FINAL

CONSOLIDATED REPORT

Land Suitability Rating System Development

(LSRS modifications to accommodate additional crops)

Agriculture and Agri-Food Canada
Contract # 3000283404

Pettapiece Pedology

in conjunction with

Spatial Data Systems Consulting
and
A. Bootsma

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EXECUTIVE SUMMARY

This project was undertaken to expand the Land Suitability Rating System platform to accommodate alternate crops and different supporting databases. In addition, all procedures and decisions were to be documented so that the program could be reconstituted by NLWIS to support the applications of soil survey information in that setting.

The main deliverable is the compiled computer program: LSRS 3.0 – dated 20-12-2007

- It uses a spreadsheet type of approach to provide a generic, transparent platform for the assessment of land suitability ratings for the production of specified crops.
- It includes program models to determine ratings for the principal grain, oilseed and forage crops grown in Canada - specifically spring-seeded small grains, canola, corn, soybean, alfalfa and brome-timothy.
- This version uses the Soil Landscapes of Canada ver 3.0 map and databases.

A second deliverable is this report which describes the processes and procedures followed including references to research that were used to develop and support the decisions taken.

General regional testing indicated that the LSRS 3.0 program functioned properly and produced results that were within the expected range.

- It is recommended that AAFC should consider some in-depth, crop-specific testing by regional specialists to ensure that limitations have been appropriately assessed.

The report also identifies several outstanding issues that were encountered during the testing phase. This includes items related to the functioning of the SLRS program as well as other database and delivery issues and identifies some future actions to enhance the LSRS product. Included are:

- The need for consistent national databases - particularly the need to develop and maintain a catalog of agricultural modified or managed soils.
- The ability to maintain and augment or upgrade the databases associated with the LSRS program – mainly the climate files which may become particularly important for climate change studies.
- The requirement to expand the capability of the LSRS program to support assessments at more detailed scales than the 1:1M scale of the SLC and particularly to manage site or field-specific situations.

Notes:

This project was phased and each test version of the program was subsequently modified for new crops or to correct problems. All versions of LSRS3.0 dated prior to 20-10-2007 should be removed and destroyed before this version is enabled.

This program includes the publicly-available SLC3.0 database (ca 2004). Regional users are encouraged to contact their local Land Resource Unit for updated Soil Map Unit, Soil Name and Soil Layer files.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

1. INTRODUCTION

This project was initiated by a Request for Proposal from Agriculture and Agri-Food Canada in the summer of 2006 that specified modifications of the Land Suitability Rating System (AIWG 1995) to accommodate an additional suite of crops (Appendix 1. Statement of Work)

1.1 Background

1.1.1 Introduction

Rating systems for agricultural production (crops) have been around for over 100 years. Initially quite simple and qualitative, by the 1930s they were becoming more complex and quantitative (Storie 1933). In the 1960s, the United States (Klingebiel and Montgomery 1961) and Canada (ARDA 1965) introduced the broader concept of land capability. The Canada Land Inventory (CLI) (ARDA 1965) was widely accepted as a base for land use planning and general land assessments.

The CLI was a general sector capability approach that worked very well at regional levels. However, as agencies attempted to use the system at more detailed levels, short comings were apparent and by the 1980s there was an identified need for a review of the CLI. A national working group under the auspices of the Expert Committee on Soil Survey addressed the concern. The result was a Land Suitability Rating System for Agricultural Crops (LSRS) (AIWG 1995) with the first crops being spring-seeded small grains.

The LSRS followed the same concepts and approach as the CLI but added specificity and rigor to the system. It also established a single national framework based on standard climatic indices (AIWG 1995). The LSRS ratings were based on continuous scales to accommodate automated calculations. Also, the system was organized into climate, soils and landscape modules to facilitate modifications for other crops.

1.1.2 Modification Concepts

The basic requirements for the operation of LSRS are a knowledge of the optimum values (or limitations) of climate, soils and landscape characteristics for the growth and management of specific crops. The next requirement is a knowledge of the distribution of the actual values that apply to the agricultural lands across Canada. The final step is to rank the actual values in terms of their impact on the growth/yield of the crops in question and the sustainability of the associated management practices.

The 1995 LSRS publication provides protocols for the application of the suitability rating process based on fundamental climate, soil and landscape characteristics that are known to affect crop production <u>and</u> for which there are available databases across the country. It was developed for small grains , with an emphasis on barley, as this crop is grown in virtually every agricultural region of Canada.

The LSRS recognizes the three components of climate, soil and landscape because each can, by itself, limit crop production. By placing them in separate modules, changes to any one can be made without affecting the others. This is particularly useful for specific crop requirements that only require changes to one or two of the components. For example, canola or corn may have the same soil and landscape requirements but have markedly different climatic requirements. Therefore, only the climate module needs to be modified to address each of these crops. On the other hand, a modification for forage production, particularly a grazing regime, would clearly address the landscape module as well as possibly the climate module.

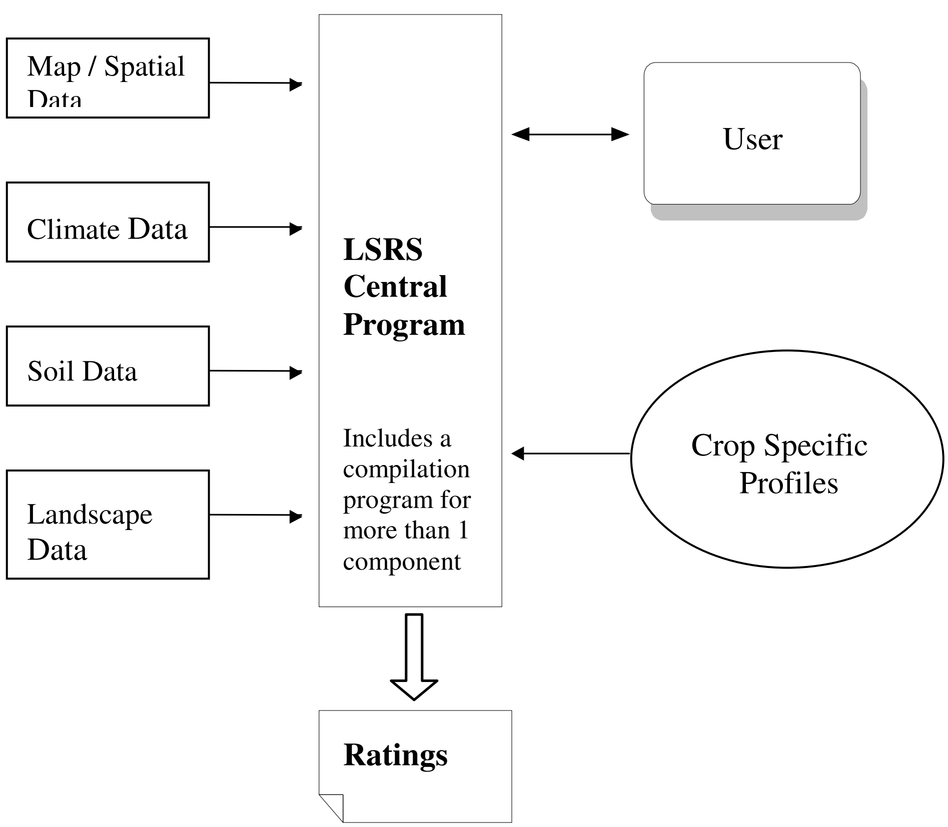
The LSRS was designed to be scale neutral and to use either site data or nationally available soil and climate data.

Climate is the key to any crop specific modification and new climatic data files are often required for new crops. That is, the new crops may not use the same climatic indexes that are now linked to the SLC database (assuming that any national level analysis will use the SLC database). Knowledgeable crop researchers, crop agronomists and agro-meteorologists must be involved with any climate modifications issues.

Soil and landscape considerations also involve local researchers and agronomists to not only determine crop specific requirements but also to provide contacts for testing and extension of the results.

The present “Alberta” program (Pettapiece and Tychon 2006) defines external profiles or models that can be crop specific. These are interfaced with the central LSRS “engine” to access appropriate input files (either standard NSDB files or site input), to process the data and display the results in an appropriate format.

LSRS - Basic Conceptual Architecture



1.1.3 Activities to date.

1.1.3.1 Initial programming (94-97). A computer program was written to determine LSRS ratings using standard National Soil Data Base (NSDB) file structures (Lelyk and Pettapiece 1997). It was written using dBase IV version 1.1 and used a batch input procedure. This program worked for a specified set of conditions.

1.1.3.2 New programming (02-06). The initial program had restricted flexibility and did not encompass recent internal system modifications. It provided no capability to aggregate results into CLI-like symbols. In 2002 a project was undertaken to write a new LSRS program to address the above concerns and a) to use Alberta Soil Survey databases (specifically AGRASID) and b) to use site data as well as national (SLC based) climate data. This spreadsheet-based program was completely transparent and could easily be modified to accommodate different crop profiles. It included the capability to aggregate lists of individual soil-landform ratings to a combined CLI-type map unit rating (Tychon and Pettapiece 2002, 2003).

The new (Alberta) platform was designed to accommodate NSDB data but the actual process had not been implemented. In addition, there was a recommendation to update the climate input from 51-80 data to 61-90 data (Pettapiece 2005). A project was conducted, as input to the national "Biomass Project" to address both the above issues and the Alberta program was modified accordingly (Pettapiece and Tychon 2006). The new program (LSRS 2.7) had the following features:

- Climate data linked to 61-90 normals
- Polygon and batch processing for Alberta (AGRASID) data
- Polygon and batch processing for national (NSDB-SLC) data
- AGRASID and SLC map interfacing
- Complete documentation
- Transparency – the spreadsheet components could be easily viewed and all results shown
- The model components could be adapted to a web-based application
- A process which allowed for the roll-up of component ratings into a CLI-type format.

1.1.3.3 Crop modifications. A project was undertaken in 2004-05 to review the requirements for modifying the LSRS program to accommodate land suitability ratings for corn and canola. The resulting discussion paper (Pettapiece 2005) indicated that such modifications were feasible and outlined the specific requirements including the need for an additional climate index (Crop Heat Unit – CHU) (Brown and Bootsma 1993) for corn and a temperature modifier for canola. Specific rating tables were included.

1.2 Objectives and Deliverables

1.2.1 Objectives

The overall objective was:

To modify the Land Suitability Rating System (LSRS) to accommodate additional crops.

Specific requirements were:

1. the additional crops to include corn, soybeans, canola and forages (alfalfa and brome)
2. the program must be national in scope and be compatible with National Soils Database (NSDB) data – specifically it must use the Soil Landscapes of Canada (SLC) databases.

It was accepted that the project would include collaboration with regional crop and agronomy specialists and with regional Land Resource Units (LRUs). Also, that support for climate data linkages to the SLC framework would be supplied by AAFC (Manitoba LRU)

1.2.2 Deliverables

The deliverables include:

1. A compiled computer program that utilizes a spreadsheet format to determine land suitability ratings for corn, soybeans, canola, alfalfa and brome grass in addition to the spring-seeded small grains.
   - it is based on the National Soils Landscapes of Canada maps
   - it includes databases for climatic indices based on 61-90 climatic normals as well as for Soil Landscapes of Canada map characteristics
2. Complete documentation outlining the procedures followed, including assumptions and specific mathematical relationships.
3. A detailed procedure for adding other crop models or for using other input databases.

1.3 The Report Format

The project was phased to allow for preliminary testing and feedback. As a result there were four interim reports dealing with specific program development and crop model concerns.

Section 2 of this report deals with the program issues, Sections 3and 4 address the crop models, Section 5 describes the regional testing, Section 6 provides an overall summary and Section 7 identifies a number of outstanding issues.

To facilitate reading and understanding, each of the major topics in Sections 2, 3 and 4 are handled as stand-alone articles in the Appendix. Each includes its own introduction, activities, testing conclusion, references and appendices. This results in some duplication but is hopefully easier to follow and to selectively reference than a single integrated document.

2. PROGRAM MODIFICATIONS

The initial Alberta LSRS program was written to accommodate the Alberta database (Tychon and Pettapiece 2003). This AGRASID database was similar to but not identical with the National Soils Database (NSDB) and differed substantially in the landscape parameters. The first program was modified to accommodate site specific data input (Pettapiece and Tychon 2005). Geographic links were used to assign climatic indices from the Soil Landscapes of Canada (SLC) database

To support the "Biomass" project within AAFC, the program was then modified to assess land suitability ratings using the SLC database including the Soil Map Unit (SMU), Soil Name (SNF) and Soil Layer (SLF) files as found in the NSDB.

All of the above were single issue modifications with a single product. The present project required major expansion of the program to accommodate an indefinite number of different crop requirements (models). The project also involved several climatic considerations including the migration of the basic small grains assessment from the 51-80 to the 61-90 climate normals database and the use of multiple climatic files.

A further consideration, to address a National Land and Water Information System (NLWIS) requirement, was that documentation be provided for the present and also for the generic procedure to add additional crop models and new climatic and soils databases.

2.1 Migrating to the 61-90 climatic normals database.

A more detailed discussion can be found in Appendix 2.

2.1.1 Introduction

There were two principal reasons for moving from the 51-80 to the 61-90 database. First, it was deemed necessary to move to a database that could be duplicated and modified using GIS techniques and the 61-90 gridded data fit that requirement. Secondly, international work on climate change was using 61-90 data as a standard and it seemed reasonable that we should strive to be consistent with that approach.

As the original LSRS manual was based on 51-90 normals, it was necessary to conduct a comparison of the two data sets and, if there were differences, to modify the original P-PE and EGDD relationships to maintain the original outcomes.

2.1.2 Results

<u>P-PE</u>. A comparison of 51-80 and 61-90 based P-PE values indicated a very close relationship (R^2 = 0.89) with the 61-90 values being slightly higher (Appendix 2).

A new rating relationship was defined. The absolute differences were only 1-2 points for equivalent P-PE values.

EGDD. A comparison of 51-80 and 61-90 based EGDD values also indicated a very close correlation ($R^2 = 0.92$). However in this case, there was more of a divergence in values with the 61-90 data being significantly higher in the cooler regions (Appendix 2).

A new rating relationship was defined with compensations of up to 8 points in the cooler agricultural areas.

The changes were documented and implemented in the SLRS program for spring seeded small grains.

2.2 Modifying the LSRS program to accommodate alternate crops and data inputs

A more detailed discussion can be found in Appendix 3.

2.2.1 Introduction

The main program modification involved the establishment of "place holders" for alternate crops. A second major activity was to develop and implement the Crop Heat Unit (CHU) database to support the suitability assessment of warm season crops.

2.2.2 Results

The CHU database was generated using the procedure documented in Appendix 3 (A. Bootsma) and appended to the database (A. Waddell). A comparison to Ontario county data indicated that the process was successful.

The LSRS program was modified to accept alternate crop models and the combined amended program and CHU database was tested using the new corn crop model. The program performed as expected.

All procedures were documented.

3. ALTERNATIVE CROP MODELS – ANNUAL GRAINS

The original impetus for development of the LSRS (AIWG 1995) was to provide a definitive replacement for the Canada Land Inventory – Soil Capability for Agriculture. The small grains, with an emphasis on barley, satisfied that objective. However, the consistent national approach using small grains did not fully recognize the advantage of those areas that could grow warm season crops and therefore did not specifically account for the more important regional crops.

This project was developed to address the above concerns. In addition to the general program modifications described in Section 2 to accept new crop models, it specifically asked for the inclusion of the principal grain, oilseed and forage crops in Canada: namely, corn, soybean, canola, alfalfa and brome-timothy in addition to the small grains.

For most crop species, but particularly for the warm season crops (e.g. corn and soybean), cultivars have been developed that can tolerate climatic limitations of temperature and moisture. It is a reality that these cultivars (or in the case of canola, actual species) that can tolerate stress invariably have lower yields and that the loss of yield is proportional to the amount of stress. Therefore, while the range of climatic limitations can be expanded, it comes with a yield reduction, and the ultimate control becomes an economic decision: the comparison of a mediocre or poor yield of a high value crop vs a good yield of a less valuable crop. It is this relationship with temperature (or moisture) stress that allows for the inclusion of all cultivars in one suitability rating for the crop.

3.1 The Corn Crop Model

A more detailed discussion can be found in Appendix 4.

3.1.1 Introduction

The main difference for the corn suitability is the requirement for more heat relative to the small grains. The usual heat scale is the CHU which, as discussed in 2.2, was added to the climate database. Because of the increase in dry matter yield, there is also an increase in water requirement.

All other soil and landscape characteristics for corn were assumed to be the same as for the small grains.

3.1.2 Results

The CHU scale was rated such that 3500 units was considered to be no limitation and 2000 units was marginal for commercial production.

The P-PE scale was used for corn but was adjusted to recognize a 100 mm greater moisture need for this crop.

The initial results of the LSRS corn suitability rating were within the general range of expectation. Where climate was the limiting factor the ratings were 1-2 classes lower than those for small grains. On the prairies the only class 3 was in southern Manitoba.

3.2 The Soybean Crop Model

A more detailed discussion can be found in Appendix 5.

3.2.1 Introduction

Soybean is a warm season crop that, like corn, is managed within a CHU framework. It has about the same heat requirement as corn. It differs from corn in that the moisture requirements are slightly lower and are assumed to be between that of corn and small grains. It was also assumed to be slightly more sensitive to surface structure (tilth) conditions.

3.3.3 Results

The soybean crop model was defined and implemented on the LSRS platform.

Initial review of ratings indicated that the program was responding as planned. The differences from the corn show up in moderated moisture requirements (P-PE in climate and M in soil) and in greater sensitivity to tilth concerns (surf D).

The comparison to corn for a range of conditions across Canada indicates similar ratings in all cases. There are some differences in number ratings but the polygon classes are generally the same with a few instances where soybean ratings are slightly higher. This seems reasonable.

3.3 The Canola Crop Model

A more detailed discussion can be found in Appendix 6.

3.3.1 Introduction

Canola was considered to fall into the same general climatic, soil and landscape constraints as the small grains. Therefore, the canola model was set for the same parameters as small grains with two exceptions. First, it was recognized that there is documented flower abortion at temperatures above about 30^{o} C, so a climate modification factor based on the long term likelihood of number of days over 30^{o}C (Heat Index- HI) was defined. Second, the sensitivity to adverse surface structure was increased slightly to address emergence concerns.

3.3.2 Results

Initial review of ratings indicated that the program was responding as planned - the Heat Index reducing ratings where temperatures were predicted to exceed 30^{o}C during flowering and there was an increase in the surface structure (surf D) deduction in areas where tilth concerns were anticipated. The ratings are generally only slightly lower than those for small grains and would not cause a change in Suitability Class unless near a class boundary. An exception might be for the HI reduction, but this is usually associated with moisture limitations and is generally not the limiting factor.

The comparison to small grains for a range of conditions across Canada indicates similar ratings in all cases. There are some differences in number ratings but the polygon classes are the same. This seems reasonable (see introduction) and was anticipated to be the case for all except extreme situations.

4. ALTERNATIVE CROP MODELS – PERENNIAL FORAGES

Both grasses and legumes are used as forages. The various species are adapted to such a large range of climatic and soil conditions that a single rating would be rather meaningless. On the other hand, to attempt to accommodate all the represented niches would result in an irresponsible number of specific ratings that would not support general land use planning.

With the above arguments in mind, it was decided that two general categories of forages with somewhat different climatic and soil requirements should be recognized; namely legumes and grasses. Alfalfa (Medicago sativa L.), which is the most widely grown legume in Canada, was chosen as a surrogate for that group. For the grass group, timothy (Phleum pretense L.) was chosen as the surrogate for eastern and central Canada and brome (Bromus inermis Leyss.) for western Canada.

Many annual crops (grains and pulses) are also used for forage, but the emphasis here is on the perennial crops. The main difference is that the perennial crops, with no concerns for annual seeding or for frost damage to grain, have a longer growing season. This extended season is assumed to be the period with mean daily temperatures above 5^{o}C (Bootsma and Boisvert 1991)

Another critical difference is that forages are not restricted to a single “harvest”. Depending on the season length, there can be one, two or even three or four cuts. This makes the forage rating fundamentally different from those for single-crop grains and oil seeds and they should not be directly compared. For example, at the west coast, long seasons and adequate moisture commonly allow for three cuts of forages but may not have the heat requirements for corn and soybeans which could translate to Class 1 for forages but Class 3 for corn. On the other hand, southern Ontario might be Class 1 for corn but only Class 2 for forages.

Season length is correlated fairly well with accumulated Growing Degree Days (GDDs) for the range of 800 to 1600 GDD with an R^2 of 0.63 (not shown). However in the coastal regions with extended growing seasons, the relationship breaks down. This situation required the introduction of season length as an independent climatic variable.

Therefore, using the 61-90 normals, average dates for season start (Mean Daily Temperature >5^{o}C) and season end (Mean Daily Temperature <5^{o}C) and season length were calculated and added to the climate database.

4.1 The Alfalfa Crop Model

A more detailed discussion can be found in Appendix 7.

4.1.1 Introduction

The heat requirements were based on a need for about 480 GDDs per cut plus a carryover. Growing season length limitation was assessed on the estimated time to accumulate heat requirements. Moisture requirements were assumed to be same as for small grains. The only other soils concern was to recognize the sensitivity of alfalfa to acidic conditions.

As landscape conditions are not as restrictive for forages, the limitations were slightly relaxed.

4.1.2 Results

The resulting program gave values that were similar to those for small grains with a couple of exceptions. The sensitivity to pH resulted in quite low ratings (V Subclass) under strongly acidic conditions. As well, the relaxed topographic restrictions resulted in fewer T Subclass designations.

4.2 The Brome-Timothy Crop Model

A more detailed discussion can be found in Appendix 8.

4.2.1 Introduction

Nearly all the cool season C3 grasses have similar growth requirements (Moser et al. 1996). Timothy is the usual forage grass where moisture is not limiting. However, brome is more tolerant of moisture stress and salinity and is the grass of choice on the prairies.

The climate considerations were similar to those for alfalfa except that the carry over requirements were not quite as high and estimated times between cuts was slightly less.

With respect to soil characteristics, these forages have the same requirements as the C3 small grains.

4.2.2 Results

In the introduction, it was stressed that forages are not directly comparable to single-harvest crops. However, comparisons are inevitable and can be useful for pointing out differences as well as concurrences. With this in mind, the small grains ratings were used to evaluate initial forage ratings.

The LSRS ratings from brome-timothy, using a standard SLC set, were very similar to those for small grains mainly in response to a dominant moisture deficiency limitation. However, there were some notable differences.

As expected, with the relaxed landscape constraints, the T limitation is often not noted for the forages ratings. In those instances where T is the dominant limitation for small grains, this can result in a higher rating for the forages.

With the different season/heat requirements it might be expected that there would be major climatic differences in the LSRS ratings for small grains and forages. This was not always apparent. Firstly, the shorter small grain season is situated in the middle of the longer forage season (900-1600 EGDD vs 800-1800 EGDD) and the extremes are not strongly represented in the test data set. Secondly, the heat parameter is often not the most limiting climatic factor.

5. GENERAL TESTING

5.1 Introduction

Interim compiled programs of one, several and all crop models were circulated to provincial Land Resource Units for trial and comment. In addition, there were two conference calls (30 Nov and 10 Dec) for general feedback, clarification and discussions.

It must be emphasized that this was a broad review to the modified LSRS program to see if it met general expectations. It was not an in-depth assessment of crop-specific suitability ratings which should still be undertaken in conjunction with regional specialists.

5.2 Results

More detailed comments may be found in Appendix 9.

The main initial concerns were related to database inconsistencies. These were not directly within the concern of the LSRS program but they were crucial for testing and implementing the suitability assessment. The main issues related to native vs managed soil conditions, particularly the practices of draining and liming. As can be expected, a national assessment also highlighted a few inconsistencies in the application of mapping criteria and database compilations.

The above-noted database issues were addressed locally and the resulting suitability assessments were reviewed for obvious anomalies. Overall it was felt that the results were within the generally expected ranges. There were a few specific issues that require some additional review (these are identified in section 6).

Several minor program adjustments were identified and implemented. These included:

1. increasing the “V” stoniness deduction to a Class four equivalent,

2. modifying the program to include the “H” factor for forages, and

3. modifying the component rating display to include the formulas and calculations.

6. SUMMARY

This project was undertaken to expand the Land Suitability Rating System platform to accommodate alternate crops and different supporting databases. In addition, all procedures and decisions were documented so that the program could be reconstituted in NLWIS to support the applications of soil survey information in that setting.

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- The report includes a short discussion of outstanding issues that were encountered during the testing phase. This includes items related to the functioning of the SLRS program as well as other database and delivery issues and some identified future actions to enhance the LSRS product.

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- However, there still needs to be in-depth, crop-specific testing by regional specialists to ensure that limitations have been appropriately assessed.

Notes:

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This program includes the publically-available SLC3.0 database(ca 2004). Regional user are encouraged to contact their local Land Resource Unit for updated Soil Map Unit, Soil Name and Soil Layer files.

7. OUTSTANDING ISSUES

Many of the identified issues are not specific to the LSRS program but are critical for its application.

7.1 Soil Related Issues

7.1.1 Assessment of water supplying capacity

It was suggested that adding 50% of the VFS fraction to the silt content would result in a more realistic assessment of water supplying capacity. This seems particularly applicable in areas with a significant moisture deficit. A review is being carried out and if it appears appropriate to do so on a national basis the program should be so modified.

7.1.2 Surface structure in arid regions

The proxy for surface structure uses % organic carbon and extreme textures. As a result, high clay content soils in the drier regions of the prairies receive a deduction that lowers them by about one class from the previous rating. This needs to be reviewed.

7.1.3 Management modifications

The database issue of management modifications such as drainage and liming needs to be addressed. The inclusion of "agricultural" soil files has been identified and is being reviewed by the SLC working group. This should be a priority activity.

7.2 Climate Related Issues

7.2.1 Data archive

The LSRS climate indices have been calculated from the gridded (10 km) 61-90 normals and attached to SLC polygons. This data should be archived where it is available for scrutiny or where it can be accessed for developing climatic change scenarios. At present it only exists in our files which do provide for appropriate long-term care and access. It is suggested that a public centre such as the National Agriclimatic Information System (NAIS) should be approached to maintain this data.

7.2.1 Standard climate management procedures

As new crops are added to the LSRS capability and new indices required or with the desire to include biometeorological time scales to anticipate climate change scenarios, it will be necessary to add the climatic features to the SLC database. A standard documented procedure needs to be developed to facilitate that process.

7.3 General Considerations

7.3.1 SLC basemap features

The SLC is a superb asset with tremendous potential but its use is severely limited by the lack of locational base features. It follows that any interpretation based on SLC polygons, such as the LSRS crop suitability ratings, will suffer the same limitation. This drastically affects the "friendliness" and therefore potential use of the SLC for general applications. It is suggested that AAFC should address the issue of base features to increase the acceptability of this excellent information platform.

