ECOLOGICAL LAND SURVEY IN MANITOBA, A DISCUSSION AND EVALUATION

A Thesis

Submitted to

the Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Hugo Veldhuis

May, 1981

ECOLOGICAL LAND SURVEY IN MANITOBA,

A DISCUSSION AND EVALUATION

BY

HUGO VELDHUIS

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

ABSTRACT

The objectives of the study are to review the approach taken by Ecological Land Surveys (ELS) to the inventory of land resources in Manitoba and to evaluate the extent to which the survey data have ecological significance and value to users of the land resource. This evaluation suggests certain modifications to the ELS methodology to improve the usefulness of the survey data to potential users.

The analysis and evaluation of Ecological Land Survey in Manitoba is accomplished through detailed study of the maps and descriptive reports derived from the Northern Resource Information Program (NRIP). Certain weakensses are evident in the hierarchical system in terms of developing relationships between the taxonomy and the map units depicting landscape segments at the Ecosection level. Ecological integration on the NRIP ecosection map is only weekly expressed. Data collection and data presentation of the NRIP surveys are not as well developed as would be expected from a truly integrated ecological land survey.

Although the NRIP ecosection maps provide a large amount of land resource data for terrain where little previous information existed, the lack of a descriptive report and interpretation keys limit the usefulness of the data. The complexity of the ecosection map unit also limits its use as an ecological unit for planning and management purposes. Detailed descriptions explaining the ecology of the Ecosite components in each map unit are required to realize the full potential of the Ecosection map as a resource document.

The results of this evaluation suggest that the Ecological Land Survey as carried out in Manitoba could be improved through a better definition of objectives, a greater balance of expertise on the study team and a better structured and increased effort towards data collection. The uefulness of the data can be increased most readily by provision of map unit and map unit component descriptions and evaluation of these units for particular land resource uses. Increased communication with potential users during the planning stage and by means of an extension function following completion of the project should greatly facilitate use of the data.

ACKNOWLEDGEMENTS

The author wishes to gratefully acknowledge the guidance and assistance of Mr. G.F. Mills in the review and discussion of the project and editing of the manuscript. Without his support this project would not have come about.

The constructive criticism provided by Dr. J.M. Stewart, Department of Botany, and Dr. M.A. Zwarich, Department of Soil Science, in reviewing the manuscript is also sincerely appreciated.

Special thanks ar extended to Mr. R.E. Smith, Canada Department of Agriculture, for encouragement throughout the course of the project, to Mr. J. Griffiths for the preparation of all maps, sketches and diagrams, and to Miss B. Stupak for typing portions of the material.

Finally, a heartfelt thanks to all people with whom the author had the pleasure to share involvement in Ecological Land Surveys in Manitoba.

To

Anny

TABLE OF CONTENTS

TABLE OF CONTENTS cont'd

TABLE OF CONTENTS cont'd

LIST OF TABLES

LIST OF TABLES cont'd

LIST OF FIGURES

LIST OF FIGURES cont'd

LIST OF PLATES

Chapter 1

INTRODUCTION

Sound land use and management require that baseline data on aspects of the environment be as complete as possible. Land resource data can be collected according to various themes, each designed to provide information on a particular component of land. Land use planning and management decisions may be based on a single attribute of land or, preferably, a combination of land attributes. Planning or management decisions for a single attribute of land generally are based on data provided by a survey of a single resource attribute of land, characterized by a specific kind of classification with its own unique terminology.

Resource surveys which collect data on a wide range of land attributes provide information which is thought to be more useful to the collective group of land resource planners and managers than the data concerning a single attribute of the land resource. Such classifications should be broadly based and sufficiently complete to serve, directly or by means of interpretation, a wide spectrum of user groups. Multi-disciplinary surveys of land resources have developed in recent years to provide a single data base which included a large body of information on the physical and biological attributes of land. Integration of these physical and biological components into a single data base is attempted by Ecological Land surveys.

A number of Ecological Land surveys have been carried out in Manitoba during the last decade, but a review of the surveys and their application to land management has not been attempted to date.

