# RANGELAND ANALYSIS AND LAND COVER
# A COMPUTERIZED APPROACH

LOUIS ADOLPH OGAARD

Abstract. Land cover for 3,295 square miles in western North Dakota was delimited on black and white aerial photography and digitized. Rangeland acreage was correlated with major soils associations to estimate rangeland forage production and cattle carrying capacity. Rangeland carrying capacity of 37,900 cattle for all the strip mining activities proposed.

## INTRODUCTION

The increased national demand for energy has created an economic climate conducive for large scale mining of coal. The western states of Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, Washington, and Wyoming hold vast strippable reserves, i.e. those recoverable reserves considered to be accessible to surface mining according to specified conditions of economics and technology (Environmental Studies Board (NAS/NAE) 1974). Specifically, North Dakota has approximately fifteen billion short tons of strippable lignite in beds more than five feet thick and lying within one hundred feet of the surface (Averitt, 1970). The British Thermal Units (BTU) rating for this fossil fuel is about 7,230 per pound (Department of Interior, 1977), a value adequate for use in coal-fired electric generation plants. Additionally, lignite may be transformed into synthetic natural gas (SNG) through a gasification process or simply exported to energy-deficient states. Thus, North Dakota finds itself in the enviable position of selling electricity, coal for export or potentially SNG at a time when many states lack their own energy resources for self-sufficiency.

This dramatic increase in energy-related development both now and in the future will impact heavily on the rural environment of western North Dakota--the location of the preponderance of strippable reserves in the state. Several studies (Bureau of Land Management and State of North Dakota, 1978; Johnson, 1976) were initiated in the 1970's to quantify this impact and provide guidelines which allow for an orderly transition from a predominantly agricultural economy to one tied largely to coal-related development. One such study was called Resource Inventory, Monitoring, and Analysis System (RIMAS).

The Environmental Protection Agency (EPA) funded RIMAS Phase I and Phase II to address this problem of coal development in portions of Burleigh, McLean, Mercer, Morton, and Oliver counties in North Dakota (fig. I). Phase I was funded from April 1, 1976 to September 30, 1979 and Phase II from October 1, 1976 to September 30, 1979.

Phase I objectives (Nelson, 1975) included: (1) Expand Resource Inventory, Information Management, and Monitoring System (RIMS) by adding coal related natural resource, socio-economic, and environmental information, (2) Adapt General Environmental Model (GEM) and create cross-over between GEM and RIMS, (3) Stimulate impacts of coal development by geographical areas by use of RIMAS, and (4) Output and publish impact analysis reports and provide maps, graphs, and tables of data to community leaders and public officials.

Phase II objective (Nelson, 1976) included: (1) Expand the analytical capabilities of RIMAS to estimate: (a) impacts of energy transmission corridors, (b) impacts of alternative settlement patterns upon community services and transportation systems; and (2) Adapt and apply composite mapping to analyze energy development impacts on land use and cover and to identify areas where mining will have minimum negative effects.

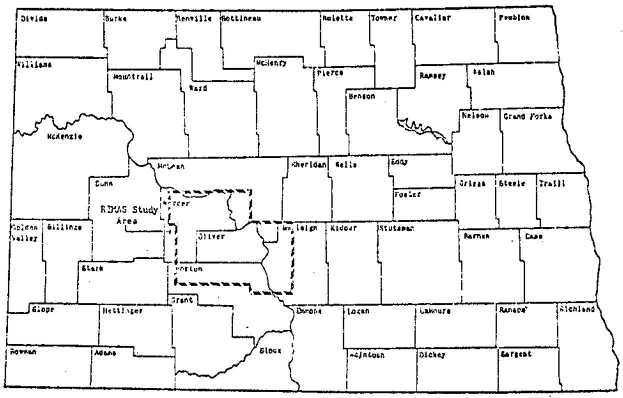


Figure I. Location of RIMAS Study Area in North Dakota.

