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**Development and Application of 'Environomic Units':
Hybrid Map Units Designed to Integrate Environmental
and Socioeconomic Data for Land Modelling**

● (C) by Ron Gelinas, B.A..

A thesis Submitted to
the Faculty of Graduate Studies and Research
in Partial Fulfilment of
the Requirements for the Degree of
Master of Arts
Department of Geography

Carleton University

Ottawa, Ontario

February 20, 1987

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DEVELOPMENT AND APPLICATION OF 'ENVIRONOMIC UNITS':
HYBRID MAP UNITS DESIGNED TO INTEGRATE ENVIRONMENTAL
AND SOCIOECONOMIC DATA FOR LAND MODELLING

submitted by Ronald J. Gelinas, B.A. Honours

in partial fulfilment of the requirements for
the degree of Master of Arts.

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ABSTRACT

Political attitudes concerning the 'state of the environment' have changed dramatically during the last two decades. Whereas in the past most politicians focussed their attention on the economy, today it appears that many suspect that a healthy environment leads to a healthy economy. Consequently, the need to integrate environmental and socioeconomic data to enable comprehensive environmental assessments is becoming progressively more important. This study presents a simple and economical concept facilitating the integration and application of both types of data.

'Environomic unit' boundaries were created by combining well-established socioeconomic map units (census divisions) with land resource map units (ecoregions) to form a hybrid framework which can accommodate both types of attribute data. The environomic map units were used to apply an existing model which described 'known relationships' and to assist in developing a hypothesis (model) suggesting new potential relationships. These modelling scenarios were aimed at testing the utility of environomic units and were completed for a study area encompassing the prairie provinces. The

major themes addressed include the potential of wind erosion to impact agricultural lands and labour force and possible links between fertilizer and herbicide application and cancer mortality. The hybrid map units proved to be a simple, economical and useful concept for integrating environmental and socioeconomic data for developing and applying land models.

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TABLE OF CONTENTS

	PAGE
1.00 INTRODUCTION	
1.10 Preamble	1
1.20 Purpose	2
1.30 Problem Definition	3
1.31 The Need to Integrate Environmental and Socioeconomic Data	3
1.32 Currently Used Integration Alternatives	4
1.33 The Need For 'Compromise' Map Units	6
1.34 Environomic Units as a 'Compromise' Approach	8
1.40 Scope and Constraints	8
1.41 Study Area	8
1.42 Scale	9
1.50 Models	9
1.51 Definition	9
1.52 Major Characteristics of Models	10
1.53 Types of Models	10
1.54 Utility of Models	11
2.00 DEVELOPMENT OF ENVIRONOMIC UNITS	
2.10 Map Units	13
2.11 Census Divisions	13
2.12 Ecoregions	14
2.20 Methods	16
2.21 Elimination of 'Line Weave'	16
2.22 Linking Attribute Data to Environomic Units	19
3.00 APPLICATION OF ENVIRONOMIC UNITS	
3.10 Mapping Guidelines	21
3.11 Computer-Assisted Cartography	21
3.12 Choropleth Mapping	22
3.13 Class Intervals - Relative Ratings	23
3.20 Attribute Data	24
3.30 Analysis	26
3.31 Analytical Approaches	26
3.32 Themes Chosen for Analysis	27
3.33 Assessments of Potential Land Degradation Due to Wind Erosion	28
3.34 Spatial Distribution Patterns or Trends	33
4.00 EVALUATION AND RECOMMENDATIONS	
4.10 Summary	47
4.11 Advantages of Environomic Units	48
4.20 Potential Problems	49
4.21 Availability of Ecoregion Data	49
4.22 Environomic Units for the North	50
4.23 Water Data	50
4.24 Microcomputer Based GIS	51
4.30 Recommendations	52
5.00 BIBLIOGRAPHY	53

LIST OF TABLES

TABLE	DESCRIPTION	PAGE
2.1	Geostatistical Units, Associated Map Scales, and Number of Map Units Covering Canada	14
2.2	ELC Map Unit Name, Associated Map Scales and Number of Map Units Covering Canada	15
3.1	Variables Included in Environmental Data Base	25
3.2	Model Used to Determine Areas Potentially at Risk to Wind Erosion	29

LIST OF FIGURES

FIGURE	DESCRIPTION	PAGE
2.1	Ecoregion and Census Division Components of Environomic Units	17
2.2	Example of 'Line Weave' Produced From the Initial Overlay of Census Divisions and Ecoregions, for a Portion of Southern Alberta	18
2.3	Labelling of Environomic Units	20
3.1	Environmental and Socioeconomic Assessments of Alberta and Saskatchewan - Potential of Wind Erosion to Impact the Agricultural Labour Force	30
3.2	Assessments of the Potential Risk for Wind Erosion on Prime Lands for Agriculture (Canada Land Inventory Classes 1,2 and 3) in the Prairie Provinces	34
3.3 (a)	Sample Environmental Variables	36
3.3 (b)	Sample Socioeconomic Variables	37
3.3 (c)	Sample Socioeconomic Variables	38
3.3 (d)	Sample Socioeconomic Variables	39
3.3 (e)	Sample Socioeconomic Variables	40
3.3 (f)	Sample Socioeconomic Variables	41
3.4	Similar Spatial Distribution Patterns Between Cancer Mortality and Fertilizer and Herbicide Application	43

LIST OF APPENDICES

APPENDIX	DESCRIPTION	PAGE
A.1	Data Sources	58
A.2	Criteria Used to Determine Classes for Composite Maps	60
A.3	Overview of Steps Involved in Developing and Applying Environomic Units	63

CHAPTER 1

INTRODUCTION

1.10 Preamble

The research described in this paper was completed by the author as a Carleton University, Geography Department graduate thesis in addition to meeting specific needs of the Ecological Research and Integrated Programs Division of the Lands Directorate, Environment Canada. The Lands Directorate's mandate is to "... promote environmentally sound uses and management of Canada's land resources in keeping with federal responsibilities and national objectives" (Lands Directorate, 1984, 2). The Ecological Research and Integrated Programs (ERIP) division is charged with promoting the development and application of a nationally uniform ecological approach to the classification of the country's land resource base, and developing and applying interpretive techniques required to address pertinent environmental issues using ecological data. Although the research presented here is of interest to the ERIP Division, the results may be useful to others who need to combine environmental and socioeconomic data to address current environmental issues.

The terms land resource, environmental, and ecological data are frequently used in this paper. Land resource data are traditionally gathered and organized within themes such as soils, vegetation, landforms, etc. Because many of these themes are interrelated and often have similar spatial distribution patterns, researchers in provincial and federal government agencies have developed an approach to integrate these themes and classify them within fixed map units. The Ecological Land Classification (ELC) system classifies different land characteristics according to natural terrestrial ecosystems (Wiken, 1978). Because the environment is viewed as a composite of different specialized themes, and ecology focuses on their interrelationships, integrated approaches to classifying land data are commonly referred to as environmental or ecological frameworks. These terms are used interchangeably within the context of this paper.

1.20 Purpose

This project aims to develop hybrid map units designed for integrating environmental and socioeconomic data for the purposes of land modelling (see section 1.50 for description of models). Examples are provided demonstrating the potential utility of these for integrating, analysing, and presenting both types of data. Environomic units is a term derived for this study by combining the terms ENVIRONMENTAL and ECONOMIC to describe the hybrid derived by merging environmental and socioeconomic map units.

1.30 Problem Definition

1.31 The Need to Integrate Environmental and Socioeconomic Data

During the last two decades, the Lands Directorate, in collaboration with other federal, provincial and territorial agencies, has dedicated much time and effort to establishing land resource data bases to assist planners and managers in developing pro-active land management strategies and to plan effectively the use of Canada's land resources. Whereas efforts initially focussed on the acquisition, compilation, and classification of land resource data, the emphasis is now on the use or application of these data to provide useful information to environmental policy and decision makers. Based on preliminary attempts within the Directorate to use these data bases to address current issues, it was clear that land data alone are not always adequate. In fact, many planning issues cannot be fully addressed without considering the socioeconomic aspects. For example, environmental impact assessment is of limited value without understanding the socioeconomic ramifications of a proposed activity. The quantification of 'resources at risk' and the process of 'environmental cost accounting' are highly effective in communicating the socioeconomic implications of current and alternative policies (e.g., number of jobs that may be lost due to environmental degradation). In short, two predominant concerns commonly emerge in most planning exercises. Environmentalists focus their attention on predicting the adverse environmental effects of a proposed activity. Friend (1979, 116) states that "one of the major objectives of the 'environmental movement' is to influence decision making at all levels of government by making explicit the

environmental costs of alternative options and actions". Advocates or promoters of the activity will predict the socioeconomic benefits. Unfortunately, activities which contribute to regional economies and the growth of the gross national product often contribute to degraded environments (Friend, 1979, 116). Invariably, both considerations must be carefully assessed before a decision is made to permit or restrict any proposed activity.

