CORRELATION OF PLANT COVER AND PRODUCTION WITH ANNUAL CLIMATE PARAMETERS: AN EXAMPLE WITH IMPLICATIONS FOR BOND RELEASE TECHNICAL STANDARDS[1]

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Abstract: A data set has been assembled over a period of nine successive years during which both percent cover and forage production data have been collected from sagebrush-grassland steppe at a Northern Great Plains site in Campbell Co., WY. Based on these data, correlations between total vegetation cover and total standing crop production and measures of climate during the period have been made. Cover data were obtained using the point-intercept method at 20 locations each year. The overall averages are based on 2000 projected points (20 samples x 100 points per sample) each year. Production data are standing crop measures from 20 one-square meter plots clipped by species each year. The first three years experienced high moisture input during the growing season. These were followed by five years of low growing season moisture input. 2005 conditions included a very wet mid-spring period sandwiched by dryness. This 9-year period included by coincidence both the lowest and second highest precipitation values in the 80-year record. During the initial eight years, total vegetation cover was most highly correlated with incident precipitation over the 4 months preceding sampling (r=0.97). A regression model based on these first eight years (1997–2004) predicted that for 2005, cover based on observed precipitation was 46.3% compared to the observed reality of 32.2%. For production, the 1997-2004 correlation with incident precipitation over the previous 6 months was moderately good (r=0.81). The regression-predicted value for 2005 was 1564 kg/ha oven-dry compared to the observed value of 1014 kg/ha oven-dry. Had there existed reclamation technical standards based on regression models using the 1997 to 2004 data (which had good to excellent correlation coefficients), they would have been inadequate to predict the actual values in a year like 2005 and would have set possibly unattainably high requirements.

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Introduction

Since passage of the federal Surface Mine Control Reclamation Act (SMCRA) in 1977 (and before in certain western states) and promulgation of regulations pursuant to that law, specific quantitative requirements regarding the replacement of vegetation on lands mined for the production of coal have been in place. Toward the end of providing quantitative targets for revegetation success at these (mostly surface) coal mines, there have often been undisturbed representatives of the original vegetation set aside for subsequent reference to establish appropriate levels of plant cover and forage production, and sometimes species diversity. These areas have sometimes later become obstacles as mine plans change and what was originally deemed "out of the way' must be mined. In order to avoid these conflicts, some mining operations have sought, and been granted, the use of fixed numbers that constitute the revegetation standards. These so-called "technical standards" are numbers, usually fixed, that do not vary with ups and downs of climatic variation. When areas on the ground are used to produce revegetation standards for a particular year, those standards are "naturally" pro-rated by environment, especially effects of available moisture, and as adjusted by soils, wind, temperature and patterns of precipitation of the year. And the same variables are limiting, or enhancing, the cover, production, or species diversity of the reclaimed areas. With no built-in climate adjustment mechanism, the technical standard may represent, on a given year, a goal unreasonably high (from the operators' point of view) or unreasonably low (from the regulators' point of view). Any desire to have a climate adjustment mechanism built into technical standards for a particular area has been thwarted by the lack of data collected in a comparable manner over a long sequence of years that could be used as reliable input to testing models. Although massive amounts of vegetation data from baseline studies exist, they normally are collected during a single year. Likewise, data from interim monitoring may include data from native comparison areas, but usually samples sizes are small and data collection occurs on a basis less frequent than annually.

Reported here are results from annual sampling of vegetation at the Belle Ayr Mine in Campbell County, Wyoming. The data were collected the years 1997 through 2005 in an area of approximately 1,650 ha of sagebrush grassland steppe used at this mine as an Extended Reference Area (ERA). These data have been submitted yearly by Foundation Coal and its predecessors to Wyoming Department of Environmental Quality Land Quality Division as part of annual reports in which, among other things, the state of progress of mined and revegetated areas is compared to applicable standards set by vegetation conditions in the ERA. As part of annual reports required under Wyoming mining laws, these data are in the public domain. This dataset from a nine-year period is suitable in length and consistent methods to provide a reasonable basis to test the viability of attempting to predict levels of plant cover, forage production or species density based on commonly available measures of climatic conditions.

