Land Suitability Rating System:

2. Implementation

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# INTRODUCTION

## Background

In 1995 Agriculture and AgriFood Canada published the Land suitability Rating system for Agricultural Crops: Spring-seeded small grains (AIWG 1995). This system (the LSRS) was developed to address a number of deficiencies identified in the 30 year old Canada Land Inventory: Soil Capability for agriculture (CLI) (ARDA 1965), namely:

1. Modifications of the CLI by several agencies had resulted in a variety of non-comparable approaches in land capability ratings across Canada.

2. The influence of climate on land suitability for crop production was not adequately taken into account.

3. Organic soils were not included.

4. Lack of specificity in definitions and application guidelines had led to inconsistent ratings among land rating practitioners.

A working group of pedologists representing all regions of Canada reviewed existing systems and recommended that the basic seven (7) class concept of the CL1 should be retained but that the individual components, climate, soil and landscape, should be rated separately using explicitly documented and rated factors. It should use an expert system approach based on accumulated experience and supporting research with modifications from field testing. Additional guidelines suggested that, as the LSRS was designed to replace the CLI, a basic suite of small grains that are grown across Canada (with the emphasis on barley) should be used in the development phase in order to provide a comparable rating to the CLI and, it must function using existing data.

The general concept was:

Climate - controls what crops can be grown (Flexibility)

Soils - control how well the crops grow (Productivity)

Landscape - controls the annual cost to manage environmental constraints   
such as erosion potential, stoniness or wetness (Sustainability)

It was recognized that there were many instances of overlap and synergy. However, by assessing each separately there were advantages with respect to simplicity, clarity and the ability to highlight specific limitations. Also, it was felt that if the major climatic-soil interactions were built into the soil factor then any remaining disparencies would be small. This approach also provides the greatest flexibility for the assessment of various environmental, crop and climatic scenarios.

In the LSRS each of the major factors was calculated on a rating scale between 0 (most limiting) and 100 (least limiting) with the final rating being the most limiting of the three factors. A class rating (comparable to the CLI was then applied (Table 1). This table became the guide for developing the individual parameter indices and for linking indices to the Classes both conceptually and mathematically.

Table 1. Relationship of index points to Suitability Class

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Suitability  Class | Index  points | Limitation level  for specified crops | General  Assessment | Comments |
| 1 | 100 - 80 | None to slight | Excellent | Prime land |
| 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 |

The criteria used to define each of the major factors were chosen for their proven ability to affect crop growth, their ability to be measured (or estimated by proxy) and were commonly available. The resultant list included 10 major components and 16 measureable parameters (Table 2).

Table 2. Components and parameters chosen to characterize the major rating factors.\*\*

|  |  |  |
| --- | --- | --- |
| 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, |
|  | Flooding potential\* | Wetness, duration of flooding, landform position |

\*\* See AIWG 1995 for definitions.

The LSRS provides a standard, nationally consistent approach for assessing land for crop growth. It uses an explicit modular format that is adaptable to local conditions, other crops and future climatic scenarios. It uses present knowledge and available data and documents all inputs and calculations.

While the Land Suitability Rating System (AIWG 1995) represented the continued evolution of the land capability concept, full implementation of the system required some further development:

1. Computer programs needed to be developed to automate the system (and to facilitate further applications),

2. The climate data needed be updated to standard, electronically available data sources.

3. The system needed to be expanded to include the major agricultural crops in Canada.

## Objectives

The objectives of this report are to describe the further development of the LSRS, namely:

1. The development and implementation of the computerization of the system,

2. The updating of the climate information to the standard 61-90 national climate normals,

3. The expansion of the system to the accommodate the major agricultural crops grown in Canada (corn, soybeans, canola, alfalfa and grass forage production), and

4. The modifications of the architecture to expand the flexibility of the system to accommodate any number of defined climate, soil and landscape inputs as well as additional crop models and geographic bases.

The discussion format will involve four phases of implementation.

Phase 1. 1993-2001: Development of the basic LSRS programming.

Phase 2. 2002-2004: Development of a transparent, user-friendly program using an Excel platform.

Phase 3. 2005-2008: Extension of the Alberta platform to accommodate national data and 5 new crops.

Phase 4. 2009-2012: Reversion to Agriculture Canada (NLWIS).

# IMPLEMENTATION

## Phase 1. 1993-2001:Development of the basic LSRS programming.

This initial phase Implementation was done by contract under the authority of the Research Branch, Agriculture and Agri-Food Canada.

### Development

The results from testing of the draft LSRS in 1993 were positive with several provisos, one of which was that automation of the system was a priority. As in-house expertise was not available at that time, a small contract was negotiated with Axion Spatial Imaging in Edmonton to initiate programming, to provide an estimate of the total expected cost and to assess the marketing potential of the product. The programming language was C++ (Borland). When the exploratory contract was completed, Agriculture and Agri-Food Canada was not in a position to make further contract commitments and this initiative was not renewed. While an operating product was never completed, the activity did bring the issue into focus and identified many of the features that needed to be addressed.

In 1994, Pl Krug of the Saskatchewan Soil Survey (Saskatchewan Centre for Soil Research, U. of S., Saskatoon) was contracted to provide programming. This time there was a better understanding of what was required and the product was restricted to a single (NSDB) data source and an elaborate computer display was not a requirement. A draft program (written in dBase IV) was submitted for review (Krug 1994).

In 1994-95, R. MacMillan (Landmapper Environmental Solutions) was asked to review the relationships between a new standard Alberta soils database (CAESA-SIP) and the National Soils Database (NSDB) and a potential interface with the LSRS program (MacMillan 1995). He wrote a program to create a LSRSBAT file to facilitate batch processing of both sets of soils data with the P. Krug LSRS program. He also made suggestions for aggregating the results of complex soil-landscape units.