1.32 Currently Used Integration Alternatives

Because environmental and socioeconomic data are collected using different map (geographic) units, integration of them is difficult. Past attempts have focussed on two major approaches: (a) the use of Geographic Information Systems (GIS); and (b) integrating all data into either environmental or socioeconomic map units.

(a) Integration Using a GIS:

The complete integration of different map coverages, including their descriptive attribute data, can be achieved through the use of a GIS. Poiker and Crain (1985, 1) define a GIS as:

... a system designed to store and manipulate data which relate to locations on the Earth's surface. A GIS must handle two distinctive types of data - graphical (spatial or geo-coded) data consisting of the geometric entities of points, lines and areas and attribute data, the non-graphical items which describe the geometric entities. Because GISs are used to manipulate extremely large quantities of data, most modern GISs employ computer technology. Typically a GIS will have three components: (1) input and editing; (2) data manipulation; and (3) output and display. [Sample GIS manipulation functions include:] ... the changing of map projection, contouring of map data, determining the intersections of overlapping polygons [topological overlay], data selection and generalization, registering and superimposing various data sets, and a whole range of statistical analyses.

Most GISs provide the capability to overlay different maps to create a composite map retaining the respective attributes. Such systems are extremely useful for integrating different environmental and socioeconomic data themes (see McCuaig and Manning, 1982, 15 and Kerr et al., 1985, 6); however, access, cost, complexity, and time may prove prohibitive in many cases. GISs are very expensive and therefore are not widely available, they are difficult to use and thus require trained personnel and the integration of different map themes commonly requires the user to follow a series of complex procedures which can be very time consuming.

(b) Integration Using Either Environmental or Socioeconomic Map Units

The second method includes integrating socioeconomic data into environmental map units (Statistics Canada, 1978, 1986; Bird and Rapport, 1986) or integrating land resource data into socioeconomic map units (Laut et al., 1980; Statistics Canada, 1986; Lynch-Stewart, 1986). All environmental and socioeconomic map units in these examples consist of 'fixed' map areas or polygons which do not change (theoretically) over time. The use of fixed map units enables the comparison of data over time (time series), and in some cases will facilitate data acquisition by providing procedural consistency.

An example of integrating land resource data into socioeconomic map units is when land resource characteristics are represented as a percent area or as the dominant feature within socio-administrative map units, such as census divisions. Planners and managers are generally uncomfortable with this concept, feeling that natural phenomena should not be represented within artificial man-made boundaries (Friend, 1979, 117). The author maintains that the

alternative of integrating socioeconomic data into a land resource framework is also problematic, as important socioeconomic distinctions can no longer be readily discerned or monitored. For example, two census divisions (counties) characterized by the same land capability for forestry, may be used and managed quite differently according to respective regional policies. However, the effects of these different policies could not be detected if the data describing the effects (gathered by census divisions) were integrated into a land resource framework. In summary,

The development of an environmental statistical data base requires the establishment of the appropriate spatial entities. The current use of administrative boundaries is on the whole unsatisfactory for describing environmental transformation. The [chosen] spatial units should be based in essence on a compromise between 'idealized' scientific criteria and the socio-political criteria, including 'arbitrary' administrative boundaries. In other words the spatial entities must accommodate both the decision making space and the natural process space (Friend, 1979, 117).

1.33 The Need For 'Compromise' Map Units

Environment Canada is currently committed to producing 'State of the Environment' reports at regular intervals. As part of this initiative, a Stakeholder Group on Environmental Reporting was recently established to consider improvements to environmental and resource data collection and reporting in Canada. As outlined in their report, one of the major shortcomings of current environmental data and reporting in Canada is that:

There is no comprehensive framework which describes the scope or extent of the interactions between human activities and the environment, upon which an environmental reporting system could be based and which would provide a better public understanding of these interactions (Stakeholder Group on Environmental Reporting, 1986, 10).

The report (page 14) suggests that a functional framework must enable:

... the economy and the environment [to] be viewed as one complete system. This is necessary first to demonstrate the interactions between human activity and environmental impact, and second to insure that collected environmental data cover all the relationships and feedback effects that link human activity, environmental impact, and changes in health or resource base. A framework is necessary to define the scope of these linkages between the economy and the environment, and to help understand these linkages. It also leads to a more comprehensive and effective environmental reporting system. Without such a framework there is a danger of ad hoc and sectoral approaches to data collection continuing. No practical, rigorous policy decisions or responses can be made unless an environmental problem can be followed from its source, through each part of the environment, to its effect on human or ecosystem health or resource stocks.

Similar needs were reflected in the UNESCO program Man and the Biosphere, which aimed "... to 'build a research bridge' between ecological, economic and social sciences as well as to elaborate a methodology for linking ecological processes and socioeconomic phenomena with each other" (Brouwer, 1986, 4).

Similarly, the Commonwealth Scientific and Industrial Research Organization, in conjunction with the Australian Department of Science and Environment, established the Australian Environmental Statistics Project aimed at developing "... a practical framework for the organization of environmental statistics and to provide through this framework, a means of integrating assessments of economic and social impact of environmental policies with assessments of the environmental impacts of economic policies" (Laut et al., 1980, 1).

The need to establish a framework that links environmental and socioeconomic data, processes, assessments, etc. is well documented

(Friend, 1979, 117; Laut et al., 1980, 1; Stakeholder Group on Environmental Reporting, 1986, 10, 14). Past attempts have primarily focussed on integrating environmental data into a socioeconomic framework or vice-versa (Statistics Canada, 1978, 1986; Bird and Rapport, 1986; Laut et al., 1980; Lynch-Stewart, 1986). Alternatively, integration is also possible using sophisticated GIS technology (Kerr et al., 1985; McCuaig and Manning, 1982).

1.34 Environomic Units as a 'Compromise' Approach

The research presented here suggests a third 'compromise' alternative which is simple and economical relative to a GIS and is more comprehensive and detailed than just environmental or socioeconomic map units. It consists of combining well-established socioeconomic map units with standardized land resource map units to form a hybrid which can accommodate both types of attribute data. The author is not aware of any other research of this nature in Canada or abroad nor did a literature review reveal any similar concepts or research.

1.40 Scope and Constraints

1.41 Study Area

Although it would be best to compile environomic units for all of Canada, such an undertaking was beyond the scope of this study. The utility of environomic units must be demonstrated through a pilot study before resources and efforts can be dedicated to mapping the whole country. The study area chosen for the pilot study consisted of the 'prairie' provinces (Manitoba, Saskatchewan and Alberta),

which represent diverse landscapes (mountains, hills and plains) as well as socioeconomic profiles. Also, because of the size of the study area, the number of map units and their respective attribute data was felt to be manageable.

1.42 Scale

The Lands Directorate specializes in addressing land-related issues of national significance (Lands Directorate, 1984, 13). Although the spatial distribution of such issues will vary greatly, the current priority is to establish small-scale national data bases. An input scale of 1:7.5 million provided a sufficient level of detail to present national overviews and also conforms to the current and anticipated national modelling initiatives of the Lands Directorate.

1.50 Models

As stated above, this project aimed to develop hybrid map units for integrating environmental and socioeconomic data for land modelling. Models are effective tools for addressing specific issues in a systematic way. Model definition, characteristics, types, and utility are discussed below.

1.51 Definition

The term 'model' is widely used and is becoming increasingly popular in various disciplines. This widespread use of the term has likely contributed to the variety of meanings associated with it. A literature review reveals that a clear, concise definition is not easy to obtain. For example, in "Models in Geography" (Chorley and

Haggett, 1967), the authors explain that a model can be a theory, a law, a hypothesis, or any other form of structured idea. In fact, the only element which distinguishes these terms from one another is the degree of probability with which they can represent or predict reality. The degree of probability (level of error tolerated) required to distinguish between these terms remains unclear.

A model is thus a simplified representation of reality which presents significant features or relationships in a generalized form. Models are selective approximations in that they do not include all associated observations or measurements. A good model should therefore filter out incidental detail so that fundamental aspects of reality remain (Chorley and Haggett, 1967, 22).

1.52 Major Characteristics of Models (based on Chorley and Haggett, 1967, 23)

- Models are selective approximations. A model must be simple enough for manipulation and understanding by its users, representative enough in the total range of implications it may have, and yet complex enough to represent accurately the system under study. Because models are different from the real world, they are analogies.
- Models are structured. Phenomena are studied in terms of their connections or interrelationships.
- Predictive models can be suggestive. In fact, such models are commonly evaluated according to their predictive capability. As such, models are often termed as 'speculative tools'.
- Predictive models should be replicable in the real world. For example, the relationships identified by the model should be true (all else being equal) in different applications.

1.53 Types of Models

Because models are used in such a wide variety of contexts, it is difficult to define even broad types of usage. One major division

is between descriptive and predictive (normative) models.

