A computer graphic system for interactive display of land qualities and potentials
by Gary Lee Ford

A thesis submitted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University

Abstract:
Maps showing quality and potential of agricultural lands are not readily available for much of the world. The objective of this study was to develop a system for interactive computer analysis of pedologic, geologic, vegetative, and climatologic information. The system produces plotter drawn maps of Montana, an area of 235,421 square kilometers, showing the distribution of agriculturally or environmentally similar areas. The use of 1:1,000,000 map scale facilitates composite analysis because many environmental variables are mapped at this intensity. The average cost of preparing a map for computer storage is less than $70, for plotting a map $5 to $20. Examples of system applications include site selection for a new experiment station, analysis of seven research centers to determine similar environments, and soil classification studies on the distribution of lands with cryic and frigid soil temperature regimes. This system promotes increased awareness of the characteristics and potentials of Montana's agricultural land.

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ABSTRACT

Maps showing quality and potential of agricultural lands are not readily available for much of the world. The objective of this study was to develop a system for interactive computer analysis of pedologic, geologic, vegetative, and climatologic information. The system produces plotter drawn maps of Montana, an area of 235,421 square kilometers, showing the distribution of agriculturally or environmentally similar areas. The use of 1:1,000,000 map scale facilitates composite analysis because many environmental variables are mapped at this intensity. The average cost of preparing a map for computer storage is less than $70, for plotting a map $5 to $20. Examples of system applications include site selection for a new experiment station, analysis of seven research centers to determine similar environments, and soil classification studies on the distribution of lands with cryic and frigid soil temperature regimes. This system promotes increased awareness of the characteristics and potentials of Montana's agricultural land.

INTRODUCTION

The purpose of this research was to design, develop, and test a computer graphic system for Montana. The system which was developed displays the spatial distribution of land qualities and management opportunities within the state. The following section discusses the need for such a system.

Description of the Land Resources of Montana

Montana is the fourth largest state in the nation. It has an area of 235,421 square kilometers (147,138 square miles). The east-west dimension is just over 550 miles at the Canadian border; the greatest north-south distance is approximately 325 miles in the west and 280 miles in the east (Taylor et al. 1974). The complex pattern of geology, landforms, soils, climate, and vegetation found within the area interact to produce a land surface which has a wide range of qualities, potentials, and limitations for use by man.

Physiographically the state can be divided into three north-south trending zones. The western third is part of the Rocky Mountains, the eastern third is on the Great Plains, and the central portion is a transition zone of plains with isolated low mountain ranges (Figure 1).

Elevations vary from 12,799 feet at Granite Peak in the Beartooth Plateau to 1,800 feet in the valley of the Kootenai River near Troy in the northwestern part of the state.

Geologically the state consists of flat lying sedimentary beds in the east, with complex units of folded, faulted, and otherwise