In 1995, G. Lelyk of the Manitoba Land Resource Unit finalized a working program using original code from P. Krug and suggested modifications form R. MacMillan (Lelyk 1996). The program was written in dBase IV ver 1.1 and distributed as a Visual dBase. It was limited to NSDB (Soil Landscapes of Canada) soil and landscape units. the SLC map was also linked to the climate maps to provide an automated climate link.

This phase was completed under the direction of W. Pettapiece of the Alberta Land Resource Unit who also supplied logic statements for individual parameter calculations.

### Applications

The first application of the automated LSRS was an assessment of soil quality and predicted trends for 15 Agroecological Resource Areas representing five Ecoregions ( Soil Zones) in Alberta. This was accomplished by linking LSRS to EPIC, the Erosion Productivity Impact Calculator (Williams et al.1990) to assess the impact of present farming practices (Pettapiece, Haugen-Kozyra and Watson 1998). The initial LSRS rating was assumed to be the present soil Quality (SQ t0). The soil parameters and present cropping systems were used to fuel EPIC runs of 30 years. The soil factors of organic matter content, texture, reaction, depth of erosion and bulk density were then used to calculate a predicted soil quality (SQ t30). A comparison of SQ t30 to SQ t0 identified trends ranging from positive (improving) in the northern Low Boreal regions to negative (deteriorating) in the southern Grasslands as well as highlighting several unsustainable management systems.

The HEMS (Hog Environmental Management Strategy) project (Eilers and Buckley 2002) was initiated in response to the expansion of swine industry in Canada, around 2000. The main functions of this methodology was to provide a description of the land resource base in terms of environmental limitations, and to serve as a decision support mechanism to assist users (provincial resource specialists, land use planners) to make environmentally sound decisions for the purpose of siting swine production units and providing recommendations for the application of manure to the land base in an environmentally sustainable manner.

A third application looked at the implications of climate change in the prairie agricultural region (Nyirfa and Harron 2001). The authors compared Land Suitability (LSRS) ratings under present climate condition to Land Suitability calculated using climate values predicted by the CGCM1 model for 2050. The results suggested that predicted precipitation increases would offset rising heat and drought concerns.

### Summary

The in-house LSRS implementation phase realized some modest gains in development and application of the LSRS.

1. By 1996 a basic dBase program had been developed to automate batch processing of the LSRS at the soil Landscapes of Canada (1:1M scale) level.

2. Three applications clearly indicated how the LSRS could be used in conjunction with other programs to predict changes in crop suitability resulting from land use and climate affects.

However, the program was basically an in-house document that was restricted to one set of data inputs, and there were still a number of deficiencies that needed to be addressed.

1. The program needed to be expanded to interface with other data sets,

2. The program needed to be made flexible to respond to local needs,

3. The program needed to be able to aggregate complex soil landscape units into single CLI-type symbols to expedite and support local, regional and national comparisons and land use decisions at all levels.

## Phase 2. 2002-2005:Development of a transparent, user-friendly program in Alberta.

This phase, under contract to Alberta Agriculture Food and rural Development (AAFRD), responded to the need for a "user-friendly", map-based LSRS interface to the new standardized Agricultural Regions of Alberta Soil Information Database (AGRASID) (Alberta Soil Information Centre 2001).

### Development

In 2002, Spatial Data systems Consulting Limited (G. Tychon) was contracted by AAFRD to extend a previously built prototype to provide an AGRASID - LSRS interface. Pettapiece Pedology (W. Pettapiece) was contracted to provide the LSRS support.

Guidelines for the contract suggested that any new program should:

1. Address known shortcomings in the basic LSRS program,

2. Be flexible to accommodate changes or additions,

3. Be transparent,

4. Consider future web-based applications,

5. Consider the aggregation of complex soil-landscape ratings into a CLI-type symbol, and

6. Consider the ability to assess individual local area (site) input.

The resultant program (LSRS 2.1) (Tychon and Pettapiece 2003) documented a new architecture with model components that were defined using Excel spreadsheets external to the main program (Fig 1).

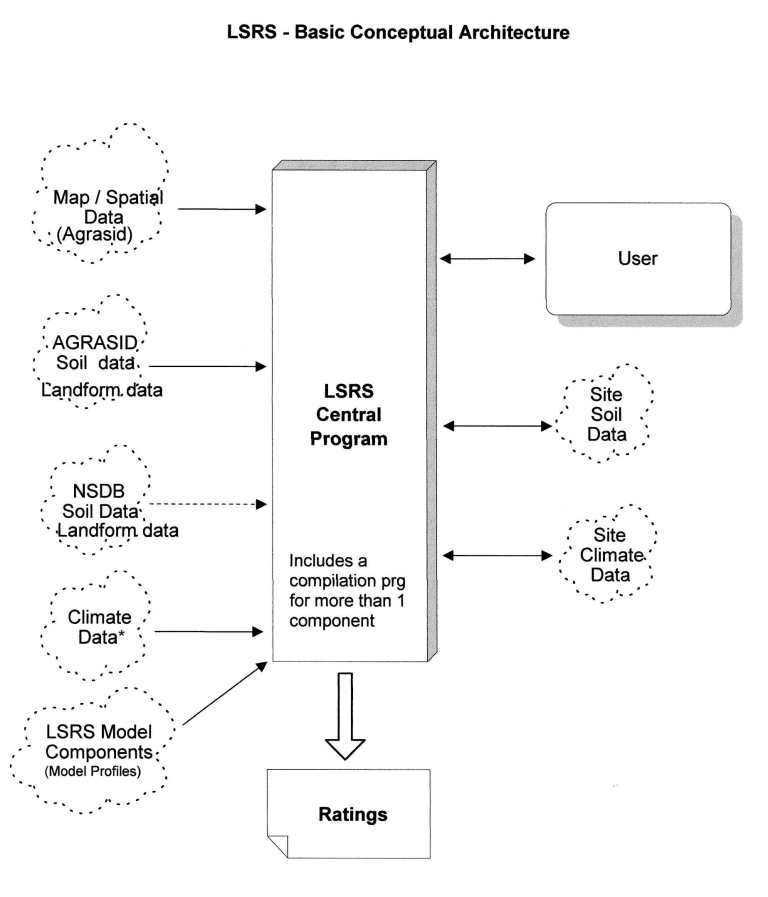


Figure 1. Schematic of the LSRS 2.1 architecture.

