**Land Suitability Rating System: a tool to evaluate crop production potential for Canada**

**Introduction**

-history and evolution of rating systems

-review of current suitability systems in use

-need for LSRS

-objectives of the paper

Introductory sections of Papers 1 – 4. Will need to undertake literature review

**Methods**

-background

Sections 2.1, 2.2, 2.3 Paper 1

-system development

Concepts and assumptions – sections 2.4, 2.5, 2.6 Paper 1

Methodology section Paper 3

-testing (how it was organized)

Extract key statements from section 5 Paper 1, section 5 and appendices of Paper 6

**Results**

-the generic system make-up

Sections 3.1, 3.2,4 and appendix of Paper 1, Use Figure on pg 6 of paper 6 as model (or Fig 1 Paper 2)

-description of models

Sections 3 and 4 and Appendices Paper 6

-comparison with CLI

Section 4 Paper 1

-testing

Section 5 Paper 1, section 5 and appendices of Paper 6

-current CanSIS program concepts

Phase 2 and 3 sections Paper 2, reference to Paper 5, more from Peter to complete

-application (reference to past and current usage of LSRS)

New write up, reference to paper 5

**Summary and Conclusions**

-statement of key attributes and strengths of current LSRS

-use in climate change assessments

-future directions

Build on Summary section Paper 3, section 6 Paper 1

**References**

Reference reports to draw from:

1. Land Suitability Rating System: a discussion WWP Jan 2014

2. Land Suitability Rating System: Implementation WWP version Mar 2014

3. Canadian Land Suitability Rating System-Overview Brierley and Pettapiece Dec 2013

4. Untitled draft, LSRS overview. Mike Bock. Jan 2014

5. Schut et al. 2012 . Soil Landscapes of Canada: building a national framework for environmental information. Geomatica 65:

6. Final Compilation Report (Contract # 3000283404) Pettapiece et al. 2007

**Land Suitability Rating System: a flexible national system to evaluate production potential for a variety of Canadian agricultural crops**

# INTRODUCTION

# METHODS

**Background**

### Preliminary Orientation

The Working Group, composed of members from each province plus the Yukon Territory, examined a number of systems presently being used to rate land for the production of agricultural crops, keeping in mind the need for national consistency and the other concerns raised by the Expert Committee on Soil Survey (ECSS 1986). The systems included those used in British Columbia (Kenk and Cotic 1983), Alberta (Alberta Soils Advisory Committee 1987), the Ottawa area (Marshall et al. 1979), Ontario (Brokx and Presant 1986), Quebec (Mailloux et al. 1964) and the Atlantic Region (Atlantic Advisory Committee 1988) as well as the CLI and Storie systems. Several climatic stratifications were also reviewed (Chapman and Brown 1966; FAO 1976; Williams 1983).

Recommendations from the initial assessment were:

1. The basic concept of the seven (7) class CLI system (ARDA 1965) should be retained. It was sound and easy to understand, and it was the basis of land legislation in several provinces.
2. Since climate, soil and landscape factors could independently control the suitability of a tract of land for crop production, each one should be rated separately.
3. Organic soils must be included and should (at least in the initial development stages) be rated for the same crops as mineral soils.
4. As a limited number of factors were common to all systems reviewed and included most of the parameters of an optimum approach to soil productivity assessment (Heddleston 1984) these should be individually defined and explicitly rated using an expert system approach (McCracken and Cate 1986) based on present knowledge and available data.
5. The individual parameter ratings should follow scientifically proven relationships and managed in a mathematical setting leading to a composite index (climate, soil and landscape) similar to the Storie approach.
6. The system should be developed using the small seeded cereals (wheat, oats and barley) with an emphasis on barley which is the one crop that is grown in every agricultural region of Canada.
7. The system must use data that was presently available across Canada.

The first recommendation provided the overall approach that should be taken while the next four addressed the major weaknesses that had been identified in the CLI approach. The final two recommendations addressed the issue of national consistency and provided further direction for system development. Following the recommendations of the Working Group, the suitability system was to be developed using the small seeded cereals. Subsequent to the development of LSRS for the small seeded spring grains

It may be noted that no mention is made of scale. The reason is that the system is meant to be scaleless- with the ability to be used at any scale appropriate to the objectives of the project and available data.

### Terminology

Many terms have overlapping usages: some have been used for more than one meaning, several have often been used for the same meaning. Following are some of the general usages employed in this report.

1. Soil vs Land (soilscape, landscape, landform)
   1. Soil Restricted to those situations specific to soil considerations.
   2. Land Used in a general sense that includes soil, landscape setting (climate and vegetation). It is a more inclusive than soil and therefore a more appropriate term in a natural systems/ecological approach.
   3. Landscape Used in a general sense that includes features such as stoniness and wetness as well as "landform"
2. Capability vs Suitability (rating, assessment, evaluation)
   1. Capability A broad concept that addressed potential is terms of crop options, productivity and sustainability. It is used in a manner, consistent with the CLI, for broad concepts and at generalized scales of detail.
   2. Suitability Has the same general concept as capability but is used for specific objectives (e.g. single crops) or at more detailed (larger) scales.