Methods

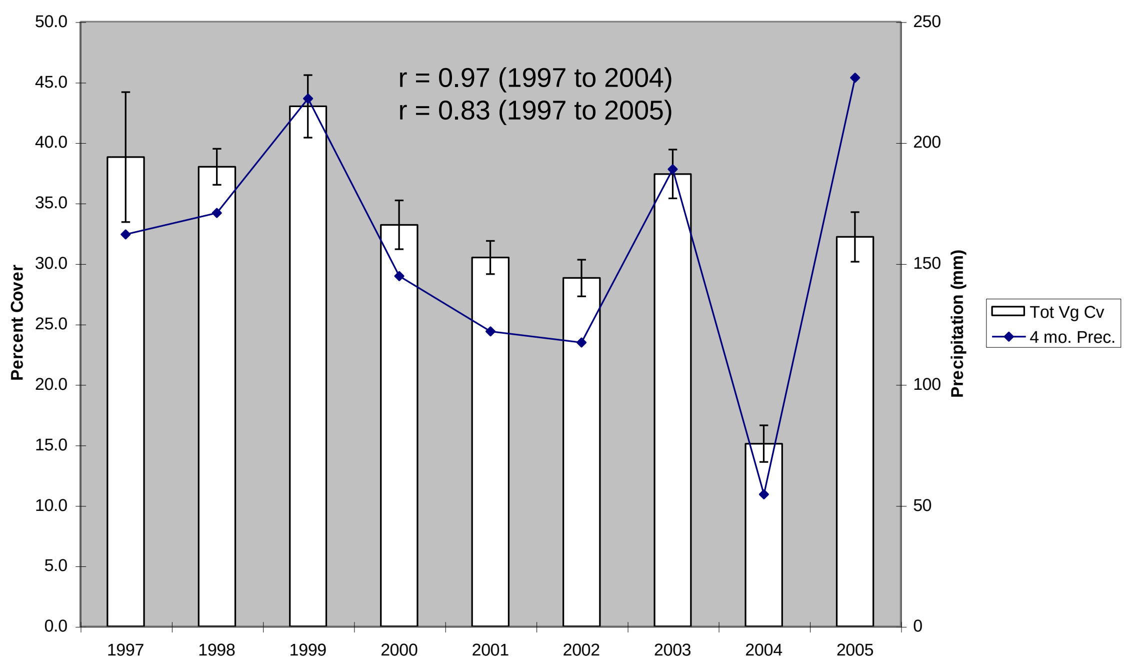
Cover data were collected each year at the same time at twenty randomly located sites scattered throughout the sagebrush grassland steppe vegetation of the ERA. Cover values were derived from a point-intercept sampling of 100 points uniformly distributed along a 50 meter transect. The equipment used was a Cover-Point Model 5 optical point projection device, which rigidly projects an optically-defined point of 0.07 mm diameter at ground level. In the normal fashion for the point-intercept method, percent cover is based on tally of interceptions ("hits") of plants with the projected point. Forage production was assessed at the same twenty sites each year by clipping all herbaceous and suffrutescent plants by species, placing them in labeled paper bags, drying them at 105°C for 24 hours, and weighing them to the nearest 0.1 gm.

Climate data used for correlation were those collected at the NOAA Gillette 9 ESE station located about 12 miles north of the sample site (WRCC 2006). This station has continuous record extending from 1925 to the present. Inasmuch as sampling occurred in very late June or early July each year, climate data were assessed for period ending in June each year. Hence the precipitation of the previous 12 months was the total from July of the preceding year through June of the sample year. Six month precipitation index was accordingly January through June and the four month index was March through June. During the study period, both the second wettest year (1999) and the driest year (2004) in the 80-year record occurred.

Correlation of Cover (Fig. 1)

After the first eight years (1997 through 2004) the correlation coefficient (r) was 0.97 for total live vegetation cover versus total precipitation in the four months preceding sampling. For the preceding six months r = 0.95 and for the 12 months preceding, r = 0.89. With the addition of the 2005 data, the r values declined: for the four previous months of precipitation, r = 0.83, for the six months previous, r = 0.80, and for the 12 months previous, r = 0.77.