The breadth of these objectives necessitated an interdisciplinary approach. The Department of Agricultural Economics, Botany, and Soils at North Dakota State University (NDSU) contributed personnel and resources during the period in which the RIMAS project was conducted. A soil scientist, two system analysts, three agricultural economists, two digitizer operators, and a botanist comprised the research team whose efforts were coordinated through the Department of Agricultural Economics, NDSU. The fruition of this three year study is embodied in a computer simulation model--a generation program in which each run represents one calendar year. Economics, demographics, local government, the environment and coal/coal-related development are the major elements addressed.

The use of such a model as a predictive tool depends heavily upon the accuracy and adequacy of a physical data base. A precise definition of the current conditions is an absolute prerequisite before a model can reliably predict a change in these conditions. To this end, the current (1975) land cover was defined at a level of detail compatible with the model requirements. The cell size for the simulation model was a section (640 acres) of land. The parameters needed for the definition of each land cover category included exact acreages and tagging of the land cover with a standardized code.

Visual inspection of the RIMAS study area revealed two predominant land uses--cropland and rangeland. The impetus toward increased strip mining for coal and energy-related development would portend significant changes in these current land uses. As an example, the Draft Environmental Statement Summary (Department of Interior, 1977) for the American Natural Gas Coal Gasification Company (ANGCGC) gasification plant and stripping operation north of Beulah, North Dakota underscores the scope of probable impact upon the land. Thirteen thousand acres will be disturbed in this operation alone--a large share of which is currently rangeland, i.e. land on which the native vegetation (climax or natural potential plant community) is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing use (Soil Conservation Service, 1976). However, no mention was made in this summary about rangeland impact. Such an oversight suggests that rangeland needs a closer examination to determine what will be lost when the strip mining process proceeds.

To analyze this and other issues relating to the computer simulation model, a sub-project with the following objectives was instituted: (1) map and determine the current (1975) land cover acreages on each section within the RIMAS study area, (2) inventory and develop productivity estimates for rangeland on a major portion of the RIMAS study area, and (3) assess the impact of strip mining on the rangeland using three levels of energy development.

## Methods

A choice was made in 1976 to delimit land cover on aerial photographs rather than rely on remote sensing technology (LANDSAT), described by the National Academy of Sciences (1977) as still in its infancy. This decision proved extremely prudent. Photo-interpretation for a portion of the RIMAS study area was already completed using high altitude color infrared imagery taken in 1975. The Environmental Research and Technology, Inc. (ERT) group had contracted with the Bureau of Land Management (BLM) to perform this interpretation as part of the west-central North Dakota environmental impact statement (Bureau of Land Management and State of North Dakota, 1978). This interpreted product was acquired by the RIMAS team in the fall of 1976.

At the same time, the BLM provided the RIMAS team with a set of black and white aerial quadrangle (quad) photographs (scale 1:24000) shot in 1975 for a seven county area, including all of the RIMAS study area. These became the backbone of our photo-interpretive work. Over a two year (1976-1978) time frame, the following analysis took place.

First, all the black and white quad photographs for the RIMAS study area were coded for land cover. Up to nine categories were discerned on each photograph. These included rangeland, cropland, rivers, lakes, woodland, strip mines, farmsteads, town/built-up, and wetland. The nature of the photographic process resulted in varying degrees of overlap between quads. Consequently, when land cover was analyzed on each quad, a certain amount of duplication occurred. Wherever possible the ERT photo-interpretation was used to decipher the land cover on photographs of poor quality.

Secondly, a Numonics Corporation electronic graphics calculator (planimeter), Model 1224, was employed to compute acreages of land cover for each section in the RIMAS study area. These acreage figures were tabulated using FORTRAN Coding Forms. This information was eventually key punched with one card per section of land (640 acres), containing all the physical data relevant to that parcel.