Rating, assessment and evaluation, when used in an "agricultural rating" context have an economic component but all three terms are used interchangeably in this report in a generic sense with no specific meaning.

1. Agriculture Used in the CLI to signify the industry but in reality it only represented the annual cash crop component which caused some confusion. It is used here only the generic context.

## System Development

### Assumptions

Arising from the preliminary discussion there were a number of assumptions or guidelines that were required to provide boundary conditions for the system.

1. Standard recommended husbandry should be assumed.
2. External economic factors such as distance to market, availability of transportation and size of farm would not be criteria. These are important for Municipal assessment and taxation but would not be part of this natural resource evaluation.
3. One-time costs such as clearing of trees or drainage would not be criteria but continuing annual costs such stone removal and erosion control should be considered in the sustainability considerations.
4. Exceptional skills or resources of the farm manager or specific cultural practices would not be considered.
5. Permafrost would not be a factor. This was based on the observation that once the vegetative cover is removed, permafrost recedes to depths greater than 1 m in any region of Canada where commercial crop production is considered feasible.

### Structure of the Land Suitability Rating System

CLASS AND SUBCLASS. The basic structure of the LSRS follows that of CLI, namely the use of two hierarchical categories – classes and subclasses. Classes are broad in scope and are based on the degree of limitation of land for production of the specified crop or crops. Seven classes are recognized: Classes 1-3 are considered arable – suitable for sustained production of the specified crop; Class 4 is considered marginal, and; Classes 5-7 are considered unsuitable or not capable of supporting sustained production under presently recommended practices. Subclasses identify the attributes that have the greatest limiting influence on the final class rating. They reflect the kind of climate, soil and landscape limitations that are present. The subclass information is critical for determining conservation and management practices and for land use planning. Subclass designations used in LSRS are: climate – temperature/aridity (H) and moisture (A); mineral soil – water supplying ability (M), structure and consistence (D), organic matter content (F), depth of topsoil (E), reaction (V), salinity (N), sodicity (Y), organic (peaty) surface (O), and drainage (W); organic soil – soil temperature (Z), water supplying ability (M), degree of decomposition (B), reaction and nutrient status (V), salinity (N), and drainage (W), and; landscape – basic landform rating/slope (T), stoniness (P), wood content (J), landscape pattern (K), and flooding (I).

It is important to note that areas assigned to the same suitability class are similar only with respect to the degree, and not the kind, of limitation for the production of the specified crop. Areas of similar class can include different climate, soil and landscape characteristics that may differ markedly and require different management practices.

FACTORS AND PARAMETERS. LSRS is an interpretive assessment based on the limitations controlling crop specific production. Three major rating factors are identified: climate, soil and landscape. The rating factor that is most limiting ultimately determines the suitability class rating. The components and measureable parameters identified to characterize and evaluate the major rating factors were selected from those used in earlier approaches to rating land for the production of agricultural crops, and acknowledged to be critical in crop production (Huddleston 1984). The following criteria were used in selecting the specific parameters used to characterize the major rating factors used in the LSRS model (Table 1):

* parameter is known to affect the ability to produce crops;
* parameter is known to affect the ability to respond to management stress (e.g., could withstand drought);
* parameter must be measurable or able to be estimated from known relationships (i.e, pedotransfer functions), and;
* parameter data must be commonly available.

**Table 1. Components and parameters chosen to characterize the major rating factorsz**

|  |  |  |
| --- | --- | --- |
| Factor | Component | Measureable parameter |
| Climate | Heat (energy) supply | Growing degree days, growing season |
|  | Moisture supply | Precipitation, evapotranspiration, growing season |
|  |  |  |
| Mineral Soils | Moisture supply | Texture, climate, rooting depth, watertable |
|  | Nutrient supply | Organic matter content, soil reaction |
|  | Physical conditions | Soil structure, soil density |
|  | Chemical conditions | Soil salinity, soil reaction |
|  | Drainage | Depth to water table, climate |
|  |  |  |
| Organic Soils | Moisture supply | Fibre content, climate, water table |
|  | Nutrient supply | Fibre type, soil reaction |
|  | Physical conditions | Soil structure, soil density |
|  | Chemical conditions | Soil reaction, soil salinity |
|  | Drainage | Depth to water table, climate |
|  |  |  |
| Landscape | Erodability potential | Slope steepness, slope length, climate |
|  | Management factors | Stoniness, drainage, pattern**y** |
|  | Flooding potential | Wetness, duration of flooding, landform position |

**z**See AIWG (1995) for definitions.

**y**Identified but not incorporated for initial development.

### Relationships and Linkages of Factors, Components and Parameters to the Suitability Assessment

In keeping with the recommendations of the AIWG, LSRS assesses the climate, soil and landscape factors independently with a precisely defined index procedure that links the results to the 7 class system. This methodology required the development of clear relationships and guidelines for the assessment of the factors.

THE RELATIONSHIP BETWEEN CLIMATE, SOIL AND LANDSCAPE FACTORS. In LSRS, the major rating factors are related to three of the major elements that describe crop production suitability:

* Climate - controls the type and range of crops that can be grown (flexibility of production);
* Soil - controls how well the crops grow (productivity), and;
* Landscape - controls the annual cost to manage environmental constraints (sustainability).

