EVALUATION OF MINESOIL QUALITY AND CAPABILITY IN ALBERTA, CANADA[1]

by

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Abstract. The objective of surface mine reclamation in the Plains Region of Alberta is to produce a landscape that has a capability for agricultural production that is equivalent to or greater than that which existed prior to mining. The process of adopting and implementing a system for measurement of reclamation success was and continues to be an evolutionary one. One of the first stages in the process was the development of soil quality criteria which were prepared to provide a basis for evaluating soils prior to disturbance and subsequent to reclamation. Criteria were outlined for soil survey and sampling programs and analytical requirements associated with baseline and post-disturbance characterization. Criteria for evaluating the suitability or quality of undisturbed and reconstructed soils were developed based on a broad range of physical and chemical parameters. Concurrent with the establishment of these criteria, a capability rating system for reconstructed soils was developed by adapting the existing Canada Land Inventory soil capability for agriculture rating system. Subsequent to this a land capability classification for arable agriculture in Alberta was developed which retains a close similarity to the previously developed systems but tends to be more quantitative. The system is based on seven classes and twenty-one subclasses or types of limitation.

Introduction

The objective of reclamation of surface mines in the Plains Region of Alberta is to produce a landscape that has a capability for agricultural production that is equivalent to or greater than that which existed prior to mining. Put in economic terms, it is clearly the intent of reclamation legislation in Alberta that the cost of assuring agricultural productivity in the post-mining landscape is to be borne as a capital investment in the land rather than as an operating cost by the farmer. The process of adopting and implementing a system for measuring reclamation success was and continues to be evolutionary and is based on several strategic activities and research efforts. This paper describes these strategic activities and summarizes some of the documents which resulted from the work conducted.

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Methods

Development of Soil Quality Criteria

Surface mining or any land disturbances arising from resource extraction and transport are intended to be only temporary disruptions to the normal use of land. Although no two sites are absolutely identical, disturbances cause similar types of problems and concerns but in varying degrees of intensity. Assurance that such disturbances are temporary is possible only if information concerning a specific site is well documented and an appropriate reclamation program is planned prior to disturbance. Evaluation of the nature of the materials at hand prior to disturbance and subsequent to reclamation, however, requires criteria by which to assess the quality of those materials. To this end a Soil Quality Criteria Subcommittee of the Alberta Soils Advisory Committee was formed in 1978 to develop criteria relative to:

a) Soil mapping and sampling for baseline and post disturbance activity;

b) Overburden sampling;

c) Analytical requirements;

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d) Physical, chemical and biological criteria for evaluating the suitability of soil materials for revegetation.

The first step in the process was to divide the province into three distinct regions to allow for the establishment of criteria that would apply to each region in general. There are differences within each of these regions but it was beyond the scope of the document (Alberta Soils Advisory Committee 1987a) produced to suggest criteria for subdivisions of each of the three major regions because individual operations within each of the major zones could have unique conditions or characteristics resulting in specific problems and requirements. The three major regions are the:

a) Plains Region which includes the Central Plains and Peace River Plains and has a predominantly agricultural land use;

b) Eastern Slopes Region which includes the Lower and Upper Foothills and the Rocky Mountains to the British Columbia border; and

c) The Northern Forested Region which includes the remainder of the province.

This paper will deal with the development of criteria for the Plains Region or agricultural areas of the province.

The next step in the process of soil quality criteria development was to provide guidelines relative to soil survey activities. A soil survey with relevant interpretations helps in understanding the soil relationships in an area prior to preparing a development plan to ensure adequate evaluation of the potential for reclamation. The survey also is beneficial in planning activities such as materials handling and soil reconstruction.