Finally, the land cover information on the black and white quads was digitized. Two digitized machines were used in this operation, Science Accessories Corporation (SAC) Models 1323 and 1341. Ancillary hardware for the Model 1341 included the Kennedy Incremental 1600 reel-to-reel recorder, an acrylic tablet with electronic sensors along two adjacent sides, and a stylus with a spark gap built into the point. The Model 1323 used an SAC Model GP-2 Graf Pen, FACIT Model 4070 tape punch, an acrylic tablet and stylus, comparable to those used with the SAC Model 1341 digitizer.

The digitizing process entailed placement of the subject material (quad) on the acrylic tablet, the coding of the attributes (land cover categories) on each side of a line to be traced, and the actual tracing of this line using the spark-gap stylus. The line is converted into a series of points, each appended with a number by the digitizing machine. State plane coordinates are digitized for each quad to ensure accurate alignment when overlaying two different maps. All these points are either recorded directly onto magnetic tape for use with the computer as in SAC Model 1341 or onto paper tape. The latter method, while more cumbersome, was the most frequently utilized during the tenure of this project. The paper tape provided a back-up in case problems arose on the magnetic tape copy. A National Cash Register (NCR) Model 736 Magnetic Encoder converted the paper tape data to magnetic tape.

Once on magnetic tape, the file (digitized data) was run through a series of PL-1 computer programs to convert the data to state plane coordinates and store on tape. These are known as the RIMS programs. This process of digitizing land cover information provided the capability to reproduce this information at any scale, and to highlight, for example, particular land cover types.

During the early stages of the RIMAS project the means for this reproduction was supplied by a CALCOMP Model 310 drum plotter together with an IBM 1620 mini-computer. In 1978, a Houston Instruments COMPLOT DP-8SV3 plotter was purchased and installed at the University. This unit was self-contained with a multiple-pen feature to allow the use of up to three colors on a plot without a machine shut down. With both machines, twelve inch white paper was the usual writing surface, and felt tip or ball point pens were the means to draw the plots.

All plots were scaled at one inch per two miles. This meant a significant reduction in scale from the 1:24000 quad photos or one inch per .38 miles. This scale shift resulted in a loss of some detail, but the process of computer graphics was exact enough to render the smaller maps useful at the new scale. The purpose for this scale change was to provide land cover information at a level compatible with General Soil Maps (1963), scale 1" = 2 miles, for the counties of interest.

The reproduction (scale 1" = 2 mi.) of the land cover information from the black and white quadrangle photographs was initially plotted on white paper, described above. These plots provided the outline of land cover but no identification (I.D.). Manual identification was accomplished by comparing the reproduced outline with the original quad. Letter designations were used as I.D.'s. These included A = agriculture (cropland), R = rangeland, RVR or RIVER = river, L or LAKE = lake, W = woodland, S = strip mine, T = town/built-up, x or F = farmstead, and WL = wetland. An index for the quad photographs together with all the quad reproductions is found in Appendix C.

Each reproduction was copied, using the Thermo-Fax machine, Model "The Secretary." A transparency infrared film, Type 533 (3M) was employed in this thermo-fax process to provide a clear copy of the land cover at a scale 1" = 2 miles.

A sheet of Milar was cut to fit over each of three General Soil Maps (1963) for Oliver, McLean, and Mercer Counties. The outline of each county was drawn onto this sheet using a Rapid-o-graph (Koh-I-Noor No. 3065HO) with a 00 tip and water-soluble ink. Subsequently each clear, thermo-fax reproduction for land cover was positioned under the Milar sheet and aligned to the appropriate location using the original quad photograph for reference. The Rapid-o-graph was employed to manually draw the rangeland onto the Milar sheet (scale 1" = 2 mi.). This overlay was then reproduced in clear (Technifax film, Catalogue No. 15P3ME) and black line (Keuffel and Esser Co., Helios black line diazo paper, No. E4216) copies, using a GAF Model 240 Diazo Printer. The utility of the clear overlay of rangeland is described below.

