prior to mining, compared with 15.5 per linear mile for the same land after reclamation. This 40% reduction in the number of gradient changes quantitatively describes a reduction in landscape diversity.

Another measure of landscape diversity is the total number of discrete slope class map units in a given area. Two areas of equal size may have the same weighted average slope. However, one might have a more diverse topography if the area were composed of several discrete, discontinuous map units of different slope classes (fig. 7). Slope class map unit analysis was conducted for 1,777 acres at the Freedom Mine. There were 502 premining slope

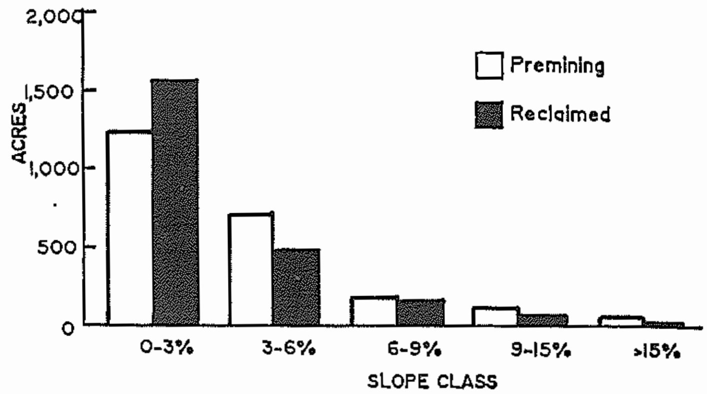

Figure 1. Comparison of premining and reclaimed land slope classes for all lands at the Freedom Mine.

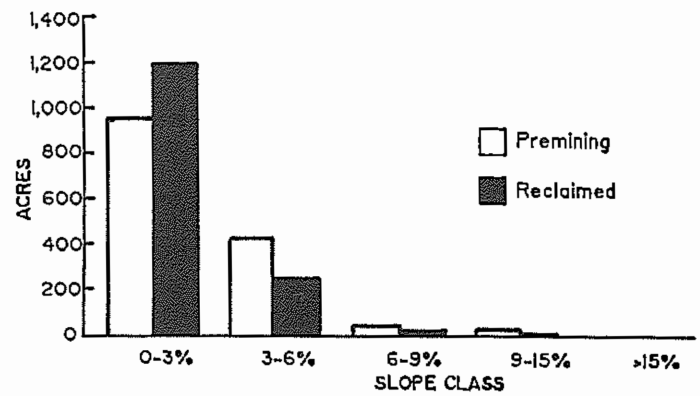

Figure 2. Comparison of premining and reclaimed land slope classes for cropland at the Freedom Mine.

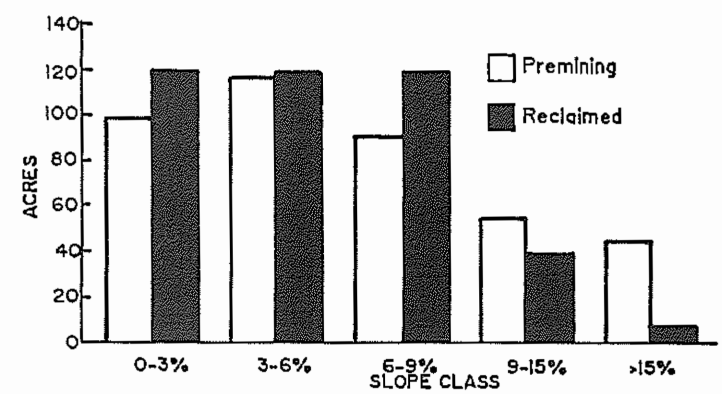

Figure 3. Comparison of premining and reclaimed land slope classes for native rangeland at the Freedom Mine.