As well as meeting the basic interface requirements, this new platform could be viewed and modified using ordinary spreadsheet software. The external model arrangement facilitated testing, refinement and ultimately the addition of alternate models for soil and landform databases, different climate scenarios and for the assessments of new crops. It was also adaptable to web-based applications. The consideration of models used as data and the visual representation aspects were significant advances.

All of the component factors were now modeled as continuous functions which facilitated the mathematical management of data and applications. Also, a draft symbol aggregation procedure was included for testing.

In 2003, a contract was let to the same contractors for extension of the LSRS work to add an area-specific (site) soil and landscape input option and to complete the aggregation testing and documentation.

The report for this work (Tychon and Pettapiece 2004) provided a revised program with complete documentation for a stand-alone LSRS program that operated in a Windows environment and utilized either the Alberta AGRASID or area-specific soil and landscape inputs. It also included a link to the Soil Landscapes of Canada (SLC) - climate relationship using either Lat-Long or legal locations. A provision (not functional) was incorporated to utilize standard NSDB inputs.

### Applications

The principal application, for which the program was developed, was to provide LSRS ratings for the polygons represented in the AGRASID database. This database was comprised of a map with attached soil and landscape data for the 26M ha area that represented the agricultural area (White Zone) of Alberta. There were over 20,000 polygons ranging from the semi-arid prairies to the subhumid forest fringe.

### Summary

At the end of this phase there was a stand-alone, windows compatible program that:

- accepted AGRASID polygon data and had a specific-area (site) data input option,

- was linked to climate data through geographic tags to the Soil Landscapes of Canada polygons,

- could be accessed via legal descriptions, map identification or polygon numbers.

The LSRS ratings were attached to map polygons in the Alberta AGRASID soil map viewer.

A limitation was that the program was restricted to soil and landscape inputs in an Alberta format.

## Phase 3. 2006-2009: Extension of the Alberta platform to accommodate NSDB data and 5 new crops.

This phase was supported by contracts with AAFC who wanted to expand the Alberta platform to national coverage based on the 1:1M soil Landscapes of Canada (SLC) map and database.

### Development

In 2005 Pettapiece Pedology (W. Pettapiece) was contracted to explore the feasibility of expanding the LSRS to accommodate more crops, specifically corn and canola and to identify what issues would need to be addressed.

The report (Pettapiece 2005) reviewed the database requirements and concluded that it was eminently feasible to add the specified crops with the proviso that the climate aspects needed to be enhanced. The LSRS was developed to use the NSDB data as found in the Map Unit, Soil Name and Soil Layer Files, so there would be no need to alter the basic soil and landscape data. The only requirement would be some minor modifications to the LSRS rating structure.

However, there were two issues related to the climate input. First, the general standard for describing the heat/energy requirements for warm season crops such as corn was Crop Heat Units (CHU). this could be addressed by the inclusion of the CHU index in the climate file.

The second, and more serious climatic issue was the need to move from the Atmospheric Environmental Services (AES) 51-80 climatic-normals to the 61-90 normals. There were several reasons for this:

1. the extrapolation of 51-80 normals station data, the latest ones available when the LSRS was being developed, could not be properly managed to recognize elevation effects without manual intervention. This meant they could not be managed in an automated system.

2. the 61-90 normals were recognized nationally and internationally as a standard base for climate change assessments, and

3. there are some recent climate surfacing techniques (McKenney et al. 2000) that provided national coverage contour maps of the 61-90 normals based on an projected 10 Km grid.

The report recommended a process to migrate the LSRS from the 51-80 to the 61-90 climate base and link LSRS index values to the SLC ver 3.0 polygons.

In 2005-2006, Pettapiece Pedology (W. Pettapiece), was contracted to modify the SLRS to accommodate NSDB-SLC data. This was in support of an identified need by PFRA to predict biomass production on a national basis. Spatial Data systems Consulting (G. Tychon) was sub-contracted to support this work.

The report (Pettapiece and Tychon 2006) included an enhanced version of the LSRS program (LSRS v 2.7) that could operate using the SLC ver 3.0 database for soil and landscape inputs. Also included was a review of the 51-80 vs 61-90 climate normals to assess specific LSRS modification requirements and a comparison of the SLRS -SLC ratings to CLI maps.

The study identified a strong correlation between the 51-80 and 61-90 climatic normals and recommended that the SLRS program should be linked to the newer 61-90 data.

The national comparison of SLRS vs CLI ratings (see Appendix 1) confirmed that the ratings were similar for the complete range of climatic, soil and landscape conditions across Canada.

The national testing of the system also identified a number of inconsistencies and errors in the NSDB database particularly related to bulk density, pH and drainage where slightly different methodologies had been used in some regions. Some of this was related to the deficiency in recognizing local land management practices such as drainage, irrigation and liming.

A detailed documentation of all the program functions accompanied the new LSRS v2.7 program.