Descriptive models are concerned with describing the real world, such as scale models, maps, series of equations, or some other analogues (Morgan, 1967); predictive models are what might be expected to occur under certain conditions. Both are used to operationalize a theory, as a guide to the derivation of testable hypotheses (Johnston, 1983, 72-73). Jeffers (1972, 17) has suggested a third major category of models called decision models, which suggest certain courses of action or response under specific circumstances. For example, such a model might represent the recommended courses of action for each possible outcome of a certain event. In a sense, they might be viewed as structured recommendations used in conjunction with descriptive and (more likely) predictive models. Jeffers emphasizes that many models can fall into more than one of the above-mentioned categories, or move from one category to another in the course of an investigation.

The model categories mentioned above can be further divided into many other sub-categories, which are usually named according to the dominant characteristic of the model. For example, models can be classed as static (steady state) vs. dynamic; deterministic vs. stochastic according to the degree of probability associated with their predictive capability; holistic vs. reductionist according to their level of detail, etc.

1.54 Utility of Models

Models primarily help researchers to better understand reality. This knowledge or understanding should in turn influence or guide.

decision makers. Manning (1986, 2) suggests that modelling procedures are used because they aid us to: (a) understand better what is happening; (b) fill specific information gaps; (c) demonstrate our understanding more effectively; and (d) exert influence on the decisions of others. Models also encourage researchers to organize their concepts and ideas and to state their assumptions explicitly.

The following research will demonstrate the utility of environomic units for applying models which require both environmental and socioeconomic data and for identifying patterns or relationships necessary to develop models.

CHAPTER 2

DEVELOPMENT OF ENVIRONOMIC UNITS

2.10 Map Units

Environomic unit boundaries were created by combining well-established socioeconomic map units (census divisions) with land resource map units (ecoregions) to form a hybrid which can accommodate both types of attribute data. Ecoregions and census divisions are similar in terms of: (1) the total number of units for Canada; (2) the average size of map units (areal extent); (3) the suggested map scales of the units; and (4) the user acceptance of the units. Both sets of units are briefly described below.

2.11 Census Divisions

Statistics Canada uses a range of map units referred to as 'census geostatistical areas' which are hierarchical and can be used to present the same data and information at different scales or resolutions (see Table 2.1).

The term census division refers to "... counties, regional districts, regional municipalities, and other similar entities

defined by provincial authorities" (Geography Division, 1982, 8).

They are the most commonly used socioeconomic reporting units for national overviews of Canada. Statistics Canada provides a diverse range of data for Canada's 266 census divisions (Statistics Canada, 1982).

<u>Geostatistical Units</u>	<u>Associated Map Scales</u>	<u># of Map Units Covering Canada</u>
Province/Territory	1:5,000,000 to 1:15,000,000	12
Census Division	1:2,000,000 to 1: 7,500,000	266
Census Consolidated Sub.	1:2,000,000 to 1: 7,500,000	2,545
Census Subdivision	1: 500,000 to 1: 2,000,000	5,710
Enumeration Area	1: 5,000 to 1: 500,000	41,197
Source: Statistics Canada, 1982 and Lefebvre, pers. com., 1986.		
Table 2.1: Geostatistical Units, Associated Map Scales, and Number of Map Units Covering Canada.		

2.12 Ecoregions

Ecological Land Survey (ELS) is a conceptual approach to gathering, compiling, integrating, and interpreting environmental data according to natural terrestrial ecosystems. A major component of ELS is the Ecological Land Classification (ELC), which deals with the integration and classification of ecological data into map units based on the natural terrestrial ecosystems. The ELC uses fixed map units to describe areas which are ecologically uniform at appropriate map scales. These units are described in terms of their geology, landforms, soils, vegetation, hydrology, wildlife and climate and have been delineated for a variety of scales and geographical

extent. Table 2.2 summarizes the ELC land unit names, corresponding map scale, and the number of map units covering Canada.

<u>ELC Units</u>	<u>Associated Map Scales</u>	<u># of Map Units Covering Canada</u>
Ecozone	1:7,500,000 to 1:20,000,000	15
Ecoprovince	1:5,000,000 to 1:10,000,000	*
Ecoregion	1:3,000,000 to 1:7,500,000	325
Ecodistrict	1: 250,000 to 1: 1,000,000	5,395
Ecosection	1: 50,000 to 1: 125,000	*
Ecosite	1: 10,000 to 1: 25,000	*
Ecoelement	1: 2,000 to 1: 5,000	*
* National Coverages for These Units are Not Yet Completed.		
Source: Rubec and Wiken, 1982.		
Table 2.2: ELC Map Unit Name, Associated Map Scale and Number of Map Units Covering Canada.		

Members of the Ecological Research and Integrated Programs Division, have recently completed an ecoregion coverage for all of Canada. As indicated in table 2.2 they are used at map scales of between 1:3,000,000 and 1:7,500,000 and by definition are areas of land which are, "... characterized by a distinctive regional climate as expressed by vegetation" (Wiken, 1978, 25).

The ELC approach of using fixed map units for reporting environmental data is a relatively new concept and has not been extensively utilized relative to census geostatistical units. The most visible application is the use of 'ecozones' in the State of the Environment report (Bird and Rapport, 1986). Ecozones, however, are much too broad and general to address most land resource issues. Ecoregions, which number approximately 325 for the country, appear to

be the most compatible with census divisions in terms of areal extent, and the number of polygons covering Canada.

2.20 Methods

Environomic units for the prairie provinces were derived by manually overlaying the census division and ecoregion coverages. The result consisted of a composite map with newly created polygons (illustrated in the top map of Figure 2.1). The two other maps in Figure 2.1 are coloured so that the original ecoregion and census division components are easily discernible within the environomic units. Details concerning guidelines used for developing environomic units are outlined below.

2.21 Elimination of 'Line Weave'

A common problem when overlaying two or more maps is when boundaries or portions of boundaries with similar spatial distributions 'weave' in and out of each other. The resultant small polygons are referred to as 'line weave' or 'sliver' polygons (see Figure 2.2). Such polygons within a given tolerance (3 millimeters square at a scale of 1:7.5 million) were eliminated by using one common boundary. In all cases, the census division boundary was used as the common boundary. Census divisions are geostatistical boundaries which are precisely delineated according to political jurisdictions. Ecoregions, on the other hand, are subjective approximations of natural terrestrial features.

ENVIRONOMIC UNITS

ECOREGION COMPONENTS OF ENVIRONOMIC UNITS

CENSUS DIVISION COMPONENTS OF ENVIRONOMIC UNITS

Figure 2.1 - Ecoregion and Census Division Components of Environomic Units.

Figure 2.2 - Example of "Line Weave" Produced From the Initial Overlay of Census Divisions and Ecoregions, for a Portion of Southern Alberta.

2.22 Linking Attribute Data to Environomic Units

Each environomic unit was given a unique identification number consisting of: (a) a two-digit province code; (b) a two-digit census division code; (c) a two-digit ecoregion code; and (d) an alphabetic character if the three previous digits did not form a unique identification number (see Figure 2.3). As such, ecoregion or census division data can be easily linked to their respective map units. For example, data describing census division 10 in Manitoba would now apply to all environomic units in Manitoba with a census division code of 10. As in all choropleth mapping exercises, this technique assumes the homogeneous distribution of any attribute throughout the whole map unit. Accepting this assumption, linking a data value acquired for an original map unit to several newly created subsets of this unit does not pose a problem. For example, if 25% of the population in census division 12 is unemployed, then 25% of the population in all environomic units derived from census division 12 is also unemployed.

Environomic units were designed to integrate environmental and socioeconomic data for land modelling purposes. The following chapter presents examples of the application of these units. A table outlining the major steps involved in both developing and applying environomic units is presented in appendix A.3.

<u>Unit #</u>	<u>Province #</u>	<u>Census Division #</u>	<u>Ecoregion #</u>	<u>Unique Identifier</u>
F471617	47	16	18	
F471618	47	17	18	
F471517	47	15	17	
F471417A	47	17	17	A
F471417B	47	17	17	B

Figure 2.3 - Labelling of Environomic Units. Each Unit has a Unique Six Character Identifier, Except When Two or More Map Units are Derived From the Same Ecoregion and Census Division, (e.g., Shaded Map Areas Where Census Division 14 Overlaps Ecoregion 17 at Two Different Locations). In Such Cases, a Seventh Unique Identifier Character is Added.

CHAPTER 3

APPLICATION OF ENVIRONOMIC UNITS

Examples demonstrating the potential utility of environomic units are presented in this chapter. Three main sections describing mapping guidelines, attribute data and actual applications are included.

3.10 Mapping Guidelines

Maps are the main focus of this section. As with any analytical tool, maps can easily be abused or mis-used. The following guidelines were used to generate all maps.