7.4 Future LSRS Enhancements

There were a number of suggestions for LSRS modifications. Some, which related to different result display formats, appeared to be local options that might be handled regionally. Others were more generic in nature and would indeed broaden the applicability of the LSRS.

7.4.1 Site-specific applications

This type of application would apply to the assessment of individual sites or fields and would require the ability to enter local site data on interactive input screens. It would also require additional default tables for data that may not be available - particularly laboratory data such % organic matter or % clay.

As climate is an integral component to the LSRS, there also needs to be a source of temperature and precipitation data. This could be done by hand using look-up maps of the LSRS climatic indices or it could be done using a geographic link to the SLC map and its associated climate database as described in this report.

A prototype, which has been developed in Alberta, includes a geographic link to the SLC climate database (Pettapiece and Tychon 2003) using legal land descriptions or latitude and longitude.

It is estimated that the time to develop a site-specific application, using the Alberta prototype would be about two months. It would be essentially a programming exercise. The main tasks would be to establish a climate linkage (automated or look-up) and to enable links to all the crop models.

7.4.2 Applications using soil survey maps of other scales

This would involve the use of soil survey map inputs at scales more detailed than the 1:1M SLC map: for example scales from 1-20,000 to 1:100,000.

A critical activity would again be to establish a link to the SLC climate database. The most efficient process would be for each province to nest all other soils maps within the SLC framework.

For each map, relational tables would need to be established for map constructs such as slope, stoniness or special soil features. Database links could then be built for each of the crop models.

It is estimated that about two months of work would be required, with the understanding that each jurisdiction would provide the SLC link and a documentation of map characteristics.

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APPENDICES

APPENDIX 1. STATEMENT OF WORK

Land Suitability Rating System Development

<u>BACKGROUND</u>

The Land Suitability Rating System (LSRS) was developed by the Agronomic Interpretations Working Group, Research Branch, Agriculture and Agri-Food Canada in 1995. It is a procedure for assessing soil landscape and climate data for growing agronomic crops within Canada. The original version of LSRS is specifically for the production of spring-seeded small grains (barley, wheat, oats, etc.). The initial project proposal included the expansion of the system to accommodate other crops but this did not occur.

LSRS was developed in response to a number of concerns regarding the Canada Land Inventory (CLI): Soil Capability for Agriculture, which was created in the 1960's. Modifications of the CLI methodology by various agencies have resulted in non-comparable ratings across Canada. Climatic variables have not been consistently assessed The lack of specificity of CLI definitions and application guidelines means that the rating process can not be consistently applied by land rating practitioners or translated into a computer program.

The LSRS procedure, documented in a 1995 Centre for Land and Biological Resources Research (CLBRR) Technical Bulletin, addressed the above concerns. The resulting methodology is transparent and may be applied in a systematic and consistent manner by people tasked with assessing the suitability of soil landscapes for agricultural crops. Also the methodology can be translated into a computer program that produces suitability ratings from a standard dataset.

Since 1995 the LSRS methodology has been transformed into a number of programs with variable success. Most recently LSRS program has been developed that interprets digital soil landscape information housed within the National Soil Database (NSDB). This program (LSRS v2.7) has been applied to develop LSRS interpretative ratings for the Soil Landscape of Canada (SLC) polygons within the agricultural region of Canada. These ratings are an assessment of the associated climate, soil and landscape attributes of the SLC polygons for the production of spring-seeded small grains.

Users of the program require land suitability ratings for additional agricultural crops. These additional crops include com, canola, soybean and forage (alfalfa and brome). The intent of this contract is to develop the additional crop modules that are compliant with the NSDB compatible LSRS program.

To achieve the objectives of this contract, the collaboration with NAIS, research scientists from various institutions, regional experts and GIS support is essential.

NLWIS Project Linkage: The work is required to meet the Soil Interpretation Team project plan /CAP under the Soil Data OPA for Phase 3 in order to meet APF agreements.

OBJECTIVE

To obtain the services of an expert familiar with the derivation of soil landscape suitability rating systems, in order to develop additional crop modules for the Land Suitability Rating System for spring-seeded small grains (LSRS v2.7) program;

- In a way that a computer program will interpret existing standardized soil landscape and climate data,
- So that suitability ratings for the production of com, canola, soybeans and forage crops (alfalfa and brome grass) will be derived in a systematic and transparent manner, as outlined in the accompanying documentation,
- And can be measured by the general acceptance of the final ratings for the various crops, by members of the Interpretation Working Group and other regional experts.

SCOPE

There are 3 phases to this contract. Phase 1 is the completion of the corn module. Phase 2 includes the development of tables for the other crops. Incorporation of the modules for the remaining crops is anticipated to proceed quicker based upon the Phase 1 experience. Phase 3 includes modification required to various modules based upon validation by regional experts.

Phase 1

Corn

Climate analysis

- Corn heat units (CHU) to be calculated from the 1961-90 climate normal data by NAIS, in consultation with contractor.
- Attach CHU values to SLC polygons, with assistance from GIS support of AAFC staff
- National validation of CHU values - review by contractor
- Incorporate CHU values within the LSRS v2.7 program

Modifications to LSRS program v2.7 - programming and testing

- Modify the program to accommodate additional crops
- Incorporate the corn module
- Test prototype program and modify as required - review by contractor
- Test / verify LSRS ratings for com nationally by members of the LSRS sub-project working group

Phase 2

Canola

Climate analysis

- Development of canola heat modifier
- Calculate heat values and attach to S1£ polygons
- Incorporate these heat modifier values within the LSRS v2.7 program

Programming and testing

- Test prototype program and modify as required - review by contractor
- Test / verify LSRS ratings for canola nationally by members of the LSRS sub-project working group

Soybeans
Determine basic climate, soil and landscape parameters
- Identify and contact regional experts
- Review pertinent literature
- Determine the required modifications to LSRS

Programming and testing
- Incorporate soybean module within LSRS program
- Test prototype program and modify as required - review by contractor
- Test *I* verify LSRS ratings for soybean nationally by members of the LSRS sub-project working group

Forage (alfalfa)
Determine basic climate, soil and landscape parameters
Identify and contact regional experts
Review pertinent literature
Determine the required modifications to LSRS
Programming and testing
- Incorporate alfalfa module within LSRS program
- Test prototype program and modify as required - review by contractor
- Test *I* verify LSRS ratings for alfalfa nationally by members of the LSRS sub-project working group

Forage (brome)
Determine basic climate, soil and landscape parameters
- Identify and contact regional experts
- Review pertinent literature
- Determine the required modifications to LSRS

Programming and testing
- Incorporate brome module within LSRS program
- Test prototype program and modify as required - review by contractor
- Test / verify LSRS ratings for brome grass nationally by members of the LSRS sub-project working group

Phase 3
Final review of the LSRS ratings for the various crops.
The interpretative products will be circulated to a wider audience of national clients. The contractor is to be available to respond to possible issues and to revise crop module components, program and documentation as required.

APPENDIX 2. MOVING FROM THE 51-80 TO THE 61-90 CLIMATE DATABASE

TABLE OF CONTENTS

List of Tables

List of Figures

A comparison of the 51-80 vs 61-90 climatic indexes used in the LSRS

1. INTRODUCTION

In the initiation stages of the LSRS modifications, the decision was made to use 61-90 climate normals as the standard climatic input (Pettapiece 2006). There were two principal reasons. First, it was deemed necessary to move to a database that could be duplicated and modified using GIS techniques and the 61-90 gridded data fit that requirement. Secondly, international work on climate change was using 61-90 data as a standard and it seemed reasonable that we should strive to be consistent with that approach.

A preliminary study (Pettapiece 2006) compared SLC data from the original hand-contoured 51-80 station data to a new SLC data set presumed to be based on 61-90 data. The results were sufficiently close to suggest that the new data could be used for LSRS ratings with no change n the original relationships (and equations).

A general update of the SLC climate data was undertaken in the spring of 2007 to fill in blanks in the CHU (crop heat unit) data. This work was done by A. Waddell, Manitoba Land Resource Unit (see Appendix for procedure). It was noted by several people (G. Lelyk, T. Brierley, W. Pettapiece) that there were some substantial differences between the "new" EGDD and P-PE data and the original files. Closer scrutiny of the data (T. Brierley, W. Pettapiece, A. Bootsma) determined that the updated (new) data was indeed based on 61-90 climate normals but that the 2006 SLC data was mistakenly taken from the original hand-contoured 51-80 maps.

Therefore, it was necessary to re-evaluate the 61-90 vs 51-80 data using the proper (updated) 61-90 SLC databases.

There were two objectives:

1. To quantify the differences between LSRS indices based on the 51-80 and 61-90 data sets.
2. To modify the appropriate SLRS programs to reflect the defined differences in the P-PE and EGDD index values for small grains.

2. COMPARISON OF THE P-PE AND EGDD INDEXES FOR SMALL GRAINS BASED ON 51-80 AND 61-90 CLIMATIC NORMALS.

A preliminary review indicated that the CHU and canola Heat Index were developed using the 61-90 data and were therefore not included in this assessment.

Two sources of data were used for the review:
a) The original (contoured) and revised SLC data - compiled by A. Waddell (Manitoba Land Resource Unit) (Appendix 1 in electronic version), and
b) The index values calculated from the 51-80 and 61-90 data for 1175 climate stations – supplied by A Bootsma (Appendix 2 in electronic version).

2.1 The P-PE Climatic Index.

The first comparison was for the SLC data compiled in Manitoba (Figure 1).

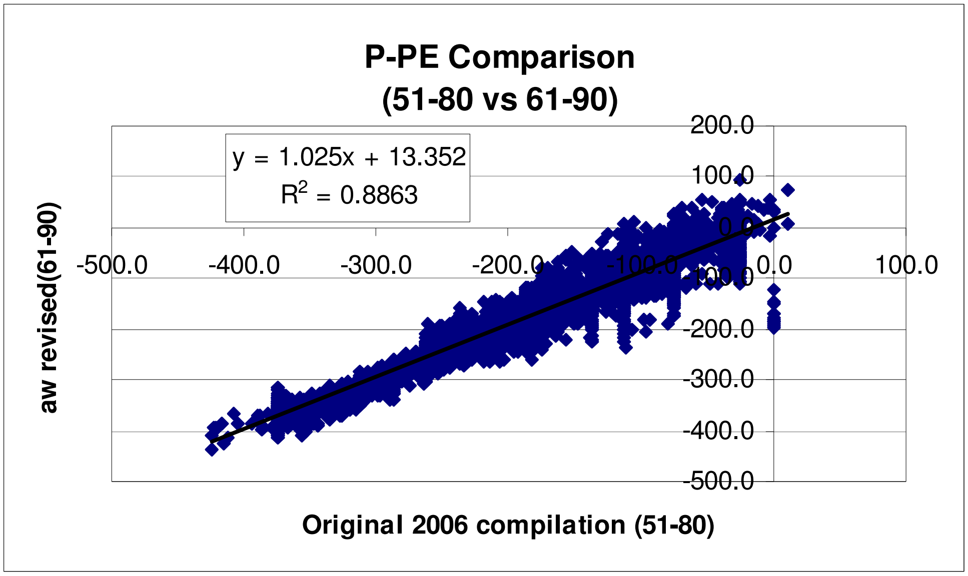

Figure 1. A comparison of P-PE values based on 51-80 and 61-90 SLC data.

There was a good correlation with an $R^2 = 0.89$. There was almost a 1:1 relationship with the 61-90 values being very slightly higher.

P-PE_61-90 = 1.025 (P-PE_51-80) + 13.352

The second comparison was for the climate station data (Figure 2).

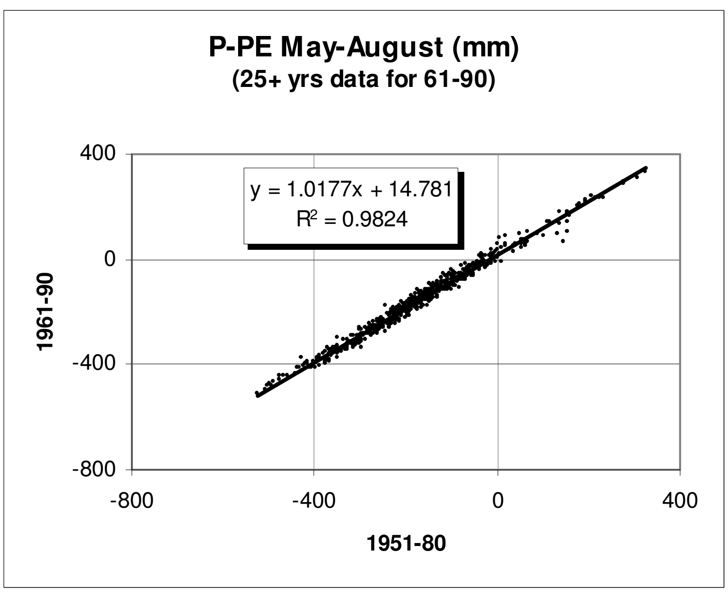

Figure 2. A comparison of P-PE values based on 51-80 and 61-90 climate station data.

The results indicate an even better correlation with an $R^2 = 0.98$. Again there is nearly a 1:1 relationship with slightly higher values for the 61-90 data.

P-PE_61-90 = 1.018 (P-PE_51-80) + 14.781

The very close agreement of the two data sources confirms a small but real shift in P-PE values.

It is recommended that the LSRS program be modified to use the 61-90 P-PE index recognizing the shift in values as represented by the comparison of the Manitoba compiled SLC data.

2.2 The EGDD Climatic Index.

The first comparison was again for the SLC data (Figure 3).

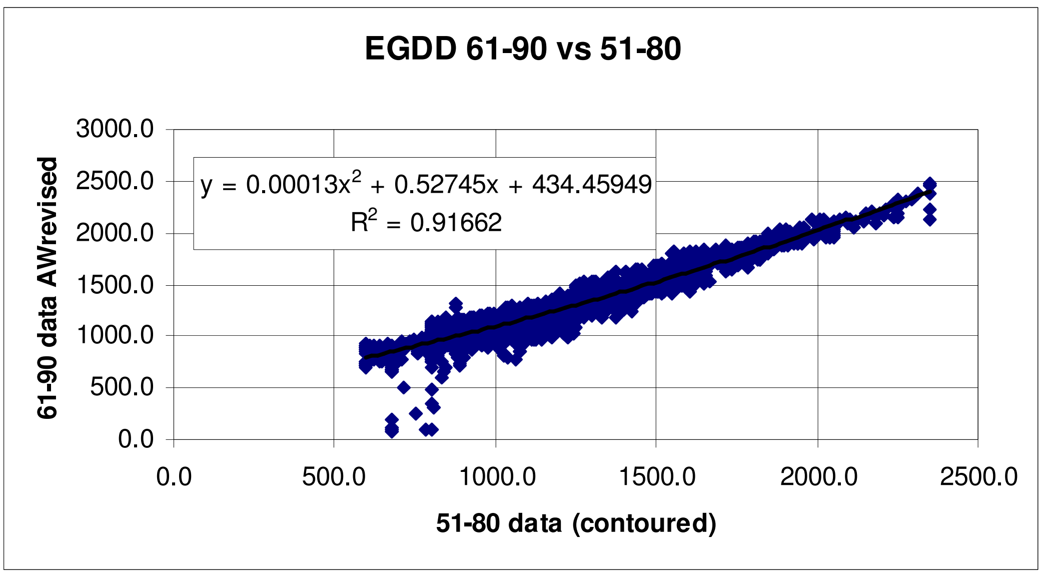

Figure 3. A comparison of EGDD values based on 51-80 and 61-90 SLC data.

The correlation of 61-90 to 51-80 data is fairly good with an $R^2 = 0.92$. However, the EGDD data, unlike the P-PE data, shows a major divergence with the 61-90 data being significantly higher in the cooler area (lower values).

EGDD_61-90 = 434.46 + 0.5275(EGDD_51-80) + 0.000133(EGDD_51-80)^2

This translates to differences (Table 1) ranging from about +20units at 2000 EGDDs to about +230 units at 500 EGDDs.

Table 1. Differences in EGDDs based on relationships of 51-80 and 61-90 SLC compilations.

51-80_EGDD	61-90_EGDD
2000	2021
1500	1525
1000	1095
500	731

The 51-80 climate station data (Appendix 2) did not have EGDDs but it did have GDDs for the period from Tmean >5°C + 10 days to fall frost. This index (SUM2) is very similar to the EGDD calculation. A comparison of the 61-90 and 51-80 data for SUM2 (Figure 4) found an excellent correlation with an R^2 = 0.97 for 1175 stations with at least 25 years of records.

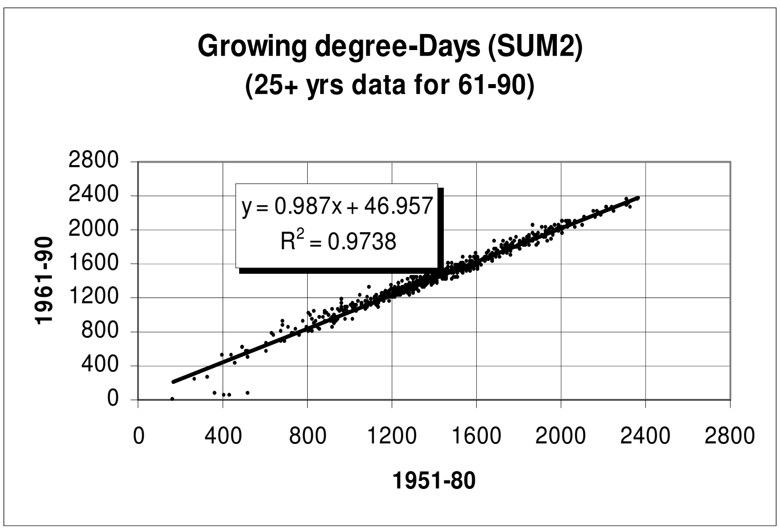

Figure 4. A comparison of GDDs based on 51-80 and 61-90 climate station data.

As with the SLC data, the station data relationship noted an increasingly positive difference for the 61-90 data at cooler locations. The station data was taken as confirmation of the trend noted in the SLC comparison.

It is recommended that the LSRS program be modified to use the 61-90 EGDD index using the relationship found in the SLC data.

3. PROPOSED MODIFICATION OF THE LSRS SMALL GRAINS PROGRAM TO ACCOMMODATE 61-90 CLIMATIC INDEXES.

3.1 Modification for 61-90 P-PE.

The first step was to establish a new P-PE-to-deduction relational table (Table 2) based on the relationship identified in Section 2.1.

Table 2. Point deductions for moisture index values based on 61-90 climate data.

P-PE_51-80	P-PE_61-90*	Point Deduction
-150	-138	0
-300	-291	30
-400	-392	50
-500	-492	70

* estimated using the relationship defined in Sec. 2.1.

The formula using the new 61-90 relationship (figure 5) is:

Point Deduction = -27.304 -0.1949 (P-PE_61-90)

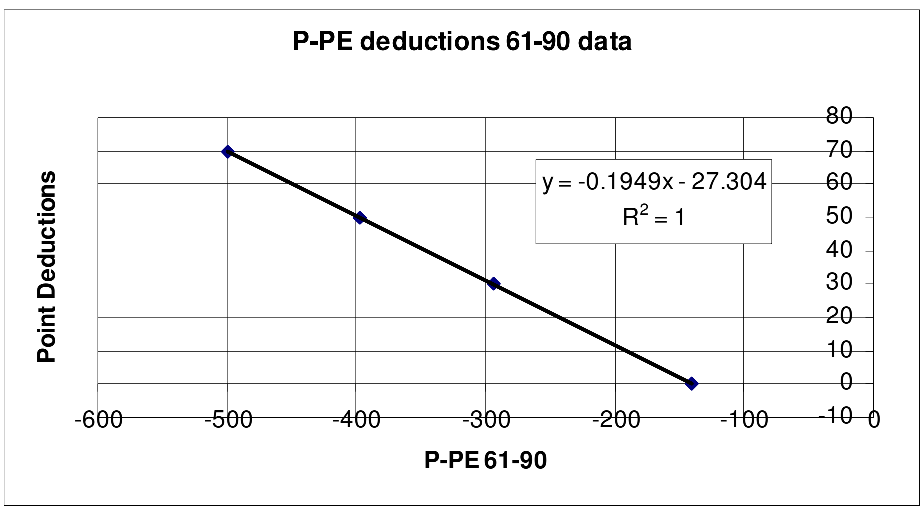

Figure 5. Point deductions for P-PE 61-90 for small grains.

This would replace the present formula (Deduction = -30 + (-0.2 (P-PE_51-80)))

The absolute differences in LSRS rating would not be large- ranging from 1-2 points for equivalent P-PE values (Table 3).

Table 3. Comparison of 51-80 and 61-90 P-PE deductions.

P-PE value	Deduction using 51-80 relationship	Deduction using 61-90 relationship
-100	0	0
-200	10	12
-300	30	31
-400	50	51
-500	70	70

3.2 Modifications for 61-90 EGDD.

Again, the first step was to establish a new EGDD to deduction relational table (Table 4) based on the relationship identified in Section 2.2.

Table 4. Point deductions for temperature index values based on 61-90 climate data.

EGDD_51-80	EGDD_61-90*	Point Deduction
1600	1619	0
1400	1434	20
1200	1259	40
1050	1135	55
900	1017	70
500	731	90

* estimated using the relationship defined in Sec. 2.2.

The formula using the new 61-90 relationship (Figure 6) is:

Point Deduction = 131.5 – 0.033 (EGDD61-90) – 0.00003(EGDD61-90)^2

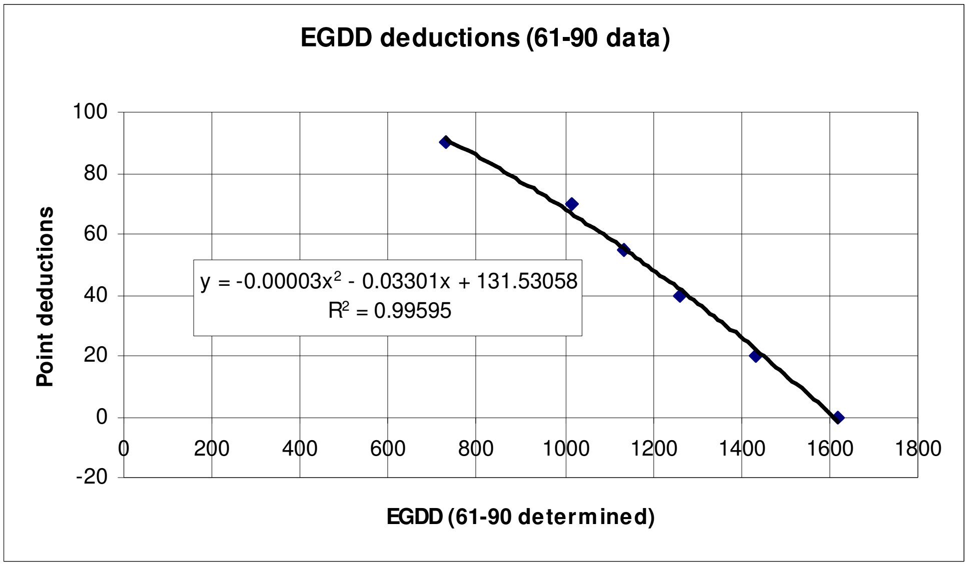

Figure 6. Point deductions EGDD 61-90 for small grains.

This would replace the present formula which is:

Deduction = 48.65 + 0.186(EGDD_51-80) – 0.000239(EGDD_51-80)^2
+ 6.49E08(EGDD_51-80)^3

In the case of EGDD there is a marked difference in the ratings for equivalent values (Table 5) For example,

Table 5. Comparison of 51-80 and 61-90 EGDD deductions.

EGDD	Deduction using 51-80 relationship	Deduction using 61-90 relationship
1600	0	1
1400	20	26
1200	40	48
1050	55	63
900	70	77
500	90	(100)

4. CONCLUSIONS

1. The differences between 51-80 and 61-90 based indices for P-PE and EGDD have been documented and defined.
2. Modifications for the LSRS mall grains ratings have been defined to allow use of the 61-90 database.

5. IMPLICATIONS FOR OTHER CROP MODELS

The changes recommended for the small grains model in order to accommodate 61-90 climate data have implications for the other models as well.

5.1 The canola crop model

The canola cop model uses the same P-PE and EGDD values as the small grains crop model. Therefore, the same recommended changes must be made to the canola model.

The only other climatic factor for canola was the heat index but as this was already based on 61-90 data no changes are required.

5.2 The corn crop model

The heat (temperature) component used for corn was assessed using the CHU scale which was based on 61-90 data so no modification is required.

The moisture limitation used the original (51-80) data and should be modified. However, the amount of difference is slight (see Sec 2.1 and 3.1) and preliminary feedback on ratings has suggested that some change might be required so it is recommended that no change be implemented at this time.

5.3 The soybean crop model

Soybeans were assessed using the same climatic factors as corn and the same comments apply. That is, there is no change required for the heat factor and the moisture deficit factor should await general testing feedback.

5.4 The alfalfa crop model

The table for the temperature proxy was established using 61-90 data so the relationship should be valid. However, the results, which were mistakenly generated using 51-80 data, will be incorrect and need to be revisited when run against 61-90 data.

As the stated objective of the moisture factor was to use the same relationship as for small grains, the formula used to determine the deduction for alfalfa should be changed to match that for small grains. However, the change is very small so it is recommended that no change be made.

5.4 The brome-timothy crop model

The same situation exists as expressed for the alfalfa model (Sec 5.4 above).

ACKNOWLEDGEMENTS

The support, commitment and contributions of J.A. Brierley, and A. Waddell of Agriculture and Agri-Food Canada have been instrumental in this assessment.

REFERENCES

Pettapiece, W.W. (Pettapiece Pedology) and G.G Tychon (Spatial Data Systems Consulting). 2006. Land suitability rating system enhancements: modification of the Alberta platform to accommodate NSDB-SLC data. A report prepared for Agriculture and Agri-Food Canada. Scientific Advisor John Fitzmaurice, Winnipeg.

APPENDIX- ATTACHING 10 KM CLIMATE DATA TO SLC POLYGONS

Procedure for Summarizing 10 km. Climate Data into SLC v 3.1 Polygons

A. Waddell, Manitoba Land Resource Unit

1. The data is supplied in a Microsoft excel spreadsheet format (.xls) with latitude, longitude, elevation, and specific climate indices that has been calculated from the original temperature and precipitation data ie. EGDD, CHU etc.

2. The .xls file is displayed as an ESRI event theme which is converted into a point shapefile as geographic coordinate with latitude on the Y axis and longitiude on the X axis. Next, the data is portrayed as points representing the entire east-west extent of Canada, and up to approximately 65_ 40′ latitude at a 10-kilometre spacing.

