CLIMATIC ADJUSTMENTS ON RECLAIMED CROPLAND YIELDS FOR FINAL BOND RELEASE[1]

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Abstract: Determining a cropland yield standard to be met for final bond release purposes can be accomplished by either trying to use actual average yield data over several years or using USDA Natural Resources Conservation Service (USDA-NRCS) productivity indices (PI) if field data is unavailable or unreliable. However, both cases are subject to variability in growing season conditions from one cropping year to the next and thus methodologies must be developed to try to account for this yearly variation. Several methods have been developed and are currently being used by the North Dakota Public Service Commission to try to "adjust" the yield standards necessary for final bond release caused by these yearly climatic variations. These methods include: 1. Developing a climatic correction factor ratio using a county-wide average yield based upon USDA-NRCS PI data and dividing that yield into the yearly average county yield reported by the USDA-North Dakota Agricultural Statistical Service (USDA-NDASS) or yield data from an area of similar soils where the actual yield was measured. This correction factor is then multiplied times the reclaimed area yield standard calculated using USDA-NRCS PI values to develop an adjusted yield standard; 2. Developing a Productivity Ratio between the reclaimed yield standard for the reclaimed tract based on USDA-NRCS PI values divided by the long-term average county yield from USDA-NRCS which is then multiplied times the annual county yield data supplied by the USDA-NDASS to develop an adjusted yield standard; or 3. Developing a crop-based weighted production ratio factor taking into consideration one of the above climatic adjustments and the acreage of all crops within the reclamation tract. Each of these methods have their own advantages and disadvantages which will be discussed and have been used successfully by several mining companies to adjust reclaimed cropland yield standards for final bond releases in North Dakota.

Additional Key Words: Weather, growing season, small grains, haylands, yields

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Introduction

North Dakota began requiring some form of reclamation of surface-mined lands in 1969 (North Dakota Century Code, 1993). At that time no topsoil was required to be saved and all ridges within 200 m of a public road or facility had to be graded and traversable by machinery. Cropland areas had to have the peaks graded and slopes reduced to 25% or less. Areas which failed to support plant growth were deemed reclaimed and available for bond release after the second seeding or planting. Thus no productivity requirements were in place.

Similar requirements remained in place until 1973 when mine operators were then required to save suitable plant growth material (SPGM), which was mainly topsoil at this time, to a depth of 0.6 m which was then respread following grading. These graded areas were to approximate the original contour. Vegetative requirements for bond release included that the cropland areas must support annual crop production but no production requirements were needed. The 1975 law improved on this in requiring up to 1.5 m of SPGM removal and the restoration of the inherent productivity of agricultural lands to levels at least equal to or better than the premine level. However, no statistical confidence limits were set and no sample adequacy requirements were necessary nor were these required in the 1977 law.

With the passage of the Public Law 95-87, the Surface Mining Control and Reclamation Act (USDI-OSMRE, 1979), and subsequent revisions to both the state and federal laws, the requirement for meeting productivity standards was further defined. Use of statistical confidence limits and sample adequacy were required for any cropland areas being submitted for final bond release.

Early research by Power et al. (1974) suggested that full restoration of cropland productivity may be difficult to achieve. Power et al. (1979) and Halvorson et al (1987) both determined that the depths of SPGM respread had a great effect on small grain productivity with some of this depending on the spoil qualities laying beneath. Topographic influences on small grain yields were also noted by Schroeder (1995) who concluded that the biggest effect was due to stored soil water in the spring and the amount of infiltration from rainstorm precipitation resulting in differences in runon and runoff from rainstorm events during the growing season on a reclaimed tract where respread depths were uniform.

Thus it would seem that the most limiting factor for crop production for undisturbed and reclaimed soils in North Dakota is moisture; both in the form of stored available soil water at planting and rainfall during the growing season. The effect of stored available water on reclaimed mineland cropland yields was further verified when Schroeder and Halvorson (1988) found soil water depletion from deeper depths in undisturbed versus reclaimed fields. This was partially explained by differences in bulk density and tillage effects which affected penetration of infiltrated water on reclaimed cropland yields by Vining and Schroeder (1992).

In the area of North Dakota where most mining occurs, the average precipitation is around 42 cm yr^{-1}. And, of this yearly moisture, about 30+% may fall in the form of snowfall in the late fall through early spring months which may or may not infiltrate into the soil depending on several factors such as if the soil is frozen. Soil water content measured to a depth of 2.5 m at over one hundred locations in undisturbed soils and spoils over eight years at no time indicated any moisture movement below that depth for either situation (Schroeder and Bauer, 1984).