3.11 Computer-Assisted Cartography

Once environomic units were coded and quality assured, they were digitized and entered into a data base to facilitate various modelling scenarios. All analysis and mapping was performed using the GIMMS computer-mapping package residing on a Data General MV 6000 minicomputer. Computer-mapping packages are commonly confused with GISs (see section 1.22) which are primarily designed to integrate (using an overlay capability) and manipulate different graphical and

attribute data sets. While some computer-mapping packages can manipulate attribute data, they are not designed to integrate different graphical data sets. As such computer-mapping packages are ideally used with fixed map units such as census divisions where only the attribute data vary. Environomic units are designed to integrate ecoregion and census division data without using a GIS overlay capability. As seen in the section 2.20, the development of environomic units consisted of completing the overlay process manually.

3.12 Choropleth Mapping

All maps presented in this section are choropleth maps, which use variable shading gradients to help identify patterns or trends over a given area. Discrepancies or anomalies above or below the norm are easily identified by assigning poignant colors to extreme class intervals. Choropleth maps require ratio data (e.g., percentages) for variables which are demographically related (e.g., socioeconomic data). Also, when using the choropleth mapping technique, a value assigned to a specific spatial unit is assumed to be evenly distributed throughout the unit.

Readers of this thesis who depend on a microfiche version should be aware that the maps in the original copies are in colour. Most of the maps reproduce very well in black and white except for Figures 3.3 (a) through 3.3 (f) where five class intervals (colours) are used and as a result one or two classes may be difficult to distinguish in black and white. In these Figures, colour was necessary to distinguish small map units where black and white shading patterns

are ineffective and impossible to discern. The most important maps (Figures 3.1, 3.2 and 3.4) copy very well in black and white and should not present any difficulties. Readers who require an accurate representation of the patterns presented in Figures 3.3 (a) through 3.3 (f) should consult one of the original copies on record at Carleton University.

3.13 Class Intervals - Relative Ratings

In the following examples, a number of maps are compared to identify potential risk areas and suggest possible relationships between themes. Consequently, a consistent methodology must be used to map each theme.

Equal class intervals were used for all maps. They are derived by taking the maximum value (recorded in the current data set) of the variable in question, minus the minimum value and dividing by the number of classes desired. As such, the term 'relative ratings' indicates that values in 'high' or 'low' classes are high or low relative to all other observations in the study area. Some suggest that equal class intervals are most appropriate with normally distributed data.

If the data are not normally distributed, alternatives include normalizing the data or using classification techniques which take into account how the data are clustered within the data set. In the latter case, the GIMMS software package has 13 different techniques available to determine class intervals; however, such techniques are often abused by cartographers who just want an even number of observations to fall into each class to produce an aesthetically

pleasing map. Normalization of data on the other hand can be a contentious issue. Some statisticians argue that all measurement systems are arbitrary; therefore transformed data are just as valid as untransformed (Norcliffe, 1977, 67). Others feel that the insistence that data should have a normal distribution is rather arbitrary. This issue can be important when using parametric tests designed to identify linear causal relationships between two or more variables. The underlying assumption is that different data variables must have the same distribution for perfect linear relationships to occur.

All examples in this study use similar spatial distributions (also referred to as 'eye ball' correlations) to establish links or associations. Although frequency distribution plots did not suggest that all variables were normally distributed, the author is hesitant to normalize data. A skewed distribution may be due to measurement error or it may be real. To what extent is nature random? In any case, this section focusses on demonstrating how environomic units can be used and not on the results obtained in the examples. It is assumed that the results would vary according to data quality and the sophistication of the models.

3.20 Attribute Data

The selection of the data variables used (see Table 3.1) was based on availability and their suitability in addressing current priority issues within the study area. For example, the degradation of prime agricultural land is currently a high profile issue in the prairie provinces. This theme was used to demonstrate how

Environmental Variables (by Ecoregion)

Average Frost-Free Period (Days)
 Mean May-September Rain (mm)
 Average Annual Growing Degree Days ($> 5^{\circ}\text{C}$)
 Average Annual Temperature ($^{\circ}\text{C}$)
 Average Annual Wind Speed (km/hr)
 Moisture Regime

Soil Classes
 Mode of Origin
 Mean Elevation (m)
 Surface Form
 Modal Vegetation

Socioeconomic Variables (by Census Division)

Number of Deaths from Cancer of Digestive Organs
 Number of Deaths from Cancer of Respiratory Organs
 Number of Deaths from Leukemia
 Number of Births
 Number of Infant Deaths

Percent Unemployment
 Percent of Total Population who Completed Grade 9
 Percent of Total Population who Completed University
 Median Income - Male
 Median Income - Female

Percent Labour Force in Agriculture
 Percent Labour Force in Mining and Oil
 Percent Labour Force in Manufacturing
 Percent Labour Force in Construction
 Percent Labour Force in Community and Personal Services

Percent of Improved Farmland to Total Area
 Total Value of Agricultural Products (\$)
 Total Value of Equipment and Machinery (\$)

Percent Summerfallow to Improved Farmland
 Fertilizer Application (Kg/Hectare)
 Irrigation as a Percentage of Improved Farmland
 Herbicide Application as a percentage of Improved Farmland
 Insecticide Application as a percentage of Improved Farmland

Table 3.1: Variables Included in Environomic Data Base

environomic units are useful to integrate, analyse and displaysocioeconomic and environmental data to address a specific issue. Eleven environmental variables (by ecoregion) describing climate, soils, land cover and topology were included in the environomic data base. The socioeconomic component (by census division) consisted of 21 variables related to health, labour force, education, income, employment and agricultural practices. A description of data sources is available in Appendix A.1.

3.30 Analysis

3.31 Analytical Approaches

Political attitudes concerning the 'state of the environment' have changed dramatically during the last two decades. Whereas in the past politicians focussed their attention on the economy, today it appears that many suspect that a healthy environment leads to a healthy economy. This initiative of creating hybrid map units designed to integrate the two types of data implies that the author believes that the two are closely related. In applying models which describe 'known relationships' or in attempting to develop models which identify 'new relationships', researchers generally make use of what is known as the scientific method. Two main paradigms ('schools of thought') can be identified in the scientific method: the inductive and deductive approaches, or modes of explanation (Norcliffe, 1977, 18). An inductive approach takes a set of unordered facts, analyses their characteristics, derives some order from the facts and thereby a model can be developed. A deductive approach is applied when a model (hypothesis) is known, and is tested

or applied using sample observations. In theory, the two approaches are separate; in practice, however, they are interconnected and cannot be applied exclusive of each other since preconceived notions of relationships assist in inductive research, while prior experiences with data often contribute in deductive research.

Both approaches were used in the following examples. For instance, one approach consisted of mapping different environmental and socioeconomic variables individually to look for spatial distribution patterns. One such pattern (section 3.34) which occurred served to generate a hypothesis (develop a model) which warrants further investigation. The other example (section 3.33) applied an existing model using the environmental units to facilitate the integration, analysis and display of data.

3.32 Themes Chosen for Analysis

Federal government Departments, such as Environment Canada typically address issues of national significance in keeping with their mandates and responsibilities. In the case of promoting environmentally-sound use and management of Canada's land resources (Lands Directorate mandate, 1984, 2), fine lines are drawn between what constitute provincial and federal roles. Consequently, the Directorate is increasingly concentrating on addressing national issues. Similarly, the themes addressed below focus on studying national (complete study area in this case) patterns and then identifying 'hot spots' based on this national perspective. Research of this nature is useful to: (1) assess specific issues at a 'macro' scale; (2) help identify priority research areas; and (3) identify

trends or anomalies which may not be apparent at a regional or provincial level.

An assessment of the potential of wind erosion to impact agricultural lands and labour force and possible links between fertilizer and herbicide application and cancer mortality are the two main themes addressed below. Although quite different, both themes are very relevant to current Environment Canada initiatives, such as environment and the economy (identifying how each affects the other), environment and health, state of the environment reporting, and environmental degradation. Also, the themes were chosen to demonstrate both the deductive and inductive analytical approaches.

3.33 Assessments of Potential Land Degradation Due to Wind Erosion

Recent figures suggest that losses from soil degradation in the prairie provinces now exceed \$1.0 billion annually (Science Council of Canada, 1986, 13). Wind and water erosion, which "... reduce the organic matter content of soil, weaken its structure, diminish its water-holding capacity, and lower productivity" (Science Council of Canada, 1986, 9), are the most widespread forms of soil degradation in Canada. Although erosion is a natural process, agricultural practices can significantly affect its occurrence. For example, the loss of topsoil through wind erosion can be greatly increased through summerfallowing, excessive tilling, or failing to leave crop residues or cover crops in place. The model presented in Table 3.2 includes environmental conditions (by ecoregions) and cropping practices (by census divisions) which tend to augment the potential for wind erosion (Coote, Dumanski and Ramsey, 1981, 25).