In 2007, AAFC contracted Pettapiece Pedology (W. Pettapiece), to modify the Land suitability Rating system (LSRS) to accommodate additional crops. Spatial Data systems Consulting (G. Tychon) and A. Bootsma were sub-contracted to support this activity. Specific actions included:

- the move to the 61-90 data base,

- development of crop models for corn, soybeans, canola, alfalfa and brome/timothy,

- testing all models for functionality, and

- documentation of the revised program including the process to add new climate, soil-landscape and additional crop models.

The final report (Pettapiece, Tychon and Bootsma 2007) was accompanied by a revised program (LSRS v 3.0) that included options for determining suitability ratings for corn, soybeans, canola alfalfa and brome/timothy as was well as spring-seeded small grains using the national SLC base. The climate database, based on the 61-90 AES normals, was comprised of a suite of climate indices that included:

- P-PE (Precipitation - Potential Evapotranspiration) using a Baier-Robertson estimate (AIWG 1995) for a defined growing season.

- EGDD (Effective Growing Degree Days -5o C) based on a defined growing season.

- CHU (Crop Heat Units -10o C base) - used for corn and soybeans.

- GDD (annual Growing Degree Days -5o C) - used for forages.

- HI (Heat Index) based on likelihood of temperatures exceeding 30oC - used as a canola climate modification.

All of these indices were linked to the LSRS program via a documented SLC polygon link (A. Waddell, see final report 2007).

The soil and landscape database was the NSDB data associated with the Soil Landscapes of Canada map (SLC ver3.0). At this point, the LSRS v3.0 package also included the Alberta AGRASID soil and landscape an specific area (site) input options as well as the original 51-80 climate indices but these were not linked to the expanded crop option.

The 2007 report also provided specific documentation So the program could be reconstituted by the National Land and Water Information Service (NLWIS) to support soil survey applications in that setting. The documentation did not include reference to the spatial map linkages that characterized the LSRS versions 2.1 to 3.0 programs as this was priority intellectual property.

### Applications

The principal application of LSRS v 3.0 was an assessment of climate change impacts on agricultural land-use sustainability in Canada (Chen et al. 2008). The main objective was to increase the understanding of potential challenges and opportunities that could affect Canadian agriculture.

The methodology involved linking the climate output from global climate change models (GCMs) to the LSRS using the Soil Landscapes of Canada (SLC) 1:1M map and database.

The authors concluded that there would be a northern shift in small grain production but it would be mainly evident in the western provinces where soil and landscapes would not be limiting. There would also be an expansion in warm season crops such as corn and soybeans into the Parkland area of the prairies where future aridity would not likely be a limitation. This trend in low-residue crops and a concomitant decrease in permanent forages could increase the risk of soil erosion. Crop seeding and maturity dates would likely shift to earlier in the year which could further impact soil erosion risk.

The increased ability of the LSRS program allowed for a more thoroughly test of the LSRS-CLI comparison across Canada. Between 5 and 20 sites (SLC) polygons were selected representing a range of soil, landscape and climatic conditions in each province. A comparison of the LSRS and estimated CLI ratings indicated that the two systems were quite similar (See Appendix 1). This supported the assumption that SLRS ratings could be used in any policy-related program that previously used the CLI.

The testing procedure also identified some database problems to be passed on to the Soil Survey Correlation staff. These include both omissions (e.g. tile drainage, liming, irrigation) and inconsistencies in data from one province to another (e.g. BD).

### Summary

The LSRS program was expanded to accommodate national, specifically the Soil Landscapes of Canada, map and soil-landscape data inputs. It now also included crop models for corn, soybeans, canola and forages (alfalfa and brome/timothy). A major addition at this stage was the migration of the climate information from 51-80 thirty year normals to the standard 61-90 data with extrapolation to a 10 km grid coverage.

Applications were expanded to national coverage and a close relationship to the CLI was confirmed. This means that any concepts, decisions or policies that were developed with reference to the CLI should hold for the LSRS which has the added advantage of a standard national system that has a consistent data driven approach. A major advancement here was the ability to compare alternative climate change scenarios, to identify geographic shifts in land suitability for a variety of crops and to assess potential opportunities and risks.

## Phase 4. 2009-2013: LSRS Migration to a new platform within CANSIS

**(Canadian Soil Information System)**

In this phase, the LSRS program is moved to AAFC, first within the purview of NLWIS and then the Canadian Soil Information System (CanSIS).

### Development

In 2007, two years before NLWIS ended, the project attempted to port version 3.0 of the LSRS into Oracle with an ArcGIS server front end but after several months of analysis it became clear that the complexity of this undertaking was too high for the project to handle, and the activity was reluctantly abandoned.

In the fall of 2009, after the NLWIS project was discontinued, P. Schut of CanSIS initiated the transformation of LSRS to a web-based service model developed on Ruby, Rails, and MySQL (Schut 2010). The port was completed by early 2010, and testing and improvements to the algorithms by T. Brierley and P. Schut in consultation with W. Pettapiece continued until 2013.

This new version of LSRS (the LSRS Calculator) is a website that is fully integrated with the rest of the CanSIS production databases and related systems. It provides the following functionality:

- The single polygon / single crop mode is a web service that returns a complete accounting of the LSRS calculation, showing the values of all inputs, interim calculations, and resultant values in the form of an custom XML document.

- The MultiCrop mode returns LSRS ratings for all six crops, for a single polygon. This response contains links to the Calculate and Summarize responses of the Calculator

- The Batch mode returns LSRS ratings for a single crop, for a predetermined set of polygons or a custom range of polygons

The LSRS Calculator supports both the SLC and the detailed soil survey (DSS) soil databases (using NSDB formats) in all provinces.

The LSRS Calculator also supports the selection of different climate scenarios.

In 2013, a soil management module was added to allow for the anticipated effects of the presence of tile drains, and the effects of amending soil pH through the addition of lime.