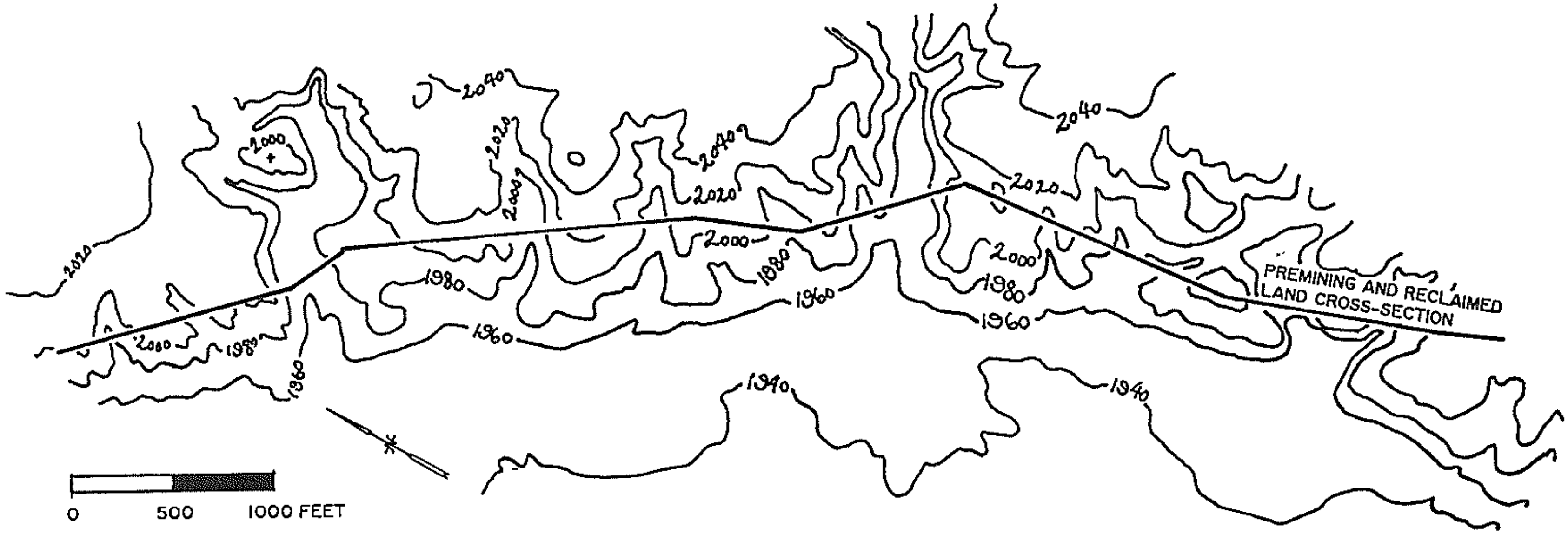

Figure 4. Topographic map of premining native rangeland.