3. To determine the specific climate indices for each SLC polygon, a mean value is calculated based on the points that occur in an SLC polygon. Since the points were spread so far apart (10 km.), an estimation or interpolation procedure was used to determine values that occur between the 10 km. points.

4. The interpolation procedure averages values of points in the neighbourhood of each cell, thus, the closer a point is to the centre of the cell being estimated, the more influence, or weight, it has in the averaging process. The result is a raster grid representing the entire point dataset as a continuous surface. The continuous surface allows a value to be determined at any location on the map limited only by the resolution of the raster grid. It is important that the resolution chosen for the grid is fine enough to account for small and narrow SLC polygons.

5. To create summary statistics for each SLC polygon, a zonal statistics function in run on the SLC polygon shape file and the interpolated raster surface. This is essentially an overlay procedure that averages all the grid cells within each SLC polygon. The result is a table (.dbf) of statistics with one record for each polygon. Polygons outside the extent of points are given a value of -999 which infers no data. The table is joined back to the SLC 3.1 map on polyid which allows a map of average values to be generated.

6. The joined database is exported with SLC number and a number derived statistics including average value for 12,353 polygons, of which 1871 are outside the study area, and have a value of -999. Note, there are some polygons on the northern fringe of the data points that will receive values since part of the polygon was contained within the raster grid.

APPENDIX 3. PROGRAM MODIFICATION PROCEDURES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDMENTS

The author would like to acknowledge and thank J.A. Brierley of the Alberta Land Resource Unit for arranging for the climate SLC linkage and A. Waddell of the Manitoba Land Resource Unit for implementing the link operations and supplying the SLC-CHU files.

1. INTRODUCTION

There were three aspects to this phase:

1. Modifying the LSRS program to accommodate alternate crops and different data inputs (such as climate).
2. Developing a Crop Heat Unit (CHU) database, attaching the database to SLC polygons and adding SLC-CHU values to the climate data file.
3. Testing to ensure the modified program operates properly in response to the above modifications.

The program was limited to operations using the national Soil Landscapes of Canada (SLC) - National Soils Database (NSDB).

It should be noted that the testing referred to here is the operation of the program and not necessarily the correctness of the capability rating for corn. The latter will more properly be evaluated by the LSRS Sub-project Working Group (AAFC and Provincial partners)

2. ACTIVITIES

2.1 M the program to accommodate alternate crops.

There were several activities involved. The principal work involved programming to establish "place holders" for additional crops (other than small grains) - for corn, soybeans, canola, alfalfa and bromegrass.

A second activity involved modifications to accommodate different kinds of climatic data such as Crop Heat Units and the anticipated canola modifier.

The procedure to add crop and climate databases was described.

2.2 Developing and enabling a Crop Heat Unit (CHU) database.

It was identified in a previous contract (Pettapiece 2005) that warm season crops such as corn and soybeans are evaluated in Canada using CHU's rather than Growing Degree Days (EGDD). It was therefore necessary to develop a CHU database and attach it to

SLC polygons so that it could be accessed in the same manner as EGDD and P-PE indices used for the small grains.

In order to be consistent with the EGDD and P-PE indices, the McKenney-gridded 61-90 monthly normals were used as the basic input. The specific procedure (Appendix 1) involved the conversion of monthly data to daily data and then CHU calculations.

The second step was the attachment of the 10K grid CHU data to SLC polygons. This was done by the Manitoba Land Resource Unit (Appendix 2).

The SLC-CHU data was then added to the climate file in the LSRS program.

2.3 Testing and evaluation.

2.3.1 Program function

Using the new corn model as the test, the program was run on NSDB databases to ensure functionality.

2.3.2 CHU-SLC link

A printout of the national CHU distribution (MB- LRU) was visually inspected to identify any anomalies. Then a "representative" SLC was selected for each county in Ontario. The CHU value assigned to each SLC was compared to the county CHU value estimated from the Ontario CHU map (OMAF Factsheet No. 93-119, Agdex 111/31).

3 RESULTS AND DISCUSSIONS

3.1 Modifying the LSRS program

The program was modified to accommodate additional crops. A detailed description of the procedure is included in Appendix 3.

In addition, modifications were made to facilitate the addition of new climate models. A detailed description of the procedure is included in Appendix 4.

A new "Install" CD was produced for testing purposes. The program was tested using the corn model and NSDB data and appears to be functioning properly.
(Note that the AGRASID database has been disabled).

3.2 The CHU database

The CHU calculations were completed using 61-90 normals (File LSRS_CHU.xls in the attached CD) and successfully linked to SLC polygons (File CHU_by_SLC_polygon_stats.dbf in the attached CD). A visual check of the national printout (Fig 1) found the results to be as expected with values of >3000 in southern Ontario and <2000 in the Boreal areas

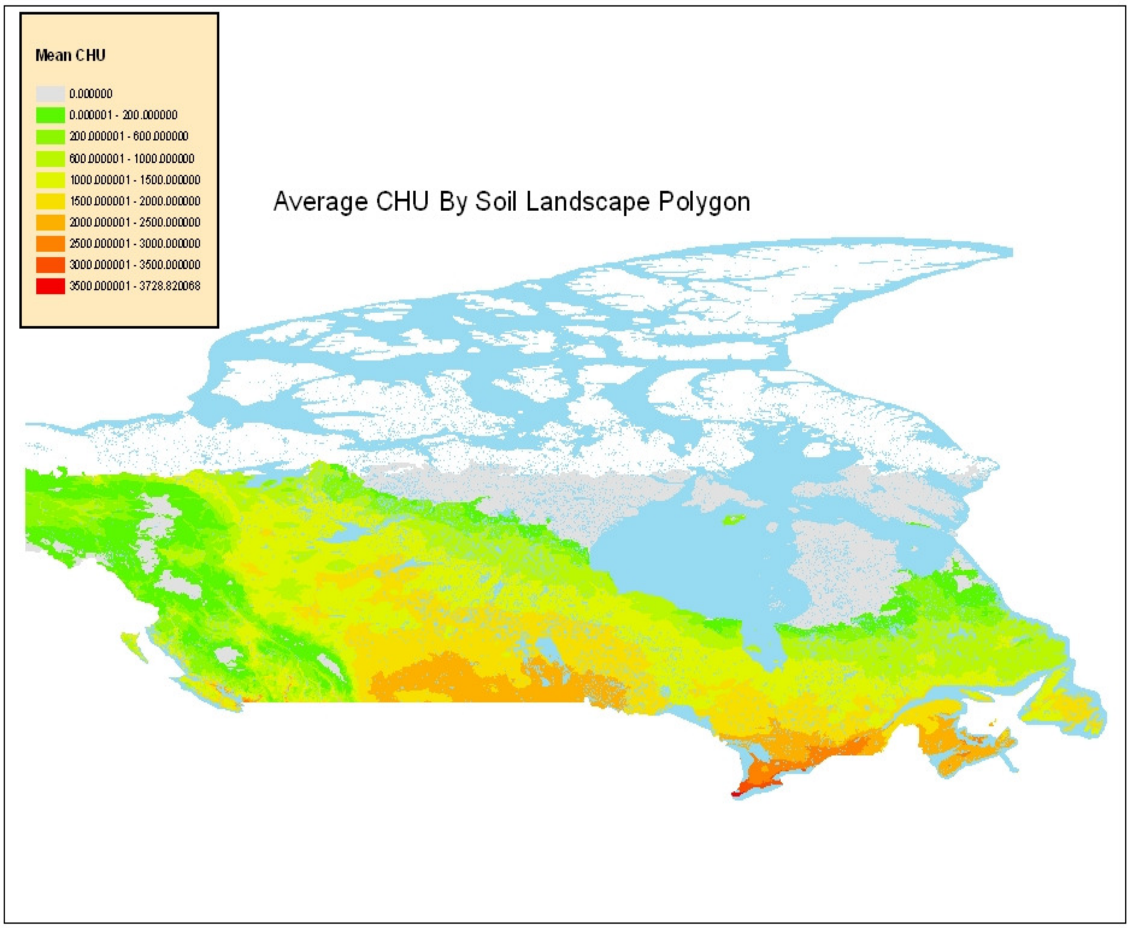

Figure 7. Average CHUs by Soil Landscape Polygon

A comparison of estimated county CHUs and the CHU values for SLC polygons representing the counties (Table 1) also showed very good compliance.

Table 1. Comparison of Ontario Counties and SLC Crop Heat Units

County	representative SLC	SLC-CHU	representative station	CHU	estimated CHU
Brant	564009	3000			3000
Elgin	565014	3230			3100
Essex	570007	3554	Harrow	3560	3500
Haldiman-Norfolk	569006	3154	Delhi	3040	3100
Hamilton	564002	3052	Hamilton	3210	3000
Chatham	565022	3398	Ridgetown	3340	3300
Lambton	570001	3244			3100
Middlesex	565006	3063	London	2900	3000
Niagara	569001	3211	Vineland	3190	3200
Oxford	564009	3000	Woodstock	2890	2900
S. Ontario		3190.6			3120
Bruce	558004	2693			2600
Dufferin	551029	2659	Redickvill	2390	2400
Grey	558002	2607			2500
Halton	564002	3052			2800
Huron	558008	2682	Brucefield	2820	2700
Peel	562001	2917			2900
Perth	557006	2838			2800
Simcoe	551021	2719			2700
Waterloo	564005	2819			2700
Wellington	560002	2643	Guelph	2680	2600
W. Ontario		2762.9			2670
Durham	554002	2755			2700
Haliburton	413010	2290			2200
Hastings	553001	2810			2600
Kawartha	554001	2681			2600
Muskoka	551009	2665			2300
Northumberland	553007	2796			2800
Parry Sound	413010	2290			2400
Peterborough	552007	2660	Peterborough	2600	2600
Pr. Edward	555006	2960	Smithfield	2940	3000
York	562001	2917			2900
C. Ontario		2682.4			2610
Frontenac	555011	2905			2600

County	representative SLC	SLC-CHU	representative station	CHU	estimated CHU
Lanark	547004	2750			2600
Leeds& Grenville	547010	2810	Kemptville	2730	2800
Lennox&Addington	555011	2905			2700
Ottawa	545006	2748	Ottawa	2890	2800
Prescott&Russell	543003	2741			2800
Renfrew	542002	2537	Petawawa	2380	2400
Stormont, Dundas	546005	2804			2800
E. Ontario		2779.94			2701
Algoma					1700
Cochrane			Kapuskasing	1720	1700
Kenora	372040	1904			2100
Manitoulin	550003	2352			2300
Nipissing					2000
Rainy River	377004	2199	Fort Francis	2330	2300
Sudbury	409009	1955			2000
Thunder Bay	388007	1558	Thunder Bay	1790	1800
Timiskaming	407003	1754	Earlton	1930	1900
N.Ontario		2071.706			2050.1

It seems reasonable to conclude that a standard national CHU database attached to the national SLC map has been established. The fact that it was developed on the standard 61-90 climate normals should make it a suitable base for any future climate change studies.

In the initial application, there were some polygons without CHU data. This was addressed by A. Waddell and a new procedure was implemented to eliminate the problem (Appendix 2)

Another concern is the poor representation of CHU values in the narrow mountain valleys in BC. The Pentiction area SLC, for example, shows CHU values of 2100 compared to expected values of > 3000. It is suggested that it is a result of the inclusion of higher elevation, side-slope grid points in the broad SLC polygons. Again, this is an issue that needs to be addressed by AAFC for future work.

4. CONCLUSIONS

1. The LSRS program has been modified to accommodate alternate crop models and some alternate climate inputs.
2. The CHU climatic index has been calculated from 61-90 normals and attached to SLC polygons along with the EGDD and P-PE indices.
3. All procedures are documented

5. ADDITIONAL COMMENTS

- The LSRS 3.0 test program, as presently implemented, only operates with NSDB data (associated with the national SLC ver.3 map)
  - i.e. it does not run on AGRASID or site data
- The LSRS 3.0 program can operate in batch mode (with an SLC link) or interactively with national SLC map.
- It was not part of this contract, but it is suggested that future consideration be given to expanding the program to accommodate other climate models (years etc.) similar to the crop models, in order to support climate change scenarios.

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7. APPENDICES

7.1 Appendix 1. Documentation for gridded CHU data

(by A. Bootsma)

1961-1990 baseline climate

Gridded monthly mean values for daily maximum and minimum air temperature were constructed by interpolating average monthly climate station data from within the 1961-1990 period (Environment Canada, 1994) as a function of latitude, longitude and elevation using ANUSPLIN (Hutchinson, 2000). ANUSPLIN uses thin plate smoothing splines as the interpolation technique (Hutchinson, 1995). The grid is 500 arc seconds and was developed by Dr. D. McKenney, Canadian Forest Services, Sault Ste Marie, using a Digital Elevation Model (DEM) data, based on the National Topographic Series 1:250,000 topographic data. For details of these particular Canadian applications see McKenney et al. (2001) (see also Price et al. 2000). The gridded climate data are available on line at: http://www.cics.uvic.ca/scenarios/index.cgi . Gridded data are only available for latitudes up to 65.72EN, as routines used for calculating daylength do not work for more northern latitudes.

Calculation of CHU from monthly gridded data

Crop Heat Units (Brown and Bootsma, 1993) were computed using the gridded monthly average temperatures as input data. Initially, 365 daily values of average maximum temperature and of average minimum temperature were generated from monthly average values for each grid point using the Brooks sine wave interpolation procedure (Brooks, 1943).

Average daily values of CHU were computed using the following formula:

$$Ymax = 3.33\ (Tmax - 10.0) - 0.084\ (Tmax - 10.0)^2; \qquad \text{if } Tmax < 10.0,\ Ymax = 0.0;$$

$$Ymin = 1.8\ (Tmin - 4.44); \qquad \text{if } Tmin < 4.44,\ Ymin = 0.0$$

Where Ymax and Ymin are the contributions to CHU from average daily maximum (Tmax) and minimum (Tmin) air temperatures respectively.

Then, $$\text{Daily CHU} = (Ymax + Ymin) / 2.0$$

Daily CHU are accumulated from starting and stopping dates determined by the dates when certain temperature threshold values are reached. Starting dates are based on a threshold for the mean daily temperature (Tmean) and stopping dates are based on mean daily minimum temperature (Tmin). The threshold temperatures were "calibrated" to correspond closely to the average date of planting in spring and the date of 10% probability of occurrence of killing frost (-2EC) in the fall. These values were documented in previous studies for eastern Canada as follows (Bootsma, 1991; Bootsma et al., 1999; 2004;2005).

	Spring (Tmean)	Fall (Tmin)
Atlantic (all longitudes ≥ -68EW)	11.0EC	5.8EC
Quebec and Ontario (longitudes between –68 and -95EW)	12.8EC	6.5EC

Temperature criteria have not been developed for western Canada, and therefore the criteria for Ontario and Quebec were also used for this region. The criteria for western Canada need to be further refined in future through research to establish more appropriate starting and ending dates for accumulating CHU in this region of Canada.

The seasonally accumulated CHU determined in this manner are called "CHUnorm". Calculating CHU from mean daily maximum and minimum air temperatures may involve some error near the start and end of the accumulation period, since the temperature averages include days when the temperature was below base values. However, this procedure has been commonly accepted as being of sufficient accuracy (Chapman and Brown 1966), and in this case, biases are eliminated by using regression-based algorithms to estimate average CHU computed using daily data (CHUave).

The algorithms used to adjust the CHUnorm values were determined by comparing CHU computed from climate normals data to those calculated using 30 years of daily temperature data using linear regression. These have been determined and documented in previous studies (Bootsma et al., 1999; 2004; 2005) and were as follows:

For Atlantic region: CHUave = 185.2 + 0.93771*CHUnorm

For Quebec: CHUave = 157.45 + 0.9194*CHUnorm

For Ontario: CHUave = 177.82 + 0.91502*CHUnorm

Algorithms have not been developed for the Prairie provinces and British Columbia, and therefore the Ontario algorithm were assumed to apply to these provinces. Further work is needed to refine the algorithms for western provinces.

Output from program:

The following variables are contained in the output file (Excel) in the order listed:

- CHUave
- Start date for accumulating CHU (Julian day)
- Stop date for accumulating CHU (Julian day)
- Latitude (decimal degrees)
- Longitude (decimal degrees)

Questions about the data or feedback should be directed to:
Andy Bootsma,
Agro-climatology Consultant
27 Trimble Crescent

Ottawa ON CANADA K2H 7M9

Tel: 613 828-3939

e-mail: bootsmaa@yahoo.ca

7.2 Appendix 2. Attaching the CHU data to SLC polygons

(by A Waddell)

Out of a total of 12,353 SLC polygons, 10,474 have been populated with CHU values. No CHU values were calculated for north of 66 degrees (which would have zero values anyway), however there are other areas in the south that have pockets of zeros, possibly a function of the elevation. The areas in the north could be given some other value to express that the data was not analysed or, given the unlikely interest in that area, they could just be left out of the database.

The attached database represents various statistics for CHU by SLC polygon. It was generated by converting the original excel data into ARCGIS point Shapefile. The points were then converted into raster format by an inverse distance interpolation in order to account for areas in the south that were not represented with enough points to do a straight point to raster conversion. The inverse distance interpolation was compared to the direct feature to raster conversion, and the results were very similar. Next, the grid was overlaid onto the SLC polygons, and a zonal statistics function was used to produce the stats for each SLC polygon.

If there are any questions, or anything else that is required, please contact:
Arnie Waddell, M.A.
GIS Specialist
Agriculture and Agri-Food Canada/Agriculture et Agroalimentaire Canada
Telephone/Téléphone: 204-474-6122
Facsimile/Télécopieur: 204-474-7633
Rm. 362A Ellis Building, U of Manitoba
Winnipeg, Manitoba
R3T 2N2
Waddella@agr.gc.ca

NOTE: These procedures were later modified to address missed polygon problems.
See Appendix (p 11) in APPENDIX 2.

7.3 Appendix 3. Adding additional crop model profiles

(by G.G. Tychon)

As of Version 2.9 of the LSRS program, support of different crop/model profiles has been added. This capability is only available for the SLC/NSDB mode.

The following outlines the steps required to add additional crop/model profiles.

Step 1: Model Profile Code, Name, and Description

The first step in adding a new crop/model profile is to:

- determine a code that the LSRS program can use to organize and reference the new crop. This code should be short (8 letters or less) and make sense in referencing the new crop/model profile.
- give the crop a "name" which will appear in the user interface when the program is run (e.g., when selecting which crop/model profile to use). This should be the name of the crop and should be less than 20 letters (it should fit in the drop down box of the LSRS program).
- give the crop a short text description which can be used in the user interface and for reporting purposes.

The table below gives the codes, names, and description of the crops/model profiles used by the LSRS program for SLC/NSDB use in Version 2.9.

Current model profile names and descriptions as used by LSRS 2.9.

Crop/Model Profile Code	Name	Description
SSSGRAIN	Small Grain	Spring Seeded Small Grain
ALFALFA	Alfalfa	Alfalfa – Forage
BROME	Brome	Brome – Forage
CORN	Corn	Corn
CANOLA	Canola	Canola
SOYBEANS	Soybeans	Soybeans

If we decided to add Canary Seed to the above list, then we might have the following:

Crop/Model Profile Code	Name	Description
SSSGRAIN	Small Grain	Spring Seeded Small Grain
ALFALFA	Alfalfa	Alfalfa – Forage
BROME	Brome	Brome – Forage
CORN	Corn	Corn
CANOLA	Canola	Canola
SOYBEANS	Soybeans	Soybeans
CSEED	Canary Seed	Canary Seed

Step 2: Create Crop/Model Profile Folder

This folder will contain the crop/model profile spreadsheet files (the components).

The folder name **MUST** be the same as the "code" decided upon in Step 1 above.

The folder must be located within the DATA_MODEL folder which is within the DATA_LSRS folder which itself is located within the LSRS install directory.

If we use our example of Canary Seed from Step 1 above, then we would create the folder:

[LSRS Install Directory]\DATA_LSRS\DATA_MODEL\CSEED

Step 3: Create the component files

Each crop/model profile requires five spreadsheet components – the first four of them (Climate.xls, Landscape.xls, Mineralsoil.xls, Organicsoil.xls) are based on information presented in Agriculture and Agri-Food Canada Technical Bulletin 1995-6E "Land Suitability Rating System for Agricultural Crops 1. Spring-seeded small grains". These are the Primary spreadsheet components. It is critical to read and understand the Technical Bulletin in order to understand the operation of the components. Some changes have been made to certain equations presented in the Technical Bulletin. These changes are documented in the LSRS help files and will also be evident upon examining the spreadsheet components themselves.

The last component (Soilscape.xls) is used by the LSRS program for user interface and information purposes.

The LSRS program loads information into the components, the components perform calculations, and then the results are retrieved by the LSRS program, aggregated, and reported to the user.

The five components used by the LSRS program are:

	Component	Comments
1	Climate.xls	Primary Component. Spreadsheet component to perform climate calculations and deductions.
2	Landscape.xls	Primary Component. Spreadsheet component to perform landscape calculations and deductions.
3	Mineralsoil.xls	Primary Component. Spreadsheet component to perform soil calculations and deductions for mineral soils.
4	Organicsoil.xls	Primary Component. Spreadsheet component to perform soil calculations and deductions for organic soils.
5	Soilscape.xls	Spreadsheet component for user interface and information display purposes.

IMPORTANT: The spreadsheet components are in Excel 4.0 format. When editing and saving components they MUST be saved in Excel 4.0 format (no other format or version of Excel).

ALL PRIMARY COMPONENTS The following information is applicable to all Primary components. The location of the information below in the spreadsheet component must not be changed. The LSRS program either places information into these cells or retrieves information from these cell locations.		
Description	Cell Reference	Additional Comments
Site number or the Polynumb of the queried soil polygon.	F1	For SLC/NSDB data this will contain the SL value.
Soilscape number. Each soil in a soil polygon is given a number in order to group all the related components together.	F2	
Climate Profile.	F3	The climate name is inserted into the spreadsheet to ensure the user is aware of what climate data is being used (one of a number of aids to avoid confusion of results).
Crop/Model Profile	F4	Text should be placed here to indicate what crop this component is being used for. E.g., "Small Grains" or "Canola"
Component Active Flag. This value is set to 0 if the component is not active and set to 1 if the component is active.	Q1	For information purposes.
Component version / control number. This is simply the year, month, and day a single number. E.g., 20030204.	M1	Can be used for versioning – is not critical.
Print Rows value. This is simply the number of rows which should be printed for the given component.	S1	This is used to avoid printing excess blank pages. The print area is A1 to Hx, where x is the PrintRows value.

Final component rating.	AX1	If a value of -999 is placed in this cell then this indicates to the LSRS program that this component is not returning a rating or that no rating is being set by this component. This is useful if an error has been determined in the calculations – the component is able to communicate this to the main LSRS program.
Final component deductions. These values are in the cells directly below the final rating and go down until a -999 value is reached (this is a terminating value). There will always be at least three (3) entries for interface consistency. If the component has less than 3 deduction entries (e.g., climate), then a 0 is inserted as a placeholder. **Important**: The values immediately to the left of the deductions give a priority value for each deduction – this is used for sorting by the LSRS program – these must not be changed. **Important**: The values immediately to the right of the deductions are the "letter codes" indicating what the deduction is for – this is used by the LSRS program when aggregating ratings – these must not be changed.	AX2, AX3, AX4, ... (going down until a cell with value –999 is reached)	Different components can have a different number of deductions. Having a list that is terminated by "-999" allows the LSRS program to extract a variable number of values.

CLIMATE COMPONENT The location of the information below in the Climate spreadsheet component must not be changed. The LSRS program either places information into these cells or retrieves information from these cell locations.		
Description	Cell Reference	Additional Comments
Moisture Index	C6	P-PE from climate file.
Heat Units or Heat Modifier (EGDD for small grains)	C11	Heat unit from the climate file. This may be EGDD, or CHU, or CANHU. Descriptive text should be changed to indicate the heat unit being used.
Excess Spring Moisture value	C18	From climate file.
Excess Fall Moisture value	C19	From climate file.
Early Fall Frost value	C20	From climate file.
Risk of Hail Index	C21	From climate file.

LANDSCAPE COMPONENT The location of the information below in the Landscape spreadsheet component must not be changed. The LSRS program either places information into these cells or retrieves information from these cell locations.		
Description	Cell Reference	Additional Comments
Region Number	C6	Supplied or determined from information in the soil files.
Percent Slope	C7	Supplied or determined from information in the soil files.
Landscape Type	C8	Supplied or determined from information in the soil files.
Stoniness	C14	Supplied or determined from information in the soil files.
Coarse Fragments	C15	Supplied or determined from information in the soil files.
Wood – Surface Wood %	C17	Supplied or determined from information in the soil files.
Wood – Subsurface Wood %	C18	Supplied or determined from information in the soil files.
Pattern	C25	Supplied or determined from information in the soil files.
Flooding – Frequency %	C27	Supplied or determined from information in the soil files.
Flooding – Inundation Period	C28	Supplied or determined from information in the soil files.

SOIL COMPONENT - MINERAL The location of the information below in the Mineral Soil spreadsheet component <u>must not</u> be changed. The LSRS program either places information into these cells or retrieves information from these cell locations.		
Description	Cell Reference	Additional Comments
Moisture Factor: P-PE Index	C6	Supplied or determined from information in the climate file.
Moisture Factor: Surface % Si	C8	Supplied or determined from information in the soil files.
Moisture Factor: Surface % C	C9	Supplied or determined from information in the soil files.
Moisture Factor: Surface % CF	C10	Supplied or determined from information in the soil files.
Moisture Factor: Subsurface % Si	C12	Supplied or determined from information in the soil files.
Moisture Factor: Subsurface % C	C13	Supplied or determined from information in the soil files.
Moisture Factor: Subsurface % CF	C14	Supplied or determined from information in the soil files.
Moisture Factor: Water Table Depth	C16	Supplied or determined from information in the soil files. Value is in cm.
Surface Factors: % OC (Organic Carbon)	C22	Supplied or determined from information in the soil files.
Surface Factors: Depth of Top Soil	C25	Supplied or determined from information in the soil files.
Surface Factors: Reaction (pH)	C27	Supplied or determined from information in the soil files.
Surface Factors: Salinity (EC)	C28	Supplied or determined from information in the soil files.
Surface Factors: Sodicity (SAR)	C29	Supplied or determined from information in the soil files.
Surface Factors: Depth Organic Horizons	C33	Supplied or determined from information in the soil files.
Surface Factors: Bulk Density of Organic Horizon	C34	Supplied or determined from information in the soil files.
Subsurface Factors: Highest BD Value	C42	Supplied or determined from information in the soil files.
Subsurface Factors: Depth to Impeding Layer	C45	Supplied or determined from information in the soil files.
Subsurface Factors: Reaction – Subsurface pH	C49	Supplied or determined from information in the soil files.

