The economics of revegetation of stripmined land for use as forage by range cattle
by Ralph Peter McQuillan

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Economics
Montana State University

Abstract:
This study deals with the economics of revegetating stripmined land for use as forage material. The benefits are measured in Animal Unit Months per acre for use by range cattle. The costs are those associated with reestablishing the forage material.

The study focuses on areas similar to those found in Eastern Montana. Stripmining involves the removal of overburden, extraction of coal, backfilling, and revegetation. The area involved in this study only includes revegetation. Revegetation involves planting of seed and maintenance until satisfaction of the bond requirements.

Linear programming is used to find which mixtures of plants give the maximum present value of forage. The objective function contains the machinery, labor, seed, other necessary costs, and the benefits (as pasture rental value). The benefits received are discounted back using an infinite discount horizon in order to keep values the same.

This allowed for analysis of the governmental requirements of a full year pasture versus seasonal pasture, and requiring certain amounts of native species to be planted. It was found the less restriction the higher the value obtainable as forage material.

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

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CHAPTER 1

INTRODUCTION

STATEMENT OF THE PROBLEM

Federal and Montana state law requires that stripmined land be reclaimed. This reclaimed land could be put to a viable use as forage for range cattle. Through planning for a specific use the reclaimed land should provide an economically useable site. The process involved after removal of the coal seam is reclamation and revegetation of the site. There are numerous reclamation costs associated with the backfilling and recontouring to the approved postmining configuration.[1] Revegetation incurs costs due to preparation for seed, fertilizing, planting, and maintaining the site until the seeded species are established. Coal mining companies face the problem of minimizing the cost of these activities while complying with the laws.

The four phases of mined-land reclamation are 1) design, engineering and overhead, 2) bonding and obtaining permits, 3) backfilling and grading, and 4) revegetation.[2] The first three phases are independent of the fourth phase, since the land must be recontoured for any future use. Therefore, only the fourth phase will be examined with regards to revegetation to pasture for range cattle.

Establishment of vegetation upon a stripmined area begins upon completion of recontouring and topsoiling. The various types of species seeded and the method used to seed the species change the cost involved in revegetation. Some of the costs may be a direct result of limits imposed by U.S. Public Law 95-87 and State laws and regulations specifying the method of revegetation and types of plant species. Montana Code states that the operator (the party reclaiming the area)

> shall prepare the soil and plant such legumes, grasses, shrubs, and trees as are necessary to establish on the regraded areas and all other lands affected a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area except that introduced species may be used in the revegetation process where desirable and necessary to achieve the approved postmining land use plan.[3]

Each mine's plan, on file with the Montana Department of State Lands, tells what the vegetative cover will be and the method by which it will be achieved.

In order that the land may be reclaimed to a more usable state, this study will maximize benefits net of revegetation costs received. The reestablished vegetation will be used as forage material for range cattle. This will involve:

(1) estimating the grass species mixture which will maximize the present value of returns generated by use as forage for cattle grazing.

(2) finding the optimal level of revegetation and the stocking rate.

NEED FOR THE PROJECT

Presently, revegetation research has not looked at the alternative vegetative uses of the stripmined site. Revegetation to a more desirable ground cover for future users would enable coal mining companies to improve relations with ranchers and at the same time return the land to non-mining uses. It has been shown that a vegetative cover can be established with relative success.[4] The study will help meet the need to show what seed mixtures should be planted. If the optimal vegetative cover is established initially it will lessen the possibility of a costly change in vegetation in the near future.

OBJECTIVES OF THE PROJECT

This study will attempt to assist companies and the state to improve revegetation by:

(1) Identifying and determining the amounts of seed, labor, machinery, the seed mixture, and the number of machine passes needed in order to provide the forage necessary to meet the nutritional requirements of range cattle and still meet the standards allowable under applicable laws and regulations;

(2) Calculating the benefits received by using the dollar value for the AUM's per acre for the value of forage as feed for range cattle.