Although it is recognized that there are many instances of overlap and synergy between the major factors, there are advantages with respect to simplicity, clarity and the ability to highlight specific limitations by assessing each factor separately. Having built the major climatic-soil interactions into the soil factor, any other remaining discrepancies are considered small. This decision is reasonable given the constraint of available data and the need for national coverage. This approach provides the greatest flexibility to assess various environmental, crop and climatic scenarios.

Each of the major factors is assessed a rating index between 0 (most limiting) and 100 (least limiting). Initially, each factor is assigned an index rating of 100. Limitations are assessed using the specific parameters identified for each factor (Table 1) and point values are deducted from the initial index ratings. The final index rating assigned is that of the most limiting of the three factors.

LINKAGE OF NUMERICAL ASSESSMENT TO THE DESCRIPTIVE CLASS STRUCTURE. As productivity is an important consideration in suitability assessments, studies of the relationships of Canada Land Inventory (CLI) classes to the yields of cereals in Alberta (Peters 1977; Peters and Pettapiece 1981) and apples in Ontario (van Vliet et al. 1979) provided the initial guidance in developing an assessment of limitations based linkage between the prescriptive numerical index ratings (0-100) and the descriptive suitability class ratings (1-7). These studies reported a reasonably good correlation for the better classes with Class 1 (none to slight limitation) generally yielding 80% to 100% of the crop maximum. Class 3 areas (moderate limitation but still considered “Good”) generally had yields about 50% of maximum or better. It was also noted that with increasing limitations - particularly landscape limitations, the yield relationships disappeared. That is, landscape features may be difficult or costly to manage but are not directly related to yield. Additional expert opinion suggested that index rating of less than approximately 1/3 of maximum (33 out of 100 points) should be considered a very severe limitation to the long-term sustainability of production.

Using the above noted considerations as a guide, a relationship framework was formulated that provides the conceptual and mathematical linkage between the factor index ratings and LSRS classes and also assisted in the development of the individual parameter indices (Fig. 1).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Suitability class | Index rating | Limitation level for specified crop | General assessment | Comments |
| 1 | 100–80 | None to slight | Excellent | Primeland |
| 2 | 79–60 | Slight | Good |  |
| 3 | 59-45 | Moderate | Fair |  |
| 4 | 44-30 | Severe | Poor | Marginal land |
| 5 | 29-20 | Very severe | Very poor | Unsustainable or unsuitable land |
| 6 | 19-10 | Extreme | Unsuitable |  |
| 7 | 9-0 | Unsuitable |  |  |

**Fig. 1.** Framework for LSRS outlining the relationship between LSRS class, index rating and degree of limitation.

INFORMATION REQUIREMENTS. Use of the rating system requires specific information for each component within the climate, soil and landscape factors. There are two main considerations.

First is the principal issue of what to measure and how to measure it. For example, climate per se is not measured. However, heat (energy) and moisture parameters have been identified. The measurable components of moisture are precipitation, evapotranspiration and length of growing season (the what to measure). Precipitation is easy to measure and there are good records covering most of Canada. Evapotranspiration is a little more difficult with fewer records. However, there are several accepted approximations in the literature that can be used (transfer function based on other data). Growing season length requires some definition of beginning and end before it can be measured. All weather data is variable at all scales so decisions are required to manage this. The LSRS decision was to follow the National Meteorological approach and use 30 year averages. In the case of climate, many parameters are closely correlated and because the Suitability system is a relative approach comparing neighbouring land areas (not absolute), there are many options that will work equally well when choosing components or that can be substituted with no loss of accuracy.

A second important issue is that of proxies. If there is no information or missing records or a lack of records at the scale of investigation, are there other measurements or features that can be used? This is particularly relevant to the soil factors and fortunately there is a good deal of scientific research and literature that defines relationships that can be used for proxies. (In the case of soils, these are often referred to as pedotransfer functions). For example, soil texture or particle size distribution can be used as a proxy for soil moisture holding potential, soil color can be used as a proxy for organic matter content or soil drainage can be used as a rough estimate of depth to water table. In the landscape analysis, slope steepness (and length) can be used as a measure of the erosion potential. these are defined for the LSRS applications (AIWG 1995) and provided as guidelines for users of the system.

Regional assessments of the suitability of land can generally be made using published data. Assessments of specific tracts of land for the production of specified crops, however, usually require specific data for the sites involved, including on-site inspection, unless the available data are unusually comprehensive.

FACTORS AND THEIR ASSESSMENT. The principal difference between CLI and LSRS relates to the method of evaluation of the limitations controlling crop specific production. CLI methodology is subjective, based upon verbal descriptions (Brocke 1977) whereas LSRS incorporates explicit, transparent deduction tables and graphs that mathematically model the relationships between the various climate, soil and landscape parameters and the limitations to crop production (as expressed by index rating point deductions) that those parameters present (AIWG 1995, Schut 2010). Unlike the subjective methodology of CLI, the parameter/deduction relationships can be described as mathematical functions, and as such, incorporated into the digital environment of computer software.