Subsurface Factors: Salinity – EC	C50	Supplied or determined from information in the soil files.
Subsurface Factors: Sodicity – SAR	C51	Supplied or determined from information in the soil files.

SOIL COMPONENT - ORGANIC The location of the information below in the Organic Soil spreadsheet component <u>must not</u> be changed. The LSRS program either places information into these cells or retrieves information from these cell locations.		
Description	Cell Reference	Additional Comments
Soil Climate: Heat Units or Heat Modifier (EGDD for small grains)	C6	Supplied or determined from information in the climate file. It is probably that different heat units will be loaded depending upon the crop/model profile. Explanatory text (e.g. the text in cell B6) should reflect the heat units being loaded and used.
Moisture Deficit Factor: P-PE Index	C13	Supplied or determined from information in the climate file.
Moisture Deficit Factor: Surface % Fibre	C14	Supplied or determined from information in the soil files.
Moisture Deficit Factor: Water Table Depth	C16	Supplied or determined from information in the soil files.
Moisture Deficit Factor: Subsurface % Fibre	C17	Supplied or determined from information in the soil files.
Surface Factors: Surface Reaction (pH)	C29	Supplied or determined from information in the soil files.
Surface Factors: Surface Salinity (EC)	C30	Supplied or determined from information in the soil files.
Subsurface Factors: Organic Depth	C44	Supplied or determined from information in the soil files. Value is in cm.
Subsurface Factors: Substrate Master Horizon	C45	Supplied or determined from information in the soil files.
Subsurface Factors: Substrate COFRAG	C46	Supplied or determined from information in the soil files.
Subsurface Factors: Substrate % Si	C47	Supplied or determined from information in the soil files.

Subsurface Factors: Substrate % C	C48	Supplied or determined from information in the soil files.
Subsurface Factors: Subsurface Reaction (pH)	C53	Supplied or determined from information in the soil files.
Subsurface Factors: Subsurface Salinity (EC)	C54	Supplied or determined from information in the soil files.

SOILSCAPE COMPONENT

The Soilscape component is used for user interface and information presentation purposes. It is not used for model calculations. But, this being said, it must be present for the LSRS program to function.

It is suggested that changes be made to accurately reflect the Site/Polynumb/SL value being loaded and the Crop/Model Profile name be included.

Description	Cell Reference	Additional Comments
Site/Polynumb/SL Number	F3	The text in cell E5 should be changed to reflect the value being loaded into cell F3.
Crop/Model Profile Name	F5	The text in cell F5 should be changed to accurately reflect the crop/model profile.
Area % of Total	C6	LSRS program will calculate and load this value.

Component Construction Note: The LSRS program only works with the first 100 rows and first 100 columns of the spreadsheet component. Information placed beyond this range will not be accessible and may cause the LSRS program to fail if it is required by the crop model profile.

Step 4: Copy Component Files to Crop/Model Profile Folder

If the component files created are not in the crop/model profile folder (created in Step 2) then they must now be copied or placed there. The LSRS program will look in this folder when the crop/model profile is configured for use by the LSRS program.

The following Components must be present within the folder after this step and the filenames must be exactly as shown below:	
1	Climate.xls
2	Landscape.xls
3	Mineralsoil.xls
4	Organicsoil.xls
5	Soilscape.xls

Step 5: Update Climate file if necessary

The climate file supplied with LSRS 2.9 for SLC/NSDB use is based on the 61-90 normals. It contains the basic climate information that was used to develop and validate the original spring seeded "small grains" model for SLC/NSDB.

Additional crop profiles may require different heat modifiers (other than EGDD). This is true of corn and canola. In the climate table supplied with LSRS 2.9 an entry (column) for Corn/Crop Heat Unit (CHU) has been included for corn and an entry (column) for Canola Heat Modifier (CANHM) has also been included for canola. Initial values have been provided for these heat modifiers. They may be replaced with better (or correct) values using the SL value as link.

If a new model/crop profile is added which cannot make use of EGDD, CHU, or CANHM then a new column must be added to the CLIMATE.DBF table and a value filled in. The value must of course be linked to the SL value in order for the program to make use of it.

In addition, the field or column must have a name. It is advised that this name should be short (no more than 6 or 7 letters) and descriptive. The name of the column will later be used in the LSRS INI file when describing the new model – it is here that the LSRS program will be provided with information linking the model with what heat modifier column to use.

Structure of CLIMATE.DBF Table as supplied with LSRS 2.9 for SLC/NSDB use					
Number	Field Name	Type	Size	Dec	Comments
01	SL	N	18		SL number. This is used to index into the climate table and locate the required record. An index file may be created based on this field.
02	ECODISTRIC	N	18		Ecodistrict.

03	ECOREGION	N	18		Ecoregion.
04	ECOPROVINC	C	05		Ecoprovince.
05	ECOZONE	N	18		Ecozone.
06	HECTARES	N	18	6	Hectares.
07	MINPPE	N	18	6	Minimum P-PE.
08	MAXPPE	N	18	6	Maximum P-PE.
09	PPE	N	18	6	P-PE
10	MINEGDD	N	18	6	Minimum EGDD.
11	MAXEGDD	N	18	6	Maximum EGDD.
12	EGDD	N	18	6	Effective Growing Degree Days. Used for "small seed", "soybeans", "brome", and "alfalfa" model profiles.
13	PPEMAY	N	18	6	P-PE for May.
14	PPESEPT	N	18	6	P-PE for September.
15	DBAVEFF	N	18		For future use (refers to early fall frost)
16	RISKHAIL	N	18		Risk of hail.
17	REGION	N	18		Region.
18	CHU	N	18	6	Corn / Crop Heat Units. Used for "corn" model.
19	CANHM	N	18	6	Canola Heat Modifier. Used for "canola" model profile.

Note: Some fields in the climate table are not necessary for the LSRS program to function. They were included during development for user information, checking purposes, and future development.

Step 6: Edit the LSRS INI file

The LSRS INI file must be changed to inform the LSRS program of the new model profile.

NOTE: It is advised that a backup of the INI file be made prior to changing it.

Edit the INI file using a plain text editor (such as Notepad).

DO NOT CHANGE ANY OTHER SETTING IN THE INI FILE OTHER THAN THOSE DEALING WITH THE MODEL PROFILES.

Task	INI file Line or lines in INI File to change or add
(1) Let the program know that there is an additional model profile or crop. Locate the line indicating the number of model profiles. LSRS 2.9 is shipped with this value set to 6. This is the number of model profiles (crops) initially anticipated for LSRS 2.9. If another model profile/crop is added, then this value must be increased. E.g., if canary seed were added, then the value of 6 would be set to 7.	NumberModels=6 (increase the value to accurately reflect the number of crop/model profiles)
(2) Create a new model description group or edit an existing one.	See (3) or (4) below.
(3) Edit existing model description group. In this case we are letting the LSRS program know that one of the currently anticipated crop/model profiles is ready to be used.	For example, if the Alfalfa components have been created (or modified) and are ready to be tested/used, then in the model group description for Alfalfa must be changed. The following line: Model-001-SLCNSDB='0' must be changed to: Model-001-SLCNSDB='1' to indicate that Alfalfa is now ready for SLC/NSDB use.

	And the line: Model-001-Name='(Alfalfa)' must be changed to: Model-001-Name='Alfalfa' The brackets have been removed. After the changes, the group of lines describing the crop/model profile should appear as follows: Model-001-Code='ALFALFA' Model-001-Name='Alfalfa' Model-001-Desc='Alfalfa - forage' Model-001-Heat='EGDD' Model-001-Agrasid='0' Model-001-SLCNSDB='1'
(4) Let the program know that there is a new crop/model profile that is ready to be used. In this case we have added an entirely new crop/model profile.	For example purposes, let us assume we are adding a 7th crop/model profile and that it is canary seed. We have decided the code will be CSEED and it uses EGDD heat units. The following lines must be added to the end of the INI file. Model-007-Code='CSEED' Model-007-Name='Canary' Model-007-Desc='Canary Seed' Model-007-Heat='EGDD' Model-007-Agrasid='0' Model-007-SLCNSDB='1' Note: It is important that the number (nnn) appearing in the "tag" (e.g. Model-nnn-Code) be unique and sequential. The next crop/model profile added would be 008, then 009, and so on. The LSRS program can support a maximum of 100 different crop/model profiles. The order that the crop names will appear in the LSRS program drop down list is the same order that they appear in the INI file.

Specifying Modifiers

In addition to the above specifications, there is also the capability to specify modifier values that can be passed from the climate file and loaded into each component (climate, landscape, etc.). The format for specifying a modifier is:
Model-XXX-Mod01=”fieldname01”
Model-XXX-Mod02=”fieldname02”
Model-XXX-Mod03=”fieldname03”
Model-XXX-Mod04=”fieldname04”
Model-XXX-Mod05=”fieldname05”
Model-XXX-Mod06=”fieldname06”
Model-XXX-Mod07=”fieldname07”
Model-XXX-Mod08=”fieldname08”
Model-XXX-Mod09=”fieldname09”
Model-XXX-Mod10=”fieldname10”

Where:

XXX is the crop/model number as described above and

“fieldname” is the name of a field occurring in the climate file. A maximum of 10 modification values may be specified for a crop/model profile. The modification values must be of type “string” or “text”. Once they are loaded into the spreadsheet component then they can be cast to required type by the user.

As an example canola requires an additional heat modifier which has field name “CANHM” in the climate file. If canola was crop/model number 3 in the INI file, then we have the line:

Model-003-Mod01=”CANHM”

specified to let the LSRS program know that the value in field CANHM must be passed to the various components. If no modification value is specified, then a “-“ will be passed to the component for fieldname and field value.

The modifiers specified are placed in the same grid cell location in all spreadsheet components so that all components may make use of the values if need be. The values are passed as “strings” or text and it is upon the handle the values once they are passed to the spreadsheet component.

Value	Grid Cell Location
“title 1 – fieldname”	I79
“title 2 – field value”	J79
Model-XXX-Mod01 fieldname	I80
Model-XXX-Mod01 value	J80
Model-XXX-Mod02 fieldname	I81
Model-XXX-Mod02 value	J81
Model-XXX-Mod03 fieldname	I82

Model-XXX-Mod03 value	J82
Model-XXX-Mod04 fieldname	I83
Model-XXX-Mod04 value	J83
Model-XXX-Mod05 fieldname	I84
Model-XXX-Mod05 value	J84
Model-XXX-Mod06 fieldname	I85
Model-XXX-Mod06 value	J85
Model-XXX-Mod07 fieldname	I86
Model-XXX-Mod07 value	J86
Model-XXX-Mod08 fieldname	I87
Model-XXX-Mod08 value	J87
Model-XXX-Mod09 fieldname	I88
Model-XXX-Mod09 value	J88
Model-XXX-Mod10 fieldname	I89
Model-XXX-Mod10 value	J89

After making the edit changes, save the file. It must be saved as a plain text file. Not a word processing file such as MS Word.

Step 7: Run the Program and Test

Run the program to test that the INI configuration information is correct and that the components created are being accessed correctly.

(Of course the ratings returned will depend upon the data being input into the components and the equations in the components.)

Edit the spreadsheet components (Climate, Landscape, Mineralsoil, and Organicsoil) until the crop/model profile is working as desired.

7.4 Appendix 4. Adding additional climate profiles

(by G.G. Tychon)

As of Version 3.0 of the LSRS program, support for climate profiles has been provided.

The following outlines the steps required to add additional climate profiles.

Step 1: Climate File

Before configuring an additional climate profile file, the Climate file must be created.

It is important to examine the structure of the current existing climate files being used for Agrasid and SLC/NSDB use. The new climate file will have to adhere to the same structure. See Step 2 below for the location of climate files.

For additional climate profiles, it is expected that the PPE values will be different and also the value for heat units. Current heat units consist of: EGDD and CHU.

Comments for structuring a Climate Table for LSRS Program Use	
Field Name	Comments
POLYNUMB or SL	PLOYNUMB is used for Agrasid use. SL is used for SLC/NSDB use. This field is used to index into the climate table. The LSRS program uses the POLYNUMB or SL value to locate the required record. An index file may be created based on this field.
PPE	P-PE. It is anticipated that this value will be different for different climates. <u>PPE value MUST be included in each climate profile file.</u>
EGDD	Effective Growing Degree Days. This heat unit is used for "small seed" as well as other crops. <u>EGDD value MUST be included in each climate profile file.</u> Other heat units which may be present are: CHU – Corn/Crop Heat Unit. CANHM – Canola Heat Modifier. Again, these heat modifier values will be different for different climates.
PPEMAY	P-PE for May. A default value is currently used.
PPESEPT	P-PE for September. A default value is currently used.
DBAVEFF	For future use (refers to early fall frost)
RISKHAIL	Risk of hail.
REGION	REGION must be present for SLC/NSDB use.

The climate file must be a dBase file.
The name of the climate file should be short, descriptive, and contain no blanks. It is suggested it adhere to the format of the existing climate files.

For Agrasid, the filename starts with "CA_" and for SLC/NSDB, the filename starts with "CN_".

NOTE:

Additional fields may be added to the climate file and then passed to the LSRS program as "modifiers". These modifiers are then accessible to the crop/model profiles. See Adding crop/model profile documentation for further information.

Step 2: Climate Folder

The Climate file(s) must be in the appropriate folder for the LSRS program to find and access them.

For Agrasid use, the Climate file(s) must be in folder
[LSRS Install Directory]\DATA_LSRS\DATA_AGRASID\A_CLIMATE

For SLC/NSDB use, the Climate file(s) must be in folder
[LSRS Install Directory]\DATA_LSRS\DATA_CLSNSDB\CN_CLIMATE

Step 3: LSRS INI File

The LSRS INI file must be changed to inform the LSRS program of the new climate profile.

NOTE: It is advised that a backup of the INI file be made prior to changing it.

Edit the INI file using a plain text editor (such as Notepad).

Locate the [Climates] section within the INI file and add lines to describe the additional climate. In many ways the specification of additional climates mirrors the process of adding additional crop profiles. Note that Agrasid (lines with AGS as part of the line) is specified separately from SLC/NSDB (lines with SLCNSDB as part of the line).

Example of [Climates] section of INI file.

```
[Climates]

Climate_Default_AGS_ModelCode='CA_DEFAULT'
Climate_Default_AGS_ModelName='Agrasid Default'
Climate_Climate_AGS_ModelDesc='Agrasid Default'
Climate_Default_AGS_ModelHeat='EGDD'

Climate_AGS_NumberModels=1

Climate_AGS_Model-001-Code='CA_DEFAULT'
Climate_AGS_Model-001-Name='Agrasid Default'
Climate_AGS_Model-001-Desc='Default Climate for Agrasid'
Climate_AGS_Model-001-Heat='EGDD'



Climate_Default_SLCNSDB_ModelCode='CN_NORM6190'
Climate_Default_SLCNSDB_ModelName='61-90 Normals'
Climate_Climate_SLCNSDB_ModelDesc='61-90 Normals'
Climate_Default_SLCNSDB_ModelHeat='EGDD,CHU'

Climate_SLCNSDB_NumberModels=1

Climate_SLCNSDB_Model-001-Code='CN_NORM6190'
Climate_SLCNSDB_Model-001-Name='61-90 Normals'
Climate_SLCNSDB_Model-001-Desc='61-90 Normals for SLC/NSDB'
Climate_SLCNSDB_Model-001-Heat='EGDD,CHU'
Climate_SLCNSDB_Model-001-Mods='CANHM'
```

(*In the above line we have specified additional modifiers which are present in the climate file. This lets the LSRS program know what are modifier fields and what are not modifier fields.)*

Task	Comments
Let the program know that there is an additional climate.	Increase the value associated accurately reflect the number of climates. For Agrasid, increase the value associated with: Climate_AGS_NumberModels=1 For SLC/NSDB, increase the value associated with: Climate_SLCNSDB_NumberModels=1
Let the program know that there is an additional climate profile file ready to be used.	For Agrasid lines similar to below: Climate_AGS_Model-001-Code='CA_DEFAULT' Climate_AGS_Model-001-Name='Agrasid Default' Climate_AGS_Model-001-Desc='Default Climate for Agrasid' Climate_AGS_Model-001-Heat='EGDD' The number (001 in the above) will increase with each additional climate (002, 003, etc.). The Code is the name of the dbf climate file without the extension (i.e., .dbf). The LSRS program will add the extension when accessing the file. The Name specified will appear in the LSRS program drop down list and also for user interface purposes. The Desc value is used to additional reporting purposes. The Heat value is used to let the program know what "heat" units are available for use and supported by the climate file. The "heat" units are separated by a comma if there are more than one. The "heat" units names are the same as the fieldnames in the climate file. For SLC/NSDB, the same process applies. The format of the lines is: Climate_SLCNSDB_Model-001-Code='CN_NORM6190' Climate_SLCNSDB_Model-001-Name='61-90 Normals' Climate_SLCNSDB_Model-001-Desc='61-90 Normals for SLC/NSDB' Climate_SLCNSDB_Model-001-Heat='EGDD,CHU_M,CANHM' Note: It is important that the number (nnn) appearing in the tag be unique and sequential. The LSRS program can support a maximum of 100 different climate

	profiles. The order that the climate names will appear in the LSRS program drop down list is the same order that they appear in the INI file. As noted above, if there are "modifier fields" present in the climate file, then they should be specified to let the LSRS program know what are modifier fields and what are not modifier fields. A line similar to the following must be added: Climate_SLCNSDB_Model_001-Mods='modfieldname1,modfieldname2,modfieldname3' The modifier fields must be of type string, text, or character.

After making the edit changes, save the file. It must be saved as a plain text file - not a word processing file such as MS Word.

Step 4: Testing

Final step is to run the LSRS program to test that the INI configuration information is correct and that the climate file and its contents are being accessed correctly.

APPENDIX 4. CORN CROP MODEL CONSIDERATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDMENTS

The author would like to acknowledge and thank J.A. Brierley of the Alberta Land Resource Unit for arranging for the climate SLC linkage and A. Waddell of the Manitoba Land Resource Unit for implementing the link operations and supplying the SLC-CHU files.

Appreciation is expressed to the specialists who freely responded to questions and provided suggestions about corn: K. Reid, OMAF, who commented on corn requirements and passed on the request to A. Nadler in Manitoba who also provided comments and references. Dr. L. Reid, AAFC, Ottawa provided insight on hybrids and heat units and Dr. L. Ma was contacted regarding corn agronomy.

1. INTRODUCTION

There were two aspects to this phase:

1. Modifying the LSRS program to reflect corn requirements.
2. Testing to ensure the modified program operates properly in response to the above modifications.

The program will be limited to operations using the national Soil Landscapes of Canada (SLC) - National Soils Database (NSDB).

It should be noted that the testing referred to here is the operation of the program and not necessarily the correctness of the capability rating for corn. The latter will more properly be evaluated by the LSRS Sub-project Working Group (AAFC and Provincial partners)

2. ACTIVITIES

2.1 Corn Crop model

2.1.1 Climate, Soil and Landscape Requirements.

2.1.1.1 Introduction

The following information is mainly taken from a previous contract (Pettapiece 2005) that looked at the LSRS requirements for the assessment of corn and canola.

The most obvious amendment required for consideration of land suitability for corn was that of heat units (cf Brown and Bootsma 1993, Bootsma et al. 1999, Bootsma et al. pers. comm.). The only changes from the small grains model related to the CHU heat unit relationships and the recognition of a greater water requirement as identified in a previous contract (Appendix 3).

The new relationships were defined and new formuli incorporated into the corn model. The modifications are documented in the rating information LSRS program associated with the LSRS program.

2.1.1.2 LSRS Climatic Requirements / Ratings

2.1.1.2.1 Heat requirements

The concensus from all researchers and extension people was that CHUs (Corn Heat Units or Crop Heat Units) was the most appropriate index for ranking corn heat requirements. It correlates very well with standard Growing Degree Day (GDD) values and indexes such as that used in the U.S., but has been specifically developed to recognize the threshold and physiological requirements of corn. In addition, all cultivars are rated on their CHU requirements and both extension and crop insurance agencies in all provinces use this index.

Note: the CHU index has been shown to work equally well for other warm season crops such as soybeans hence the name change to Crop Heat Units.

Literature reviews (Brown and Bootsma 1993) and consultations (L. Reid per. com.) have suggested the following critical values:

- 1900 - 2000 CHUs is the economic limit (present) for corn production
  (Class 4-5 boundary: assign a 70 point deduction)
- about 2300 CHUs is the limit for grain corn
  (Class 3-4 boudary: assign a 55 point deduction)
- about 2700 CHUs (Guelph, Ottawa) is considered a moderate limitation
  (just into Class 3: assign a 40 point deduction)
- about 3500 CHUs presents no limitation
  (assign a 0 point deduction)

The EGDD equivalents would be about:

- 1250 or near the Class 2-3 boundary for small grains
- 1500 or Class 1 for small grains

- 1800 and 2350 which are not achieved on the prairies

Putting it another way around, a marginal situation for corn is only a slight limitation for spring cereals.

Conversion of the statements to LSRS rating would suggest the following relationship:

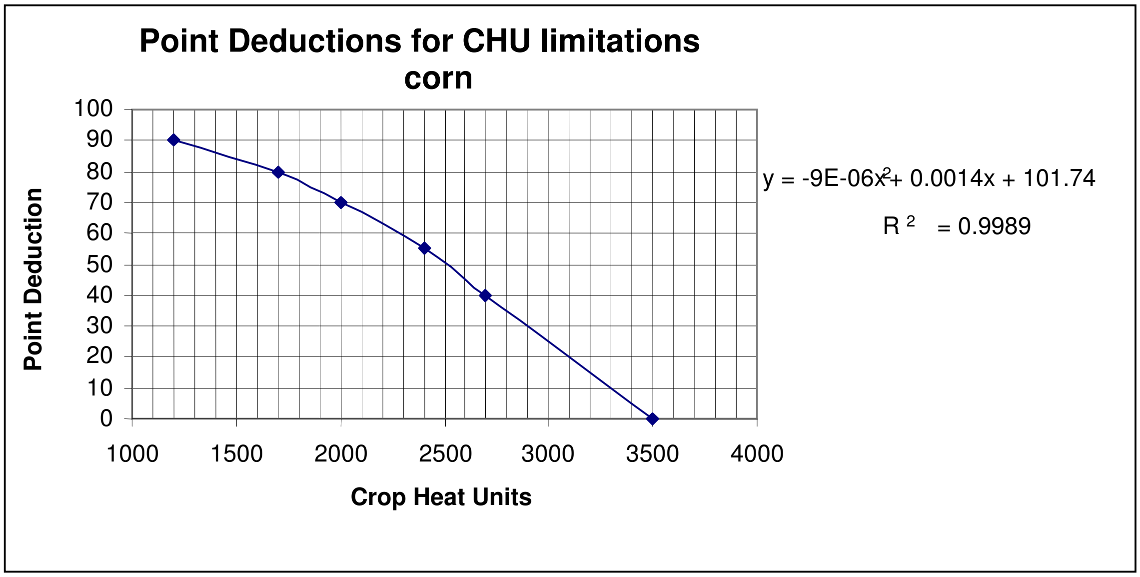

Figure 1. Point deductions for CHU limitations for corn.

Note: corn, a C4-type plant, is not significantly affected by daylength.

2.1.1.2.2 Moisture Requirements

General concensus was that P-PE was a reasonable, well established and accepted index. The question then is the rating. It seems reasonable that a crop that can produce up to a maximum of 14 t/ha dry matter must require more water than cereals with a maximum of 5-6 t/ha. Literature (Bootsma et al. pers. comm., Agricultural Climate of Manitoba (web site)) and consultations suggest the following general relationship:

- a P-PE of –100 mm is a slight limitation
  (assign middle of Class 1 = 10 point deduction)
- a P-PE of –200 to -250 mm (Winnipeg, Ottawa) is a moderate limitation
  (assign -250 to the 3-4 boundary = 40 point deduction)
- a P-PE of –350 to - 400 (Brown Soil Zone) is a severe limitation
  (assign -400 to 4-5 boundary = 70 point deduction)

That is, the curve for corn, using the same P-PE index that was used for small grains, is shifted up by about 100 units: what was Class 2 (slight limitation) for small grains is a Class 3-4 (moderate to severe) limitation for corn.

Conversion of the above statements to LSRS ratings would suggest the following relationship (Fig. 2).

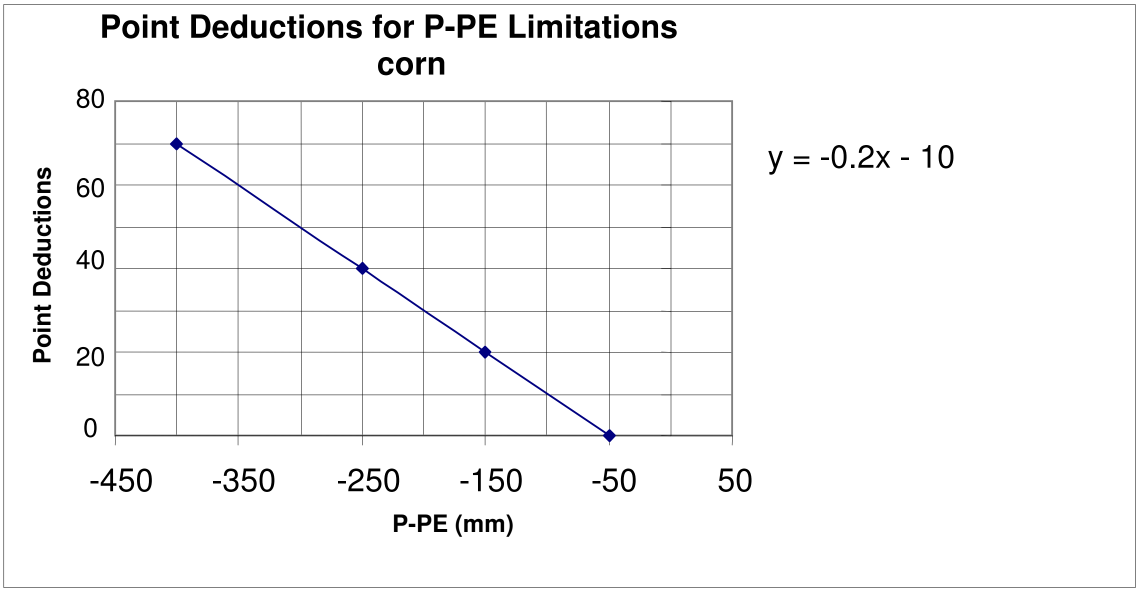

Figure 2. Point deductions for P-PE limitations for corn.

2.1.1.3 Soil Requirements / Ratings

2.1.1.3.1 Water supplying ability

The water supplying ability of a soil includes a link to the P-PE rating and will automatically incorporate the increased climate limitation in its droughtiness assessment.