PROCEDURE OF THE PROJECT

In order to calculate the return on a reclaimed site the following procedure will be used:

A) Identify feasible types of vegetative cover, method of seeding (including machinery types and costs), and the cost or rental value per AUM per acre.

B) Calculate the net present value for revegetation activities:

1) Compute the cost associated with revegetation. Costs per acre will be based on 1982 data. This will be done for mining sites similar to the Peabody, Western Energy, and Decker Coal Mines in eastern Montana. Prices were obtained from various seed and implement dealers.

2) Compute the benefit derived as forage for range cattle. Benefits will be calculated from the revegetated area's pasture rental value for range cattle. This will determine the value of the reclaimed-revegetated site in present value terms, under an infinite horizon.

C) Determine the combinations of activities with the highest net present value as indicated by linear programming.

There will be full year pasture and seasonal pasture models in the study. The grazing will take place for 269 days of the year broken down into segments of ninety-two, eighty-eight, and eighty-nine days for the seasonal pastures. Therefore grazing will be possible for most of the year on a revegetated site. Hay will be feed for the remainder of the year.

RECLAMATION BACKGROUND

As coal becomes a more prevalent energy source more lands will need to be reclaimed because of stripmining for coal. Stripmining is presently the most economical method of removing coal from the ground (except in deep or sloping deposits) and, of all methods, the safest.[5] After mining, the spoils site is to be reclaimed to remove or reduce any scars upon the land, but primarily for the preservation of the renewable soil resource. This is in essence the reason for Public Law 95-87 as passed by the United States Congress and the prior Montana Stripmining and Reclamation Act.[6]

According to a Bureau of Mines study, the greatest cost incurred in stripmining is derived from the first three phases (refer to page 1) and only about 2-7% of total cost is for revegetation.[7] Though revegetation is not a major portion of the total cost it may be the most important portion because of its future benefit for the renewable soil resource, high visibility to all parties, and the amount of variation allowed by law.

The revegetation process begins when a site is selected as a potential mine location. State law requires that revegetation plans be submitted to the Department of State Lands with the mine permit application, prior to the commencement of mining. State law further requires a performance bond to be forfeited if the mining site is not reclaimed to conform to current regulations.[8] The length of the bonding period is ten years after completion of revegetation. The required paper work takes time, but is designed to ensure that work will be done which results in a site that approximates or improves upon the original state.[9]

Backfilling and grading is time consuming and the most costly of the first three phases of reclamation, according to a Bureau of Mines study in 1977.[10] In this particular phase the land is recontoured to the approximate original topography unless the mining company is granted a variance due to special circumstances as recognized by the Montana Department of State Lands. Once recontouring is completed the revegetation phase will commence. This study will examine sites that have been reclaimed to a grade of no more than seven percent.

All reclamation-revegetation falls under the jurisdiction of state and federal laws.[11] State law takes primacy over Federal law when the State's regulatory program is approved (for being at least as stringent as Federal law) by the United States Department of Interior. In addition to requiring recontouring of stripmined land, Montana law also stipulates the general types of vegetation permitted.[12] Seeded vegetation must be composed primarily of native species with provision for inclusion of other species for special use pastures. These special use pastures must also be approved by the state.

REVEGETATION REVIEW

Most reclamation-revegetation research concentrates on technical methods used to reclaim stripmined lands. There is little literature currently available on the benefits from revegetation of stripmined lands. Steve Young of the Montana State University Reclamation Unit is conducting research on plant response, and grazing effects on stripmine revegetation. Ron Ries of Mandan, North Dakota is currently in the fifth year of a ten year study measuring the effects of grazing on stripmine spoils.[13] Data on plant dry matter production is very limited and data on compatability among plants and the effect upon growth is even more limited.