The objectives of this study are:

1. to provide an in-depth description and critical analysis of the approach taken by Ecological Land Surveys to the inventory of land resources in forested terrain in Manitoba;
2. to evaluate the extent to which ecological land survey data have ecological significance and their value to users of land resource data;
3. to suggest modifications to the Manitoba Ecological Land survey methodologies and the kind and level of integration of potential users in the planning process and data presentation phase, in order to enhance the capability of the maps and reports to satisfy needs of potential users.

The objective of the study are met by an evaluation of Ecological Land Survey, as carried out under the Northern Resource Information Program (NRIP) in Manitoba, through a review of ecological land survey in general and a comparison to the Ecological Land Surveys produced in the Cormorant Lake Pilot Project in Manitoba and the James Bay Project in Quebec.

Chapter 2

THE LAND RESOURCE

"Land, in its broadest sense, is a segment of space where plants grow, animals roam, people live, water flows in rivers and collects in pools" (Zoltai, 1969). Rowe (1980) described land as "a continuum over the planet's surface, comprising an air layer resting on an earth layer, with organisms and soils sandwiched at the energized interface." Land is a three-dimensional entity, having a horizontal plane, as well as a vertical dimension, extending for a certain distance above and below the earth's surface.

The components that make up land are of two kinds: 1. physical components such as surficial materials, the form of these materials, the soils developed on them and the associated drainage system, including both surface and ground water; and 2. biological components in the form of vegetation, wildlife and man. The interactions of these components are governed and driven by energy derived from climate. A look at land in this fashion comes conceptually very close to the concept of an ecosystem as defined by Odum (1959) as "an area of nature, that includes living organisms and non-living substances interacting to produce an exchange of materials between the living and the non-living parts."

However land means different things to different people. Many people tend not to look at land according to such holistic descriptions.

When referring to land some people identify it by one of its components or the use that is being made or can be made of it. Different points of view and different interests often result in land use controversy between concerned groups.

The most complete knowledge possible of the landbase and related resources is essential for sound land use and management. Inventory of land or its components should aim to collect data in a way that will allow for a balanced evaluation of the potential uses of the land and the impact these uses may have in a short and long term time frame.

Land attributes that are important for land use in any area with respect to agriculture or forestry are climate, relief, water, vegetation and soil conditions (Vink, 1975). Other factors such as geology and artificial lanscape elements may also be of great importance depending on the type of land use.

In this chapter single attributes of land like surface deposits, topography, climate, soil and vegetation are discussed and some of their interactions and interrelationships mentioned. In the last sections of this chapter, the ecosystem as the holistic land element is discussed and its significance to land use and management noted.

SURFACE DEPOSITS AND TOPOGRAPHIC EXPRESSION

Geomorphology is concerned with form and structure of surface materials. It includes characteristics such as slope, arrangement of slopes to produce landforms, relief, and resulting drainage patterns. The organization and distribution of landforms in the landscape includes spatial relationships both of materials in the horizontal plane (surface distribution) and vertical plane (stratigraphy, thickness). Properties and conditions of surface materials include characteristics that are obtained and observed in the field as well as properties that are measured in the laboratory. The former include moisture regime, the latter chemical and physical properties. Other properties that are described and documented are texture, coarse fragments and organic material characteristics. The temperature regime is an important property of surface deposits particularly with respect to permafrost characteristics and distribution.

Geomorphic processes may be both originating and modifying processes. The former are responsible for producing the original landform and the latter are those processes that have acted or still are acting to change the surface (Fulton *et al*., 1974). The form of the deposits and their structural and textural properties are to a large extent dependent on the mode of deposition.

Topography

Topography is often directly related to the mode of deposition and nature of the surficial deposits. Lacustrine deposits are usually level or very gently sloping except in areas where the topography of underlying materials (bedrock, till) affects the relief of the lacustrine sediments whereas till landforms range from level to undulating, hummocky to rolling, and ridged.

Relief and topography play an important role in controlling or conditioning the type and effect of soil-forming processes (Eilers et al, 1977). Soil formation and vegetation characteristics often directly relate to landscape position. In rolling or undulating terrain the tops of the knolls tend to be more arid than the adjacent depressional sites. Differences in parent material, geographic location, temperature and precipitation determine the extent to which the apex may be too dry or the low lying areas too wet for optimal plant growth.