2.1.1.3.2 Other soil factors

There is no indication that other soil factors will be any different for corn than for the small grains (seed bed may not be so critical??)

2.1.1.4 Landscape Requirements / Ratings

There is no indication that the landscape factors need any adjustment: the erosion potentials and mechanical limitations are assumed to be the same as for small grains.

2.2 Testing and evaluation.

2.2.1 Program function

Using the new corn model as the test, the program was run on NSDB databases to ensure functionality.

2.2.2 Implementation of the corn model

Ontario county production statistics for grain corn was accessed (http://www.omafra.gov.on.ca/english/stats/crops/ctygrcorn.html) for the years 2001 through 2005. Yields were compared to CHU values and SLRS climate and soil ratings. Only relative rankings were evaluated.

As a general test, the same national set of SLC polygons that were used for the biomass project (Pettapiece and Tychon 2006) were rated using the corn model and the results compared to the small grains ratings.

3 RESULTS AND DISCUSSIONS

3.1 The corn model

The corn suitability model was implemented and the program, using NSDB databases, was used to generate SLC ratings. In an attempt to assess some measure of reliability, LSRS climate and soil ratings were compared to Ontario counties yield statistics and county CHU values (Table 1). It was felt that this could at least address relative rankings.

Table 1. Comparison of County yields to CHUs and SLRS climate ratings.

County	rep SLC	SLC-CHU	Ave 02-05	Yield High 01-05 Bu/ac	t/ha	LSRS climate	soil	class
Brant	564009	3000	130.25	156	9.81	68	55	3
Elgin	565014	3230	135.5	160	10.06	88	62	2
Essex	570007	3554	124.75	151	9.49	100	55	3
Hald-Norf	569006	3154	131.75	145	9.12	83	37	4
Hamilton	564002	3052	125.5	139	8.74	69	50	3
Chatham	565022	3398	124	144	9.05	68	48	3
Lambton	570001	3244	128.75	154	9.68	68	48	3
Middlesex	565006	3063	128.5	151	9.49	68	50	3
Niagara	569001	3211	114	130	8.17	87	48	3
Oxford	564009	3000	139.75	164	10.31	68	55	3
Bruce	558004	2693	114	126	7.92	60	46	3
Dufferin	551029	2659	115	130	8.17	58	47	3
Grey	558002	2607	112.75	123	7.73	56	49	3
Halton	564002	3052	106.5	115	7.23	69	52	3
Huron	558008	2682	137.5	151	9.49	59	49	3
Peel	562001	2917	113	135	8.49	62	43	4
Perth	557006	2838	137.75	158	9.93	67	56	3
Simcoe	551021	2719	118.25	122	7.67	60	44	4
Waterloo	564005	2819	122.5	139	8.74	66	60	2
Wellington	560002	2643	123.25	138	8.68	57	57	3
Durham	554002	2755	121	124	7.80	63	52	3
Hastings	553001	2810	110.25	116	7.29	63	51	3
Northumberland	553007	2796	117.25	125	7.86	65	55	3
Peterborough	552007	2660	104.5	115	7.23	58	35	4
Pr. Edward	555006	2960	104.75	113	7.10	71	63	2
York	562001	2917	113	125	7.86	62	43	4
Frontenac	555011	2905	115.75	123	7.73	67	58	3
Lanark	547004	2750	113.25	126	7.92	59	40	4
Leeds& Gren	547010	2810	116	126	7.92	65	55	3
Lennox&Add	555011	2905	105.25	122	7.67	67	58	3
Ottawa	545006	2748	133.25	144	9.05	62	42	4
Prescott&Russ	543003	2741	135	152	9.56	62	43	4
Renfrew	542002	2537	106	121	7.61	53	42	4
Storm,Dundas	546005	2804	138.25	153	9.62	65	60	2
Manitoulin	550003	2352	92.3	103	6.48	40		
Sudbury		2000	107.25	123	7.73	30		
Thunder Bay	388007	1558	93.3	105	6.60	23		
Timiskaming	407003	1754	101.75	114	7.17	27		

The results of some basic comparisons (Figures 3, 4) indicated similar degrees of correlation between county CHU vs county yield and LSRS climate rating vs county yield. The R^2 values of 0.31 and 0.30 are essentially the same and show a positive correlation. This also illustrates the faithful linking of LSRS climate rating to CHU values.

The LSRS soil rating vs county yield had an R^2 of 0.06 which suggests no correlation. Given the amount of variation in each county, the probable selective use of better lands in each polygon and the uncertainty of having picked representative polygons, this result is not entirely surprising. The local testing at a more detailed scale should clarify this concern

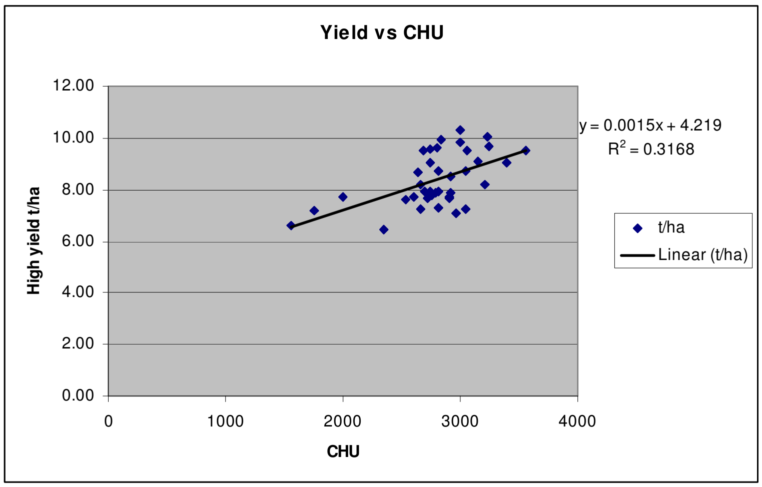

Figure 8. Yield vs CHUs for Ontario Counties

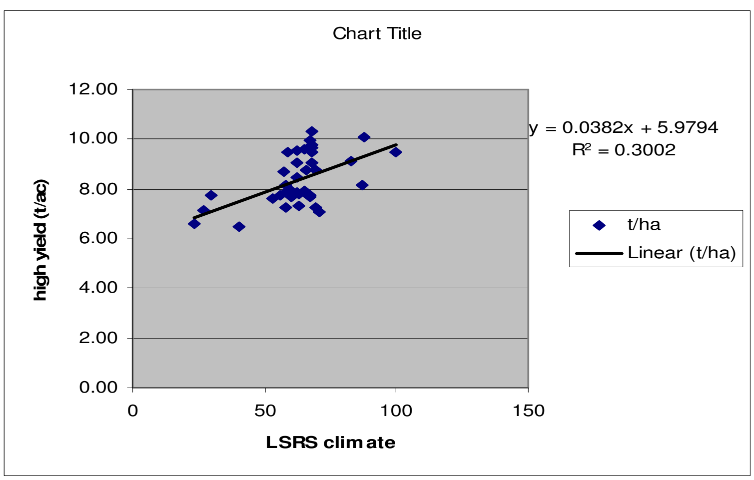

Figure 9. Yield vs LSRS climate ratings for Ontario Counties

A very general second comparison was that of corn suitability vs small grains suitability for a selected set of SLC polygons from each province (Table 2).

Table 2. Comparison of LSRS corn and small grain ratings for selected SLC polygons across Canada

Province	area	SL#	LSRS - Corn	LSRS - Small Grains
BC	Fort St John	581008	7WV(10)	7WV(10)
	Fort St John	585015	6HDT(6) – 6HW(4)	4DT(6) - 6W(4)
	Prince George	982044	6HA(7) – 7M(3)	3HT(7) - 6M(3)
	Prince George	982041	6HT(8) – 7MT(2)	3HT(8) - 6MT(2)
	Penticton	1007020	6MT(5) – 7MTN(4) - 4AHW(1)	6MT(5) - 7MTN(4) - 4W(1)
	Penticton	1007019	6MTD(8) – 6MT(2)	6MTD(8) - 6MT(2)
	Lower Fraser	959004	6W(10)	6W(10)
	Lower Fraser	959011	7WV(10)	7WV(10)
	Lower Fraser	959019	4HA(6) – 5MT(2) – 7V(2)	2T(4) - 3M(4) - 7V(2)
AB	Foremost	828012	5MT(10)	4MT(9) - 6M(1)
	Vulcan	793001	5HA(10)	2M(10)
	Neutral	771005	5MT(9) – 5W(1)	3MT(9) - 5W(1)
	Wetaskiwin	727011	5H(5) – 5HM(4) – 5HW(1)	3H(5) - 3HM(4) - 5W(1)
	Lloydminster	729003	5HM(8) – 5W(2) – 6M(1)	2HM(8) - 5W(2) - 5M(1)
	Camrose	731002	5HAD(9) – 5W (1)	3D(9) - 5W(1)
	La Corey	680002	6H(9) – 6HW(1)	3H(9) - 5W(1)
	Grande Prairie	599001	6H(8) – 6HN(1) – 6HW(1)	3H(8) - 4N(1) - 5W(1)
	Clairview	591027	6H(9) – 6HW(1)	3H(9) - 5W(1)
	High Level	586001	6H(8) – 6HW(2)	3(8) - 6W(2)
SK	Regina	792004	4M(9) – 5W(1)	3M(9) - 5W(1)
	Saskatoon	736008	4HM(9) – 5W(1)	2M(9) - 5W(1)
	Melfort	705005	5HA(9) – 5W(1)	2(9) - 5W(1)
	Meadow Lake	680012	6H(9) – 6MV(1)	3H(9) - 4MV(1)
	B topo	820002	5MT(10)	4MT(10)
	C topo	810003	6MT(9) – 5W(1)	4MT(9) - 5W(1)
	Sandy (Black)	742002	6M(8) – 4HM(2)	5M(8) - 3M(2)
MB		709007	5HA(5) – 5HMD(4) – 5W(2)	3(5) - 2H(4) - 5W(2)
		717004	7WB(6) – 5DMP(4)	7WB(6) - 4DMP(4)
		724008	4DMV(6) – 5M(3) – 7M(1)	4DW(6) - 5W(3) - 6MD(1)
		763001	4HAW(10)	5MD(7) - 5W(2) - 3W(1)
		849009	3HAW(6) – 5W(4)	2W(6) - 5W(4)
		854002	4HA(9) – 5W(1)	1(6) - 2(3) - 5W(1)
ON	Chatham	565022	3M(5) – 5W(5)	3(5) - 6WV(5)
	Guelph	564005	4TMP(5) – 7WBV(3) – 3MT(2)	7VTP(5) - 7VW(3) - 7V(2)
	Ottawa	545001	6WVT(7) – 3MT(3)	7V(7) - 7VT(3)
	Ottawa	543005	4M(4) – 5M(3) – 5WV(3)	5VM(4) - 3M(3) - 7V(3)
	Ottawa	543009	6WV(7) – 3MT(2) – 5MT(1)	7V(7) - 2MT(2) - 6VT(1)
	Ottawa	545004	4MDW(9) – 4MT(1)	7V(9) - 7VT(1)
QU	Montreal	541011	3W(10)	3W(10)
	Quebec City	540102	4PMT(7) – 4M(3)	4PT(7) - 3(3)
	Chicoutimi	441007	5HD(10)	3HDT(10)
	poorly drained	540098	6W(7) – 4DW(3)	5W(7) - 4DW(3)
	Imperfect. drained	540074	4MDW(6) – 6W(4)	3DW(6) - 5W(4)
	Organic	541053	7WVB(10)	7WVB(10)

Table 3 continued

Province	area	SL#	LSRS - Corn	LSRS - Small Grains
NB	Caribou	494001	3HT(6) – 5DW(2) – 6WT(2)	2T(6) - 5DW(2) - 6WT(2)
	Siegas	493002	4H(8) – 6MPV(1) – 7W(1)	2(6) - 3W(3) - 7W(1)
	Thibault	486011	5HT(8) – 5HTW(1) - 7WTJ(1)	3HT(8) - 3TW(1) - 7WTJ(1)
	Belldune	485001	4HTW(6) – 6W(3) – 5M(1)	3WT(6) - 6W(3) - 3M(1)
	Tormentine	504033	4W(9) – 6W(1)	3W(9) - 6W(1)
	King	503024	5DTW(6) – 3TDM(3) -6WTD(1)	5DTW(6) - 3TD(3) - 6WTD(1)
NS	Kentville	518004	6MT(6) – 4MT(4)	4MT(8) - 6MDT(2)
	Kentville	518005	DATA	3T(9) - 7W(1)
	Truro	517006	6W(7) – 3WTD(3)	6W(7) - 3WTD(3)
	Truro	507003	4DTM(8) – 6WD(2)	3DT(8) - 6WD(2)
	Sydney	523003	4HTD(10)	4DTW(10)
	Sydney	523004	6W(9) - 4HTD(1)	6W(9) - 3DT(1)
PE		535001	4DTM(8) – 6DVM(1) - 7WD(1)	3DT(8) - 5DV(1) - 7WD(1)
		536003	4MTD(7) – 7W(2) - 6DVM(1)	3DT(7) - 6W(2) - 5DV(1)
		537003	3MT(6) – 4DTM(4)	3T(6) - 3DT(4)
NL	Codroy Valley	463013	6HTV(10)	4TVP(10)
	Codroy Valley	463011	NO DATA	5TVP(7) - 7WT(3)
	Central	471012	NO DATA	4HTV(6) - 7WT(4)
	Central	466043	5HTV(6) – 7WV(4)	4TVP(6) - 7WV(4)
	St Johns	475007	5HTD(10)	4DTV(10)
	St Johns	471017	5HPV(10)	5HPV(10)

The results appear reasonable with similar ratings where climate is not limiting (such as in southern Ontario) and lower corn suitability for comparable heat and moisture limitations (such as on the prairies).

It appears from the above cursory evaluation the corn suitability rating is at least generally in the expected range. It awaits further local testing to substantiate this observation.

One major source of error is in the assessment of drainage. The Ontario NSDB database does not recognize artificial (tile) drainage which is common for much of cultivated southern Ontario. Quebec data (e.g.SLC540074) does recognize drainage modification and this is reflected in a suitability rating of 4M vs 6M for poor drainage.

A personal observation is that restricted drainage on one hand and lack of moisture on the other, may both be assessed too harsh a penalty in the corn suitability rating. This needs to be checked.

An additional concern is that the CHU - corn relationships which were developed for central Canada have not been verified for western Canada. They have been tested and slightly modified for the Atlantic region but have not been fully tested in the west. This is another issue that AAFC might address given the increasing interest in corn in southern Manitoba and possibly other areas in the west.

3.2 Programming, Testing and Evaluation

The programming was completed and enabled.

Initial testing noted a couple of problems, one with previous programming. These were successfully corrected before general model testing.

General testing was accomplished using both batch mode and individual SLC runs for corn as well as small grains and corn. All worked as expected.

A new "Install" CD was created for comprehensive testing.

4. CONCLUSIONS

1. The corn model has been implemented.
2. A new "Install" CD for LSRS 3.0 was created to support corn suitability testing.
3. All procedures are documented

5. ADDITIONAL COMMENTS

- The LSRS 3.0 test program, as presently implemented, only operates with NSDB data (associated with the national SLC ver.3 map)
  - i.e. it does not run on AGRASID or site data
- The LSRS 3.0 program can operate in batch mode (with an SLC link) or interactively with national SLC map.

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APPENDIX 5. SOYBEAN CROP MODEL CONSIDERATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDMENTS

The author would like to acknowledge and thank E. Cober and M. Morrison who responded to questions, provided suggestions and reviewed background documents for soybeans.

J.A. Brierley of the Alberta Land Resource Unit arranged for the climate SLC linkage and A. Waddell of the Manitoba Land Resource Unit implemented the link operations and supplied the SLC files.

1. INTRODUCTION

There were three aspects to this phase:

1. Reviewing the climate, soil and landscape requirements for commercial soybean production.
2. Modifying the LSRS program to reflect soybean requirements.
3. Testing to ensure the modified program operates properly in response to the above modifications.

The program will be limited to operations using the national Soil Landscapes of Canada (SLC) - National Soils Database (NSDB).

It should be noted that the testing referred to here is the operation of the program and not necessarily the correctness of the capability rating for canola and soybeans. The latter will more properly be evaluated by the LSRS Sub-project Working Group (AAFC and Provincial partners)

2. ACTIVITIES

2.1 Soybean Crop Model

2.1.1 Climate, Soil and Landscape Requirements

2.1.1.1 Introduction

Soybean [Glycine max (L.) mer.] is a crop that has a relatively high heat requirement (Major et al, 1975). Indeed, the American soybean industry recognizes 13 Maturity Groups based on temperature and photoperiod (Boersma and Specht 2004). Maturity Groups are also recognized in Canada[1] where the general approach is to rate cultivars on Crop Heat Unit (CHU) requirements (Brown and Bootsma 1993, OMAFRA 2002, OOPSCC 2006[2]). Photoperiod sensitivity is a concern when selecting varieties but as there is a strong correlation between days to maturity and yield (Voldeng et al. 1997) (Table1, Figure 1) it seems reasonable to assume that producers will grow the latest maturing variety possible (which is related to CHU ratings).

Table 1. Yield vs days to maturity for soybean cultivars (1976-1992)

Cultivar	Maturity (days)	Yield (Kg/ha)
Maple Arrow	117	3145
McCall	111	3122
Maple Presto	101	2250
Maple Amber	110	2839
Bicentennial	119	3350
KG20	110	3048
Apache	119	3286
Baron	105	2915
Maple Ridge	106	2945
Maple Isle	109	2796
KG30	116	3222
OAC Libra	122	3489
OAC Scorpio	118	3324
Maple Donovan	123	3588
Maple Glen	116	3401
9061	122	3796
SOO-88	119	3414
OAC Frontier	113	3236
Maple Belle	111	2938
KG41	118	3450
PS42	118	3652
AC Bravor	125	3483
Nordet	107	2946
OAC Eramosa	105	2797
AC Harmony	112	3249
9071	125	3846

[1] Dr. M. Morrison, Soybean breeder, Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Ottawa
[2] OOPSCC = Ontario Oil and Protein Seed Crop Committee. See: http://www.oopscc.org/vartrial.php

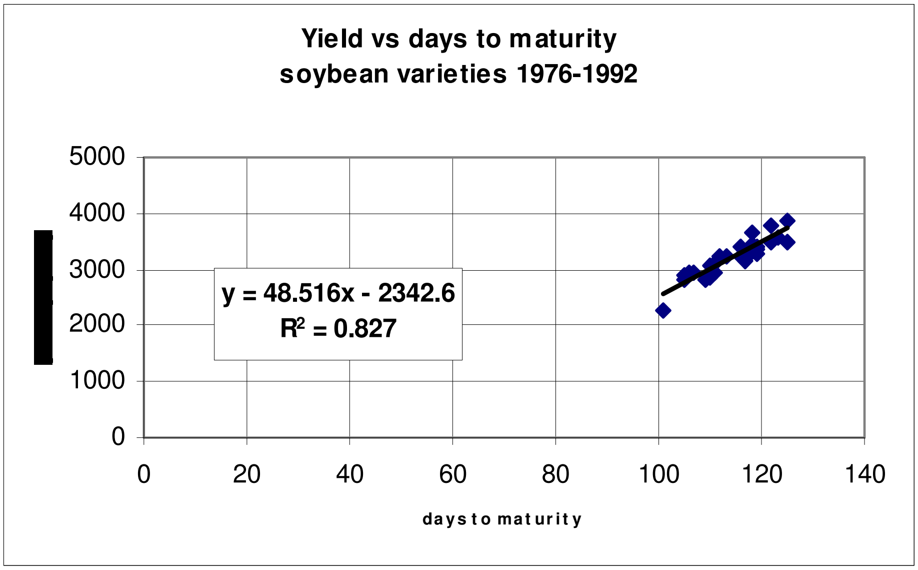

Figure 10. Yield vs days to maturity for soybean cultivars (1976-1992)

A similar relationship was found by Bootsma et al. (2005) for eastern Canada (Figure 2)

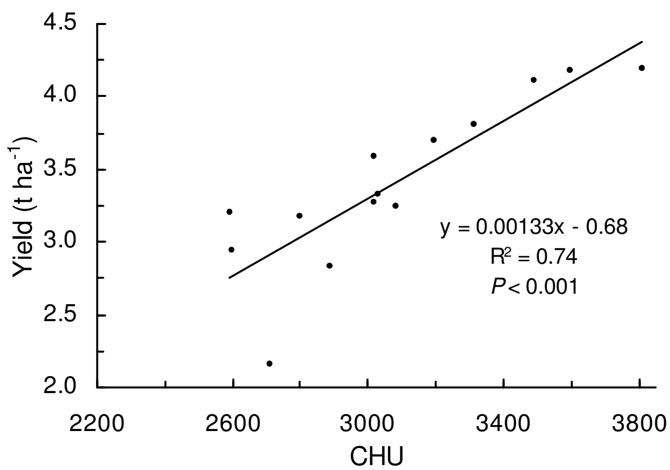

Figure 11. Relationship between present day average soybean yields from variety trials and average Crop Heat Units (CHU) based on data from the period 1996-2000.

The CHU requirement for soybeans is very similar to that for corn (E. Cober pers. Comm[5], OMAFRA 2002). The limit for commercial production of soybeans is about 2000 CHU (E. Cober pers. comm.)

The water requirement for soybeans is also a major consideration ranging from 450 to 600 mm per season depending cultivars and soil conditions (Boersma and Specht 2004). This is about 50 mm available water per week during the peak water use periods. Drought stress reduces both the total biomass production and also the proportion of harvestable seeds. It is suggested that soybean water requirement is not quite as high as that for corn but higher than for small grains (E. Cober pers. comm.)

Soybean soil requirements appear to be similar to that of the grains although they may be, like canola, slightly more sensitive to problems of crusting affecting emergence (OMAFRA 2002).
Landscape requirement should also be similar to that for other field crops.
Soybeans are similar to corn in that they are a warm season crop that is managed within a CHU framework. Soybeans can also be considered in a context similar to that of corn in that many cultivars have been developed that can tolerate climatic limitations of temperature relatively short, cool seasons. Also like corn, it is a reality that those cultivars that can tolerate stress invariably have lower yield and that the loss of yield is proportional to the amount of stress. Therefore, while the range of climatic limitations can be expanded, it comes with a yield reduction, and the ultimate control becomes an economic decision: the comparison of a mediocre or poor yield of a high value crop vs a good yield of a less valuable crop.

2.1.1.2 LSRS Climate Requirements / Ratings

Given the above discussion, the major considerations would appear to be with the climatic controls.

2.1.1.2.1. Heat Requirements

It is suggested that the CHU scale be used with the same rankings as used for corn.

2.1.1.2.2 Moisture Requirements

It is suggested that P-PE should be used but with the point deduction set between that for corn and that for the small grains (Figure 3).

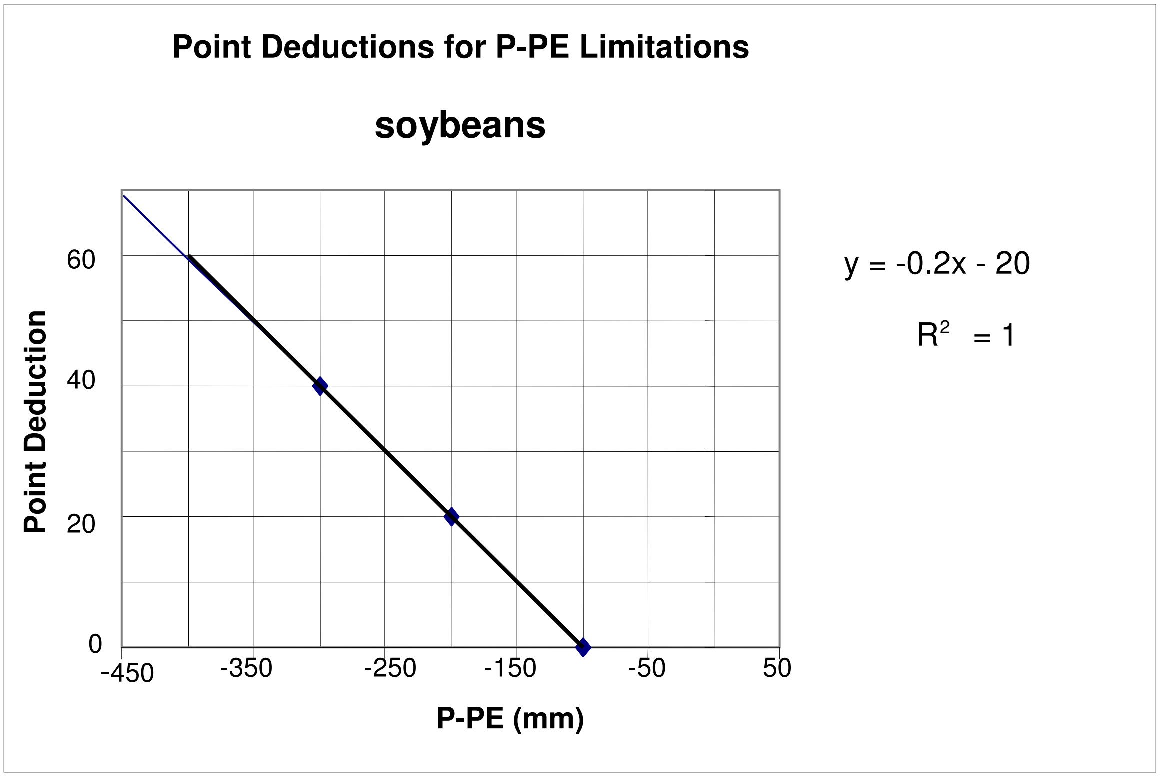

Figure 12. Point deductions for P-PE limitations for soybeans.

<u>2.1.1.3 LSRS Soil Requirements / Ratings</u>

2.1.1.3.1 Water supplying ability

The water supplying ability of a soil includes a link to the P-PE rating and needs to be adjusted as follows to incorporate the increased climate limitation in its droughtiness assessment:

Deduction = ((100 + (P-PE))/-50)*10

2.1.1.3.2 Other soil factors

Most other soil factors for soybean production appear to be similar to those for corn or the small grains. The only exception might be the susceptibility to emergence problems relating to crusting where they appear to be more like canola. It is suggested that the following modification be made to the surface structure limitation.

Deduction = 2.5 / %OC + ((% S – 60) / (%OC*3)) + ((% Si – 50) / (%OC*0.8)) + ((% C – 50) / (%OC*0.5))

It is also suggested that the maximum deduction for surface structure be raised to 15 points from the present 10 point deduction.

2.1.1.4 LSRS Landscape Requirements / Ratings

There is no indication that the landscape factors need any adjustment: The erosion potentials and mechanical limitations are assumed to be the same as for small grains.