Because so many factors are thus related to the ultimate productivity of undisturbed and reclaimed croplands, it becomes difficult to set productivity levels for reclamation bond release if production history of a field premine were to be used since so many of these factors vary from year to year. This paper will explain the procedure used by North Dakota's regulatory agency to set unadjusted reclaimed cropland productivity levels and how these levels are "adjusted" for yearly variability in growing conditions.

Methods and Materials

In order to calculate productivity levels to be met for final bond release, North Dakota uses a two-stage process. The first stage develops an unadjusted yield standard while the second step adjusts that standard for management and/or growing season climatic effects.

Step 1. Calculation of Unadjusted Yield Standard

In order to develop the methodology to be consistent across the state, the North Dakota Public Service Commission Reclamation Division decided to use the USDA-NRCS (2000) productivity index (PI) values. The detailed soil survey information submitted within each permit is used to determine the soil series present within each reclamation tract or field that will be used for cropland following reclamation. The PI values are based upon a system of rating the best (prime) soils at 100 and decreasing the values as the inherent productivity of the premine soils decrease due to either physical and/or chemical factors (such as wetness or sodicity) or slope. A spring wheat yield is also set by USDA- NRCS (2000) to represent the equivalent yield for a soil with a PI equal to 100.

As shown in Table 1, both prime and nonprime soil series are listed along with their respective PI values and area. The prime soil series, Bowbells, also shows how the PI index value decreases as the slope increases. The summed weighted yield (based on a spring wheat yield value of 2.49 Mg ha^{-1} for a soil with a PI equal to 100) is then divided by the area of the field and this becomes the unadjusted yield (X_{UD}) for that field.

Table 1. Calculation of the unadjusted standard yield for spring wheat.

Soil Series	Slope	Productivity Index Value	Yield (Mg ha^{-1})	x Premine Hectares	= Weighted Yield (Mg)
Bowbells	A (0-3%)	100	2.49	20	49.8
Bowbells	B (3-6%)	95	2.36	10	23.6
Williams	A (0-3%)	90	2.24	10	22.4
Zahl	B (3-6%)	57	1.42	15	21.3
			Total	55	117.1

Unadjusted Yield Standard = X_{UD} = 117.1/55 = 2.13 Mg ha^{-1}

Step 2. Climatic Correction of Unadjusted Yield Standard

Once the unadjusted yield standard for spring wheat has been calculated, the value is adjusted to "correct" the yield standard to try to take into consideration management and growing season weather. This correction may be done in one of the following three ways:

a) The estimated annual county yield data (X_C) as reported by the USDA-NDASS (1956-current) may be used. Because one of the management factors used for spring wheat may include the use of fallow, a “first” correction for management is applied to any data reported after 1995 (before then the data was separated by fallow or continuous management). Twenty years of data was used to correlate reported spring wheat yields following fallow or continuous cropping with the reported average spring wheat yield for the county in order to estimate the effect of cropping management. For example, as shown below, if the data to be used is from Oliver County then one of the two regression equations is applied to the reported county data to adjust for management.

Following Fallow: Estimated Yield $(X_{EST}) = 1.03X_C + 0.155$ (1)

Continuous Cropping: Estimated Yield $(X_{EST}) = 1.09X_C – 0.\ 366$ (2)

Once the county data has been corrected for management, the climatic correction factor (CF) is calculated by dividing X_{EST} by the weighted average yield for all cropland in the county (X_{WT}) developed by the USDA-NRCS (2000) in the same manner as calculated in Step 1 for the reclaimed tract (for Oliver County this figure is 1.89 Mg ha^{-1}). Assuming the reported county yield was 2 Mg ha^{-1} and the management was following fallow, then X_{EST} would be 2.22 Mg ha^{-1} and the CF factor would be calculated as:

$$\text{Climatic Correction Factor (CF)} = X_{EST}/X_{WT} = 2.22/1.89 = 1.17 \quad (3)$$

This CF value would then be multiplied times the unadjusted standard yield (X_{UD}) developed in Step 1 to give an adjusted yield standard (X_{AD}) of 2.49 Mg ha^{-1} as the yield to be equaled or exceeded to meet final bond release productivity standards as shown on Equation 4:

$$\text{Adjusted Yield Standard } (X_{AD}) = X_{UD} * CF \quad (4)$$

b) A second method that may be applied is to use a control area (an area containing some of the predominant premining soil series or similar soil series which existed in the reclaimed tract prior to mining) to calculate the CF value if an area can be located within a reasonable distance of the reclaimed tract and is managed by the same producer. The area is to be identified at least two years prior to the first year data is collected and put in the same management. The actual yield of the control area would be divided by the unadjusted yield of the control area calculated by using the same methodology used in Step 1 using the soil series contained within the control area. The adjusted yield standard for the reclaimed area would again be calculated by taking the CF value times the unadjusted yield standard.

c) The final methodology that can be used is to develop a Productivity Ratio (PR) which is defined as the ratio between the unadjusted yield standard of the reclaimed tract and the long-term weighted average yield value for the county. The PR value is calculated as:

$$\text{Productivity Ratio (PR)} = X_{UD} \div X_{WT} \qquad (5)$$

This PR value is then multiplied by the estimated county yield value (X_{EST}) to give the adjusted yield standard.