Aspect may have a marked effect on soil development and vegetation type, especially in areas were moisture deficiency is common during the growing season. Undulating and rolling topography results in characteristic patterns of soils and vegetation. In rolling terrain in sub-humid climates south facing slopes may have grass vegetation while the north slopes support aspen. Under cool humid climates, depressional areas are invariably occupied by organic soils while lower slopes often have wet soils with thick organic surface horizons.

Materials

Textural properties of surficial materials are also related to mode of deposition. For example, tills usually consist of materials that are mixed and non-sorted with textures ranging from clay to fine loam and sand. Lacustrine sediments, on the other hand, are usually well sorted and stratified, ranging in texture from heavy clays to silts and fine sand.

The chemical characteristics (eg. calcareousness, acidity, salinity) of surficial materials are closely related to the original materials (bedrock, older surface deposits) that contributed to its composition.

The kind of material and its physical and chemical composition are of great importance to the formation of soils and growth of plants. Physical properties related to particle size distribution determine to a large extent characteristics of the soil such as water holding capacity, structure and water movement through the soil. Chemical properties influence nutrient levels and inherent fertility, which in turn affect and are affected by plant growth.

CLIMATE

Weather is the state of the atmosphere at a given moment or for a short period, whereas climate is commonly regarded as the generalized weather for a long period of time (Shaykewich and Weir, 1977). Climate of a region is usually identified by a broad descriptive terminology like Boreal Temperate, moist sub-humid, while its parameters are defined by means of data from meteorological stations. Usually monthly average and yearly total values for the thermal and moisture attributes of climate are provided. Detailed information on distribution of events like heavy rain, or extreme values for frost-free periods and temperatures also form part of a climatic description. Information on the probability that such extremes might occur is of great importance to many biological uses of land such as agriculture, forestry and wildlife.

Climatic Elements

Climatic elements such as temperature and precipitation are of major importance to soil formation and vegetation distribution, but elements like wind, humidity or cloudiness have significance as well. Temperature is largely a function of the amount of solar radiation reaching a given area. Although each area on earth receives potentially the same amount of sunlight (barring cloudiness) on an annual basis, intensity of radiation diminishes from the equator to the poles as result of angle between the sun rays and the surface of the earth. Consequently land areas farther north have colder climates than areas closer to the equator. Elevation and proximity to large water bodies influence atmospheric circulation and so modify local climate to a great degree, causing areas to be either colder or warmer than would be expected on the basis of insolation alone.

Precipitation in the form of rain and snow is the major source of moisture available for plant growth. Locally dew, fog and humidity play a role but are insignificant compared to the total precipitation. In cold climatic areas, rainfall during the spring and summer months is of prime importance to the process of soil and vegetation formation. Run off from snow is important in charging the upper layer of soil with moisture and in its erosive and depositional effects on the landscape and in the recharging of depressions and wetlands.

Climate, Soil and Vegetation

Effect of climate on soil and vegetation is both direct and indirect in regulating processes of soil formation and influencing vegetation distribution. The formation of major vegetation zones is dependent on climate. Temperature modification (micro-climate, soil-climate) is largely dependent on topography and structure of vegetation. Similarly the type and rate of organic material accumulation on or below the soil surface relates directly to the type of vegetation (grass vs forest) (Crompton, 1962). This in turn affects the soil flora and fauna and the cycling of nutrients through the system.

Direct effects of climate are related to physical and chemical weathering of rock material, minerals and the breakdown of organic matter. The rate of, and balance between processes in horizon differentiation ie. additions, removals, transfers and transformations (Simonson, 1959), are largely governed by temperature of the soil and its moisture status. Minimum temperature and moisture conditions are required for the processes to take place, whereas too much moisture may reduce the rate of these processes significantly.

Temperature and precipitation commonly vary according to altitude and latitude. Under moist, cool conditions, evaporation losses are low and more moisture can infiltrate and leach the soil. Soils developed under these conditions eg. soils under forest cover, are often deeply leached, whereas soils in northern regions, which contain permafrost or stay frozen for a long time have shallow sola resulting from an excess supply of moisture in combination with low soil temperatures. Many soils under such cold climatic conditions are churned by the action of freezing and thawing resulting in strongly disturbed profiles which are relatively shallow (Zoltai and Tarnocai, 1974).