There are two general categories of grasses: cool-season and warm-season grasses. The warm-season grasses are harder to establish and maintain than the cool-season grasses.[14] The cool-season grasses are generally used to establish the original ground cover. This provides for a stabilization of the soil and reduces erosion of the redistributed topsoil.[15]

Once the soil is stabilized, warm-season grasses which seem to grow more slowly will have a chance to become established. A balance between warm-season and cool-season grasses is implied by Montana's Stripmining and Reclamation Act in order to provide a diverse groundcover capable of regeneration and seasonal growth. The act requires that a primarily native species seed mixture (fifty-one percent or more of the actual productivity) be used in the reclamation of the mine spoil site.[16]

The following is a partial list of seeds currently used in reclamation programs:

Thickspike Wheatgrass	Russian Wildrye
Streambank Wheatgrass	Common Buffalograss
Western Wheatgrass	Smooth Brome
Beardless Wheatgrass	Mountain Brome
Slender Wheatgrass	Regar Brome
Pubescent Wheatgrass	Canada Wildrye
Whitman Wheatgrass	Creeping Wildrye
Tall Wheatgrass	Alkali Bluegrass
Crested Wheatgrass	Green Needlegrass
Kentucky Bluegrass	Western Yarrow
Sideoats Grama(+)	Canada Bluegrass
Blue Grama(+)	Alfalfa Medic
Blue Flax	Purple Prairie Clover
Cicer Milkvetch	White Prairie Clover
Prairie Sandreed(+)	Eski Sainfoin
Indian Rice Grass	Switchgrass
Alkali Sakaton(+)	Prairie Cordgrass(+)
Sand Dropseed(+)	Big Bluestem(+)

Weeping Lovegrass(+)
Fourwing Saltbrush
Lewis Flax
Prairie Coneflower

Sand Bluestem(+)
Needle and Thread
Winterfat

These seeds are both warm-season(+) and cool-season grasses. The list of seeds used comes from revegetation plans on file with the Montana Department of State Lands.

Edward J. DePuit showed in his study that forage from the mine site at Colstrip is higher in nutritional value on a dry weight basis during the spring grazing period, than at other times.[17] In his study cattle on mine spoils were able to gain more weight than those grazed on nearby native pasture. Ron Ries at the USDA office in Mandan, North Dakota is also doing studies on cattle weight gain on mine spoils with control plots of native range.[18]

Soil variability appears to have little influence upon the nutritional value of forage grown throughout a certain reclamation area. The soil seems to be sufficiently mixed during the mining process to remove variability in its composition.[19] Previous studies showed that the nutritional content appeared constant over a mine spoils site whether the revegetative area was new, two years old, or fifty years old.[20] This permitted the assumption that plant response will be the same throughout the revegetated area. Nutritional value of forage will be assumed to not vary in a planted area.

CHAPTER 2

DEVELOPMENT OF THE MODEL

PROGRAMMING MODEL

Linear programming is the method that will be used to calculate net returns in this study. A budgeting method can not be used because maximum and minimum variables are utilized. The problem does not use any time series data that were not able to be transformed into present value terms. Thus dynamic programming could have been used but was not necessary. Linear programming is the simpler of the two programming techniques to use on this problem.

Linear programming is a mathematical tool used to find an optimal solution to a problem with a linear objective function and linear constraints. These constraints specify maximum or minimum levels for certain variables and linear combinations of variables and precise levels for other variables and combinations. Then through an iterative process the best solution to the problem which satisfies the constraints is found.

The constraints on the linear program are designed to ensure that the vegetation chosen meets the needs of range cattle forage production. The following alternatives will be looked at:

1) Plant the acreage such that there are three separate pastures that may be used over a year. This type of planting will require a special use permit (see figure 1).

2) Plant the acreage so one pasture supplies all the needs for a full year and meets the requirements of a full season pasture as specified in the current regulations (see figure 2).

These two alternatives also have two subparts for each:

a) Plant seed mixtures that are primarily composed of native grass species,

b) Plant seed mixtures in any proportion regardless of whether the species are introduced or native species. If the results are introduced species of fifty percent or greater proportion, then a special permit is required as a variance from existing regulations.