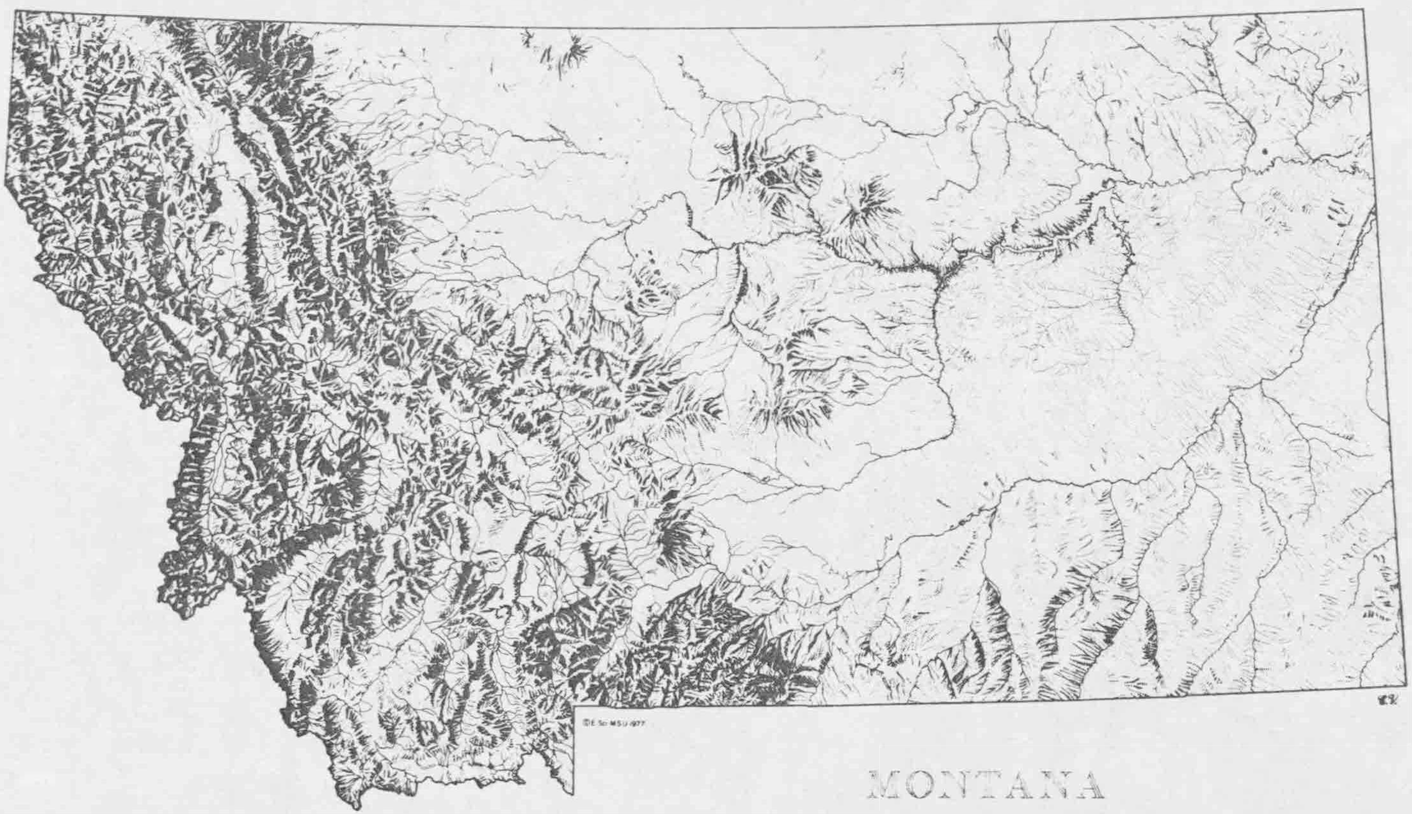

Figure 1. Physiographic diagram.

disturbed igneous, sedimentary, and metamorphic material in the west. Some portions of western Montana as well as the area north of the Missouri River in the east were extensively glaciated.

Temperatures range from a high of 117^{o}F at Medicine Lake in 1937 to a low of -70^{o}F at Rogers Pass in 1954. Although snowfall is great in many areas, more precipitation occurs as rain. Annual precipitation varies from less than 12 inches in southcentral Montana to over 100 inches in the mountains of the west. The average length of the frost-free season ranges from less than 30 days at high mountain locations to over 135 days in eastern Montana. Wind may be an important agent in some areas in the deposition of snow as in a blizzard or in its removal by a chinook.

The natural vegetation of the area covers a precipitation and elevation transect from xerophytic species through grasses to coniferous forest and finally alpine tundra. A recent climax vegetation map of the state by Ross and Hunter (1976) identified 62 different units based upon soils and climate.

The complex pattern of parent material, climate, relief, and vegetation found within the state interact to produce extensive amounts of five of the soil orders listed in Soil Taxonomy (USDA 1976). These are: Entisols, Aridisols, Inceptisols, Mollisols, and Alfisols.