Figure 3.1 illustrates the result of applying the model in Table 3.2 to the Alberta and Saskatchewan portion of the environomic data base. The conditions of low soil moisture (Map 1), low mean summer precipitation (Map 2) and high mean summer wind speed (Map 3) combine in certain areas to allow a situation of high risk for wind erosion to develop. These conditions, combined with the cropping

Areas Potentially at Risk to Wind Erosion =

Areas which are Characterized by:

Low Precipitation	AND
Low Moisture Regime	AND
High Average Summer Wind Speed	AND
High Percent Summerfallow	

Table 3.2: Model Used to Determine Areas Potentially at Risk to Wind Erosion

practices of summerfallowing (Map 4), which leaves farmland exposed without vegetative cover during the growing season, can further increase the risk of soil erosion. The environomic units which were characterized by all of these conditions are represented as the red polygons (high potential risk for wind erosion) in Map 6 of Figure 3.1. Appendix A.2 describes the criteria used to determine classes for all composite maps (derived from combining two or more maps) created in Figures 3.1, 3.2, and 3.4. In this example, the environomic units facilitated the integration of data gathered by both ecoregions and census divisions to apply a model designed to identify areas at risk to wind erosion. Potential risk maps of this nature are useful to highlight areas where land resource planners and managers must take counter measures to avoid the problem.

ENVIRONMENTAL AND SOCIOECONOMIC ASSESSMENTS OF ALBERTA AND SASKATCHEWAN - POTENTIAL OF WIND EROSION TO IMPACT THE AGRICULTURAL LABOUR FORCE

Figure 3.1 - Wind Erosion is Brought About by a Combination of Environmental Variables and Man's Activities Through Agricultural Practices. This Illustration Identifies Areas With Such Conditions and Predicts the Potential of Wind Erosion to Impact on the Agricultural Labour Force.

Simply identifying areas with a high potential risk for wind erosion may not by itself have a great impact. Unless such scenarios can be linked to people's physical or economic well-being, they are not likely destined to get decision makers to take notice. In this case, those employed in the agricultural industry would likely be the first to be affected by wind erosion. Consequently, the map highlighting potential risk areas for wind erosion (Map 6) was combined with a map showing the distribution of those employed in the agriculture labour force sector (Map 5). The composite map (Map 7) illustrates 'hot spots' where the risk of wind erosion is high and the percent labour force in agriculture is high.

Figure 3.1 demonstrates how environomic units can be used to integrate, analyse and display different data sets to address a particular issue. Many other iterations using the same or other data variables are possible. For example, if a researcher did not agree with the variables used to determine wind erosion risk areas, these could be easily changed (depending on data availability). More interestingly, predicting the socioeconomic implications of wind erosion is the real challenge. This example simply attempted to identify the likely areas where the immediate socioeconomic impacts would be greatest, that is, where a large percentage of the labour force depends on agriculture. More sophisticated models which can be used to predict the progressive and cumulative effects of different factors on agricultural yields and in turn the impacts on the regional economies could easily be applied using environomic units. Models of this nature are currently being developed by the Land Evaluation Group at the University of Guelph (Brklacich and Smit,

1986). A more detailed approach to analysing the potential socioeconomic impacts of wind erosion by considering the total value of agricultural products and the total value of equipment and machinery will be completed by the author once the 1986 census data are available in July of 1987. In any case, the above demonstrates the utility of environomic units to integrate, analyse and display environmental and socioeconomic data using the deductive scientific method.

So far, all data used were available by either ecoregion or census division, which is the reason for having established environomic units. However, it is also possible to represent other data which are not collected by ecoregion or census division as a percentage of the total areal extent of each environomic unit or as the dominant feature within the unit.

In the mid-sixties, the Lands Directorate, in conjunction with other federal and provincial government agencies, undertook the Canada Land Inventory (CLI) which rated Canada's land based on its capability to support different renewable resources, such as agriculture, forestry, wildlife and recreation. The CLI program sought to provide "a comprehensive survey of land capability designed to provide a partial data base for broad-scale resource and land use planning" (Coombs and Thie, 1979). The CLI study area covers roughly 2.6 million square kilometers of southern Canada, providing reconnaissance-type information useful for land development planning at the municipal, regional, provincial and federal levels of government. The inventory is commonly referred to by land resource planners and managers to assess the potential value of particular

parcels of land. Because Canada does not have an over-abundance of prime agricultural land (usually defined as CLI classes 1, 2 and 3), decision makers must be careful not to lose this valuable supply to an irreversible land activity such as urbanisation. Map 2 in Figure 3.2 shows environomic units which have CLI classes 1,2 or 3 as the dominant capability. This was derived by manually overlaying environomic units with CLI agricultural capability (Surveys and Mapping Branch, 1980). This map was combined with the wind erosion risk map (Map 1 in Figure 3.2) to further assess the implications of wind erosion. The red polygons in Map 3 represent the prime agricultural lands which are threatened by a high risk of wind erosion. Figure 3.2 serves to identify wind erosion 'hot spots' based on a second criterion (land capability) and to demonstrate the flexibility of the environomic units in integrating non-ecoregion or non-census division data to address an issue. Figures 3.1 and 3.2 provide planners and decision makers with a general assessment outlining areas which are valuable because of their agricultural capability and the labour opportunities they provide and which are threatened by wind erosion. Even though other areas are threatened by wind erosion, this exercise identifies the priority areas according to land quality and the labour opportunities they provide.

3.34 Spatial Distribution Patterns or Trends

Plotting various themes using the environomic framework can facilitate the identification of spatial trends, relationships and anomalies or discrepancies which may not be apparent in tabular

ASSESSMENTS OF THE POTENTIAL RISK FOR WIND EROSION ON PRIME LANDS FOR AGRICULTURE (CANADA LAND INVENTORY CLASSES 1, 2, AND 3) IN THE PRAIRIE PROVINCES

POTENTIAL RISK FOR WIND EROSION

DOMINANT PRIMAARY CLASS OF LAND CAPABILITY FOR AGRICULTURE

POTENTIAL RISK FOR WIND EROSION ON PRIME LANDS FOR AGRICULTURE (CANADA LAND INVENTORY CLASSES 1, 2, AND 3) IN THE PRAIRIE PROVINCES

Figure 3.2 - Prime Agricultural Lands Threatened by Wind Erosion.

form. Figures 3.3 (a), (b), (c), (d), (e) and (f) contain sample environmental and socioeconomic 'mini-plots' of some of the variables in the environmental data base, within which interesting trends can easily be observed. For example, socioeconomic profiles of northern Saskatchewan and Manitoba are characterized by: a high percentage of infant births (Map 4, Figure 3.3 (d)), a high percentage of infant deaths (Map 5, Figure 3.3 (e)), high percent unemployment (Map 1, Figure 3.3 (b)) and a high percentage of the population with less than grade nine education (Map 2, Figure 3.3 (b)). The cities of Edmonton, Calgary, Regina and Winnipeg are highlighted by higher values for female median income (Map 5, Figure 3.3 (e)) and university education (Map 3, Figure 3.3 (b)). Similar spatial distribution patterns between mean frost free period (Map 1, Figure 3.3 (a)), number of growing degree days (Map 3, Figure 3.3 (a)), mean annual temperature (Map 4, Figure 3.3 (a)) and soil moisture regime (Map 6, Figure 3.3 (a)) are also evident in the southern portion of the prairies. A coding error is easily detected in Map 5 (Figure 3.3 (e)) where a large ecoregion in the northern portion of Saskatchewan and Manitoba is dark grey (very low) on the Saskatchewan side and light grey (low) on the Manitoba side. The same ecoregion cannot have two different classifications. More and more patterns emerge each time the maps are observed. Many of these appear quite logical, whereas the reason for other patterns is less evident.

A recurrent theme throughout the Position Paper on Environmental Reporting (Stakeholder Group on Environmental Reporting, 1986) is the link between the environment and health. One field of research which attempts to link environmental conditions

SAMPLE ENVIRONMENTAL PARAMETERS

Figure 3.3 (a)

SAMPLE SOCIOECONOMIC PARAMETERS

Figure 3.3 (b)

SAMPLE SOCIOECONOMIC PARAMETERS

Figure 3.3 (c)

SAMPLE SOCIOECONOMIC PARAMETERS

Figure 3.3 (d).

SAMPLE SOCIOECONOMIC PARAMETERS

Figure 3.3 (e)

SAMPLE SOCIOECONOMIC PARAMETERS

Figure 3.3 (f)

with physical well-being is medical geography. Environomic units are ideal for examining environmental characteristics (collected by ecoregions) which are possibly related to human health (collected by census geostatistical areas). A current (high profile) issue is the possible link between environmental conditions and the occurrence of cancer. Many scientists believe that cancer is in very large part an environmentally determined disease or group of diseases. The late Dr. George Oettle remarked that "... based on African experience, 80% or more of human cancer is environmentally determined and theoretically can be prevented" (Davies, 1979, 49). Studying the spatial distribution trends of environmental and socioeconomic variables can lead to interesting hypotheses. Davies (1979) recounts that when the Ugandan Agricultural Department published a map of the distribution of banana trees in Uganda, it coincided with the distribution of cases of human bladder cancer. Davies also comments on a similar experience that he and his brother encountered: "... all the first cases of this Lymphoma (Burkitt Lymphoma Cancer) that we mapped came from the northern province of Uganda. Examination showed that by mapping the Lymphomas in this way, we had mapped the radioactive areas of Northern Uganda" (Davies, 1979, 49).