The document (Alberta Soils Advisory Committee 1987a) provides guidelines relative to recommended inspection density, soil profile characteristics, landscape features to be recorded, and map presentation. Use of the photo mosaic base is recommended in part because it is particularly helpful in working with post disturbance landscapes. Guidelines pertinent to sampling for baseline or evaluation purposes including sampling intensity and sampling methodology are described. Similarly, guidelines pertinent to post-disturbance or reconstructed soil sampling are provided. Again, this includes guidelines regarding sampling intensity and sampling methodology. For example, the document states that "sampling of reconstructed soils should be done on the basis of layers or materials such as topsoil, subsoil and spoil and on depth intervals within each of these discrete layers".

Analytical requirements are defined for both baseline characterization and post-disturbance or reconstructed areas. The minimum analytical requirements listed aid in properly characterizing soils for classification and mapping purposes and making interpretations relative to the quality of the soils as they occur in the undisturbed and reconstructed states. Preferred methods of analysis are described.

Soil suitability evaluations are made by considering the interaction of various soil properties and characteristics to give an overall rating of the degree of suitability. Three categories of suitability and one category to indicate unsuitability are used. The four categories are as follow:

a) Good (G) - None to slight soil limitations that affect use as a plant growth medium;

b) Fair (F) - Moderate soil limitations that affect use but which can be overcome by proper planning and good management;

c) Poor (P) - Severe soil limitations that make use questionable. This does not mean the soil cannot be used, but rather careful planning and very good management are required;

d) Unsuitable (U) - Chemical and/or physical properties of the soil are so severe reclamation would not be economically feasible or in some cases impossible.

In agricultural areas the selective salvage of topsoil and subsoil and subsequent sequential replacement of these materials is currently practiced. It is also useful to characterize the material below the subsoil in the predisturbance setting because this usually becomes the "spoil" upon which the reconstructed soils are built. In some instances these parent materials can and do become part of the reconstructed subsoil. To facilitate the identification of suitable sources of soil materials for replacement, it is recommended that the upper five metres be characterized prior to disturbance. Topsoil is defined as the surface "A" (organo-mineral) horizons of the soil profile. Subsoil is defined as the "B" horizon(s) and the upper portion of the parent material.

The criteria for evaluating the suitability of the soils for their use as topsoil and subsoil are provided in Tables 1 and 2. The ratings (good, fair, poor, unsuitable) are determined by assessing the site factors and analytical data in terms of the limits presented in the criteria tables. Each horizon or layer is rated relative to the individual parameters and an overall rating can be developed for each horizon or layer. The most limiting property (rating) determines the ultimate rating for each horizon or layer.

A number of the parameters assessed and used in developing ratings are interrelated. For example, sodicity, saturation percentage and texture are closely related. Therefore, in the event that a given soil horizon or layer has a fair rating assessed for each of these parameters and a fair or better rating for the remainder of the parameters considered, the overall rating for that horizon or layer should be fair.

It is important to note some parameters are more important than others in terms of assessing quality and there are those where management practices can overcome or compensate for some limitations. The intent of this system is not to suggest the extent to which management practice could impact ratings that are developed. For

Table 1. Criteria for evaluating suitability of topsoil in the Plains Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.4	4.5 to 5.4 & 8.5 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stoniness Class	S0, S1	S2	S3, S4	S5
Texture	FSL, VFSL, L, SL, SiL	CL, SCL, SiCL	LS, SiC, C[2], S, HC[3]	
Moist Consistency	very friable, friable	loose	firm, very firm	extremely firm
Organic Carbon (%)	>2	1 to 2	<1	
$CaCO_3$ Equivalent (%)	<2	2 to 20	20 to 70	>70

[1]Materials characterized by an SAR of 12 to 20 may be rated as <u>poor</u> if texture is sandy loam or coarser and saturation % is less than 100.

[2]C - May be upgraded to fair or good in some arid areas.

[3]HC (Heavy Clay) - May be upgraded to fair or good in some arid areas.