2.2 Programming, Testing and Evaluation

The proposed changes were programmed into the canola crop model and the soybean crop model. The models were enabled in the LSRS program and the models run using NSDB databases to ensure functionality.

A new "install" CD was developed for interim testing purposes.

Canola ratings were then generated for a selected suite of SLC polygons across Canada. This was the same national set of SLC polygons that were used for the biomass project (Pettapiece and Tychon 2006) and for evaluating the corn model (Pettapiece et al. 2006). The results were compared to ratings for small grains and visually inspected to identify any anomalies (a test of reasonableness).

Soybean ratings were generated from the same SL list and compared to corn ratings.

3 RESULTS AND DISCUSSIONS

3.1 Soybean Crop Model

Initial review of ratings (Table 2) indicated that the program was responding as planned. The differences from the corn show up in moderated moisture requirements (P-PE in climate and M in soil) and in greater sensitivity to tilth concerns (surf D).

The comparison to corn for a range of conditions across Canada (Table 3) indicates similar ratings in all cases. There are some differences in number ratings (Table 2) but the polygon Classes are generally the same with a few instances (MB-717004, ON-545004) where soybean ratings are slightly higher. This seems reasonable.

3.2 Programming, Testing and Evaluation

The programming was completed and enabled.

Initial testing noted a couple of problems, one with previous programming. These were successfully corrected before general model testing.

General testing was accomplished using both batch mode and individual SLC runs for soybeans as well as small grains and corn. All worked as expected.

A new "Install" CD was created for comprehensive testing.

Table 2. Comparison of climatic and selected soil ratings for small grains, canola, corn and soybeans for selected SLC polygons across Canada.

SL#	Crop	deduction				Climate rating	deduction		Soil rating
		P-PE	EGDD	CHU	H I		M	Surf D	
Kentville, NS 518004 (soil 1)	Small grains	0	0	-	-	100	44	10	34
	Canola	0	0	-	6	94	44	13	31
	Corn	19	-	47	-	53	64	10	15
	Soybeans	9	-	47	-	53	54	13	21
Ottawa, ON 565022 (soil 2)	Small grains	12	0	-	-	88	41	0	55
	Canola	12	0	-	13	75	41	0	55
	Corn	32	-	3	-	68	56	0	40
	Soybeans	22	-	3	-	78	49	0	47
Saskatoon, SK 736008 (soil 1)	Small grains	29	21	-	-	71	36	0	61
	Canola	29	21	-	6	65	36	0	61
	Corn	49	-	66	-	34	56	0	41
	Soybeans	39	-	66	-	34	46	0	51
Prince George, BC 982044 (soil 3)	Small grains	20	50	-	-	50	16	10	64
	Canola	20	50	-	0	50	16	12	54
	Corn	40	-	90	-	10	32	10	42
	Soybeans	30	-	90	-	10	24	12	47

P-PE = precipitation – potential evapotranspiration (aridity index),
EGDD = effective growing degree days (GDD>5^{o}C modified for daylength)
CHU = crop heat units, HI = heat index (canola deduction)
M = moisture deduction recognizing climate and soil water supplying capacity
Surf D = adverse surface structure (poor tilth, crusting)

Table 3. Comparison of LSRS ratings for small grains, corn and soybeans for selected SLC polygons across Canada.

Prov.	area	SL#	LSRS - Small Grains	LSRS - Corn	LSRS - Soybeans
BC	Fort St John	581008	7WV(10)	7WV(10)	7WV(10)
	Fort St John	585015	4DT(6) - 6W(4)	6HDT(6) – 6HW(4)	6HDT(6) – 6HW(4)
	Prince George	982044	3HT(7) - 6M(3)	6HA(7) – 7M(3)	6H (7) – 7M(3)
	Prince George	982041	3HT(8) - 6MT(2)	6HT(8) – 7MT(2)	Missing climate data
	Penticton	1007020	6MT(5) - 7MTN(4) - 4W(1)	6MT(5)-7MTN(4) - 4AHW(1)	6MT(5)-7MTN(4) - 4AHW(1)
	Penticton	1007019	6MTD(8) - 6MT(2)	6MTD(8) – 7MT(2)	6MTD(8) – 7MT(2)
	Lower Fraser	959004	6W(10)	6W(10)	6W(10)
	Lower Fraser	959011	7WV(10)	7WV(10)	7WV(10)
	Lower Fraser	959019	2T(4) - 3M(4) - 7V(2)	4HA(6) – 5MT(2) – 7V(2)	4HA(6) – 4MT(2) – 7V(2)
AB	Foremost	828012	4MT(9) - 6M(1)	5MT(10)	5MT(10)
	Vulcan	793001	2M(10)	5HA(10)	5HA(10)
	Neutral	771005	3MT(9) - 5W(1)	5MT(9) – 5W(1)	5HMT(9) - 5W(1)
	Wetaskiwin	727011	3H(5) - 3HM(4) - 5W(1)	5H(5) – 5HM(4) – 5HW(1)	5H(5) - 5HM(4) - 5HW(1)
	Lloydminster	729003	2HM(8) - 5W(2) - 5M(1)	5HM(8) – 5W(2) – 5M(1)	5HM(8) - 5W(2) - 5M(1)
	Camrose	731002	3D(9) - 5W(1)	5HAD(9) – 5W (1)	5HD(9) - 5HW(1)
	La Corey	680002	3H(9) - 5W(1)	6H(9) – 6HW(1)	6H(9) - 6HW(1)
	Grande Prairie	599001	3H(8) - 4N(1) - 5W(1)	6H(8) – 6HN(1) – 6HW(1)	6H(8) - 6HN(1) - 6HW(1)
	Clairview	591027	3H(9) - 5W(1)	6H(9) – 6HW(1)	6H(9) - 6HW(1)
	High Level	586001	3(8) - 6W(2)	6H(8) – 6HW(2)	6H(8) - 6W(2)
SK	Regina	792004	3M(9) - 5W(1)	4M(9) – 5W(1)	4M(9) – 5W(1)
	Saskatoon	736008	2M(9) - 5W(1)	4HM(9) – 5W(1)	4HM(9) – 5W(1)
	Melfort	705005	2(9) - 5W(1)	5HA(9) – 5W(1)	5H(9) – 5W(1)
	Meadow Lake	680012	3H(9) - 4MV(1)	6H(9) – 6MV(1)	6H(9) – 6HMV(1)
	B topo	820002	4MT(10)	5MT(10)	5MT(10)
	C topo	810003	4MT(9) - 5W(1)	6MT(9) – 5W(1)	5MT(9) – 5W(1)
	Sandy (Black)	742002	5M(8) - 3M(2)	6M(8) – 4HM(2)	6M(8) – 4HM(2)
MB		709007	3(5) - 2H(4) - 5W(2)	5HA(5) – 5HMD(4) – 5W(2)	5HM(5) - 5H(4) - 5W(2)
		717004	7WB(6) - 4DMP(4)	7WB(6) – 5DMP(4)	7WB(6) – 4DMP(4)
		724008	4DW(6) - 5W(3) - 6MD(1)	4DMV(6) – 5M(3) – 7M(1)	4DW(6) - 5W(3) - 7MD(1)
		763001	5MD(7) - 5W(2) - 3W(1)	6MD(6) - 4M(2) - 5W(2)	6MD(6) - 4M(2) - 5W(2)
		849009	2W(6) - 5W(4)	3HAW(6) – 5W(4)	3HAW(6) – 5W(4)
		854002	1(6) - 2(3) - 5W(1)	4HA(9) – 5W(1)	4H (9) – 5W(1)

Table 3 continued

Prov.	area	SL#	LSRS – Small Grains	LSRS - Corn	LSRS - Soybeans
ON	Chatham	565022	3(5) – 5W(5)	3M(5) – 5W(5)	3M(5) – 5W(5)
	Guelph	564005	4TP(5) - 7WVB(3) - 4VT(2)	4TMP(5) – 7WBV(3) – 4VMT(2)	4TMP(5) – 7WBV(3) – 4VMT(2)
	Ottawa	545001	6VWT(7) – 2T(3)	6VWT(7) – 2MT(3)	6VWT(7) – 2HMT(3)
	Ottawa	543005	3M(4) - 4M(3) – 7WV(3)	4M(4) – 5M(3) – 5WV(3)	3M(4) – 5M(3) – 5WV(3)
	Ottawa	543009	6WV(7) – 2TM(2) – 4MT(1)	6WV(7) – 3MT(2) – 5MT(1)	6WV(7) – 3MT(2) – 5MT(1)
	Ottawa	545004	3DW(9) – 3TM(1)	4MDW(9) – 4MT(1)	4MDW(9) – 3MT(1)
QU	Montreal	541011	3W(10)	3W(10)	3W(10)
	Quebec City	540102	4PT(7) - 3(3)	4PMT(7) – 4M(3)	4PTM (7) – 4M(3)
	Chicoutimi	441007	3HDT(10)	5HD(10)	5HD(10)
	poorly drained	540098	5W(7) - 4DW(3)	6W(7) – 4DW(3)	5W(7) – 4DW(3)
	Imp. drained	540074	3DW(6) - 5W(4)	4MDW(6) – 6W(4)	3DW(6) - 5W(4)
	Organic	541053	7WVB(10)	7WVB(10)	7WVB(10)
NB	Caribou	494001	2T(6) - 5DW(2) - 6WT(2)	3HT(6) – 5DW(2) – 6WT(2)	3HT(6) – 5DW(2) - 6WT(2)
	Siegas	493002	2(6) - 3W(3) - 7W(1)	4H(8) – 6MPV(1) – 7W(1)	4H(6) - 4HW(3) - 7W(1)
	Thibault	486011	3HT(8) - 3TW(1) - 7WTJ(1)	5HT(8) – 5HTW(1) - 7WTJ(1)	5HT(8) – 5HTW(1) - 7WTJ(1)
	Belldune	485001	3WT(6) - 6W(3) - 3M(1)	4HTW(6) – 6W(3) – 5M(1)	4HTW(6) – 6W(3) – 4M(1)
	Tormentine	504033	3W(9) - 6W(1)	4W(9) – 6W(1)	3W(9) – 6W(1)
	King	503024	5DTW(6)-3TD(3)-6WTD(1)	5DTW(6) – 3TDM(3) - 6WTD(1)	Missing climate data
NS	Kentville	518004	4MT(8) - 6MDT(2)	6MT(6) – 4MT(4)	6MT(6) – 3MT(4)
	Kentville	518005	3T(9) - 7W(1)	NO SOIL DATA	NO SOIL DATA
	Truro	517006	6W(7) - 3WTD(3)	6W(7) – 3WTD(3)	Missing climate data
	Truro	507003	3DT(8) - 6WD(2)	4DTM(8) – 6WD(2)	Missing climate data
	Sydney	523003	4DTW(10)	4HTD(10)	4HTD(10)
	Sydney	523004	6W(9) - 3DT(1)	6W(9) - 4HTD(1)	7WD(9) - 4HTD(1)
PE		535001	3DT(8) - 5DV(1) - 7WD(1)	4DTM(8) – 6DVM(1) - WD(1)	3DT(8) - 6DV(1) - 7WD(1)
		536003	3DT(7) - 6W(2) - 5DV(1)	4MTD(7) – 7W(2) - 6DVM(1)	3DT(7) - 7W(2) - 6DV(1)
		537003	3T(6) - 3DT(4)	3MT(6) – 4DTM(4)	3HT(6) - 4DT(4)
NL	Codroy Valley	463013	4TVP(10)	6HTV(10)	6HTV(10)
	Codroy Valley	463011	5TVP(7) - 7WT(3)	NO SOIL DATA	NO SOIL DATA
	Central	471012	4HTV(6) - 7WT(4)	NO SOIL DATA	NO SOIL DATA
	Central	466043	4TVP(6) - 7WV(4)	5HTV(6) – 7WV(4)	5HTV(6) – 7WV(4)
	St Johns	475007	4DTV(10)	5HTD(10)	5HTD(10)
	St Johns	471017	5HPV(10)	5HPV(10)	Missing climate data

4. CONCLUSIONS

1. The LSRS program has been modified to accommodate a soybean crop model.
2. A Heat Index for canola has been calculated from 61-90 normals and attached to SLC polygons along with the EGDD and P-PE indices.
3. A new "Install" CD for LSRS 3.0 was created to support suitability testing for soybean as well as small grains and corn.
4. All procedures are documented

5. ADDITIONAL COMMENTS

- The LSRS 3.0 test program, as presently implemented, only operates with NSDB data (associated with the national SLC ver.3 map)
  - i.e. it does not run on AGRASID or site data
- The LSRS 3.0 program can operate in batch mode (with an SLC link) or interactively with national SLC map.
- It was not part of this contract, but it is suggested that future consideration be given to expanding the program to accommodate other climate models (years etc.) similar to the crop models, in order to support climate change scenarios.
  This modified LSRS program appears well positioned to evaluate agricultural responses to climate change.

It is suggested that a specified agency (perhaps the National Agroclimatic Information Centre) should be asked to take responsibility for the development and maintenance of the climate databases.

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APPENDIX 6. CANOLA CROP MODEL CONSIDERATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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J.A. Brierley of the Alberta Land Resource Unit arranged for the climate SLC linkage and A. Waddell of the Manitoba Land Resource Unit implemented the link operations and supplied the SLC files.

1. INTRODUCTION

There were four aspects to this phase:

1. Reviewing the climate, soil and landscape requirements for commercial canola production.
2. Developing a heat modification factor for canola and adding SLC-Heat modification values to the climate data file.
3. Modifying the LSRS program to reflect canola requirements.
4. Testing to ensure the modified program operates properly in response to the above modifications.

The program will be limited to operations using the national Soil Landscapes of Canada (SLC) - National Soils Database (NSDB).

It should be noted that the testing referred to here is the operation of the program and not necessarily the correctness of the capability rating for canola and soybeans. The latter will more properly be evaluated by the LSRS Sub-project Working Group (AAFC and Provincial partners)

2. ACTIVITIES

2.1 Canola Crop model

2.1.1 Climate, Soil and Landscape Requirements.

2.1.1.1 Introduction

In many respects, canola (Brassica spp.) falls within the general climatic, soils and landscape parameters used to assess small grains limitations and the present LSRS can be used as a gross proxy. This is not surprising as it is grown in the same geographic area. However, there are a number of refinements that can be made if consideration is confined to a particular genus/species.

Canola can be considered in a context similar to that of corn in that cultivars have been developed that can tolerate climatic limitations of temperature and moisture. Also like corn, it is a reality that these cultivars (or in the case of canola, actual species) that can tolerate stress invariably have lower yield and that the loss of yield is proportional to the amount of stress. Therefore, while the range of climatic limitations can be expanded, it comes with a yield reduction, and the ultimate control becomes an economic decision: the comparison of a mediocre or poor yield of a high value crop vs a good yield of a less valuable crop.

A meeting of prairie canola investigators in 1996 has been used as a basis for the canola considerations. This has been augmented by recent assessments of research literature on specific, identified concerns. A general source of information has been the Canola Growers Manual (Thomas 2003).

2.1.1.2 LSRS Climatic Requirements / Ratings

2.1.1.2.1 Heat requirements

Growing Degree Days appears to be a reasonable index and the present scale used for small grains seems appropriate. The long season, higher yielding (B. napus) varieties perform best in the areas with more than about 110 frost free days which correlates with accumulations of greater than about 1200 EGDDs. Shorter season (B. rapa) varieties perform well down to about 1000 EGDDs or less. Also, research (Morrison et al. 1989) suggests that a baseline temperature for Brassica is about 4.4^{o}C which is close to the 5^{o}C used for EGDD.

We have no specific information on the warmer end except for the documented issue of flower abortion associated with temperatures greater than about 30 ^{o}C (Angadi et al. 2000, Morrison and Stewart 2002, Gan et al. 2004). Although correlated with EGDDs, this is a different concept and it is suggested that the phenomenon should be handled as a modifier. In Saskatchewan, Angadi et al. (2000) found a 54% reduction with 7 days at 35^{o}C during the flowering period. Gan et al. (2004) found 59% for a ten day period at 35^{o}C. Reductions were also found in Ontario by Morrison and Stewart (2002) who correlated the amount of reduction with maximum daily temperatures over a threshold of 29.5^{o}C.

The next step is to translate the above information into the rating scheme. Anecdotal evidence has suggested about a 1 bushel (3-4% ?) decrease in yield for every day of missed flowering (over about 30°C). Considering the above greenhouse experiments, it would suggest a decrease of about 6-8% for every day at 35°C. Earlier discussions, at a LSRS review meeting (March 18, 2005), suggested that we try a 5% reduction for every day with a temperature above 30°C. This could be based on a 50% probability using the 61-90 normals for the flowering period June 15 to July 15.

The concept seems clear, but the mechanics for calculating a variable temperature scale and a variable flowering period are somewhat loose. It is suggested that direction be taken from the Morrison and Stewart (2002) paper where a Heat Index based on temperatures over a threshold times the number of days these temperatures occurred would be logical approach. This is similar to calculating GDDs over a specific datum. For our purposes, because we are working with long term averages over fairly large areas, it would seem reasonable that the threshold be rounded up to 30°C (re the 29.5°C suggested by Morrison and Stewart). Morrison and Stewart also suggested defining the flowering period in terms of accumulated heat units instead of calendar days - similar to the presently used definition of growing season. The suggested values, based on Morrison and Stewart (2002) and the Canola Manual (2005) (and using B. napus) would be from 600 GDD to 1100 GDD for the flowering period. That is, the heat index (HI) would be calculated as accumulated daily total of maximum temperature over a 30°C threshold (Tmax – 30) for the period between 600 and 1100 GDDs. The calculations would use the 61-90 normals.

The next issue is to translate the Heat Index deductions into something resembling the 3% to 7% per day suggested earlier. Assuming an average temperature over 30 (for the period in question) to be say 33 then the Heat index / 3 would be the days equivalent? It should then approximate a 1-1 relationship (3% per day x Heat index /3 = 1).

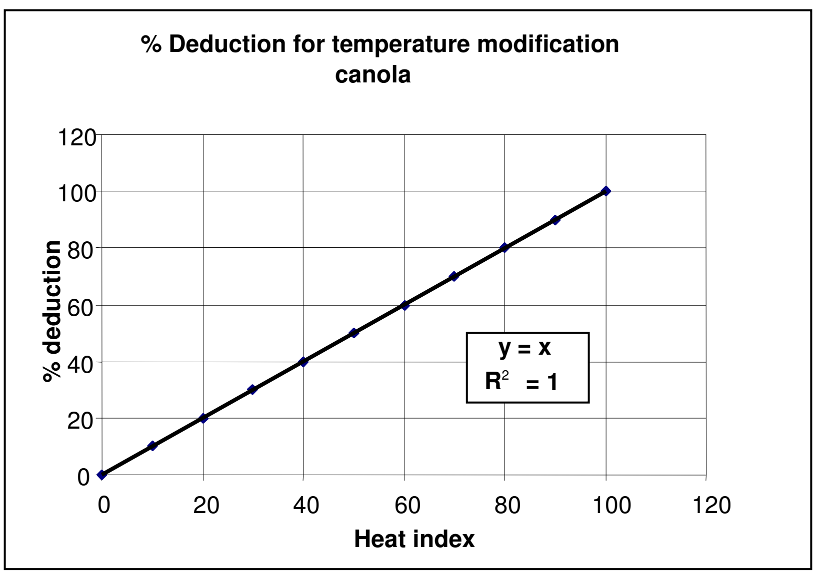

Figure 13. Percent deductions for temperature modifications for canola.

This would be the recommended approach.

2.1.1.2.2 Moisture Requirements

Personal communications with P. Thomas[3] in Alberta and S. Brandt[4] in Saskatchewan suggest that canola responds in a similar manner to the small grains with respect to moisture stress. It is therefore suggested that no modifications of this factor is required.

2.1.1.3 LSRS Soil Requirements / Ratings

2.1.1.3.1 Surface structure (crusting).

Anecdotal evidence indicates that crusting can cause an emergence problem with canola. Recent personal communications (Thomas, Brandt) suggest that this, while still a problem, is not as big a concern with direct seeding which is now more common. However, it is suggested that the surface structure category should receive an increased emphasis for canola over small grains: possibly up to a 15 point deduction re the present 10 point deduction.

Based on the above it is suggested that the surface structure calculation be modified to:

$$\text{Deduction} = 2.5 / \%OC + ((\% S - 60) / (\%OC*3)) + ((\% Si - 50) / (\%OC*0.8)) + ((\% C - 50) / (\%OC*0.5))$$

Also, it is suggested that the maximum deduction be increased to 15 points (vs the small grains at 10)

2.1.1.3.2 Salinity.

There is evidence (Redman et al. 1994) to suggest that canola is more sensitive to salinity than small grains. However, Steppuhn and Wall (1999), Thomas (pers. comm..), Brandt (pers. comm.) and Steppuhn[5] (pers. comm.) all suggest that there is not much difference from the small grains. It is therefore suggested that no change be contemplated for salinity.

2.1.13.3 There is no evidence to suggest that any other factors should be adjusted.

2.1.1.4 LSRS Landscape Requirements / Ratings

There is no indication that the landscape factors need any adjustment: the erosion potentials and mechanical limitations are assumed to be the same as for small grains.

[3] Presently President, Brassica Corp Ltd., Lacombe, Alberta (formerly canola specialist with Alberta Agriculture Food and rural Development)
[4] Agriculture and Agri-Food Canada, Scott, Saskatchewan
[5] salinity specialist, Agriculture and Agri-Food Canada, Swift Current, Saskatchewan

2.1.2 Developing and Enabling a Heat Index (HI) Modifier.

The recommended approach requires the use of daily maximum temperatures. However, the gridded 61-90 climate data that we are using does not provide daily maximum temperatures (only means which reduce extremes) and does not allow calculation of BMTS data Therefore, we need a proxy based on available data. A comparison was made of mean maximum temperatures for July (July Tmax) against frequency of days with temperatures > 30°C (as published by the Meteorological Services of Canada (MSC) 1971-2000 normals (Environment Canada 2002)). The results indicated a quite close relationship (Table 1) with an R^2 of about 0.9 for July and June (not shown).

Table 1. Comparison of July mean maximum temperature to frequency of days over 30°C (from MSC 1971-2000 normals,).

Station	July Tmax	Days >30		
		July	June	June + 1/2 July
Lethbridge CDA	25.6	5.3	1.5	4.15
Lacombe CDA	22	0.6	0.2	0.5
Edmonton A	22.2	0.5	0.2	0.45
Beaverlodge CDA	21.5	0.5	0.1	0.35
Medicine Hat A	26.9	8.1	3	7.05
Regina A	25.7	4.7	2.9	5.25
Saskatoon A	24.9	3.3	2	3.65
Swift Curr CDA	24.8	4.3	1.7	3.85
Scott CDA	23.6	1.8	1	1.9
Melfort CDA	23.6	1.6	1.7	2.5
Yorkton	24.3	2.3	1.4	2.55
Estevan	26.5	6.7	2.8	6.15
Deloraine	26.1	5.2	2.4	5
Brandon A	25.2	3.4	1.8	3.5
Winnipeg A	25.8	4	2.5	4.5
Morden CDA	25.9	4.5	2.6	4.85
The Pas	23.4	1.2	0.7	1.3
Ottawa CDA	26.4	4.3	2.3	4.45
Kapuskasing	23.5	1.5	1	1.75
Harrow	27.2	5.4	2.8	5.5
Vineland	26.9	5.8	2.5	5.4

To approximate the flowering period, the assumption was made that most of the June days would be in the latter half of the month and those for July would be evenly distributed. The June 15 to July 15 (the main flowering period) could then be defined as June plus ½July. This figure (Table 1, Figure 2) also had the same close relationship and therefore has been suggested as the proxy for the Heat Index.

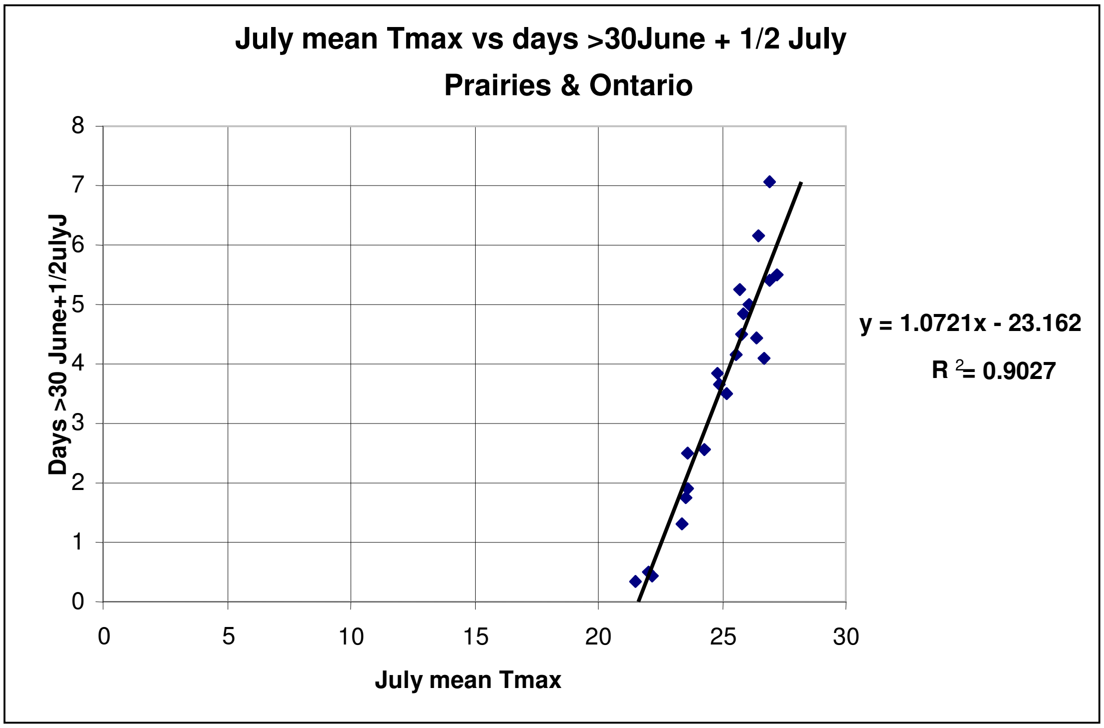

Figure 14. Relationship of Tmax to frequency of days > 30°C.

The mean maximum July temperature has been added to the LSRS database and days > 30°C is calculated as 1.072 (Tmax) – 23.162. Days over 30 has also been added to the climatic database.

Knowing that the temperature effect begins by 30°C (27°C has been suggested by Morrison and Stewart) and that a > 35°C temperature reduces yields by 6-8%/day, it is suggested that a 3%/day be used as a general “days > 30°C” proxy.