A quantification of rangeland resources was acquired through the use of standard methodology of the Soil Conservation Service (1976). This system of analysis revolves around the range site, i.e. a distinctive kind of rangeland that differs from other kinds of rangeland in its ability to produce a characteristic natural plant community. Major factors which impinge on range site genesis include soil type, topography, and rainfall. Differences in species composition, percent composition, and productivity occur from one range site to another. These variable features are tied most directly to soil type (Shaver, 1977). The equation from soil type to range site is made in Advisory SOILS-ND-2 (Ekart, 1978). These equations provide the basis for a computerized approach to rangeland inventory.

Using published descriptions (Omodt et al., 1968) of the major soil associations in the RIMAS study area, component soils were equated to range sites. As described above, each range site has characteristic species, species composition, and productivity. These distinctive characteristics allow one to quantify expected rangeland resources.

The analysis of rangeland in the portions of McLean, Mercer, and Oliver Counties within the RIMAS study area was accomplished with a computer program (FORTRAN IV) called ZRANGE. This program, while specifically for the RIMAS study area, was designed for easy modification to accommodate rangeland anywhere within North Dakota.

Internal documentation in the form of comment cards has been included within the program. These comments are intended to facilitate programming changes desired by the user. There are a number of options available including variable growing and range conditions. Additionally, a required sequence of steps must be followed to set up the program for a particular county.

## Results and Discussion

Land cover analysis is the one facet of PHYDAT with the potential for comparison to other studies in the region (McKeon, 1977; Bureau of Land Management and State of North Dakota, 1978; U.S. Department of Agriculture and North Dakota State University, 1976; Soil Conservation Service, 1970). The Regional Environmental Assessment Program (REAP) placed reliance on LANDSAT imagery for their land cover determination. Most scenes used for this venture were taken the summer of 1975. The Bureau of Land Management (BLM) used color infrared, high altitude photography taken the summer of 1975. The North Dakota Crop and Live stock Statistics, 1975 provides planted cropland acreage data accrued through a statistical survey of farmers. The black and white aerial quadrangle photographs used as the basis for land cover determination in PHYDAT were taken in August, 1975. This congruence of time frame is the one common thread between these studies.

Differences emerge when one compares the categories of land cover employed within each study. For instance, the mixed, fallow, and uncategorized categories of REAP have no direct analogues in either PHYDAT or the BLM endeavor. The grassland and shrubland categories of BLM equate to PHYDAT rangeland while the barren designation of REAP approximates the strip mine designation of PHYDAT. PHYDAT distinguishes between rivers and lakes while REAP and BLM lump these under "water" or "water surface," respectively. Additional minor discrepancies exist.

Two years elapsed between the time the quadrangle photographs were taken and all the land cover within the RIMAS study area was analyzed. This interim prevented any meaningful statistical treatment because land cover is a dynamic entity. Pressures to turn rangeland into cropland or strip-mined land is one example of change. The drainage of wetlands is another.

The mutability of land cover does not diminish the importance of quantification. A baseline study such as PHYDAT provides a standard by which change may be measured.

Land cover acreage as a function of county is found in Table 1. Certain land cover patterns within the RIMAS study area may be discerned from these data. McLean County exhibits the largest percentage/acreage of wetland and the lowest percentage/acreage of rangeland. The Missouri Coteau, of which McLean County is a part, is a major location of "prairie potholes" or wetlands, created through the glaciation process. Our wetland data corroborate this fact. The large proportion of land in crops explains the small percentage of rangeland found in the county.

Portions of McLean and Mercer Counties together with all of Oliver County represent the area analyzed for rangeland resources. This analysis included hand-drawn overlays of rangeland for each of these counties, acquisition of rangeland acreage as a function of major soil area, and the application of the computer program ZRANGE to these acreage data.