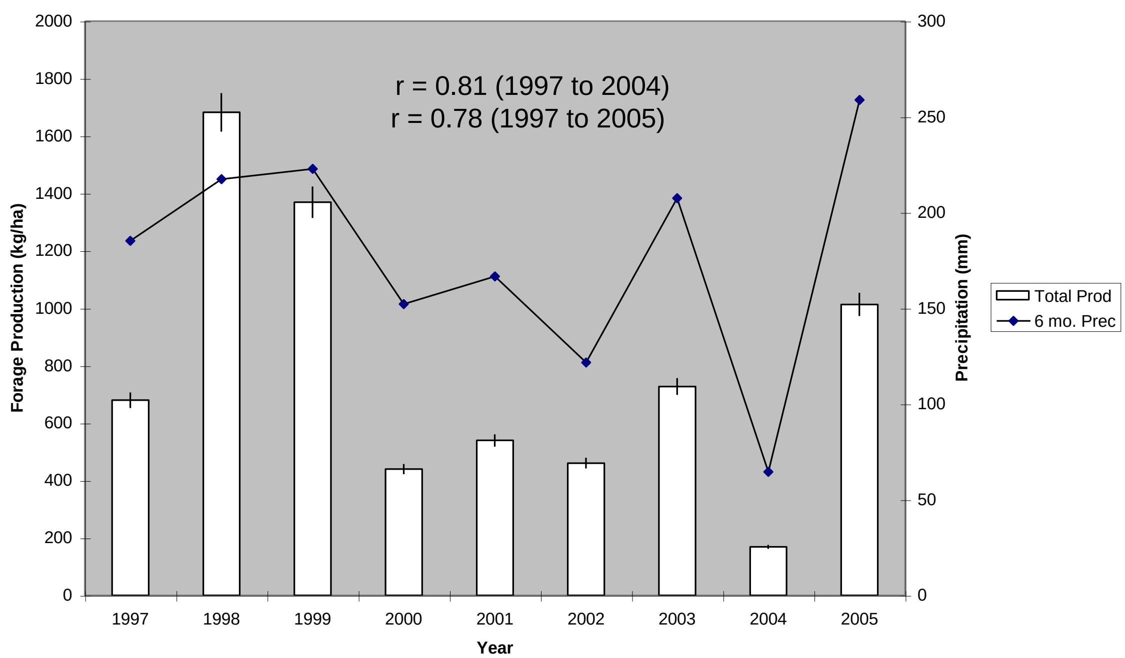
Figure 1. Total Live Vegetation Cover versus Cumulative Precipitation of the Four Months Previous to Sampling



Correlation of Forage Production (Figure 2)

Forage production in this dataset has varied widely in approximate response to precipitation. Variation in forage production spanned a full order of magnitude with a high in 1998 of approximately 1680 kg/ha to a low in 2004 of 168 kg/ha. Up through 2004, the highest r value for forage production versus climatic variables was 0.81 in relation to the cumulative precipitation from the six months prior to sampling. But this value was barely greater than those for the four month (r = 0.80) and twelve month (r = 0.75) correlation coefficients. With the addition of the 2005 data, the values declined to 0.78 for the six month cumulative precipitation value and 0.72 and 0.76 for the four month and twelve month indices, respectively.

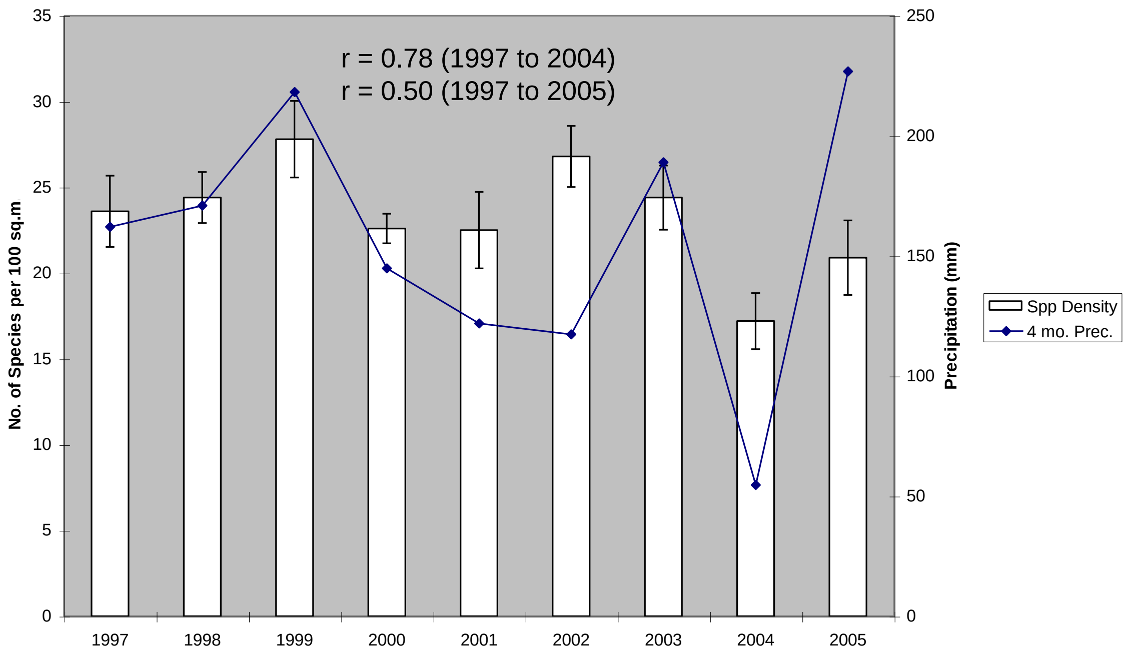
Figure 2. Production versus Cumulative Precipitation for the Six Months Previous to Sampling