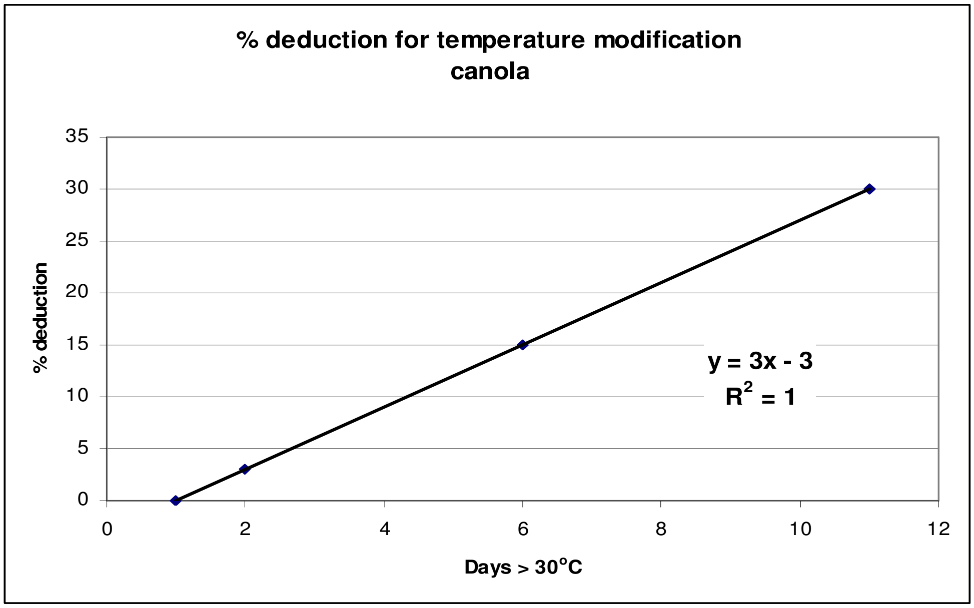

Figure 15. Percent deductions for temperature modifications for canola.

The percent deduction would be applied to the Basic climate rating (lowest of A or H) such that
Basic climate rating x ((100 - % deduction)/100)

Eg if basic rating = 50 and % deduction = 5
the final climate rating = 50 x (100 – 5)/100 = 50 x .95 = 47.5

2.2 Programming, Testing and Evaluation

The proposed changes were programmed into the canola crop model and the soybean crop model. The models were enabled in the LSRS program and the models run using NSDB databases to ensure functionality.

A new "install" CD was developed for interim testing purposes.

Canola ratings were then generated for a selected suite of SLC polygons across Canada. This was the same national set of SLC polygons that were used for the biomass project (Pettapiece and Tychon 2006) and for evaluating the corn model (Pettapiece et al. 2006). The results were compared to ratings for small grains and visually inspected to identify any anomalies (a test of reasonableness).

3 RESULTS AND DISCUSSIONS

3.1 Canola Crop Model

Initial review of ratings (Table 2) indicated that the program was responding as planned. The Heat Index reducing ratings where temperatures were predicted to exceed 30^{o}C during flowering and there was an increase in the surface structure (surf D) deduction in areas where tilth concerns were anticipated. The ratings are generally only slightly lower than those for small grains and would not cause a change in suitability Class unless near a class boundary. An exception might be for the HI reduction, but this is usually associated with moisture limitations and is generally not the limiting factor.

The comparison to small grains for a range of conditions across Canada (Table 3) indicates similar ratings in all cases. There are some differences in number ratings (Table 2) but the polygon Classes are the same. This seems reasonable (see introduction) and was anticipated to be the case for all except extreme situations.

3.2 Programming, Testing and Evaluation

The programming was completed and enabled.

Initial testing noted a couple of problems, one with previous programming. These were successfully corrected before general model testing.

General testing was accomplished using both batch mode and individual SLC runs for canola as well as small grains and corn. All worked as expected.

A new “Install” CD was created for comprehensive testing.

Table 2. Comparison of climatic and selected soil ratings for small grains, canola, corn and soybeans for selected SLC polygons across Canada

SL#	Crop	deduction				Climate rating	deduction		Soil rating
		P-PE	EGDD	CHU	H I		M	Surf D	
Kentville, NS 518004 (soil 1)	Small grains	0	0	-	-	100	44	10	34
	Canola	0	0	-	6	94	44	13	31
	Corn	19	-	47	-	53	64	10	15
	Soybeans	9	-	47	-	53	54	13	21
Ottawa, ON 565022 (soil 2)	Small grains	12	0	-	-	88	41	0	55
	Canola	12	0	-	13	75	41	0	55
	Corn	32	-	3	-	68	56	0	40
	Soybeans	22	-	3	-	78	49	0	47
Saskatoon, SK 736008 (soil 1)	Small grains	29	21	-	-	71	36	0	61
	Canola	29	21	-	6	65	36	0	61
	Corn	49	-	66	-	34	56	0	41
	Soybeans	39	-	66	-	34	46	0	51
Prince George, BC 982044 (soil 3)	Small grains	20	50	-	-	50	16	10	64
	Canola	20	50	-	0	50	16	12	54
	Corn	40	-	90	-	10	32	10	42
	Soybeans	30	-	90	-	10	24	12	47

P-PE = precipitation – potential evapotranspiration (aridity index),
EGDD = effective growing degree days (GDD>5^{o}C modified for daylength)
CHU = crop heat units, HI = heat index (canola deduction)
M = moisture deduction recognizing climate and soil water supplying capacity
Surf D = adverse surface structure (poor tilth, crusting)

Table 3. Comparison of LSRS ratings for small grains, canola, corn and soybeans for selected SLC polygons across Canada.

Prov.	area	SL#	LSRS - Small Grains	LSRS - Canola	LSRS - Corn
	Fort St John	581008	7WV(10)	7WV(10)	7WV(10)
	Fort St John	585015	4DT(6) - 6W(4)	4DT(6) - 6W(4)	6HDT(6) – 6HW(4)
	Prince George	982044	3HT(7) - 6M(3)	3HT(7) - 6M(3)	6HA(7) – 7M(3)
	Prince George	982041	3HT(8) - 6MT(2)	Missing climate data	6HT(8) – 7MT(2)
BC	Penticton	1007020	6MT(5) - 7MTN(4) - 4W(1)	6MT(5) - 7MTN(4) - 4W(1)	6MT(5)-7MTN(4) - 4AHW(1)
	Penticton	1007019	6MTD(8) - 6MT(2)	6MTD(8) - 7MT(2)	6MTD(8) – 7MT(2)
	Lower Fraser	959004	6W(10)	6W(10)	6W(10)
	Lower Fraser	959011	7WV(10)	7WV(10)	7WV(10)
	Lower Fraser	959019	2T(4) - 3M(4) - 7V(2)	2T(4) - 3M(4) - 7V(2)	4HA(6) – 5MT(2) – 7V(2)
	Foremost	828012	4MT(9) - 6M(1)	4MT(9) - 6M(1)	5MT(10)
	Vulcan	793001	2M(10)	2M(10)	5HA(10)
	Neutral	771005	3MT(9) - 5W(1)	3MT(9) - 5W(1)	5MT(9) – 5W(1)
	Wetaskiwin	727011	3H(5) - 3HM(4) - 5W(1)	3H(5) - 3HM(4) - 5W(1)	5H(5) – 5HM(4) – 5HW(1)
AB	Lloydminster	729003	2HM(8) - 5W(2) - 5M(1)	2HM(8) - 5W(2) - 4M(1)	5HM(8) – 5W(2) – 5M(1)
	Camrose	731002	3D(9) - 5W(1)	3D(9) - 5W(1)	5HAD(9) – 5W (1)
	La Corey	680002	3H(9) - 5W(1)	3H(9) - 5W(1)	6H(9) – 6HW(1)
	Grande Prairie	599001	3H(8) - 4N(1) - 5W(1)	3H(8) - 4N(1) - 5W(1)	6H(8) – 6HN(1) – 6HW(1)
	Clairview	591027	3H(9) - 5W(1)	3H(9) - 5W(1)	6H(9) – 6HW(1)
	High Level	586001	3(8) - 6W(2)	3(8) - 6W(2)	6H(8) – 6HW(2)
	Regina	792004	3M(9) - 5W(1)	3M(9) - 5W(1)	4M(9) – 5W(1)
	Saskatoon	736008	2M(9) - 5W(1)	2M(9) - 5W(1)	4HM(9) – 5W(1)
SK	Melfort	705005	2(9) - 5W(1)	2(9) - 5W(1)	5HA(9) – 5W(1)
	Meadow Lake	680012	3H(9) - 4MV(1)	3H(9) - 4MV(1)	6H(9) – 6MV(1)
	B topo	820002	4MT(10)	4MT(10)	5MT(10)
	C topo	810003	4MT(9) - 5W(1)	4MT(9) - 5W(1)	6MT(9) – 5W(1)
	Sandy (Black)	742002	5M(8) - 3M(2)	5M(8) - 3M(2)	6M(8) – 4HM(2)
		709007	3(5) - 2H(4) - 5W(2)	3(5) - 2H(4) - 5W(2)	5HA(5) – 5HMD(4) – 5W(2)
		717004	7WB(6) - 4DMP(4)	7WB(6) - 4DMP(4)	7WB(6) – 5DMP(4)
MB		724008	4DW(6) - 5W(3) - 6MD(1)	4DW(6) - 5W(3) - 6MD(1)	4DMV(6) – 5M(3) – 7M(1)
		763001	5MD(7) - 5W(2) - 3W(1)	5MD(6) - 4M(2) - 5W(2)	6MD(6) - 4M(2) - 5W(2)
		849009	2W(6) - 5W(4)	2W(6) - 5W(4)	3HAW(6) – 5W(4)
		854002	1(6) - 2(3) - 5W(1)	1(6) - 2(3) - 5W(1)	4HA(9) – 5W(1)

Table 3 continued

Prov.	area	SL#	LSRS – Small Grains	LSRS - Canola	LSRS - Corn
ON	Chatham	565022	3(5) – 5W(5)	3(5) - 5W(5)	3M(5) – 5W(5)
	Guelph	564005	4TP(5) - 7WVB(3) - 4VT(2)	4TP(5) - 7WVB(3) - 4VT(2)	4TMP(5) – 7WBV(3) – 4VMT(2)
	Ottawa	545001	6VWT(7) – 2T(3)	6VWT(7) – 2T(3)	6VWT(7) – 2MT(3)
	Ottawa	543005	3M(4) - 4M(3) – 7WV(3)	3M(4) - 4M(3) – 7WV(3)	4M(4) – 5M(3) – 5WV(3)
	Ottawa	543009	6WV(7) – 2TM(2) – 4MT(1)	6WV(7) – 2TM(2) – 4MT(1)	6WV(7) – 3MT(2) – 5MT(1)
	Ottawa	545004	3DW(9) – 3TM(1)	4MDW(9) – 3TM(1)	4MDW(9) – 4MT(1)
QU	Montreal	541011	3W(10)	3W(10)	3W(10)
	Quebec City	540102	4PT(7) - 3(3)	4PT(7) - 3(3)	4PMT(7) – 4M(3)
	Chicoutimi	441007	3HDT(10)	3HDT(10)	5HD(10)
	poorly drained	540098	5W(7) - 4DW(3)	5W(7) - 4DW(3)	6W(7) – 4DW(3)
	Imp. drained	540074	3DW(6) - 5W(4)	3DW(6) - 5W(4)	4MDW(6) – 6W(4)
	Organic	541053	7WVB(10)	7WVB(10)	7WVB(10)
NB	Caribou	494001	2T(6) - 5DW(2) - 6WT(2)	2T(6) - 5DW(2) - 6WT(2)	3HT(6) – 5DW(2) – 6WT(2)
	Siegas	493002	2(6) - 3W(3) - 7W(1)	2(6) - 3W(3) - 7W(1)	4H(8) – 6MPV(1) – 7W(1)
	Thibault	486011	3HT(8) - 3TW(1) - 7WTJ(1)	3HT(8) - 3TW(1) - 7WTJ(1)	5HT(8) – 5HTW(1) - 7WTJ(1)
	Belldune	485001	3WT(6) - 6W(3) - 3M(1)	3WT(6) - 6W(3) - 3M(1)	4HTW(6) – 6W(3) – 5M(1)
	Tormentine	504033	3W(9) - 6W(1)	3W(9) - 6W(1)	4W(9) – 6W(1)
	King	503024	5DTW(6)-3TD(3)-6WTD(1)	Missing climate data	5DTW(6) – 3TDM(3) - 6WTD(1)
NS	Kentville	518004	4MT(8) - 6MDT(2)	3MT(8) - 6MDT(2)	6MT(6) – 4MT(4)
	Kentville	518005	3T(9) - 7W(1)	NO SOIL DATA	NO SOIL DATA
	Truro	517006	6W(7) - 3WTD(3)	Missing climate data	6W(7) – 3WTD(3)
	Truro	507003	3DT(8) - 6WD(2)	Missing climate data	4DTM(8) – 6WD(2)
	Sydney	523003	4DTW(10)	4DTW(10)	4HTD(10)
	Sydney	523004	6W(9) - 3DT(1)	6WD(9) - 3DT(1)	6W(9) - 4HTD(1)
PE		535001	3DT(8) - 5DV(1) - 7WD(1)	3DT(8) - 5DV(1) - 7WD(1)	4DTM(8) – 6DVM(1) - WD(1)
		536003	3DT(7) - 6W(2) - 5DV(1)	3DT(7) - 6W(2) - 5DV(1)	4MTD(7) – 7W(2) - 6DVM(1)
		537003	3T(6) - 3DT(4)	3T(6) - 3DT(4)	3MT(6) – 4DTM(4)
NL	Codroy Valley	463013	4TVP(10)	4TVP(10)	6HTV(10)
	Codroy Valley	463011	5TVP(7) - 7WT(3)	NO SOIL DATA	NO SOIL DATA
	Central	471012	4HTV(6) - 7WT(4)	NO SOIL DATA	NO SOIL DATA
	Central	466043	4TVP(6) - 7WV(4)	4TVP(6) - 7WV(4)	5HTV(6) – 7WV(4)
	St Johns	475007	4DTV(10)	4DTV(10)	5HTD(10)
	St Johns	471017	5HPV(10)	Missing climate data	5HPV(10)

4. CONCLUSIONS

1. The LSRS program has been modified to accommodate a canola crop model and some alternate climate inputs.
2. A Heat Index for canola has been calculated from 61-90 normals and attached to SLC polygons along with the EGDD and P-PE indices.
3. A new “Install” CD for LSRS 3.0 has been created and is included to support suitability testing for canola and soybean as well as small grains and corn.
4. All procedures are documented

5. ADDITIONAL COMMENTS

- The LSRS 3.0 test program, as presently implemented, only operates with NSDB data (associated with the national SLC ver.3 map)
  - i.e. it does not run on AGRASID or site data
- The LSRS 3.0 program can operate in batch mode (with an SLC link) or interactively with national SLC map.
- It was not part of this contract, but it is suggested that future consideration be given to expanding the program to accommodate other climate models (years etc.) similar to the crop models, in order to support climate change scenarios.
  This modified LSRS program appears well positioned to evaluate agricultural responses to climate change.
- It is suggested that a specified agency (perhaps the National Agroclimatic Information Centre) should be asked to take responsibility for the development and maintenance of the climate databases.

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APPENDIX 7. ALFALFA CROP MODEL CONSIDERATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDMENTS

The author would like to acknowledge and thank the many people who offered frank comments and advice at various stages of the forage initiative: particularly Jane Thornton, Manitoba Forage Specialist, and Dr. Bruce Coulman, University of Saskachewan.
Thanks also to J.A. Brierley for expediting and supporting the project.

GENERAL REPORT INTRODUCTION

There were four aspects to this phase:

1. Reviewing the climate, soil and landscape requirements for legume (alfalfa) forage production.
2. Adding to the climate database Growing Degree Days over 5^{0}C (GDD) and a Growing Season Length defined by the time greater than 5^{0}C (GSL).
3. Modifying the LSRS program to reflect alfalfa requirements.
4. Testing to ensure the modified program operated properly in response to the above modifications.

The program will be limited to operations using the national Soil Landscapes of Canada (SLC) - National Soils Database (NSDB).

It should be noted that the testing referred to here is the operation of the program and not necessarily the correctness of the capability rating for alfalfa and brome-timothy. The latter will more properly be evaluated by the LSRS Sub-project Working Group (AAFC and Provincial partners)

Note:
1. Since this report was written, the forage ratings have been converted to a new climate base.
   - using a longer growing season (GDD>5^{0}C and growing season length.
2. The test results in this report were based on an EGDD proxy (see Appendix 3)

1. INTRODUCTION

Both grasses and legumes are used as forages (McCartney and Horton 1997). The various species are adapted to such a large range of climatic and soil conditions that a single rating would be rather meaningless. On the other hand, to attempt to accommodate all the represented niches would result in an irresponsible number of specific ratings that would not support general land use planning. It is recognized that a general rating would not address the concerns of a forage specialist who deals with site-specific conditions (J. Thornton[6] pers. comm..), however it was felt that the main objective of a suitability rating that was initially to use the 1:1M soil Landscapes of Canada database (or 1:100,000 regional data) should be to support regional land use planning rather than site-specific decision making.

With the above arguments in mind, it was decided that two general categories of forages with somewhat different climatic and soil requirements should be recognized; namely legumes and grasses. Alfalfa (Medicago sativa L.) which is the most widely grown legume in Canada was chosen as a surrogate for that group. For the grass group, timothy (Phleum pretense L.) was chosen as the surrogate for eastern and central Canada and brome (Bromus inermis Leyss.) for western Canada.

It should be noted that the LSRS system could be modified to address any number of site-specific situations. It is the presumed objective of a general lands use objective that predicates the present decision of two categories.

Many annual crops (grains and pulses) are also used for forage, but the emphasis here is on the perennial crops. The main difference is that the perennial crops, with no concerns for annual seeding or for frost damage to grain, have a longer growing season. This extended season is assumed to be the period with mean daily temperatures above 5^{o}C (Bootsma and Boisvert 1991)

Another critical difference is that forages are not restricted to a single “harvest”. Depending on the season length, there can be one, two or even three or four cuts. This makes the forage rating fundamentally different from those for single-crop grains and oil seeds and they should not be directly compared - especially at a regional or local level. For example, at the west coast, long seasons and adequate moisture commonly allow for three cuts of forages but may not have the heat requirements for corn and soybeans.

Season length is correlated fairly well with accumulated Growing Degree Days (GDDs) for the range of 800 to 1600 GDD (Figure 1) with an R^2 of 0.63 (not shown). However in the coastal regions with extended growing seasons, the relationship breaks down. This situation required the introduction of season length as an independent climatic variable.

[6] J. Thornton, Government of Manitoba Forage Specialist. Brandon, MB.

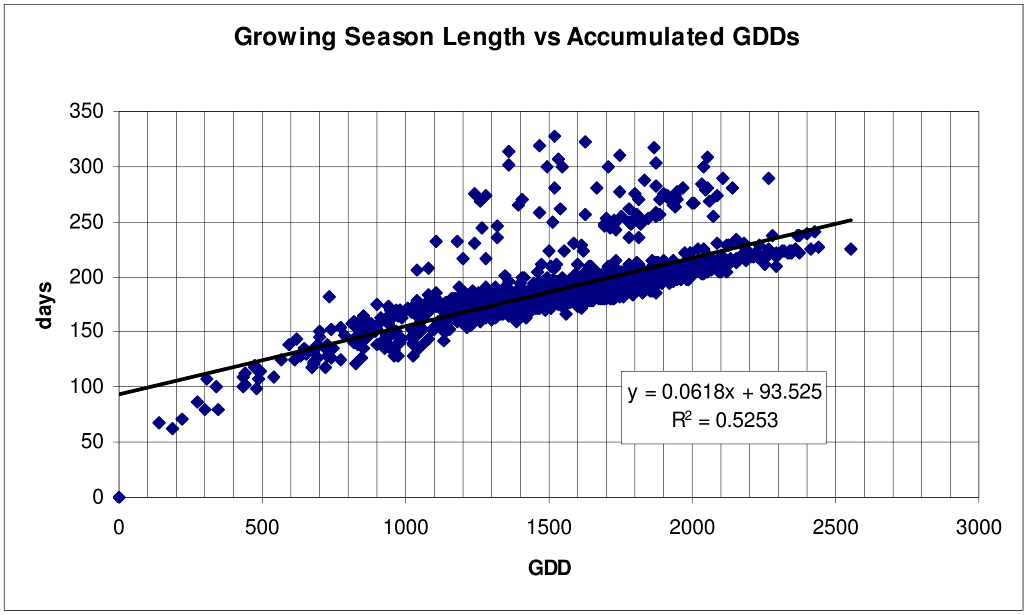


Figure 16. Growing season length vs accumulated GDDs (based on 61-90 station data).

Note: all stations with growing season >230 days are located on the west coast.

2. ACTIVITIES

2.1 Legumes – Alfalfa Crop Model

2.1.1 Introduction

Alfalfa, like other crops is limited by climatic and soil constraints. In general, it responds positively to increases in temperature and increases in moisture availability up to the point of decreasing oxygen supply in the rooting zone (impeded drainage) (Undersander et al. 1991).

The main soil constraint is a sensitivity to low pH (Goplin et al. 1987). The LSRS landscape rating is a recognition of erosion potential and workability or management constraints (slope steepness , stoniness) both of which are of a lesser concern for the management of forages than for annual crops.

2.1.2. Climate Requirements/Ratings

<u>2.1.2.1 Heat Requirement / Rating</u> (LSRS Section 3.2, Figure 3.2)

According to Bootsma and Boisvert (1991) it requires about 480 GDDs (Growing Degree Days > 5°C) to produce a first cut of alfalfa and one should allow for about 450 GDDs for crop carryover requirements. Therefore the minimum heat requirement for alfalfa is about 930 GDDs. This was considered the “marginal” requirement or the Class4-5 boundary. The minimum requirement for Class 1 was taken as the ability to support 3 cuts per year. This translates into (3 x 480) + 450 = 1890 GDDs. The ability to support two cuts per year, ((2x480) + 450 = 1410 GDDs) should be in Class 3. The ability to produce one cut with no carry over (480 GDDs) should represent the Class 5-6 boundary. The maximum deduction was set at 90 points.

Based on the above considerations, deductions were assigned as follows:

Table 1. Point deductions assigned to GDDs for alfalfa.

GDD	Class description	Point deduction
480	Class 5-6 boundary	80
930	Class 4-5 boundary	70
1410	Lower part of Class 3	50
1890	Bottom of Class 1	20

The Alfalfa climatic temperature (heat) factor then becomes (Figure 2):

Deduction = 89.02 + 0.0067(GDD) – 0.000016(GDD)(GDD)

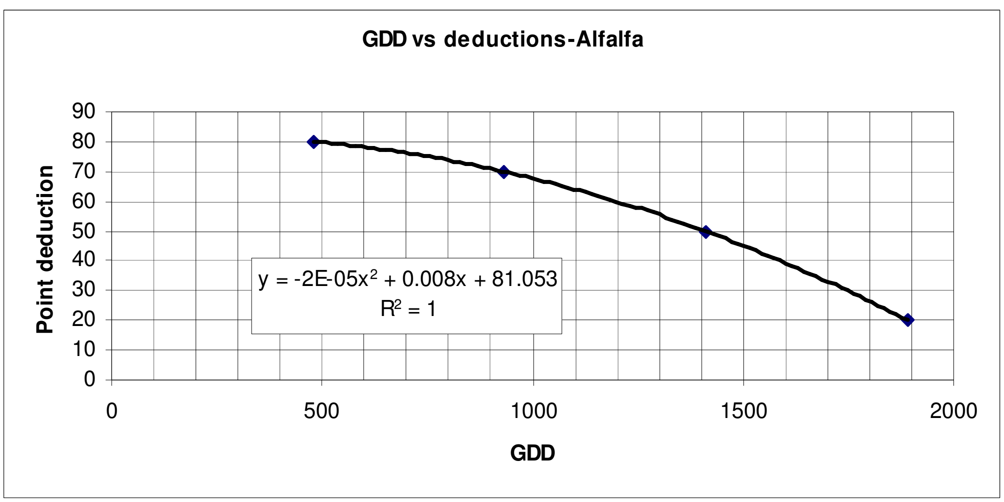


Figure 17. Accumulated Growing Degree Days >5°C vs point deductions for alfalfa.

2.1.2.2 Length of Growing Season Requirement / Rating

Length of season requirements were established using monthly climatic data and the GDD requirements from the previous section for one, two and three cuts of alfalfa. Bootsma and Boisvert (1991) suggest a minimum of 45 days between cuts.

Table 3. Estimated days for alfalfa cuts.

Cut	GDD	Est. days
1	480	65
2	480	45
3	480	45
carryover	450	55

Note that the beginning and end of season, spring and fall, take longer to accumulate heat units due to lower temperatures. Coastal British Columbia, with lower temperatures, particularly in the winter season, takes up to 20 days longer for both spring and fall but more than compensates with the longer growing season so is not limited in this respect.

Based on the above, the number of days per cut are estimated as follows:

- One cut = 65 + 55 = 120 days
- Two cuts = 65 + 45 + 55 = 165 days
- Three cuts = 65 + 45 + 45 + 55 = 210 days

Using the same considerations as for temperature requirements, the season length is assessed as:

Table 4. Point deductions assigned to growing season length for alfalfa.

Cut	days	Class description	Point deduction
1 – no carryover	65 days	Class 5-6 boundary	80
1 - carryover	120	Class 4-5 boundary	70
2	165	Lower part of Class 3	50
3	210	Bottom of Class 1	20

The growing season factor for alfalfa becomes (Figure 3):

Point deduction = 72.052+ 0.2889(GSL) -0.0026(GSL)(GSL)

(where GSL = growing season length in days)

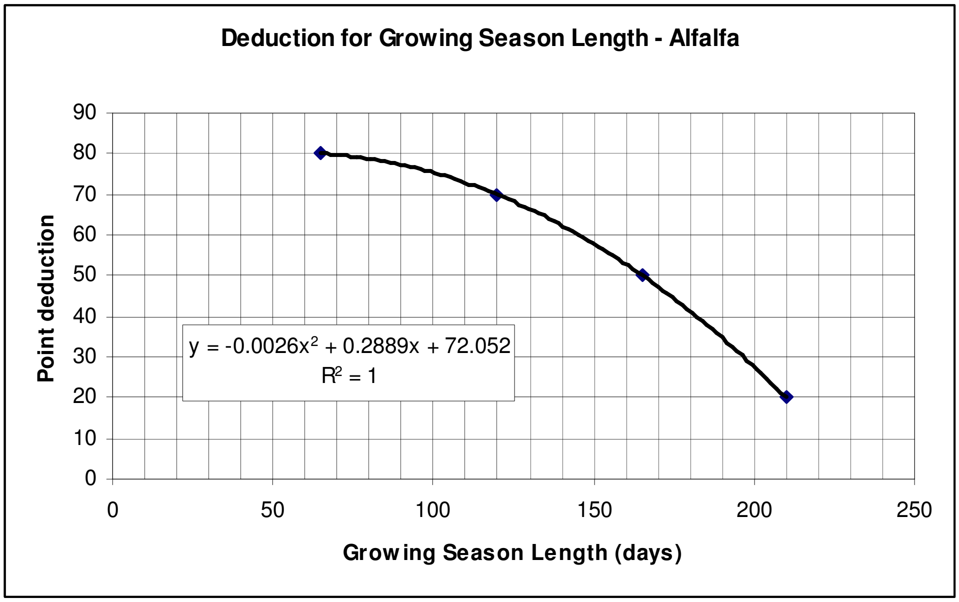


Figure 18. Deduction for growing season length for alfalfa

The heat rating or temperature factor (H) will be the most limiting of the GDD and GSL. For alfalfa, these two values are quite close with the controlling factor generally being GDD in the shorter season and cooler areas (<1600 GDD) and GSL in the longer season and or warmer areas (>2000 GDD).