Rangeland acreages for each county were summed by major soil area to ascertain potential relationships between rangeland and soil type. Based on these relationships, general statements may be made concerning the soils upon which most rangeland is found. An assessment of those soils which comprise at least 5 percent of the total rangeland acreage for each of the three counties suggests the following: (1) Topography is characterized by strongly sloping, hilly and steep, strongly rolling or rolling conditions, and (2) Zahl and Cabba soil areas predominate with concomitant thin upland and shallow range sites.

These results are not unexpected. Rugged terrain and poor soil conditions are not conducive for conversion to cropland. The economic outlook associated with such a conversion would not be favorable. Difficulties one might encounter would be an inaccessability to farm equipment and potentially poor crop yields. These major soil areas on which most rangeland is found may have small areas of potentially good cropland, but again, inaccessability and the small farmable area preclude conversion into this land use.

Much of this land is a valuable source of primary and secondary rangeland to the cattle rancher. An estimation of this value in terms of potential carrying capacity is obtained through the use of ZRANGE.

A total of 1,769 sections of land in McLean, Mercer, and Oliver Counties was analyzed through the use of this computer program. Table 2 summarizes estimated carrying capacity for the rangeland in each of these counties. These data are developed for excellent, good, and fair range conditions. The assumption is that one Animal Unit Month (A.U.M.) is the amount of forage required to support a cow-calf one month. The table of recommended initial stocking rates (Soil Conservation Service, 1975) provides the basis for the computation of carrying capacity for each section. These stocking rates are tied to the vegetation zone in which the counties in question occur.

Rangeland acreage figures in ZRANGE correspond to the "acres of range" found in PHYDAT. The total rangeland acreage for each section is broken down on the basis of potential range sites expected. This range site acreage multiplied by initial stocking rate data gives an estimate of carrying capacity on that range site. This technique is repeated for all expected range sites. A summation of these data provides the carrying capacity figure for the entire section.

Table 1. Land Cover Acreage for the Portions of Burleigh, McLean, Mercer, Morton, and Oliver Counties Within the RIMAS Study Area

| Land Cover Category | Burleigh Acreage | % | McLean Acreage | % | Mercer Acreage | % | Morton Acreage | % | Oliver Acreage | % |
|---|---|---|---|---|---|---|---|---|---|---|
| Cropland | 204,521 | 49.24 | 155,855 | 62.93 | 230,658 | 44.28 | 195,958 | 43.12 | 182,013 | 38.69 |
| Rangeland | 185,042 | 44.55 | 69,832 | 28.19 | 255,886 | 49.12 | 236,240 | 52.00 | 266,474 | 56.65 |
| River | 2,802 | 0.68 | 4,684 | 1.89 | 3,773 | 0.72 | 4,242 | 0.93 | 5,818 | 1.24 |
| Lake | 0 | 0.00 | 1,534 | 0.62 | 10,428 | 2.00 | 49 | 0.01 | 412 | 0.09 |
| Woodland | 6,960 | 1.68 | 8,557 | 3.46 | 5,836 | 1.12 | 6.086 | 1.34 | 9,003 | 1.91 |
| Mine | 277 | 0.07 | 754 | 0.30 | 8,651 | 1.65 | 253 | 0.06 | 2,758 | 0.59 |
| Farmstead | 3,466 | 0.84 | 2,027 | 0.82 | 3,684 | 0.71 | 4,006 | 0.88 | 3,091 | 0.66 |
| Town/Built-up | 10,463 | 2.51 | 1,317 | 0.53 | 1,694 | 0.33 | 6,998 | 1.54 | 389 | 0.08 |
| Wetland | 1,829 | 0.43 | 3,120 | 1.26 | 350 | 0.07 | 568 | 0.12 | 442 | 0.09 |
| Total | 415,360 | 100.00 | 247,680 | 100.00 | 520,960 | 100.00 | 454,400 | 100.00 | 470,400 | 100.00 |