Climate can not be observed directly. Meteorological data have to be collected over a period of time in order to make valid statements about climatic characteristics. Climatic characterization is an integral part of the data requirement for land and soil evaluation. However such data is seldom adequate for detailed land evaluation purposes and often not available for inaccessible regions of the north.

In general terms, climate can be inferred from a careful study of soil and vegetation properties. Such inferences are often used to help define climatic regions where other climatic data are not available (Mills, 1976).

SOIL

Soils comprise the uppermost part of the earth's surface. They have developed where the action of water (liquid and frozen), wind, temperature and organic decay have resulted in the aggregation of unconsolidated mineral and organic particles - the regolith. The combined effect of climate and organic life modified by topography acting on the regolith over time results in the formation of soils.

Soil Formation

Simonson (1959) proposed the view that soil genesis consists of two overlapping processes: 1. the accumulation of parent materials and, 2. the differentiation of horizons in the profile. The first process is largely of concern to the surficial geologist while the second process is mostly of concern to the soil scientist. However, an understanding of the first process greatly facilitates the work of the pedologist in producing a soil map. Soil formation involves the differentiation of horizons on a given parent material due to additions, removals, transfers and transformations within the soil system. These processes take place in most and probably in all soils, but the rate at which they take place varies widely. Shifts in balance among combinations of processes are responsible for soil differences and horizon differentiation rather than a single process by itself. This view explains the existence of soils as a continuum over the land surface and also explains the lack of sharp boundaries between soils (Simonson, 1959).

State Factors in Relation to Soil Formation

The processes involved in soil differentiation are governed by the combined effect of climate, organic life and topography on the regolith over time. Although often described as soil forming factors, none of these factors is a former, creator, or force. They are rather the independent variables (state factors) that define the state of the soil system (Jenny, 1961). None of these state factors are uniform from area to area with the result that the soil forming processes they govern also vary in their combined effect from location to location. This variation results in a population of soils in which each member has a unique combination of characteristics.

The idea that soil formation is dependent upon environmental factors is generally credited to the Russian soil scientist Dokuchaev. He established the concept that climate, subsoil (parent-material), vegetation, fauna, man, age of land surface and relief are the significant pedogenic factors (Crocker, 1952). More recently it has been determined that Dokuchaev related the factors in an equation as follows (Jenny, 1961):

$$s = f(cl,o,p)t^o$$

where s represents soil, cl climate of a given region, o the organisms (plant and animals), p the "geologic substratum" and t^o is relative age (youthfulness, maturity, senility).

The equation published by Jenny (1941) is quoted more commonly and is given below:

$$1)\quad s = f(cl,o,r,p,t \ldots)$$

which equation he later expanded (Jenny, 1961) to:

$$2)\quad l,s,v,a = f(cl,o,r,i,t)$$

where l = any ecosystem property or ecosystem

s = any soil property or soil

v = any vegetation property or vegetation

a = any animal property or all properties

cl = climate

o = organisms

r = topography

i = initial state of system,at t=o, i=parent material

t = time

The dots stand for unspecified components. Climate (cl) is and organisms (o) may be functions of time (t); but topography (r) and parent material (p) are never time dependent (Jenny, 1961). Factors p and r pertain to initial states and as such remain invariant. During genesis p becomes soil and some of the r components (eg. slopes) become soil properties that may vary with erosion and its depositions (Jenny, 1980).

The number of factors in soil formation can be expanded by differentiation within the five state factors. The water table and often man are listed as separate factors in relation to soil formation (Ellis, 1938). Man is seen as a disturbing force in comparison to other factors and the results of his activity are often destructive to some degree and cause sudden change in a dynamic equilibrium.

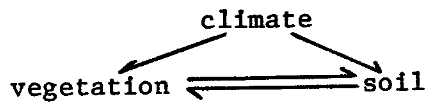
Time is not considered a factor in the same way as the other state factors; time is a dimension, like space is a dimension. For that reason the equation is sometimes written in the following manner:

$$s = f(cl,o,r,p...)t$$

The role of time is nevertheless important in the formation of soils and vegetation communities and exerts a strong influence on these attributes of land.