Table 2. Criteria for evaluating suitability of subsoil material in the Plains Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.5	4.5 to 5.4 & 8.6 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<3	3 to 5	5 to 10	>10
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stone Content (% Vol)	<3	3 to 25	25 to 50	>50
Texture	FSL, VFSL, L, SiL, SL	CL, SCL, SiCL	S, LS, SiC, C, HCL[2]	Bedrock
Moisture Consistency	very friable, friable	loose, firm	very firm	extremely firm
Gypsum $CaCO_3$ Equivalent (%)	The suitability criteria for sodicity (SAR) may be altered by the presence of high levels of either lime ($CaCO_3$) or gypsum ($CaSO_4$) in excess of other soluble salts.			

[1]Materials characterized by an SAR of 12 to 20 may be rated as <u>poor</u> if texture is sandy loam or coarser and saturation % is less than 100.

[2]HCL - Heavy Clay Loam.

example, an unmined or reconstructed soil could be rated fair, poor, or unsuitable on the basis of degree of stoniness while the remaining parameters considered are not limiting. In this instance the rating should be qualified with a statement to the effect that management practice (stone picking) could be used to result in a better soil material.

Discussion

Soil Capability vs Soil Productivity

The coal development policy for Alberta (1976) stated that "the primary objective in land reclamation is to ensure that the mined or disturbed land will be returned to a state which will support plant and animal life or be otherwise productive or useful to man at least to the degree it was before it was disturbed. In many instances the land can be reclaimed to make it more productive, useful, or desirable than it was in its original state; every effort will be made towards this end".

In 1979 the Alberta Research Council initiated the Plains Hydrology and Reclamation Project (PHRP) which involved a holistic approach to reclamation by integrating studies of geology, hydrogeology and soils in a mining area and in the adjoining unmined areas. One of the subobjectives of this study was to evaluate the productivity potential of post-mining landscapes and the significance of changes in productivity as a result of mining (Moran et al. 1981). During the proposal stage of the project it was felt that the concept of productivity was one that could be utilized in comparing pre-mining and post-mining situations. Although initially it appeared feasible to measure productivity, the approach was modified to include the characterization of reconstructed soils and to determine their suitabilities and limitations for agricultural production.

Capability for agriculture was chosen as the basis for evaluating the product of reclamation rather than productivity primarily because capability considers intrinsic properties of the landscape. Productivity, on the other hand, addresses a parameter that is very much subject to alteration by management practices. In simple terms, a given level of productivity can be achieved from either good land with minimal management input or poorer land with greater management input. The significance of this is that in the latter case, removal of management input results in deterioration of productivity. Therefore, using productivity as a measure of reclamation performance does not allow for separation of the relative contributions of the land itself and management inputs.

Doll and Wollenhaupt (1985) indicated that sole dependence upon vegetation establishment and production without measuring the degree of re-establishment of the root zone factors that govern root growth is neither a reliable nor a cost-effective approach to measurement of reclamation success. Smith (1983), in quoting excerpts from the USDA Soil Survey Manual described the difficulty and uncertainty of establishing precise soil productivity values. Precise statements about soil productivity must be related to a specific type of soil, a certain type of crop or combination of crops and a specific set of management practices.

Development of a Capability Rating System for Reconstructed Soils

The development of a capability rating system for reconstructed soils was based upon the evaluation of various parameters which were compared to similar parameters of undisturbed soils (Macyk 1986). The system to be developed required a "common thread" with an existing system used to rate the capability of natural or undisturbed soils so that relevant comparisons could be made.

At the time, the system used to rate soil capability in Alberta was the Canada Land Inventory (CLI) soil capability for agriculture rating system (Canada Land Inventory 1965). The CLI soil capability system for agriculture is an interpretive grouping that can be made from soil survey information wherein mineral soils are grouped into seven classes according to their potential and limitations for agricultural use. It is comparable to the USDA-Land Capability Classification System which is based on three levels of classification including eight classes (Klingbiel and Montgomery 1961).

To ensure continuity between the existing CLI system which assessed the suitability of a soil for a given use prior to disturbance, the system or component classes associated with reconstructed soils had to reflect a respectively similar capability (Macyk 1987).