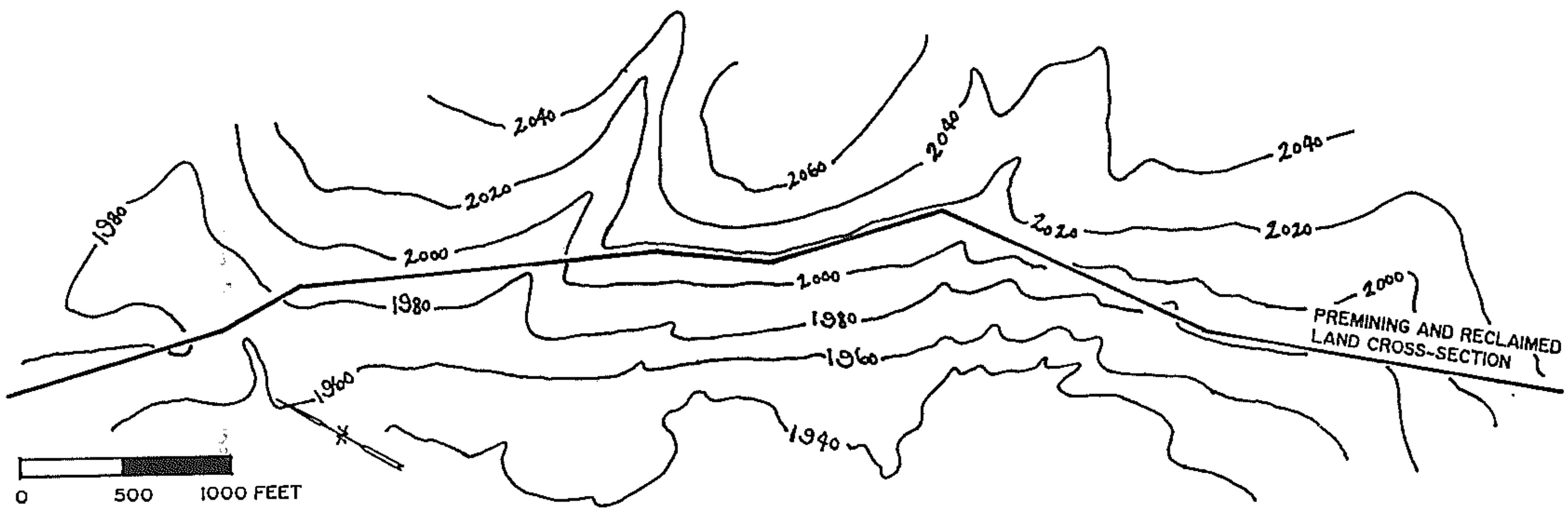

Figure 5. Topographic map of reclaimed native rangeland; this is the same area shown in Figure 4.

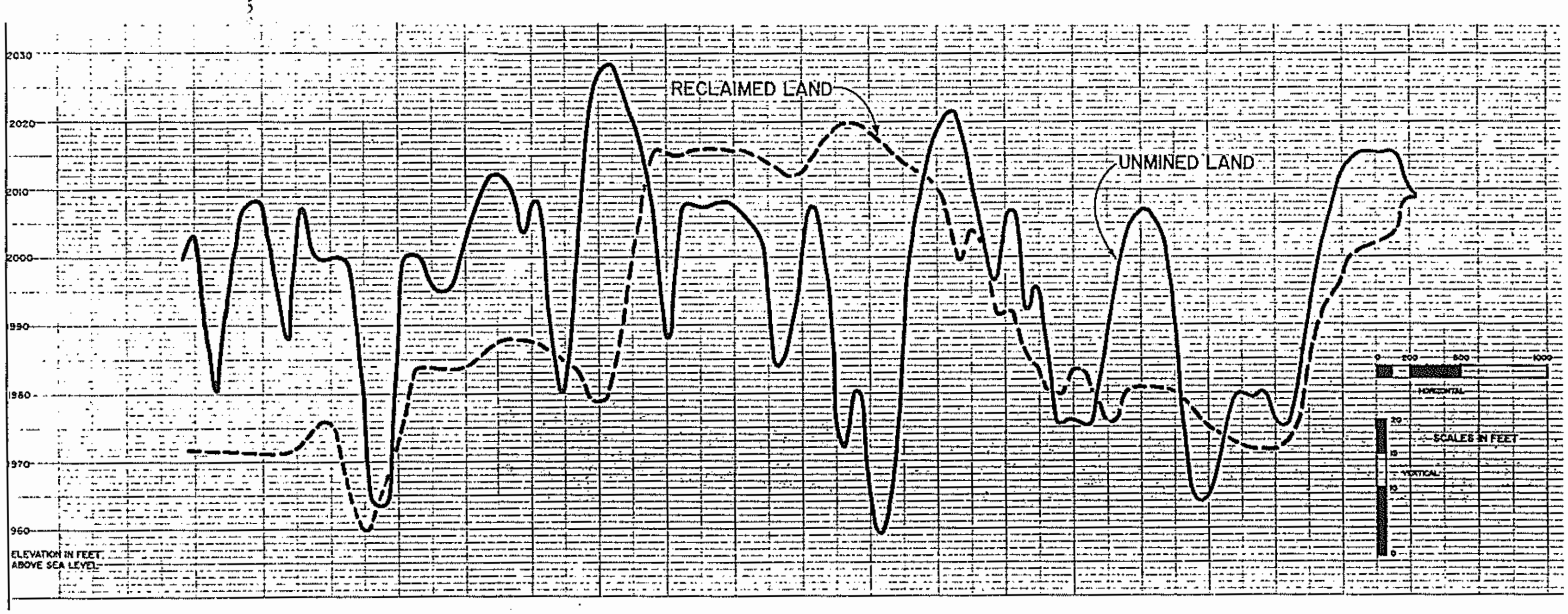

Figure 6. Cross-sectional profiles before and after mining and reclamation.