Table 2. Estimated Cattly Carrying Capacity (A.U.M.'s) Under Excellent, Good, and Fair Range Conditions for the Portions of McLean, Mercer, and Oliver Counties Within the RIMAS Study Area

| Range Condition | Mercer County (# of cattle) | McLean County (# of cattle) | Oliver County (# of cattle) |
|---|---|---|---|
| Excellent | 122,806 | 41,132 | 133,361 |
| Good | 96,488 | 30,348 | 105,246 |
| Fair | 62,419 | 20,747 | 67,430 |

Forage production estimates are based upon published Soil Conservation Service (1975) data. A range of productivity figures (lbs./acre) is given for each range site in every vegetation zone within North Dakota. The high figure of this statistical range is used to compute annual production under favorable growing conditions. The midpoint between the extremes is used to calculate annual production under normal growing conditions. The low figure is used to determine forage production under poor growing conditions. These estimates assume that the range is in excellent condition. Less than this optimum condition would result in lower productivity and different percent species composition.

## Recommendations

A labor-intensive technique is described to quantify land cover in general and rangeland in particular. This approach to rangeland analysis could be a useful and timely tool by which the North Dakota Public Service Commission could gauge strip mining impact.

Current aerial photography could be used to update the data base (PHYDAT) and enhance accuracy. Such a technique is inexpensive compared to the cost of digital analysis of satellite imagery (LANDSAT).

## LITERATURE CITED


Bureau of Land Management and State of North Dakota. 1978. West-central North Dakota Regional Environmental Impact Study. 242 p. State of North Dakota, Bismarck, North Dakota.

Department of Interior. 1977. Draft Environmental Statement ANG Coal Gasification Company, North Dakota project. 416 p. Bureau of Reclamation, Bismarck, North Dakota.

Ekart, S. C. 1978. Soil Interpretations - Range Site Designations. Soil Conservation Service, U.S. Department of Agriculture, Bismarck, North Dakota. Unpublished.

Environmental Studies Board (NAS/NAE). 1974. Rehabilitation Potential of Western Coal Lands. 198 p. Ballinger Publishing Co., Cambridge, Massachusetts.

Johnson, A. W. 1976. The REAP Economic-Demographic Model-1. North Dakota Regional Environmental Assessment Program, Bismarck, North Dakota.

McKeon, J. B. 1977. Land Cover Analysis of North Dakota. Resource Environmental Assessment Program. 28 p. Bismarck, North Dakota.

National Academy of Sciences. 1977. Resource Sensing from Space: Prospects for Developing Countries. 202 p. National Academy of Sciences, Washington, D.C.

Nelson, W. C. 1976. Resource Inventory, Monitoring, and Analysis System (RIMAS) - Proposal Phase II. Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota. Unpublished.

Nelson, W. C. 1975. Resource Inventory, Monitoring, and Analysis System (RIMAS) - Proposal Phase I. Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota. Unpublished.

Omodt, H. W., G. A. Johnsgard, D. D. Patterson, and O. P. Olson. 1968. The Major Soils of North Dakota. Department of Soils Bulletin No. 472. 60 p. North Dakota State University, Fargo, North Dakota.

Shaver, J. C. 1977. North Dakota Rangeland Resources. Society for Range Management/Old West Regional Range Program. 118 p. Bismarck, North Dakota.

Soil Conservation Service. 1976. National Range Handbook. Soil Conservation Service. 78 p. Washington, D.C.

Soil Conservation Service. 1975. Range Sites and Conditions Guides for North Dakota. Soil Conservation Service, Bismarck, North Dakota. Unpublished.

Soil Conservation Service. 1970. North Dakota Conservation Needs Inventory. Soil Conservation Service. 161 p. Bismarck, North Dakota.

U.S. Department of Agriculture and North Dakota State University. 1976. North Dakota Crop and Livestock Statistics, 1975. Statistical Reporting Service, U.S. Department of Agriculture and Department of Agricultural Economics, Ag. Statistics No. 38. 76 p. North Dakota State University, Fargo, North Dakota.