At the time that the reconstructed soil capability rating system was being developed under the auspices of the Plains Hydrology and Reclamation Project, a system was being developed to provide a single, consistent assessment of agricultural capability in the province. The systems commonly used included the Farmland Assessment Schedule of Municipal Affairs (Department of Municipal Affairs 1979), the Public Lands System (Storie 1933) and the CLI - Soil Capability for Agriculture (Brocke 1977, Canada Land Inventory 1965). This most recently developed system is based on land and environmental factors as they affect dryland agriculture including the common crops and management systems of the day (Alberta Soils Advisory Committee 1987b). It can be used to assess the agricultural capability of the post- as well as the pre-disturbed condition. The component factors are all measurable climate, soil or landscape features that affect plant growth and which are not dependent on undisturbed sites or traditional taxonomic classifications.

The latest system retains a close similarity to the previously used CLI - Soil Capability for Agriculture system but tends to be more quantitative. The classes which are the broadest category in the system provide an assessment of the degree of intensity of the limitation. A range of index points is assigned to each class. The land capability classes are defined as:

Class 1 - These lands have no significant limitations for crop production (80 to 100 index points).

Class 2 - These lands have slight limitations that restrict the range of crops or require modified management practices (60 to 79 index points).

Class 3 - These lands have moderate limitations that restrict the range of crops or require special management practices (45 to 59 index points).

Class 4 - These lands have severe limitations that restrict the range of crops that can be grown or require special management practices or both (30 to 44 index points).

Class 5 - These lands have very severe limitations for sustained arable agriculture. Annual cultivation using common cropping practices is not recommended (20 to 29 index points).

Class 6 - These lands have such severe limitations for arable agriculture that cropping is not feasible even on an occasional basis (10 to 19 index points).

Class 7 - These lands have no capability for arable agriculture (0 to 9 index points).

It is important to note that lands within a capability class are similar only with respect to the degree of intensity of limitation. Any one class may include many different kinds of soil and land characteristics which require a variety of management practices.

The second major category of the system is the subclass which describes the type of limitation responsible for the class designation. The subclass is a grouping of soils and lands with the same kind of limitation. Twenty-one different types of limitations are recognized as a result of adverse climate, soil or landscape characteristics. The subclasses are defined as follows:

Climate (C)
- moisture limiting factor (A)
- temperature limiting factor (H)

Soils (S)
- texture in mineral soils (M)
- structure and consistence in mineral

Soils (D)
- organic matter content (F)
- depth of Ah or Ap in mineral soils (E)
- acidity/alkalinity (V)
- salinity (N)
- sodicity/saturation percentage (Y)
- calcareousness (K)
- peaty surface (O)
- depth to nonconforming layer (R) (D) (M)
- drainage (W)

Organic soils (O)
- organic soil temperature (Z)
- degree of decomposition (B)
- wood content (I)
- nutrient status (G)
- salinity (N)
- depth of deposit (X)
- subsurface acidity (V)
- drainage (W)

Landscape (L)
- slope (T)
- surface stoniness (P)
- pattern (J)

Data are required for each of the factors identified within the climate, soils and landscape components when using the rating system. These data can be obtained from maps and reports and specific site inspections. The level of detail of information required is determined by the purpose of the capability rating. For example, more detailed information would be required for development of capability ratings for reconstructed soils in a portion of a surface mined area than for ratings for a municipal district or county level assessment.

Data pertinent to climatic parameters are based on long term (1951-1980) records. Soil and landscape data are more site specific than the climate requirements and should be collected in the field wherever possible. Standards established by the soils community in Canada are followed in the definition and description of individual parameters.

Climate Factors. Climate plays a major role in the definition of agricultural capability in Alberta. The indices developed for this evaluation relate to dryland agriculture, the common crops of the area and the summer growing season. The climate rating is based on two principal variables including an energy factor and a moisture factor. Four modifiers including spring moisture, fall moisture, fall frost and hail are also recognized as having an impact on the climatic assessment of agricultural capability.