Because the LSRS is integrated with the CanSIS production tables, all updates to the underlying databases are automatically reflected in LSRS ratings.

### Applications

With climate change scenario data readily available for much of the country, the LSRS was used to evaluate the sensitivity of corn to forecasted climate change in the Lower Fraser Valley. The Land Suitability Rating System effectively integrated multiple climate, soil and landscape factors to illustrate that land suitability will be affected by both temperature and precipitation changes with a general trend toward an increasing requirement for irrigation in order to maintain corn production in the region through the coming century (Gasser et al. in press).

In 2013, Agriculture and Agri-Food Canada contracted Saskatchewan Research Council, Environmental Division ( Jeff Thorpe) to compare standardized Rangeland suitability Ratings used in the Prairie Ecozone (MB, SK, AB) to LSRS ratings for managed forage (brome). There was a very positive relationship with climate (particularly the moisture factor) and the majority of soil factors with the notable exception of sands which require a strong management input (Thorpe 2013). The results indicate that the development of a grazing module is eminently feasible and should be considered.

An additional activity was to review the potential of using LSRS to evaluate the land suitability for high-value specialty crops. Modified crop models were developed for considering land suitability for Gala apples and Merlot grapes in the Okanagan Valley (Pettapiece 2011). Special requirements, particularly climate considerations, may involve additional modifications.

LSRS has again been used to identify irregularities in soil data and debug the CanSIS data tables.

### Summary

The Land Suitability Rating System (LSRS) is now fully integrated into the Canadian Soil Information system (CanSIS) with links to national and provincial soil-landscape databases and maps. National scale analyses, using the LSRS alone or in conjunction with other programs and models, are facilitated in a web-based environment utilizing the LSRS Calculator.

The use of LSRS in climate change assessments appear particularly useful. The feasibility of adding specialty crops such as apples and grapes and grazing suitability have been demonstrated and the potential of LSRS to provide credible support for land use decision making at local, provincial and national levels has also been shown.

# SUMMARY AND DISCUSSION

During the period from 1995 - 2008, a series of phased contracts, under the supervision of several branches of Agriculture and Agri-Food Canada and the Conservation and Development Branch of Alberta Agriculture Food and Rural Development, saw the conversion of the Land Suitability Rating system (LSRS) from a labour-intensive, hands-on procedure to a functional stand-alone, windows compatible computerized process. The programming developments were accompanied by an increasing array of applications from single site or map polygon ratings to complex analyses linked with other computer models to evaluate future land conservation and development opportunities and risks.

The final product addressed all the continuing development issues identified in the original technical bulletin (AIWG 1995). The LSRS was evaluated and tested at each stage. The most significant modification was the migration of the climate database from the 51-80 AES normals to the standard and more accessible 61-90 normals. An ancillary benefit of the testing was the identification of errors and inconsistencies in the national soils databases.

The flexibility of the system was expanded on several fronts. First, was the ability to use different data inputs: for soils and landscapes it included the Alberta AGRASID and area-specific (site) data and then the Soil Landscape of Canada data; for climate it included the 61-90 base and the 71-2000 normals and several GCM outputs. Then the original system and program was expanded to accommodate a broader suite of crops including canola, corn and soybeans and alfalfa and brome/timothy. Also involved was the additions of several new climatic parameters. This increased flexibility was accomplished through the development of a platform architecture that allowed for various data input models for soil and landscape and climate factors and for any number of defined crop requirement models.

The final phase moved the LSRS program to CanSIS and a web-based environment with increased ability to interface with other models and programs.

The development (operationalization) of the LSRS was been driven by the kinds of applications that were required. The first objective of the LSRS initiative was to provide an updated replacement of the Canada Land Inventory: Soil Capability for Agriculture (CLI) that addressed a number of identified shortfalls in the CLI. These concerns, including a lack of internal specificity and transparency which lead to a lack of consistency in application and the need for automation, have been accomplished. In-house testing has confirmed that the LSRS ratings are very similar to those of the CLI and that the LSRS can therefore be used for any land use or policy decisions that previously referenced the CLI.

Studies looking at potential climate change risks and opportunities at national and regional levels have utilized and demonstrated the flexibility characteristics incorporated into the LSRS.

One aspect of flexibility that was lost with the move to CanSIS was the stand-alone local field use option.

The Land Suitability Rating System is intended to be used at field or smaller scales and while the LSRS system itself is not scale dependent, there are inherent limitations in the data bases themselves that vary with the scale being used.

For example, soil and landscape data at a point may be quite specific, but map data will always contain some variability with the amount depending on both the type of landscape and the scale. Larger scale map such as 1:20 K to 1:50 K are generally more uniform than smaller 1:100 K or 1:1 M scale maps. While map data can be further intensified through the use of landform analysis (MacMillan et al. 2000, 2005), and the individual components better identified and characterized, it does not reduce the total amount of variability within the map polygon.

In the case of climate, one could use specific climatic indices for a "what if" analysis but for general assessments we know that yearly variations must be recognized and accommodated. The standard national database appropriately uses 30 year normals and the indices derived from them are in reality 50% probabilities that are then extrapolated from the station network. At scales of about 1:1 M or smaller, with soil landscape units of several hundreds of km2 , the fit is quite appropriate but it must be recognized that the same inherent variability is carried to the larger scales as well.

It must be remembered that the LSRS is an application tool that was developed to utilize available data. While it uses relationships (e.g. pedotransfer functions) that were developed by the research community, it is not a detailed crop growth research model.

## Outstanding Issues and Opportunities.

While the LSRS is now a fully operational methodology for assessing land suitability for a range of crops an scales, there are some areas that should be reviewed.