Based on a general review of all maps, it appeared that mortality due to cancer of the digestive organs (Map 1, Figure 3.3 (c)), mortality due to cancer of the respiratory organs (Map 2, Figure 3.3 (c)), fertilizer application (Map 1, Figure 3.3 (d)) and herbicide application (Map 4, Figure 3.3 (d)) all had relatively high concentrations in southern Manitoba. Consequently, these concentrations were examined more closely in Figure 3.4, where cancer

SIMILAR SPATIAL DISTRIBUTIONS BETWEEN MORTALITY - CANCER OF THE DIGESTIVE ORGANS AND FERTILIZER AND HERBICIDE APPLICATION IN MANITOBA

Figure 3.4 - Similar Spatial Distribution Patterns Between Cancer Mortality and Fertilizer and Herbicide Application.

of the digestive organs (Map 2) was combined with fertilizer application (Map 1) and herbicide application (Map 3). Although the spatial distributions did not match perfectly (Maps 4 and 5, Figure 3.4), the same four polygons were flagged in both maps. This may only be reflecting a similar distribution between fertilizer and herbicide application or it may be reflecting some association between all three variables. Further investigations of such results are required to establish cause-effect relationships; however, trends or patterns of this nature can lead to formulating hypotheses. In this case, a similar spatial distribution trend is less significant because of the limited span of the study area. It would be preferable to verify if the pattern persists for the whole country before suggesting a relationship. Identifying trends of this nature could conceivably lead to major discoveries and such research should be an important pursuit. In an age of automation, inductive research, which relies on much data processing, will likely become increasingly popular. The use of integrated map units such as environomic units will facilitate the process of linking environmental conditions to health.

As in the wind erosion scenarios (section 3.33), this analysis served as a screening exercise where potential 'hot spots' were identified. A hypothesis suggesting the link between herbicide and fertilizer application and cancer mortality was also formulated; this can be tested for the rest of Canada. This and other hypotheses will be tested when the national environomic coverage is completed. Using the inductive scientific method, a researcher should not expect to find a significant relationship in each attempt. Years of research

may be required to find even one important relationship by looking for common spatial distribution patterns. No matter how well different spatial distributions match, they cannot serve as conclusive evidence that relationships exist. Such trends may be reflecting multiple, indirect, or delayed causes and effects and therefore only imply that the variables are associated (Friend, 1986, 4). For example, many phenomena are multivariate in nature and a given variable may be influenced by many other variables, so that independent variable X may account for only a portion or none of the variation in variable Y. As such, similar spatial distributions can only serve to generate hypotheses which warrant further investigation. Such hypotheses or models, "... in the final analysis, are constructs for simplifying reality and often provide the basis for 'real world' behaviour" (Friend, 1979, 118).

Although the example in Figure 3.4 did not use environmental conditions collected by ecoregion to link to health characteristics (cancer mortality and fertilizer and herbicide application were all collected by census division), it demonstrates the potential usefulness of environomic units for this type of research.

A major step facilitating this type of research will occur when other variables related to the state of the environment (e.g., air quality, acid deposition, toxic wastes, etc.) are available by ecoregion. It will then be possible to compare the spatial distributions of such environmental conditions with the occurrence of non-communicable diseases. Investigations of this nature can only increase our knowledge of the distribution and possibly the causes of

such diseases and perhaps someday help develop appropriate control measures.

The above examples have demonstrated the utility of environomic units to integrate, analyse and display environmental and socioeconomic data. Environomic units proved to be a flexible and useful tool for inductive and deductive research requiring both types of data. While this section focused on possible applications of environomic units, a brief evaluation outlining some of the shortcomings and potential problems are presented in the next chapter.

CHAPTER 4

EVALUATION AND RECOMMENDATIONS

4.10 Summary

Environomic units are a simple and economical concept designed to integrate environmental and socioeconomic data. Accepting the premise that both types of data are required to address current environmental issues, three data integration approaches (as outlined in sections 1.32 and 1.34) are possible. The first consists of describing all attribute data as a percent area or according to the dominant feature within fixed map units. Alternatively, graphical and attribute data themes can be overlaid using a GIS to create a composite graphical and attribute data set. The third option, environomic units, is a compromise approach which incorporates strengths of the two other techniques such as overlay and fixed map units. In a sense, environomic units can be viewed as two standard data collection 'funnels': ecoregions for environmental data and census divisions for socioeconomic data. Given that Statistics Canada and Environment Canada are the main data collectors, environomic units can therefore accommodate a majority of available data.

4.11 Advantages of Environomic Units

Because environomic units are a hybrid of census divisions and ecoregions, both environmental and socioeconomic data can be integrated without using a GIS overlay capability. In fact, as seen in section 2.20, the development of environomic units consisted of completing the overlay process manually. The intent was to integrate two well-established sets of map units which can accommodate a majority of available socioeconomic and environmental data. In this way, the overlay process, elimination of line weave (see section 2.21), quality assurance, etc. are completed once, and the composite result is subsequently used as the standard map units in the future. Integration using a GIS may still be desirable if other types of map units must be integrated.

The use of environomic units is comparatively cheap. A user can simply obtain Environment Canada and Statistics Canada data to use with the corresponding map units manually or with the help of a data base management system and/or a computer mapping package. The hybrid units are not designed to compete with GIS technology, but rather to provide a simple and economical alternative. In fact, environomic units could complement GISs by providing 'quick and dirty' overviews to determine whether a more sophisticated GIS study is required.

Finally, because environomic units retain the original census division and ecoregion boundaries, they are more comprehensive and detailed than when all socioeconomic data are integrated into ecoregions or vice-versa.

Based on the results presented in this study, the author believes that environomic units work and that further research and development should be dedicated to this concept. However, potential problems have been identified during the course of this study. These and possible solutions are outlined below.

4.20 Potential Problems

4.21 Availability of Ecoregion Data

The current ecoregion map of Canada is only a draft. No attribute data, except those collected for this pilot study have been coded for the ecoregions. Conceptually, the ecological land classification boundaries are the environmental equivalent of census (geostatistical) boundaries; however, in practice the Lands Directorate does not have the necessary resources to complete environmental inventories at regular intervals. A short term alternative to obtain data for ecoregions is to aggregate ecodistrict data describing Canada's land cover and land activity to the ecoregion level. The ecodistrict land cover and land activity data base is the best national environmental data base available. Because ELC boundaries are nested (see section 2.12), the attributes of ecodistricts can easily be aggregated into ecoregions and thus environomic units. Also, it should not be difficult to represent generalized variables describing air quality, acid deposition, toxic wastes, etc. (currently monitored by Environment Canada) using ecoregions. Environment Canada's current commitment to state of the environment reporting is also encouraging this type of data integration.

4.22 Environomic Units for the North

Census divisions and ecoregions are very well matched both in size and in number in southern Canada. North of the 60th parallel, however, there are only 6 census divisions (e.g., Yukon is one census division) which is inadequate to address northern issues.

Enumeration areas (EAs) would be a more reasonable substitute for census divisions (e.g., the 88 EAs in the North correspond to communities) except that Statistics Canada's confidentiality guidelines restrict many of the census division variables from being available at the EA level. Consequently different data variables would be available for EAs in the North and census divisions in the South. An inconsistent data base may make it difficult to study national patterns or trends; however, the major environmental, social, cultural, and economic differences between the North and South may justify treating them separately.

The large census divisions (distracting and deceiving when using bright colors) in the northern portions of the prairie provinces have been broken into smaller map units for the 1986 census.

4.23 Water Data

The ecoregion map units can easily accommodate a vast array of environmental variables related to landforms, soils, vegetation, wildlife and climate. Census divisions accommodate all pertinent variables related to human activity. Water is the only major component which is under-represented using environomic units. All water data collected by the Inland Waters Directorate (IWD) of Environment Canada are available on a watershed (drainage basin)

basis. IWD has developed a hierarchy of watershed boundaries designed to report water characteristics at various levels of detail. It has been suggested that a hybrid of land, socioeconomic and water map units would make for a comprehensive spatial framework; however, based on preliminary tests, the resulting composite was extremely clustered and difficult to recognize and interpret. Given that most water variables are collected from sampling stations (point data) it may be possible to simply integrate these into environomic units. The disadvantage of this method is that the potential sphere of influence (the watershed) of each point is not known.