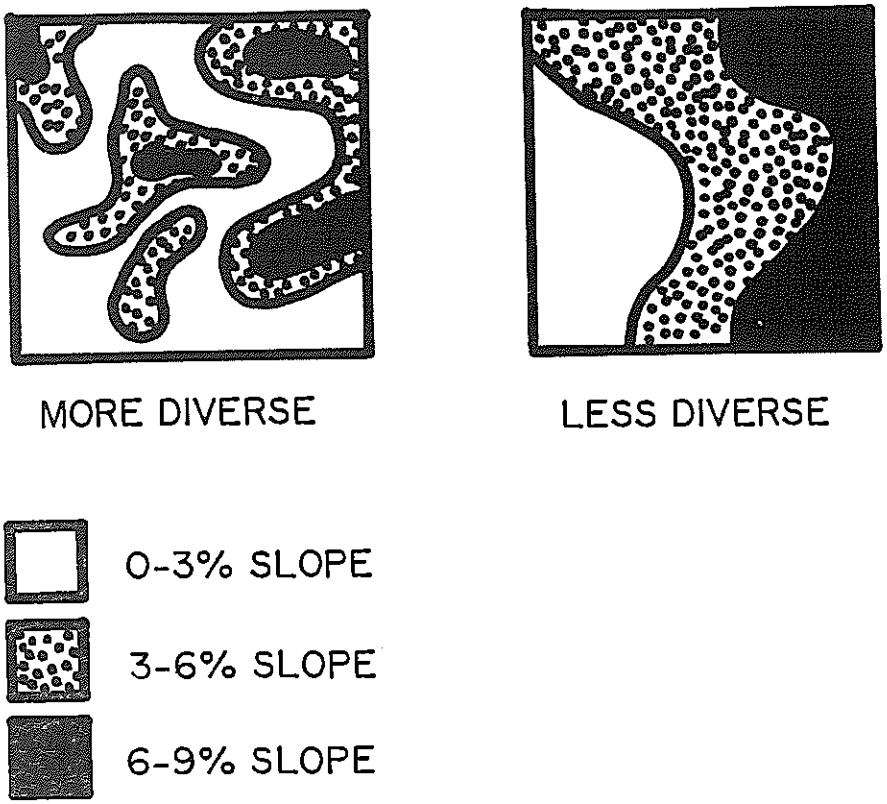

Figure 7. Comparison of two areas with the same weighted average slope, but different slope map unit distributions make one area more topographically diverse than the other.

class map units, with an average 3.54 acres per map unit. After mining and reclamation, there are now 408 slope class map units, with an average 4.36 acres per map unit. This is a 19% decrease in the number of discrete slope class map units and a corresponding 23% increase in average map unit size. This information can also be used to quantify changes, in this case a decrease, in landscape diversity.

Summary and Conclusions

Premining and reclaimed landscapes were compared at the Freedom Mine, a large surface coal mine in western North Dakota. This comparison demonstrates that average slopes decreased for both cropland and native rangeland. These slope changes are considered favorable from a production agriculture standpoint. Landscape diversity decreased when comparing quantitative measures of up-down gradient changes and numbers of slope class map units. Reduced landscape diversity appears to correlate with landscapes improved for agriculture, suggesting that reclamation standards for vegetative production and diversity are in conflict. Possibly a vegetative diversity standard is necessary that ties to landscape diversity, instead of premining conditions which no longer exist in the reclaimed landscape.

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