1. National climate database integrity.

Testing the LSRS identified some anomalies in the climate related assessments of land suitability (see Appendix 2). It was noted that there were often considerable differences between site (station) data and the extrapolate climate surfaces (e.g. the 10 km grid). As the areas in question were located where there was often a scarcity of network control and where there were often substantial elevational differences, it was recommended that this situation should be reviewed.

Apparently, at this time there is no agency with the mandate to address this concern.

2. Specific-area (site) input documents.

The move of the LSRS to CanSIS provided many advantages not least of which were integration and maintenance. However, one of the features that was lost was the option of a PC-based program that land evaluation practitioners could use to input site data for local area specific assessments.

Such an option would greatly expand the potential access and use of LSRS at local and regional levels to support such activities as land management, land use, reclamation and remediation.

3. Expansion of the suite of "crop" models.

The clear indication that climate change is a reality suggests that there will be opportunities and decision related to new "crop" choices. These could range from specialty, particularly orchard, crops to tree crops. The feasibility of adding grazing capability has also been identified.

The addition of these capabilities to enhance the range and usefulness of applications should be considered. Indeed, If the system was made accessible to the private sector, there is every likelihood that a variety of expansions could and would occur.

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# APPENDICES

## Appendix 1. National Comparison of LSRS and CLI Ratings (2006)

**1.1 Introduction**

One of the objectives of the work supporting the modification of the LSRS rating procedure is to develop a standard national rating. Therefore, it seems reasonable to include at least a cursory comparison and evaluation of the LSRS results with the only existing national assessment – the CLI from the 1960’s.

**1.2 Procedure**

Along with the request to the provinces for typical SLC polygons, was a request for an estimate of the principal CLI ratings for the same areas. Once the modifications were completed on the LSRS program, it was used to rate the 65 polygons representing a range of conditions across Canada. The resultant ratings were compared to the locally estimated CLI ratings.

**1.3 Results**

It should be noted at the outset that, while closely allied in basic assumptions, these two ratings are not identical in all respects. For example, the LSRS rates small grains, focusing on barley, for all regions while the CLI is based on the main local crops, such as corn in Ontario, and starts the ranking at Class 1 in each region. Also, the LSRS rates Organic soils, and as applied here using a national database, cannot account for local modifications such as drainage, irrigations or liming that are not in the database.

In spite of that preamble, the results of the two ratings are quite similar (Tables 4.1, 4.2).

In fact, as shown in the summary table (Table 4.2) nearly 50% are in the same class and nearly 90% are within one class. Many of the minor differences and some of the larger differences are attributable to climate, others relate to local features such as drainage or irrigation that are not documented in the database and others can be related to problems with the database values (see ON).

The issue of soil structure limitations has been discussed earlier when modifications were made to the program to reflect database entries. As can be seen here, there are some instances where the LSRS rates structure (D) as less restrictive than the CLI and other instances where it is more restrictive. It appears that the problem is not one of one system being better or worse than the other but rather that database inconsistencies need to be addressed.

Climate has been identified as a reason for many of the differences. Again, it is not to suggest that one system is better than the other, but only that climate accounts for the difference. In most cases it was within one class.

Table 1.1. Comparison of SLRS to CLI for selected SLC polygons across Canada.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Province | area | SL# | est CLI | LSRS 06 | Comments |
|  | Fort St John | 581008 | dom O (5CW) | 7WV(10) | OK – organic rating |
|  | Fort St John | 585015 | dom 5C | 4DT(6) - 6W(4) | LSRS +1 climate |
|  | Prince George | 982044 | dom 4DXT (3X, 5W) | 3HT(7) - 6M(3) | LSRS +1 (no D) |
|  | Prince George | 982041 | dom 5TD (7T) | 3HT(8) - 6MT(2) | LSRS +2 (T,D) |
| BC | Penticton | 1007020 | dom 3TM | 6MT(5) - 7MTN(4) - 4W(1) | LSRS -3 (irrigated ?) |
|  | Penticton | 1007019 | dom 6TR (7RT) | 6MTD(8) - 6MT(2) | Similar (LSRS no R) |
|  | Lower Fraser | 959004 | dom 4W | 6W(10) | drained = 2WN / 3WV(8) - 7N(2) |
|  | Lower Fraser | 959011 | dom O7WF | 7WV(10) | similar |
|  | Lower Fraser | 959019 | dom 2WTA | 2T(4) - 3M(4) - 7V(2) | Similar |
|  | Foremost | 828012 | dom 4S | 4MT(9) - 6M(1) | Similar |
|  | Vulcan | 793001 | dom 2C (5T) | 2M(10) | same |
|  | Neutral | 771005 | dom 5TS | 3MT(9) - 5W(1) | LSRS +2 (topography, climate) |
|  | Wetaskiwin | 727011 | dom 2S (6W) | 3H(5) - 3HM(4) - 5W(1) | LSRS -1 (climate) |
| AB | Lloydminster | 729003 | dom 2C (5W) | 2HM(8) - 5W(2) - 5M(1) | similar |
|  | Camrose | 731002 | dom 2S (3S) | 3D(9) - 5W(1) | LSRS -1 (D) |
|  | La Corey | 680002 | dom 3C (4D, 5W) | 3H(9) - 5W(1) | similar |
|  | Grande Prairie | 599001 | dom 2C (3S) | 3H(8) - 4N(1) - 5W(1) | LSRS -1 (climate) |
|  | Clairview | 591027 | dom 3C | 3H(9) - 5W(1) | same |
|  | High Level | 586001 | dom 4D (O) | 3(8) - 6W(2) | LSRS -1 (roll-up?) |
|  | Regina | 792004 | 2C | 3M(9) - 5W(1) | LSRS -1 (climate) |
|  | Saskatoon | 736008 | 2M | 2M(9) - 5W(1) | same |
| SK | Melfort | 705005 | 1 | 2(9) - 5W(1) | LSRS -1 |
|  | Meadow Lake | 680012 | 3D (4 D) | 3H(9) - 4MV(1) | similar |
|  | B topo | 820002 | 3T | 4MT(10) | LSRS -1 (climate/M) |
|  | C topo | 810003 | 4T | 4MT(9) - 5W(1) | similar |
|  | Sandy (Black) | 742002 | 4 M (3M) | 5M(8) - 3M(2) | LSRS -1 (climate) |
|  |  | 709007 |  | 3(5) - 2H(4) - 5W(2) |  |
|  |  | 717004 |  | 7WB(6) - 4DMP(4) |  |
| MB |  | 724008 |  | 4DW(6) - 5W(3) - 6MD(1) |  |
|  |  | 763001 |  | 5MD(7) - 5W(2) - 3W(1) |  |
|  |  | 849009 |  | 2W(6) - 5W(4) |  |
|  |  | 854002 |  | 1(6) - 2(3) - 5W(1) |  |