4.24 Microcomputer Based GIS

Significant developments have been made in GIS over the last decade. Major technological changes have led to the first generation of microcomputer-based GISs. Although most of these systems are limited subsets of the minicomputer and mainframe versions, some microcomputer-based GISs currently offer impressive capabilities at a reasonable cost. Should these systems become more powerful, time and cost effective and more widely available, data integration using GIS technology could become a more viable option in the future and in turn could reduce the need for environomic units. However, if the trend of acquiring environmental data and socioeconomic data based on fixed map units continues, it will not be necessary to use a GIS to integrate these two types of data. As mentioned in section 2.30, the two methods can complement each other very well.

4.30 Recommendations

It is recommended that:

1. Environomic units for all of Canada be completed. The resolution of the framework is ideal to study national patterns and trends.
2. National ecoregion data coverages describing the state of the environment be established. These data are crucial for national modelling applications.
3. A suitable and effective method to represent water related variables in the environomic units be developed.
4. The use of the environomic concept for current and future initiatives such as state of the environment reporting be encouraged. The Alberta provincial government recently expressed an interest in obtaining environomic units for their province. They believe that they will be ideal for providing provincial overviews of environmental and socioeconomic trends.
5. The environomic concept be refined and applied at different working scales. Some applications may require units with a higher resolution than is provided by the combination of census divisions and ecoregions. Therefore, the same concept could be applied using environmental and socioeconomic frameworks such as census sub-divisions and ecodistricts.
6. An empirical test designed to measure the accuracy of environomic units be completed. Because environomic units are smaller than the original ecoregions or census divisions, it would be interesting to aggregate detailed environmental and socioeconomic data to the environomic unit level to see if the results are similar to the methodology outlined in this paper.

BIBLIOGRAPHY

- Atmospheric Environment Service, 1982. **Canadian Climate Normals - Temperature**, (A Publication of the Canadian Climate Program, Volume 2, Environment Canada, Toronto, Ontario).
- Atmospheric Environment Service, 1982. **Canadian Climate Normals - Precipitation**, (A Publication of the Canadian Climate Program, Volume 3, Environment Canada, Toronto, Ontario).
- Atmospheric Environment Service, 1982. **Canadian Climate Normals - Degree Days**, (A Publication of the Canadian Climate Program, Volume 4, Environment Canada, Toronto, Ontario).
- Atmospheric Environment Service, 1982. **Canadian Climate Normals - Wind**, (A Publication of the Canadian Climate Program, Volume 5, Environment Canada, Toronto, Ontario).
- Atmospheric Environment Service, 1982. **Canadian Climate Normals - Frost**, (A Publication of the Canadian Climate Program, Volume 6, Environment Canada, Toronto, Ontario).
- Bailey, R.G., S.C. Zoltai and E.B. Wiken, 1985. **Ecological Regionalization in Canada and the United States**, (In: Geoforum, Vol. 16, No. 3, pp. 265-275).
- Berry, B.J., Conkling, E.C. and D.M. Ray, 1976. **The Geography of Economic Systems**, (New Jersey: Prentice Hall, Inc.).
- Bird, P.M. and D.J. Rapport, 1986. **State of the Environment Report for Canada**, (Environment Canada, Ottawa, Ontario).
- Brklacich, M. and B. Smit, 1986. **The Effects of Climate Change on the Terrestrial Biosphere**, (In: Perspectives on Land Modelling Workshop Proceedings in preparation, Lands Directorate, Ottawa, Ontario).
- Brouwer, F.M. 1986. **Integrated Environmental Modelling: Design and Tools**, (unpublished PhD Thesis, University of Amsterdam, Netherlands).
- Carley, M.J. 1984. **Cumulative Socioeconomic Monitoring**, (Report Prepared for Government of the Northwest Territories and the Department of Indian Affairs and Northern Development, Vancouver, British Columbia).
- Chorley, R.J. and P. Haggett, 1967. **Models, Paradigms and the New Geography**, (In: Socioeconomic Models in Geography, R.J. Chorley and P. Haggett (eds) London: Methuen & Co. Ltd.).
- Conkling, E.C. and M. Yeates, 1976. **Man's Economic Environment**, (New York: McGraw-Hill Book Company).

- Coombs, D.B. and J. Thie, 1979. **The Canada Land Inventory System.** (In: Planning the Uses and Management of Land, M.T. Beatty, G.W. Petersen and L.D. Swinsdale (Eds.), Agrohomy Service of the American Society of Agriculture, No. 21, Madison, Wisconsin).
- Coote, D.R., J. Dumanski and J.F. Ramsey, 1981. **An Assessment of the Degradation of Agricultural Lands in Canada.** (Land Resource Research Institute, Agriculture Canada, Ottawa, Ontario).
- Davies, J.N.P. 1979. **Difficulties in the Approach to the Mapping of the Environment in Cancer.** (In: Harvard University's Laboratory for Computer Graphics, Computer Mapping in Education, Research and Medicine, Harvard Library of Computer Mapping, Cambridge, Massachusetts).
- Environment Canada, 1986. **World Conservation Strategy - Canada.** (Prepared by D.F.W. Pollard and M.R. McKeehnle, Conservation and Protection, Environment Canada, Ottawa, Ontario).
- Environmental Conservation Service Task Force, 1980. **Ecological Land Survey Guidelines for Environmental Impact Analysis.** (Ecological Land Classification Series, No. 13, Lands Directorate, Environment Canada, Ottawa, Ontario).
- Friend, A., 1979. **Ecological Mapping and Socioeconomic Statistics.** (In: Applications of Ecological (Biophysical) Land Classification in Canada, C.D.A. Rubec (ed), Ecological Land Classification Series, No. 7, Lands Directorate, Environment Canada, Ottawa, Ontario).
- Friend, A., 1986. **Federal Government Data Bases Relevant for Environmental Risk Management.** (Paper Prepared for the Institute for Environmental Studies, University of Toronto, for a monograph on 'Information Needs for Environmental Risk Management, Ottawa, Ontario).
- Geography Division, 1982. **Geography and the 1981 Census of Canada.** (Working Paper No. 2, Geography Series, Geography Division, Statistics Canada, Ottawa, Ontario).
- Gierman, D.M., 1981. **Survey of User Requirements for Land Use Data: Canada Land Use Monitoring Program.** (Working Paper Series No. 15, Lands Directorate, Environment Canada, Ottawa, Ontario).
- Jeffers, J.N. 1972. **Systems Modelling and Analysis in Resource Management.** (in: Journal of Environmental Management, 1:13-28).
- Jameson D.A., Moore, M.A., and P.J. Case, 1982. **Principles of Land Resource Management Planning.** (Land Management Planning Office, United States Department of Agriculture, Washington, D.C.).
- Johnston, R.J. 1983. **Geography and Geographers.** (Baltimore, Maryland: Edward Arnold Publishers Ltd.).

- Johnston, R.J. 1983. **Philosophy and Human Geography**. (Baltimore, Maruland: Edward Arnold Publishers Ltd.).
- Jorgensen, S.E. 1986. **Fundamentals of Ecological Modelling - Developments in Environmental Modelling 9**. (New York: Elsevier Science Publishing Company Inc.).
- Lands Directorate, 1978. **The Canada Land Inventory: Objectives, Scope and Organization**, (Canada Land Inventory Report No. 1, Lands Directorate, Environment Canada, Ottawa, Ontario).
- Lands Directorate, 1984. **The Lands Directorate: Its Mandate and Mission**, (unpublished internal Lands Directorate document, Environment Canada, Ottawa, Ontario).
- Laut, P., Firth D. and T.A. Paine, 1980. **Provisional Environmental Regions of Australia**, (Working document, CSIRO Australia and Department of Science and Environment, Melbourne Australia).
- Lefebvre, S. (Head, Cartographic Unit, Geography Division, Statistics Canada) Personal Communication, Telephone Interview, October 30, 1986, Ottawa, Ontario).
- Lynch-Stewart, P. 1986. **A Census Division Perspective of Resources Potentially at Risk Due to Acid Deposition in Eastern Canada**, (Working Paper Series report in preparation, Lands Directorate, Environment Canada, Ottawa, Ontario).
- Kerr, A.K., Manning, E.W., Seguin, J. and L.J. Pelton, 1985. **Okanagan Fruitlands: Land-Use Change Dynamics and the Impact of Federal Programs**, (Land Use in Canada Series, No. 26, Lands Directorate, Environment Canada, Ottawa, Ontario).
- Manning, E.W. 1986. **Towards Sustainable Land Use: A Strategy**, (Working Paper Series Report No. 47, Lands Directorate, Environment Canada, Ottawa, Ontario).
- Manning, E.W. 1986. **Models and the Decision Maker**, (In: Perspectives on Land Modelling Workshop Proceedings in preparation, Lands Directorate, Ottawa, Ontario).
- Mouaig J.D. and E.W. Manning, 1982. **Agricultural Land-Use Change in Canada: Process and Consequences**, (Land Use in Canada Series, No. 21, Lands Directorate, Ottawa, Ontario).
- Morgan, M.A. 1967. **Hardware and Models in Geography**, (In: Socio-Economic Models in Geography, R.J. Chorley and P. Haggett (eds) London: Methuen & Co. Ltd.).
- Norcliffe, G.B. 1977. **Inferential Statistics for Geographers: An Introduction**, (Hutchingson & Co. Ltd., London, England).