The major land uses in the eastern two-thirds of the state include livestock raising on the more arid portions, with small grain production where precipitation is more favorable. In the west, the timber industry is an important part of the economy of many communities.

The Need for Land Resource Information

This brief description of Montana's land resources illustrates the complexity and diversity of the physical geography of the state. This wide spectrum of surface features complicates land management since each area will respond to a treatment in a slightly different manner. Resource inventories must be accomplished to identify the qualities, potentials, and limitations of this diverse area. In addition to this landscape complexity there are also ethical, legal, and economic justifications for these inventories.

There was a time in our nation's past when the practice was to remove the resources that could be easily extracted from a location and then move on to a less-populated area, often leaving a badly degraded landscape behind (Udall 1969). However, since little frontier remains in the 48 contiguous states to escape to, our society must learn how to use its fixed land base without impairing its productivity.

Nearly 30 years ago Aldo Leopold (1949) was advocating a land ethic: "A land ethic . . . reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity."

Only in recent years has this concept been given widespread attention. Proponents of the land ethic believe that an area should not be mindlessly manipulated but should be managed on the basis of its ecological characteristics. However, before this can be accomplished the manager must identify these characteristics, i.e., inventory the resources.

Legislation has also been instrumental in the generation of land resource information. In particular, the National Environmental Policy Act of 1969 and the Montana Environmental Policy Act of 1971 require that any activity which will have a major impact on the environment must be thoroughly studied and documented and alternatives proposed. These acts also involve the public in the planning and review process. Litigation based upon these laws has frequently stopped a proposed activity because of insufficient resource data to justify the action.

Some areas of Montana have been badly degraded by man's use of the land. It is estimated that by 1974 140,000 acres of the state's farmland had been taken out of production by saline seeps (Miller et al. 1976). It is also estimated that by 1980 the strip mining of coal in eastern Montana will have disturbed 5,500 acres (Northern Great Plains Resource Program 1975) and it is not yet certain that reclamation will be successful. In some areas, wind and water erosion remain serious problems. In addition, each year more of Montana's farmland is converted to other uses because of urban sprawl, road construction, and other activities.

The population of the state will continue to increase and with competition between uses for this land it is essential that determinations be made of the qualities, limitations, and potentials of the area so it will be used wisely, without impairing its long-term productivity.

In this thesis land is considered to be the result of the synthesis of geology, soils, climate, and vegetation into a landscape which has a particular set of qualities or characteristics which influence how it can be used. In most cases, without enormous costs, these properties can only be slightly modified by man.

This definition suggests that before the limitations and potentials of land can be determined resource inventories will be necessary in many different disciplines. Research of the Montana Agricultural Experiment Station has shown that even when consideration is limited to the natural landscape, the number of pedologic, geologic, biologic, hydrologic, and climatologic factors which may be significant exceeds 1,400 (Plantenburg et al. 1974). Of this large number approximately one-fourth may be determined or estimated from a modern soil survey (Nielsen 1977). However, decisions about the best use of land cannot be based upon soil qualities alone. Other aspects of the physical environment as well as economic and political considerations are also important.

The Present Status of Resource Inventory Mapping

The amount and quality of natural resource information available for an area varies greatly. While some locations in the state have adequate detailed data for planning, most do not. Figure 2 shows the status of soil surveys in Montana. Detailed mapping in most other disciplines is similarly incomplete. Also currently unavailable is a statewide land use map.

Because of this paucity of detailed resource inventories it is imperative that existing generalized data be utilized until better information is available. This level of information can help prevent land degradation and facilitate wise land use if utilized properly. Furthermore, it is essential that this resource information be disseminated in a form which will communicate its meaning.

Planners, the public, and other users of resource information are often critical of inventory reports which are full of jargon and fail to communicate the significance of the data (Woolfe 1978). One of the best ways to present resource information is with clear, well-presented maps.

Land Resource Maps

Maps are an effective method of showing relationships because they display the spatial distribution of the resource. The user does not have to sort through pages of text or graphs and tables. A well-