Time is required for a process to show effect through changing state of object observed. Studies have shown that it may take several hundred years for some soil horizons to form, while other soils may develop over 2000 to 10000 y. Parsons _et al_. (1970) found cambic horizons formed in a little more than 500 y whereas Bt horizons formed within 5250 y. On the other hand Crocker and Major (1955) showed that marked change in pH, calcium carbonate content, organic carbon and total nitrogen can be observed in periods of 35 to 50 y. A well developed Brunisol examined on a former marine beach in Northern Manitoba was found to be at least a few thousand years old (Mills and Veldhuis, 1978).

Except for an interdependence between climate, organisms and time, the state factors are considered to be independent variables. Climate changes over time. Although changes may be slow, some very different climates may have influenced soil development since its inception. (Mills and Veldhuis, 1978). Bryson and Wendland (1966) established some tentative climatic patterns for the last 10 000 y in North America; patterns which suggest dramatic changes in climate during that period. Past climates may still have an indirect effect on vegetation through species distribution (Löve, 1959) and through vegetation, an effect on soils. The state factor o includes both animals and plants. With respect to soil, this includes the soil flora and fauna as well as the flora and fauna on and above the soil surface. The vegetation cover is usually seen as the most important aspect of the factor o, as it provides the organic material needed to sustain animals as well as the soil flora and fauna. Vegetation provides the means of intercepting energy from the atmosphere and transferring it to other forms in the soil system. However, interrelationships must be acknowledged, as composition, structure and growth of vegetation are influenced by other elements in the factor o. Plant and animal populations may change fairly rapidly over time. The cyclic nature of some animal populations (Colinvaux, 1973) is a well established fact as is the pattern of succession in vegetation communities. (Kershaw, 1973; Dansereau, 1957). There are also important interrelationship between climate, soil and vegetation which can be represented by the triangle:



(Jenny, 1958)

It implies that climate affects soil and vegetation independently, that soil (edaphic factors) influences vegetation, and that vegetation reacts upon soil. It suggests that the soil-plant relationship is difficult to interpret. Major (1951) established the concept:

$$v = f(cl, o, r, p, t \ldots)$$

This equation indicates that vegetation is as much governed by environmental factors as is soil and that these factors are identical to the ones directing soil formation. This similarity in controlling factors fosters the idea of correlation between vegetation and soil type, as long as both are still in tune with climate. On the other hand, it also suggests that the vegetation factor cannot be considered to be independent.

Soil, Climate and Vegetation

The principle of varying one factor while others are kept constant has found wide spread application in soil survey and land classification. It permits one to make inferences about soil development on the basis of information on state factors. For example, within a region of uniform present (and historic) climate it is possible to predict soil development on a particular parent material in a particular topographic setting on the basis of information obtained on soils developed under similar conditions, but in a different area within the region. Conversely, regions with uniform climate can be established by comparing soils on similar parent materials and in similar physiographic settings. Similarity between soils usually means development under the same set of climatic conditions, whereas dissimilarity may point to variations between all or a number of climatic elements.

VEGETATION

Plant cover can be considered in two ways: 1. as an assemblage of plant species (flora) or 2. as a community of plant individuals and plant groups. Flora refers to kinds of plants (species) in a chosen landscape, regardless of number of individuals of each species present. Accordingly the flora of an area is described by a species list. Vegetation, on the other hand, refers to quantity and quality of growth. Vegetation has structure and shows changes over time in structure, species and number of individuals.

The vegetation component is strongly influenced by climate and similar factors in the environment which interact in soil formation. The plant factor in turn is one of the state factors affecting soil formation.

State Factors in Relation to Vegetation Formation

A plant community is an aggregation in definite proportions of more or less interdependent plants, utilizing the resources of a common habitat which they either maintain or modify (Dansereau, 1957). Particular vegetation characteristics result from interactions of organisms (plants and animals), parent soil material, relief or topography under the influence of climate over a period of time. The definition has been