- Peuquet, D.J. 1984. **A Conceptual Framework and Comparison of Spatial Data Models**, (In: Cartographica, Volume 21, Number 4, Winter 1984, University of Toronto Press, Toronto, Ontario).
- Pierce, T.W. and J. Thie, 1981. **Land Inventories For Land Use Planning In Canada**, (In: Planning Future Land Uses, G. Petersen and M. Beatty (Eds.), American Society of Agronomy Special Publication, No. 42, pp. 57-71).
- Poiker, T. and I. Crain, 1985. **Geographical Information Systems**, (Article Prepared for the Canadian Encyclopedia, Ottawa, Ontario).
- Rubec, C. and E.B. Wiken, 1982. **Ecological Land Survey: A Canadian Approach to Landscape Ecology**, (Presented to Vith International Symposium on Landscape Ecological Research, Piestany, Czechoslovakia, October 26-31, 1982).
- Rump, Paul C. 1983. **Land Inventories In Canada**, (Paper for China in Canada: A Geography Conference, Canadian Association of Geographers and McMaster University, Nov. 2-3, 1983, McMaster University, Hamilton, Ontario).
- Science Council of Canada, 1986. **A Growing Concern: Soil Degradation in Canada**, (Council Statement, Science Council of Canada, Ottawa, Ontario).
- Stakeholder Group on Environmental Reporting, 1986. **A Position Paper on Environmental Reporting in Canada**, (unpublished internal Environment Canada document, Environment Canada, Ottawa, Ontario).
- Statistics Canada, 1978. **Human Activity and the Environment**, (Statistics Canada, Ottawa, Ontario)
- Statistics Canada, 1982. **CANSIM: 1981 Census of Canada - User Summary Tapes**, (Statistics Canada, Ottawa, Ontario).
- Statistics Canada, 1986. **Human Activity and the Environment - A Statistical Compendium**, (Statistics Canada, Ottawa, Ontario).
- Steinke, T. and R. Lloyd, 1983. **Judging the Similarity of Choropleth Map Images**, (In: Cartographica, Volume 20, Number 4, Winter 1983, University of Toronto Press, Toronto, Ontario).
- Surveys and Mapping Branch, 1980. **Soil Capability for Agriculture**, (The National Atlas of Canada, 5th Edition, Energy, Mines and Resources Canada, Ottawa, Ontario).
- Welch, D.M. 1980. **...For Land's Sake**, (Lands Directorate, Environment Canada, Ottawa, Ontario).
- Whyte, R.O. 1976. **Land and Land Appraisal**, (The Hague: Dr. W. Junk B.V. Publishers).

Wiken, E.B., 1978. **Ecological (Biophysical) Land Classification: An Analysis Of Methodologies**, (unpublished M.Sc. Thesis, University of British Columbia).

Wiken, E.B., 1979. **Rationale and Methods of Ecological Land Surveys: an Overview of Canadian Approaches**, (In: Land/Wildlife Integration (compiled and edited D.G. Taylor), Ecological Land Classification Series No. 11, Lands Directorate, Environment Canada, Ottawa, Ontario).

Yeates, M. 1985. **Land in Canada's Urban Heartland**, (Land Use in Canada Series, No. 27, Lands Directorate, Environment Canada, Ottawa, Ontario).

APPENDIX A.1

DATA SOURCES

A. Environmental Variables

- . Average Frost-Free Period (Days)
- . Mean May-September Rain (mm)
- . Average Annual Growing Degree Days (> 5 C)
- . Average Annual Temperature (C)
- . Average Annual Wind Speed (km/hr)

Source: The above variables were obtained from the Canadian Climate Normals (1951 - 1980). Canadian Climate Program. Atmospheric Environment Service, Environment Canada, 1982. A map of climate stations was overlaid onto the ecoregion coverage and the mean of all stations within an ecoregion was used. Most stations within one ecoregion provided similar data (ecoregions are indirectly based on climate as expressed by vegetation).

- . Moisture Regime
- . Soil Classes
- . Mode of Origin
- . Mean Elevation (m)
- . Surface Form
- . Modal Vegetation

Source: These variables were compiled by members of the ERIP Division, Lands Directorate, Environment Canada, 1986.

B. Socioeconomic Variables

- . Number of Deaths from Cancer of Digestive Organs
- . Number of Deaths from Cancer of Respiratory Organs
- . Number of Deaths from Leukemia
- . Number of Births
- . Number of Infant Deaths

Source: Vital Statistics Division, Statistics Canada, 1984.

- . Percent Unemployment
- . Percent of Total Population who Completed Grade 9
- . Percent of Total Population who Completed University
- . Median Income - Male
- . Median Income - Female
- . Percent Labour Force in Agriculture
- . Percent Labour Force in Mining and Oil
- . Percent Labour Force in Manufacturing

- . Percent Labour Force in Construction
- . Percent Labour Force in Community and Personal Services

Source: 1981 Census of Canada, Statistics Canada, 1982.

- . Percent of Improved Farmland to Total Area
- . Total Value of Agricultural Products (\$)
- . Total Value of Equipment and Machinery (\$)
- . Percent Summerfallow to Improved Farmland
- . Fertilizer Application (Kg/Hectare)
- . Irrigation as a percentage of Improved Farmland
- . Herbicide Application as a percentage of Improved Farmland
- . Insecticide Application as a percentage of Improved Farmland

Source: Census of Agriculture, Statistics Canada, 1981.

APPENDIX A.2

CRITERIA USED TO DETERMINE CLASSES FOR COMPOSITE MAPS

Legend

L = Low
M = Moderate
H = High

Criteria Used to Determine Classes for Map 6 (Figure 3.1)					
RELATIVE RATINGS					COMPOSITE RATINGS
MOIST (Map 1)	PRECIP (Map 2)	WIND (Map 3)	SUMFAL (Map 4)		(Map 6)
IF	AND	AND	AND	THEN	
L	L	H	H		H
L	L	H	M		M
L	L	M	H		M
L	L	M	M		M
L	M	M	H		M
L	M	M	M		M
M	L	H	M		M
M	L	M	H		M
M	L	M	M		M
M	M	H	M		M
M	M	M	H		M
M	M	M	M		M
L	M	H	H		M
M	L	H	H		M
M	M	H	M		M
L	M	H	M		M
M	L	M	M		M
M	M	M	H		M
M	M	M	M		M
M	L	M	M		M
M	M	M	M		M
ELSE					L

Criteria Used to Determine Classes for Map 7 (Figure 3.1)

RELATIVE RATINGS		COMPOSITE RATINGS
RISK (Map 6)	LABOUR (Map 5)	(Map 7)
IF	AND	THEN
H	H	H
M	M	M
H	M	M
M	H	M
ELSE		L

Criteria Used to Determine Classes for Map 3 (Figure 3.2)

RELATIVE RATINGS		COMPOSITE RATINGS
RISK (Map 1)	CLI (Map 2)	(Map 3)
IF	AND	THEN
H	H	H
M	M	M
H	M	M
M	H	M
ELSE		L

Criteria Used to Determine Classes for Map 4 (Figure 3.4)

RELATIVE RATINGS		COMPOSITE RATINGS
PERT (Map 1)	MORT (Map 2)	(Map 4)
IF	AND	THEN
H	H	H
M	M	M
H	M	M
M	H	M
ELSE		L

Criteria Used to Determine Classes for Map 5 (Figure 3.4)

RELATIVE RATINGS		COMPOSITE RATINGS
Herb (Map 3)	MORT (Map 2)	(Map 5)
IF	AND	THEN
H	H	H
M	M	M
H	M	M
M	H	M
ELSE		L

APPENDIX A.3

OVERVIEW OF STEPS INVOLVED IN DEVELOPING AND APPLYING ENVIRONOMIC UNITS

1. Manually Overlay Census Divisions and Ecoregions (section 2.20).
 - Eliminate line weave (section 2.21);
 - Develop unique environomic identification codes based on the original census division and ecoregion codes (section 2.22).
2. Digitize Environomic Units Into a Computerized Data Base (section 3.11).
3. Type Attribute Data Describing Environmental and Socioeconomic Themes Into a Computerized Data Base (section 3.20).
4. Use Computer-Assisted Cartography to Facilitate Analysis.
 - Deductive Analytical Approach (section 3.33)
Apply existing models by mapping individual and/or composite variables as specified in model.
 - Inductive Analytical Approach (section 3.34)
Map environmental and socioeconomic variables to look for similar distribution patterns or trends which may lead to generating hypotheses (models).

END

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FIN