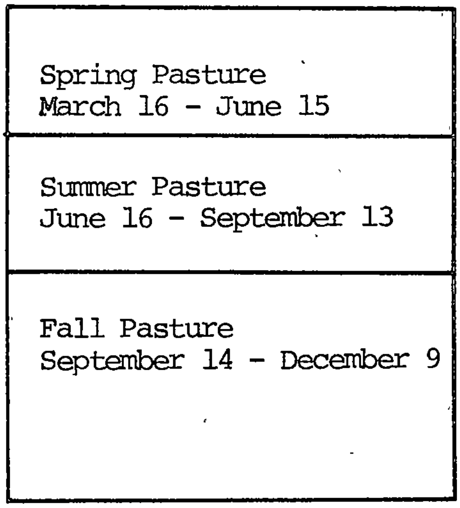

Figure 1. Seasonal Pasture

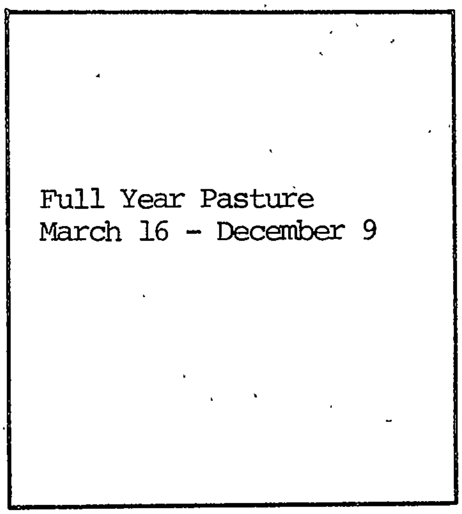

Figure 2. Full Year Pasture

Four models will be developed from the alternatives stated above. The first model is seasonal pasture, the second model is seasonal pasture with the native seed constraint, the third model is full year pasture, and the fourth model is full year pasture with the native seed constraint. They will all have the general objective function form:

$$Z = B - C$$

Where Z is the return derived from subtracting the costs(C) from the benefits(B). The values in the objective function are a dollar value for a particular activity. The linear program computes the return in a model from the amount of a particular activity times the dollar value of that activity per unit.

The benefits in this study are evaluated in terms of present value of the rental stream for the AUM (animal unit month) per period.

$$B = \Sigma \text{ AUM rentals (discounted)}$$

By summing the present value of AUM rentals one arrives at the value of the benefits. Thus the only way to increase the benefits is to either increase the value of the AUM or increase the number of AUM's. Since we are assuming a fixed value of the AUM per period, the stocking rate of the AUM (the number of AUM's per acre) is the only variable that can change.

The costs in the study are the summation of all variable costs costs incurred. Only variable costs are counted because fixed costs are not affected by the levels of the activities.

$$C = \Sigma \text{ Cost of activity}_i$$

The variable costs are the costs of seed and the number of machine passes to plant the site. In order to keep from adding the nutritional value and dry matter amounts across seasons in the models (due to limitations of linear programming and thereby double counting the forage), the seeding costs are separated for each of the three nutritional requirement seasons.

The first model to be derived, which has seasonal pastures and no constraint on the native or non-native seeds, has the fewest actual constraints. The remaining three models include additional constraints.

The first constraints on the model are dietary constraints. These dietary constraints are broken down into requirements for three periods of the year. This is to ensure proper nutrition for the AUM.

The first of these dietary constraints are dry matter(DM) constraints on the maximum and minimum amounts of forage intake. These will regulate the actual weight of the forage material that is consumed by the AUM. The second set of dietary constraints is on the amount of digestible protein(DP) intake, and the third is on the metabolizable energy(ME) intake. These two constraints are necessary to make sure the AUM has the proper nutrient levels.