Table 1.1 continued

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Province | area | SL# | est CLI | LSRS 06 | Comments |
|  |  |  |  |  |  |
| ON |  |  |  |  | Database problem - pH |
|  |  |  |  |  |  |
|  | Montreal | 541011 | 2W | 3W(10) | LSRS -1 (drainage) |
|  | Quebec City | 540102 | 3F - 4M | 4PT(7) - 3(3) | similar |
|  | Chicoutimi | 441007 | 2W - 3S | 3HDT(10) | LSRS -1 (climate) |
| QU | poorly drained | 540098 | 3W | 5W(7) - 4DW(3) | LSRS -2 (drainage) |
|  | Imperfect. drained | 540074 | 4M - 4F | 3DW(6) - 5W(4) | LSRS +1 (moisture?) |
|  | Organic | 541053 | O | 7WVB(10) | Organic rating |
|  | Caribou | 494001 | dom 3T | 2T(6) - 5DW(2) - 6WT(2) | LSRS +1 (topography) |
|  | Siegas | 493002 | dom 3D or 4D | 2(6) - 3W(3) - 7W(1) | LSRS +1 (D) |
| NB | Thibault | 486011 | dom 2T | 3HT(8) - 3TW(1) - 7WTJ(1) | LSRS -1 (climate) |
|  | Belldune | 485001 | dom 3WF | 3WT(6) - 6W(3) - 3M(1) | similar |
|  | Tormentine | 504033 | dom 3WD | 3W(9) - 6W(1) | similar |
|  | King | 503024 | dom 4TDW | 5DTW(6) - 3TD(3) - 6WTD(1) | LSRS -1 (D) |
|  | Kentville | 518004 | dom 4S, 3S (2S, 4W) | 4MT(8) - 6MDT(2) | similar |
|  | Kentville | 518005 | dom 2S (3W, 3S, 5T, 6I) | 3T(9) - 7W(1) | LSRS -1 (topography) |
| NS | Truro | 517006 | dom 5W (2I, 3I, 3S, O) | 6W(7) - 3WTD(3) | LSRS -1 (wetness) |
|  | Truro | 507003 | dom 2S (3W, 4W, 3T, 6I) | 3DT(8) - 6WD(2) | LSRS -1 (D) |
|  | Sydney | 523003 | dom 3P (5W) | 4DTW(10) | LSRS -1 (D,T) |
|  | Sydney | 523004 | dom 5W (O, 7P) | 6W(9) - 3DT(1) | LSRS -1 (wetness) |
|  |  | 535001 | dom 2FD (3DW, 4WD, 7WD) | 3DT(8) - 5DV(1) - 7WD(1) | LSRS -1 (D) |
| PE |  | 536003 | dom 2FD (3FM, 4WD, 7WD) | 3DT(7) - 6W(2) - 5DV(1) | LSRS -1 (D) |
|  |  | 537003 | dom 3T (4T) | 3T(6) - 3DT(4) | same |
|  | Codroy Valley | 463013 | 4TP(6), 5W(4) | 4TVP(10) | similar |
|  | Codroy Valley | 463011 | 5T(5), 3X(3), 2C(2) | 5TVP(7) - 7WT(3) | similar |
| NL | Central | 471012 | 4PF(7), 6WP(3) | 4HTV(6) - 7WT(4) | similar |
|  | Central | 466043 | 5PW(4), 4FM(4), O(2) | 4TVP(6) - 7WV(4) | LSRS +1 (?) |
|  | St Johns | 475007 | 4FP(5), 5WP (3), O(2) | 4DTV(10) | similar |
|  | St Johns | 471017 | 3F(4), 5TP(4), 4PF(2) | 5HPV(10) | LSRS -2 (climate) |

Table 1.2. Summary of LSRS and CLI ratings by province.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Province | Same class | Within 1 class | > 1 class difference | Reason for 2 class or more difference | total |
| BC | 4 | 2 | 3 | Irrigation, drainage | 9 |
| AB | 6 | 3 | 1 | topography | 10 |
| SK | 3 | 4 | - |  | 7 |
| MB\* |  |  |  |  | 6\* |
| ON\* |  |  | 6 | A pH database problem | 6\* |
| QU | 2 | 3 | 1 | drainage | 6 |
| NB | 3 | 3 | - |  | 6 |
| NS | 1 | 5 | - |  | 6 |
| PE | 1 | 2 | - |  | 6 |
| NL | 4 | 1 | 1 | climate | 6 |
| Total\* | 24 | 23 | 6 |  | 53 |
| Percent of total | 45 | 44 | 11 |  |  |

\* MB and ON not counted in the analysis

The roll-up procedure appears to approximate the CLI format quite well. However, it was noted that there were several instances where the LSRS roll-up did not include any subclass symbols. Part of the logic in the roll-up is that no symbol is listed if the deduction is less than 20 points or percent. Therefore, several small limitations can result in a final class rating with no subclass symbol. This does not happen very often with a limited number of soils in the polygon. However, when there are up to 8 or 10 soils, a situation not uncommon in the SLC ver3 database, it appears that dilution leads to elimination. This problem does not affect the utility of the LSRS program for estimating biomass production but should be addressed by the Soil Survey Interpretations group.