The moisture component is a simplified moisture balance calculation based on monthly precipitation (P) and potential evapotranspiration (PE) (Baier and Robertson 1965). The energy component is based on an effective growing degree day (EGDD) calculation which includes length of season, degree days, day length and diurnal temperature range parameters. The start of the growing season is taken as the first occurrence of five consecutive days with mean temperatures above 5°C after March 15. The end of the growing season is represented by the average date of first occurrence of 0°C after July 15. The number of degree days over 5°C are accumulated over the season defined above.

Soil Factors. Mineral soils are defined as those which have less than 40 cm of surface peat. The rating for mineral soils includes consideration of surface features (0 to 20 cm), subsurface features (20 to 100 cm) and drainage. Emphasis is placed on the surface (0 to 20 cm) layer because it represents the portion that is managed or the portion where seed is placed, seedlings develop and the major portion of nutrients are found.

The rating of the surface represents the basic soil rating with the subsurface and drainage factors used as modifiers. Eight parameters including texture, structure and consistence, organic matter, depth of topsoil, acidity, salinity, calcareousness and peaty surface are recognized for characterization of the surface 0 to 20 cm. Sodicity is an additional factor that is suggested for use in developing ratings for reconstructed soils.

Point deduction criteria were developed for each of the above mentioned parameters, however, space limitations allow for inclusion of examples of point deduction criteria for only a few parameters. For example, point deduction criteria for surface soil acidity and saturation percentage as they would apply to reconstructed soils are presented in Table 3.

Landscape Factors. The features associated with the landscape evaluation include topography, stoniness and landscape pattern or obstacles to farming. Topography represents the basic rating with stoniness and pattern as modifiers.

Length and steepness of slope are the controlling landscape parameters. As slope increases above 10% there are increasing machinery limitations, however the main concern is the sustainability of the productive capacity of the land.

Final Capability Rating. Determination of a final capability rating involves determination of the most limiting component and other significant components. For example, the individual component ratings and the final capability rating derived therefrom for a given parcel of land might be:

Climate Rating = 2A
Soil Rating = 3M
Landscape Rating = 1
Final Capability Rating = 3M

When a rating for a parcel of reconstructed land is applied it is done so based on the properties of the reconstructed soils determined at a specific time. It is important that all users understand and accept the concept that change is likely to, and certainly will occur in these reconstructed soils and the associated appropriate capability rating may also change. The capability rating system and, therefore, any particular rating assigned as applied to reconstructed soils is based on existing conditions and not on what the conditions are perceived or predicted to be some time hence.

Relating Productivity to Capability

The capability ratings that can be applied to reconstructed soil areas allow for an ordered ranking of relative capability; however, these ratings do not provide for quantification or allow for the detailed assessment of production capacities and for the effects of different management techniques. This can only be accomplished through the measurement of yield.

Peters and Pettapiece (1981) indicated that there is a predictable relationship between yields of agricultural soils and CLI capability classes and subclasses within any one climatic zone. Evaluating the relationship between capability ratings and yield or productivity levels pertinent to reconstructed soils has not been completed in Alberta. Productivity or yield measurements have been made in controlled plot experiments (Graveland et al. 1988, Can-Ag Enterprises Ltd. 1987) and in uncontrolled field size measurements associated with operating mines (Logan 1988).

Controlled experiments will be required to provide conclusive results regarding the relationship between productivity and capability in reconstructed soil settings.

Table 3. Point deductions for surface soil sodicity and saturation percentage.

Sodicity (SAR)	Saturation Percentage (Sat %)	Points Deducted
4	60	0
8	80	10
12	120	30
16	160	50
20	>160	80

Disclaimer

The recommendations and conclusions in this report are those of the author and not necessarily those of the Alberta Government or its representatives.

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