The next type of constraint is on the acreage. It will be assumed for computational purposes that one acre is being planted and that forage on this acre will meet the needs of a yet to be determined portion of the AUM during the periods under consideration. This makes the model useful for any number of acres as it is on a per acre basis.

In order to keep the number of animals constant throughout the year the value of the AUM increases. This is accounted for in equality constraints which reflect the aging and increase in size and weight of the animals that comprise the AUM. The AUM is then calculated using a herd size and the needs for the herd over a period of time.

The final constraint in the first model is the constraint on the number of machine passes. The initial planting may require more than one pass of the Brillion packer seeder in order to plant the seed mixture. The Brillion packer seeder has two boxes, one will contain the seed mixture and the other will contain fertilizer. Due to differences in the size of the seeds, the seeds will be broken into two groups. Only one group will be able to be planted in a pass, therefore a maximum of two passes may be necessary.

Each pass will be assumed to be made over the entire acreage. A fractional pass was not allowed, and the seed mixture planted was evenly distributed over the acreage. This requirement is necessary for the even distribution of the seed and is the generally accepted method of planting a seed mixture. This necessitates the use of an integer constraint on the pass activities, so as to make a whole pass over the acreage.

The second model will have all the previous constraints with an additional constraint for the seeding of primarily native grass species. This constraint is used in order to meet one of the two governmental regulations on revegetating a stripmine site.

The third model incorporates the second governmental regulation of planting a site that will provide forage for the AUM on a yearly basis. The method by which this model and the the fourth model make a full year pasture is by equating the seeding requirements for the seasonal pastures. This model does not include the seed constraint the second model incorporated.

The fourth model incorporates the native seeding requirement as does the second model and also the full year requirements of the third model. This is the most restrictive model in that it incorporates both government regulations. In terms of constraints it is also the most restrictive model.

Since the bonding period is ten years and the grasses in the study are relatively long lived one will not have to worry about a second reseeding in the near future. This will allow for evaluation of the forage on a one time planting horizon. The grass's yield of dry matter will also be considered constant over the ten year period (as more data becomes available this assumption may be changed in future studies as well as incorporating risk).

CHAPTER 3

DEVELOPMENT OF THE COEFFICIENTS AND THE ACTUAL MODEL

SEEDING OF SITE

In seeding a reclaimed area a 110 hp. tractor is used to pull a Brillion packer seeder. Certain of the seeds may be planted together in one pass of the Brillion packer seeder. However, due to size differences the seeds to be used in this study will be broken down into two groups for planting. This will make at most two passes of the Brillion necessary to plant the area. All the seeds planted in a pass will be planted at the same depth in the soil. Germination of a certain seed will be assumed constant throughout any acreage that is planted.

The Brillion packer seeder is twelve feet long and is tractor pulled and is assumed to have an efficiency of seventy percent. The formula used to compute acres per hour is:

$$\text{acres per hour} = \frac{\text{mph} * \text{width of coverage} * .70}{8.25}$$

Using this formula all grasses are planted by the Brillion seeder at a rate of 4.07 acres/hour. The 8.25

is computed by dividing the square feet in an acre by the number of feet in a mile. The rate of pull for the tractor has been assumed at four miles per hour for seeding.

USE OF RANGE CATTLE AS A DATA BASE

Vegetation growth on reclaimed land will be evaluated as forage for range cattle since this is the primary use of range land in Southeastern Montana. The mine site will be grazed by a standardized herd with a stocking rate to be chosen by the optimization process. The standardized AUM used will be computed assuming the following proportions in the herd. For every 100 cows there will be twenty-four replacement heifers, eighty-four calves (forty-two steers and forty-two heifer calves), and four bulls. All calves will be assumed to be born on March 16 and will have a birth weight of seventy-five pounds (Table 1). Calves will be sold on November 1st with a finishing weight of 420 pounds.

The weight of the cattle will be assumed at 1100 pounds for the cows, 783 pounds finishing weight for the