**1.4 Summary**

The LSRS ratings are quite closely allied to the CLI ratings. This means that any concepts, decisions or policies that were developed with reference to the CLI should hold for the LSRS which has the added advantage of a standard national system that has a consistent data driven approach.

The testing procedure identified some database problems that should be passed on to the Soil Survey Correlation staff. These include both omissions (e.g. drainage, liming, irrigation) and inconsistencies in data from one province to another (e.g. BD).

## Appendix 2. Climate Concerns

A special note needs to be made about the climate issue because it took up a considerable amount of time over the years of implementation. There was no doubt about the importance of climate in any agricultural rating nor was there a concern about how climate was managed within the LSRS program. the problem was establishing the most appropriate database and developing an appropriate automated link the LSRS program. It involved aspects of recognized standards and data maintenance.

1. The national Atmospheric Environmental Service (AES) 30 year normals was the obvious basic data source. The nationally collected, standardized, maintained and updated on a regular basis. At the time of LSRS development (1987-1993) the 51-80 data was the most recent and therefore chosen. However, extrapolation of station data was not consistent. Where there was a good network of stations and reasonably level topography, as was generally the case in established agricultural area, the results were excellent but in fringe areas or areas with considerable elevation differences, the results were often unreliable and poor. Automatically generated contours would completely ignore uplands (even mountains) if there were no stations on the upland. Therefore human intervention was required to rationalize the climate - landscape relationship. this was an expert opinion exercise based on local experience. It produced a food product but was difficult to replicate or automate in a logical manner and comparison to future data sets would be problematic.

The initial automation of the LSRS (see Phase 1) implemented the climate link by digitizing the index contours, electronically overlaying this with the by-then available soils Landscape of Canada (SLC) 1:1M map and assigning a median value of the index to each polygon. As soil formation reflects a climate input and as the scale was appropriate for general climate assessments the process worked quite well. However, the concerns about standards, maintenance and future correlations remained.

2. The decision to move to the 61-90 AES 30 year normal base was logical (see Phase 3 Pettapiece 2005). The first action required was to compare the 61-90 to the 51-80 values so that any differences could be accommodated by a revision to the initial (AIWG 1995) relationships. The initial analysis (Pettapiece and Tychon 2006) suggested that the indices were comparable and that the migration could proceed with no other LSRS modifications.

3. With the development of new indices to support warm season crops (corn, soybean) and forage models (Pettapiece, Tychon and Bootsma 2007) some inconsistencies were noted between those calculated directly for the original 61-90 data and those supplied form the 61-90 climate to SLC linkage. A review of the issue found that an incorrect file of 61-90 data had been sent to the contractors. the correct data was located and the comparison re-examined. Indeed, there were some small differences, particularly at the cooler end of the agricultural range, and program adjustments were made to realign the new LSRS climate ratings with the original 51-80 base (Pettapiece, Tychon and Bootsma 2007).

During the move to the 61-90 data indices a new procedure linking these values to the SLC map base was also introduced (see A. Waddell p34 in (Pettapiece, Tychon and Bootsma 2007).

4. Testing of the new LSRS v 3.0 program identified lower than anticipated climate ratings between 54oN and 58o N and in the rising elevation areas along the uplands of western Alberta. It was not clear whether the difference s were caused, and could be corrected, by program modifications or by basic data problems. A review of station site data vs SLC polygon data from the contouring, extrapolation and linking procedure found consistent variances that suggested this needed to be tested and resolved before program changes were made. In nearly all cases the site data for GDD were higher than the polygon data.

It is conceivable that most of the stations in the rather sparsely populated networks in these areas are located at lower elevations that the majority of the landscape units or that station contouring is not quite an exact fit with the landform contours. However, repeated efforts to elicit some help from agencies with responsibility for national climate databases were unsuccessful. As this kind of review is beyond the scope of the LSRS implementation work, the problem remains unresolved.

The concern is principally with those ratings based on GDD (and EGDD). There are program modifications that could be implemented but that seems premature without some certainty as to the primary problem.

**THIS ISSUE NEEDS TO BE REVIEWED AND RESOLVED.**

## Appendix 3. Additional applications of the LSRS

There were several other LSRS applications that did not directly relate to the program development and implementation.

1. Pipeline reclamation assessment criteria.

The principal criterion for pipeline reclamation certification states that the Right-of-Way should be returned to a capability at least as good as before disturbance. If an initial review suggested that there may be a problem with the reclamation, a quantitative assessment procedure (Fedkenheuer and Pettapiece (eds) 1999) was developed and recommended to identify the specific problem and to help direct corrective measures. This procedure used in part the soil and landscape portion of the LSRS. As before and after comparisons must be done at equivalent sites then climate would be the same and was not required.

Another slightly modified version of the LSRS (CEMA 2006) is used for assessing reclamation of large scale disturbances in the forested area (Green Zone) in Alberta.

2. Municipal assessment for woodlots.

A procedure similar to the farmland assessment procedure was developed for assessing woodlots. The procedure (Glover and Pettapiece 2001) used natural regions (ecological regions) as a base within which soil and landscape features from LSRS were used to create an index that was then adjusted with economic considerations. The crops under consideration were aspen and white spruce.