Results and Discussion

The methodologies described above have been mainly applied to single crop fields. Many of the reclamation tracts, however, are getting larger and may contain more than one crop. For these areas, the same methodology may be applied to each crop. Once the adjusted yield (X_{AD}) has been calculated for each crop, it is divided into the actual yield of the crop to produce a Production Ratio Factor (PRF) for each crop. This PRF value is then multiplied times the hectares for each crop and the resultant unitless values are summed over all crops. If that sum exceeds the actual number of hectares, then the tract has been deemed to have met the productivity requirement for final bond release for that year of data. If the sum is less than the actual number of hectares, then that year of data cannot be used for bond release purposes. In this context one crop may not by itself meet the productivity requirement for final bond release but that deficit may be nullified by another crop more than exceeding the requirement and thus the entire tract may meet the requirement. This method is especially useful when hayland is part of the cropland mix where excellent early growth conditions occur and droughty conditions occur later in the growing season affecting row crop growth.

Use of the PI methodology and adjusting for climate has made the calculation of the yield standards to be met for final bond release easier to develop for both the mining industry and the regulatory agency. However, it is recognized that are several major assumptions in using these methods for correction. First, and foremost, is the assumption that the USDA-NRCS PI index values represent true and accurate productivity value relationships among soil series.

Secondly, the use of the USDA-NDASS reported data may have some inherent errors. For instance, how accurate are the numbers supplied to USDA-NDASS by the farmer cooperators? There is an old saying that when farmers discuss yields over coffee that they are excellent but turn very poor when talking to the tax man or insurance adjuster. Are the values more of an estimate than actual values that could be verified by elevator storage receipts or bin measurements on the farmstead? In addition there are cases where only a few values are reported per county. It is then the norm for USDA-NDASS to merge data over a larger area (such as several sections) rather than relying on only a few numbers within any section. How does this reflect the differences in rainfall over a wider area since it is a given that summer rainstorms can be very localized thus affecting one crop one place and having no effect on a crop not far away or even across the road. Merging of data would definitely have an effect on sample size and probably on sample variability.

Additionally, the USDA-NDASS data is not generally available for use until the spring of the following year. This means that mining companies need to wait until then to determine whether or not the requirement has been made. Use of a control area, however, allows for the mining companies to know within a short time if the requirement has been met and negates some of the effect of different management factors such as planting dates, weed control, fertility, etc. If enough years of data are then available, bond release applications can be put together during the winter months rather than summer months when other duties may take precedent.

Thirdly, the PI index numbers have only really been worked up for spring wheat. Even though USDA-NRCS has developed conversion factors to go from one crop to another, how well do these conversion factors work? Can you really state that a spring wheat crop of so many Mg ha^{-1} is the same as so many Mg ha^{-1} of oats? Since the growing cycles are somewhat different between crops then maybe too the conversions don't work as nicely as expected. In a similar manner, using the PR value may not be valid if the ratio for spring wheat does not apply across crops.

And finally, are the climatic effects on one small grain crop growth the same as on another one. What about throwing hayland yields into the equation? Good moisture in the spring may result in very heavy hay growth such that the hayland yield could possibly make a reclamation tract exceed the productivity requirement where more than one crop is used when all other crops failed to meet or exceed their adjusted yield standards as briefly mentioned above. Is this true to the meaning of the "equal to or better than" part of the law?

Conclusions

The combined use of USDA-NRCS PI index values and the climatic correction factor estimate used by the North Dakota regulatory agency and mining companies has been used to final bond release over 700 ha of cropland mined under the 1979 law. The methodology is fairly simple to use and can be used for reclaimed fields that contain nonprime soils, prime soils, or a combination of both since a weighted average yield is developed for the entire tract. Use of the methodology recognizes that it is imperfect due to some of the assumptions involved in some of the data collection and calculations that assume correlations not yet proven by valid scientific research but the method does seems to be working in the manner required to try to account for climatic variability from year to year. The methods developed can be, and will be, modified if better knowledge becomes available in the future.

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