Correlation of Species Density (Figure 3)

Through 2004, the highest correlation to precipitation was r = 0.78 for the four months previous to sampling. Correlation for the twelve months previous (r = 0.70) and six months previous (r = 0.69) were somewhat lower. Including the 2005 data the highest r value was again for the four months previous (r = 0.50). For six months (r = 0.41) and twelve months (r = 0.46) the relation had become even weaker.

Figure 3. Species Density versus Cumulative Precipitation of the Four Months Previous to Sampling



Discussion

From the Belle Ayr ERA data cited here, it is apparent that levels of plant cover, species density, and especially forage production are highly responsive to differences in yearly climatic variation. In light of such variation, the high utility of the reference area approach to setting yearly revegetation performance standards is clear. Attempting to generate reasonable goals through technical standards faces great difficulty in light of the potential variation documented at the Belle Ayr ERA. Use of a straight arithmetic average would be the simplest approach, but this of course will be expected in a given year to be lower than it "should" be (i.e. less than the true biological potential as controlled by climatic conditions) about half the time and higher than it "should" be about half the time.

These data point out the possibility that what seems, based upon a period as long as eight years, to be a strong predictive model, can, given a (ninth) year like 2005 be substantially off-mark. 2004 was an extremely dry year, and 2005 began as an extension of that trend. Through the first three and one-half months, the 2005 moisture conditions continued to be stressfully low. In mid-April and early May substantial snow and rain events occurred that brought the total precipitation leading up to the 2005 growing season to a level well above average (July to June 456 mm in 2004-2005 versus 398 mm, the long-term (80 yr,) average). The mid-spring moisture spike in 2005 was not supported in June or early July, which were below average. Had the 1997 to 2004 data been used in a regression model prediction, 2005 levels of precipitation would have predicted about 46.3% total vegetation cover. The observed reality was 32.2%. Predicted forage production would have been 1564 kg/ha, while observed reality was about 1014 kg/ha. Had a technical standard based on the regression of 1997 to 2004 data been used, the resulting cover standard of 46.3% would have been unachievable; 2005 reclaimed areas sampled at Belle Ayr averaged 35.3% cover, about 3% above the "real" standard of 32.2% measured in the ERA. For forage production, however the seemingly excessive regression-predicted standard of 1564 kg/ha was actually achievable; 2005 reclaimed areas sampled at Belle Ayr averaged 1639 kg/ha.

2005 constituted a very unusual year in terms of precipitation. As touched on above, it amounted to one spike of moisture in an otherwise dry year that followed an extremely dry year. It is doubtful that the 165 mm of moisture received in April and May 2005 was completely stored in the shallow soil (i.e. the typical main grass root zone of 30 to 45cm). Although the perennial grasses did respond with substantial growth (as did annual species), there was little replacement of root zone moisture in June and early July. Probably there was a substantial flow through to the lower soil, the effects of which may not be reflected in the growth of deep-rooted plants until 2006. Thus, in summary, 2005 moisture was distributed in a pattern that provided limited support to the primary providers of cover and forage, the perennial grasses, and at least some of that moisture escaped either to deep soil or elsewhere without causing plant growth to occur in proportion to the total moisture input.

Summary

Setting revegetation performance standards for plant cover and forage production that are reasonable from both the operators' and regulators' points of view is difficult when those standards are not based upon on-the-ground vegetation units (plant communities) that automatically integrate the environmental conditions of the mine area. Given that technical standards based on straight arithmetic averages will be either too high or too low most of the time, the need to have some basis for adjustment of goals each year is apparent. Data reported here collected annually over a nine-year period demonstrate both the potential for development of a predictive mathematical "model" and the possibility that such constructions still may produce standards that will be inappropriately high or low. It is clear that while technical standards offer the simplicity of having no comparison areas on a mine site, and no need to sample comparison areas, they are accompanied by a substantial problem: Compared to the use of standards based on comparison areas, there will exist many more (bond release test) years that revegetation success (relative to cover and production) cannot be proven because the (technical) standards of success are inadequately linked to environmental conditions.

Literature Cited

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