The above is the recommended approach for temperature requirements for alfalfa. However, this requires new climatic parameters that are not in the present database: namely GDD for the period >5°C and the growing season length represented by that period. It is felt that evaluations of climate change will consider a Biometeorological Time Scale (BMTS) which will use the >5°C growing season. When the BMTS approach is ready for implementation, the above characteristics can be included in the LSRS program. In the meantime, it was felt that a proxy using present climatic parameters should be attempted.

2.1.2.3 Moisture Requirement/Rating (LSRS Section 3.1, Figure 3.1)

Bootsma and Boisvert (1991) in evaluating the FORYLD forage model described the Moisture Stress Factor (MSF) in terms of average moisture deficit (D) such that:

$D = P + \theta i - PE$

Deficit (surplus) = precipitation + soil moisture– potential evapotranspiration

Or $D = (P - PE)$ + soil moisture.

The P-PE is the same factor as that used for small grains except that it is calculated for the longer season forage season. Adding the soil moisture component makes it equivalent to the M factor used in the LSRS soil component.

As with the heat component, a comparison was made of the standard (May – Aug) P-PE used in the small grains assessment and the longer season (May – Sept) P-PE suggested for forages (Figure 4). The comparison involved over 2000 stations across Canada and again, there was a very good correlation (R^2 = 0.9839. With the good correlation it seemed reasonable that, with conversion, the present P-PE index could be used for forages.

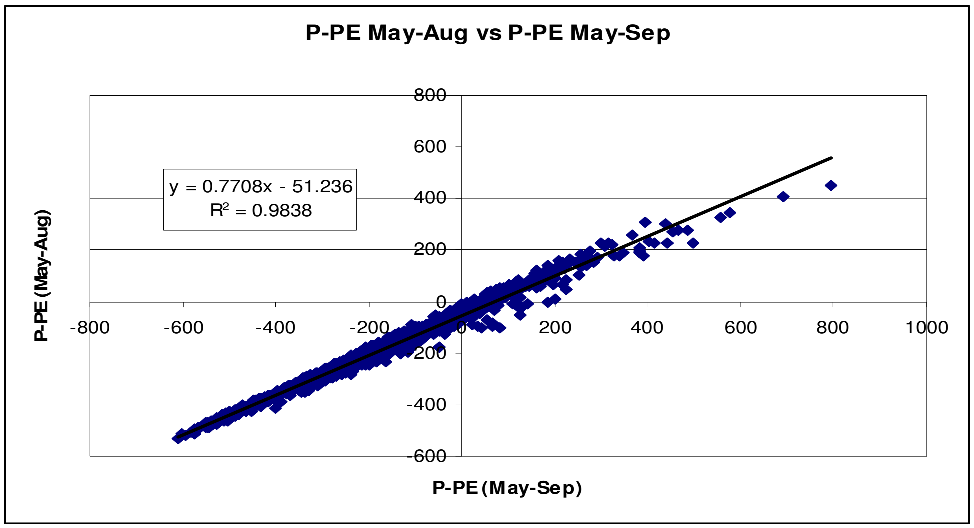


Figure 19. Comparison of P-PE (May toAug) to P-PE (May to Sep).

The next step, that of assigning limits and deductions, followed the same process as for other crops.

It was felt that a yield of about 2.5 t/ha would represent the lower practical limit (Class 4-5 boundary, 70 point deduction) of forage production. This is the average yield for a loam soil in the Brown Soil Zone in western Canada (Bootsma et al. 1995) and approximates the limit of present forage production. This is essentially the same as for small grains and it is suggested that the same value of P-PE, that is -500, should represent a 70 point climate deduction.

For the soil component (M) that translates into a 70 point deduction (Class 5) for a sandy loam soil at a P-PE = -400 (The Brown Soil Zone).

As an approximation of the upper limit (Class 1) a comparison was made of potential to actual yields as noted by Bootsma and Boisvert (1991) and Bootsma et al (1994) (Table 4).

Table 5. Potential and actual alfalfa yields and climatic and soil for selected research sites.

	Alfalfa yield		% yield	P-PE[1]	Soil	LSRS[2]	P-PE[1]	LSRS[2]
location	potential	rain fed	reduction	May-Sep	AWC	M factor	May-Aug	M factor
Charlottetown	12.7	9.2	27	-39	150	0	-72	0
Ottawa	14.1	10.0	30	-171	130	10	-182	12
Ridgetown	17.5	12.7	26	-220	200	15	-208	12
Swift Current	15.0	3.8	75	-362	150	60	-325	45

[1] from 51-80 climate data provided by A. Bootsma

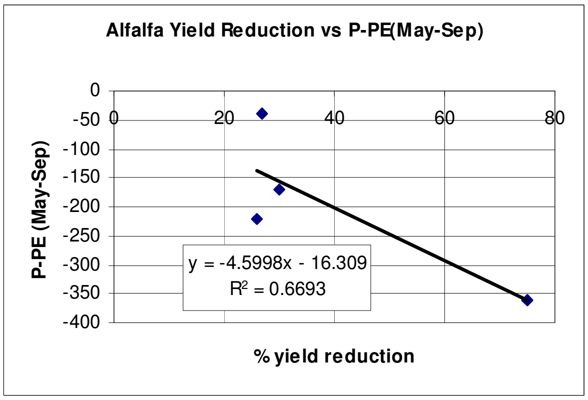
[2] calculated from LSRS manual

Using the premise Yield (actual) = Yield (potential) x MSF (moisture stress factor), it was assumed that those areas with little difference between potential and actual yields should have low moisture deficit constraints. Conversely, those with large differences (keeping the soil component similar) should be the result of high moisture stress.

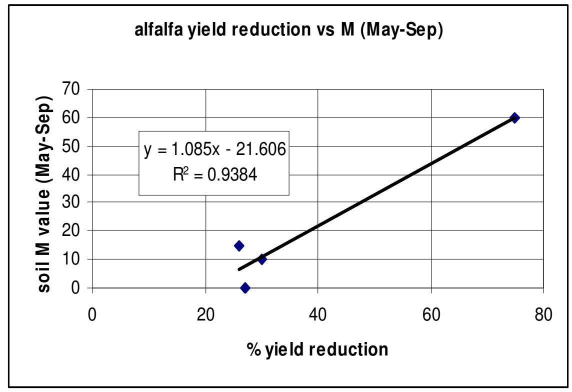
The number of controls is small but the trends support the argument (see Appendix 1 for correlation support). The correlation for yield reduction in alfalfa vs P-PE(may-Sep) (Fig 5 a) has an R^2 = 0.6693. This is not high but it does not take into account soil water holding capacity (WHC). The M factor of the LSRS soil component combines P-PE with WHC and when this is compared to yield reduction (Fig 5 b) the R^2 is 0.9384 which is quite good.

The comparative values for P-PE (May-Aug) and associated LSRS-M values(Fig 5 c, d) are 0.681 and 0.9209 which are very close to the first set and support the close correlation between P-PE (May –Sep) and P-PE (May-Aug).

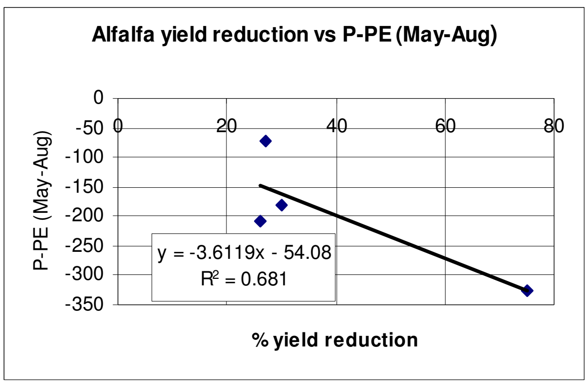
The above relationships appear to be reasonable and suggest that the present P-PE deductions as used for small grains are also appropriate for alfalfa.



a)



b)



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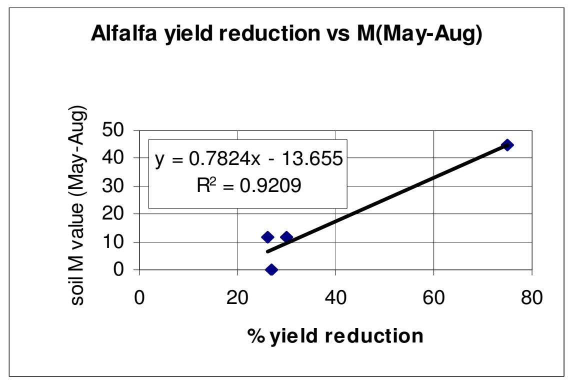

d)

Figure 20. The relationship of alfalfa yield reduction to P-PE and LSRS-M values.

2.1.3 Soil Requirements/Ratings

2.1.3.1 Soil Moisture Factor (M) Requirement/Rating

As there was no change suggested for the climatic moisture index, there is no change required for the soil moisture factor.

2.1.3.2..Surface Soil Reaction (pH) Requirement/ Rating (LSRS Section 4.2.4, Table 4.6)

As indicated in the introduction, alfalfa is sensitive to acidic conditions (low pH). There are two aspects. First, pH values below 6.0-6.5 increasingly inhibit the functioning of rhizobium bacteria (McKenzie 2005). Secondly, at pHs below about 5.5, aluminum ions, which affect root elongation, are released into the soil solution (Rechcigl et al. 1988, Kochian 1995). Both of these features have a marked effect on alfalfa productivity.

Undersander et al. (1991) suggest that yields at a pH of 5 would be less than one third of those expected at a pH of 6.5 (Figure 6).

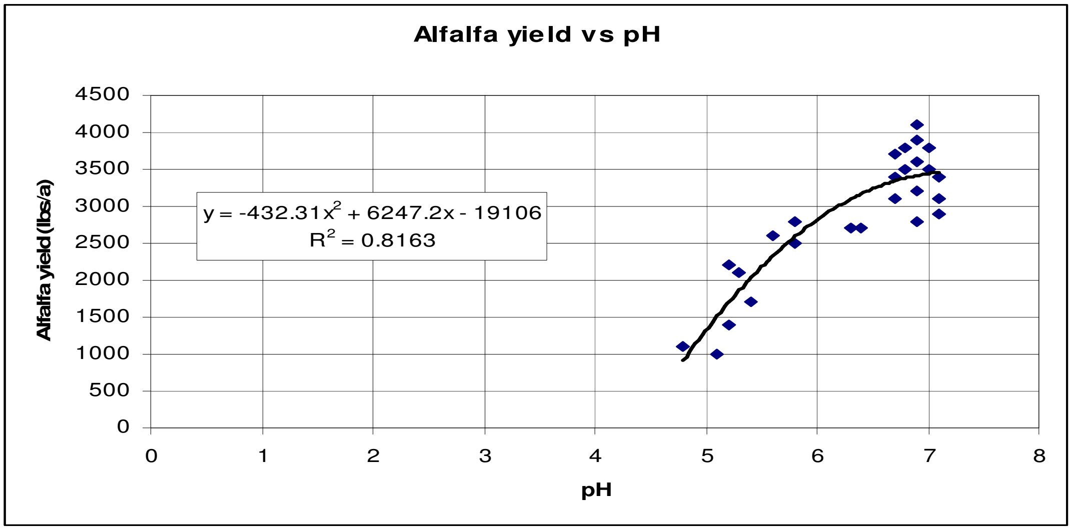

Figure 21. First cutting alfalfa yield relative to soil pH (from Undersander etal. 1991).

It is generally reported that ideal pH for alfalfa is between 6.5 and 7.5 (Goplin et al. 1987, Undersander et al. 1991). Therefore a pH of 6.5 was taken as no limitation and assigned a 0 point deduction. It appears that a pH of about 5 is becoming marginal for alfalfa and this value was assigned a deduction of 70 points deduction. If we assume a pH of 6.0 is Class 2 (and a 20 point deduction) and that a pH of 5.5 is Class 3 (a 40 point deduction) then the alfalfa – pH relationship for surface soils (Figure 7) becomes:

Point deduction = 624.5 – 161(pH) + 10(pH)(pH)

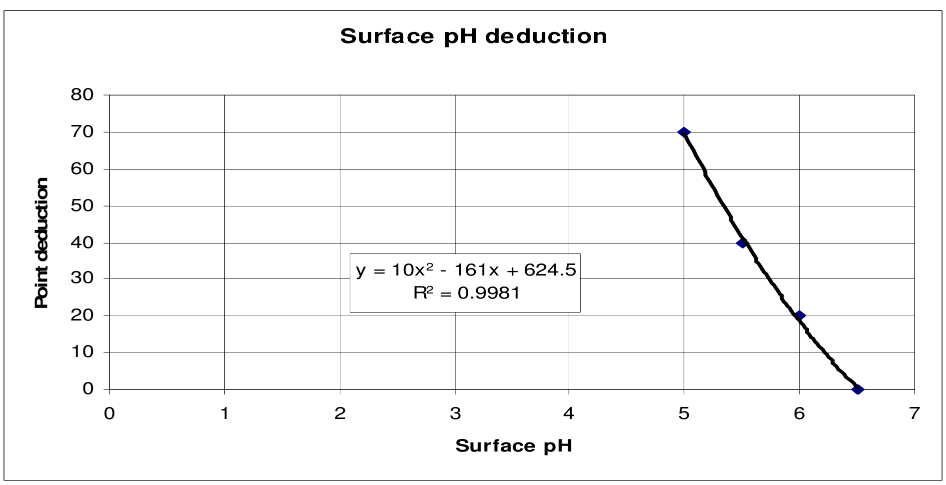

Figure 22. Point deductions for surface soil pH.

This formula is only applied where pH <= 6.5

2.1.3.3 Subsurface Soil Reaction (pH) Requirement/ Rating
(LSRS Section 4.3.3, Table 4.15)

Subsurface acidity can still be a problem as it can restrict root growth and therefore moisture availability. The following relationship (Fig 8) is suggested.

Percent deduction = 687 – 207.86 (pH) + 15.714 (pH)(pH)

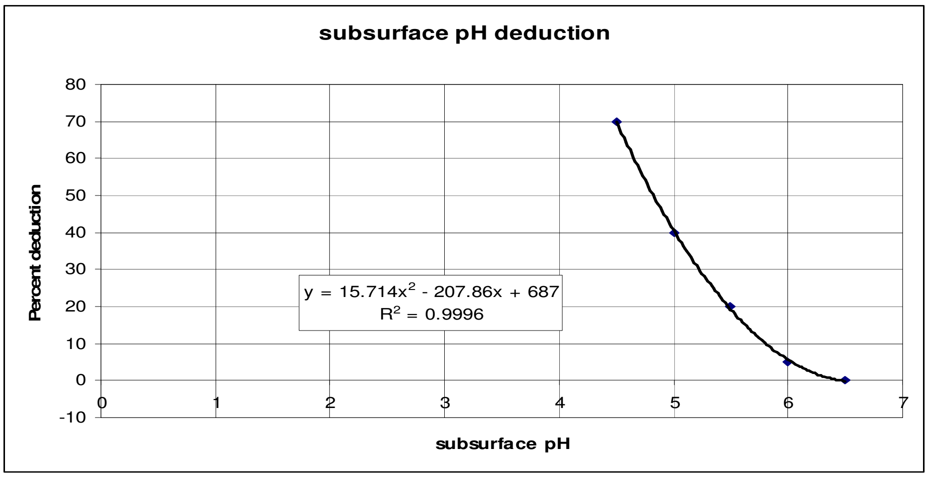

Figure 23. Percent deductions for subsurface pH.

This formula is only applied where pH <= 6.5

Note that deductions are made for the subsurface **only** if they are greater than the deduction for surface acidity.

No other modifications are suggested for mineral soils.

2.1.4 Landscape Requirements/Ratings

Landscape parameters are not as critical for forages as for annual crops. Erosion is much reduced with the continuous cover of perennial crops so slope steepness is important only as a limitation for haying (and silage) machinery. Stoniness is still a concern from a machinery perspective though perhaps not as critical at the lower stoniness classes. Gravel is not an issue from a landscape (management) perspective.

With the above in mind, the following relationships are suggested (Figures 9 and 10).

2.1.4.1 Basic Landscape Rating (slope steepness) (LSRS Section 6.1, Figures 6.2, 6.3)

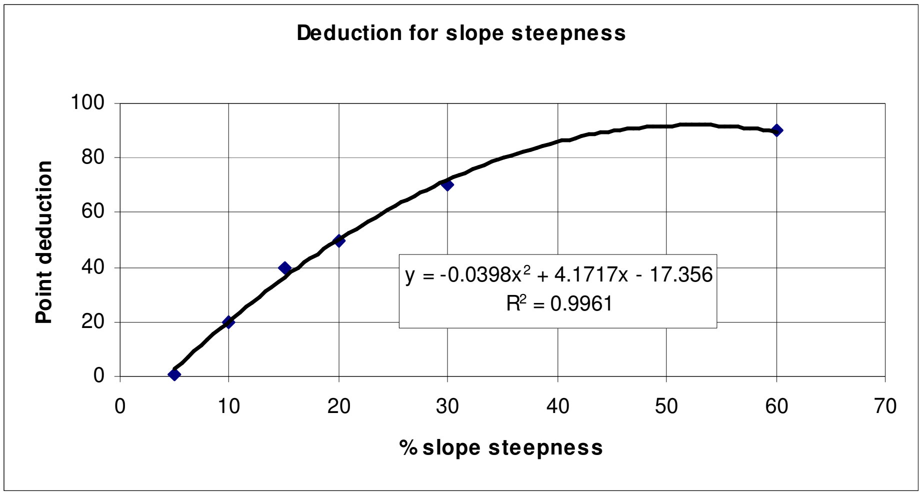

Figure 24. Point deductions for slope steepness.

Point deduction = – 17.356 + 4.1717 (% slope) -0.0398(% slope)(% slope)

This should apply to all regions and landform types.

2.1.4.2 Stoniness (LSRS Section 6.2.1, Figure 6.4)

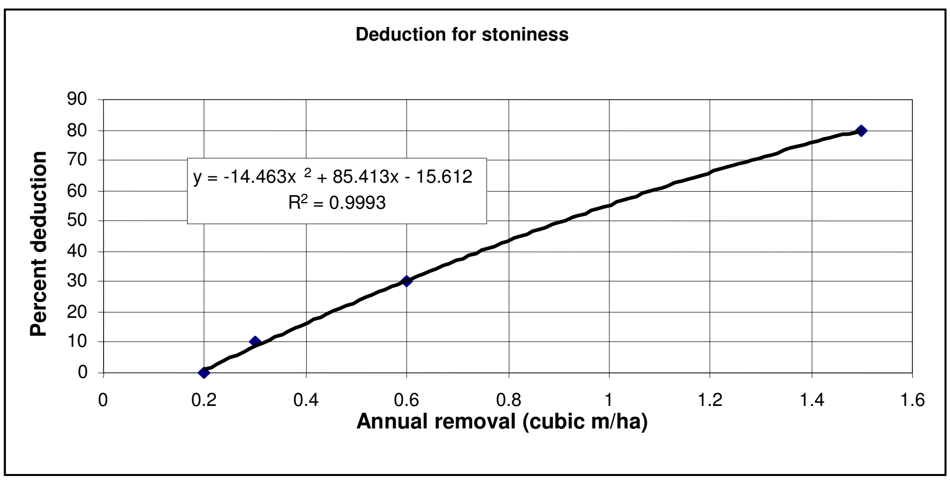

Figure 25. Percent deductions for stoniness.

Percent deduction = – 15.612 + 85.413 (annual removal) -14.463(annual removal)^2

See Appendix 2 for stoniness rating conversion to annual removal rate.

2.1.5 Organic Soil Requirements Ratings

Organic soils are often used for forage production. There are some slight differences in specific suitability criteria but overall these do not appear to be major enough to change the rating from that of small grains.

The water supplying ability and drainage relationships should remain the same. The surface structure-seedbed issue may not be as critical for perennial crops but the workability component remains. The pH effect is not as severe because the Al toxicity component is reduced but the nutrient supply and rhizobium issues remain.

3. RESULTS AND DISCUSSIONS

In the introduction, it was stressed that forages are not directly comparable to single-harvest crops. However, comparisons are inevitable and can be useful for pointing out differences as well as concurrences. With this in mind, the small grains ratings were used to evaluate initial forage ratings.

3.1 Alfalfa Crop Model

Two sets of data were used to test the general application of the Alfalfa crop model: the standard SLC set used for testing the previous crop models (Table 3) and an abbreviated set to test for extreme conditions (Table 9).

Initial review of ratings (Table 9) indicated that the program was responding as planned. The alfalfa ratings were very similar to the brome-timothy ratings (and the small grain ratings) with one major exception: the sensitivity to pH (Table 9, Table 10). Anytime the pH drops below 6.5, Alfalfa is affected. At a pH of 5.9 (Table 10) the deduction is 22 points or at least 1 class. At a pH of 4.95 it is 73 points as compared to 17 points for the grasses. The fact that the SLC database is often represented by virgin rather than managed (limed) soils makes the results look worse than may actually be the case.

As expected, with the relaxed landscape constraints, the T limitation is often not noted for the forages ratings. In those instances where T is the dominant limitation for small grains, this could result in a higher rating for the forages

All of the areas in Canada with greater than 1800 EGDDs have a growing season of at least 200 days (61-90 summaries). In British Columbia all have greater than the 210 minimum identified for a third cut of alfalfa. In central Canada, all those with greater than 2000 EGDDs have between 200 and 210 days. Even though a small portion of the country might be slightly below the length of season threshold, it is concluded that the use of the EGDDs is a reasonable proxy for the alfalfa temperature factor (H).

3.2 Programming, Testing and Evaluation

The programming was completed and enabled.

Initial testing noted a couple of problems. These were successfully corrected before general model testing.

General testing was accomplished using both batch mode and individual SLC runs for alfalfa and brome-timothy as well as small grains. All worked as expected.

A new “Install” CD was created (enclosed) for comprehensive testing.

Table 6. Comparison of LSRS ratings for small grains, brome-timothy and alfalfa for selected SLC polygons across Canada.

Prov.	area	SL#	LSRS - Small Grains	LSRS – Brome-timothy	LSRS – Alfalfa
BC	Fort St John	581008	7WV(10)	7WV(10)	7WV(10)
	Fort St John	585015	4DT(6) - 6W(4)	4DT(6) - 6W(4)	7VD(6) – 7WV(4)
	Prince George	982044	3HT(7) - 6M(3)	3H(7) - 6M(3)	4H(6) – 6MV(4)
	Prince George	982041	3HT(8) - 6MT(2)	Missing climate data	Missing climate data
	Penticton	1007020	6MT(5) - 7MTN(4) - 4W(1)	6M(6) - 7MTN(3) - 4W(1)	6M(6)-7MNT(3) - 4W(1)
	Penticton	1007019	6MTD(8) - 6MT(2)	6MTD(6) - 6MT(4)	7MTD(6) – 7MT(4)
	Lower Fraser	959004	6W(10)	6W(10)	7WV(10)
	Lower Fraser	959011	7WV(10)	7WV(10)	7WV(10)
	Lower Fraser	959019	2T(4) - 3M(4) - 7V(2)	2(4) - 3M(4) - 7V(2)	3V(4) – 5V(4) – 7VW(2)
AB	Foremost	828012	4MT(9) - 6M(1)	4M(9) - 6M(1)	4M(9) - 6M(1)
	Vulcan	793001	2M(10)	2M(10)	3HA(10)
	Neutral	771005	3MT(9) - 5W(1)	3MT(9) - 5W(1)	3MT(9) – 5W(1)
	Wetaskiwin	727011	3H(5) - 3HM(4) - 5W(1)	3H(5) - 3HM(4) - 5W(1)	4HM(5) – 4H(4) – 5W(1)
	Lloydminster	729003	2HM(8) - 5W(2) - 5M(1)	3HM(8) - 5W(2) - 4M(1)	4HM(8) – 5W(2) – 4M(1)
	Camrose	731002	3D(9) - 5W(1)	3HD(9) - 5W(1)	4VD(9) – 5W (1)
	La Corey	680002	3H(9) - 5W(1)	3H(9) - 5W(1)	4H(6) – 4V(3) - 5W(1)
	Grande Prairie	599001	3H(8) - 4N(1) - 5W(1)	3H(8) - 4N(1) - 5W(1)	4H(8) – 4V(3) – 5W(1)
	Clairview	591027	3H(9) - 5W(1)	3H(9) - 5W(1)	3H(9) - 5W(1)
	High Level	586001	3(8) - 6W(2)	3(8) - 6W(2)	7V(6(- 3H(2) – 6W(2)
SK	Regina	792004	3M(9) - 5W(1)	3M(9) - 5W(1)	3M(9) – 5W(1)
	Saskatoon	736008	2M(9) - 5W(1)	2M(9) - 5W(1)	3HM(9) – 5W(1)
	Melfort	705005	2(9) - 5W(1)	3H(9) - 5W(1)	3H(9) – 5W(1)
	Meadow Lake	680012	3H(9) - 4MV(1)	3H(9) - 4MV(1)	4H(9) – 7V(1)
	B topo	820002	4MT(10)	4M(10)	4M(10)
	C topo	810003	4MT(9) - 5W(1)	4MT(9) - 5W(1)	4MT(9) – 5W(1)
	Sandy (Black)	742002	5M(8) - 3M(2)	5M(8) - 3M(2)	5M(8) – 3HM(2)
MB		709007	3(5) - 2H(4) - 5W(2)	3H(9) - 5W(2)	3H(9) - 5W(2)
		717004	7WB(6) - 4DMP(4)	7WB(6) - 4DP(4)	7WB(6) – 4DP(4)
		724008	4DW(6) - 5W(3) - 6MD(1)	4DW(6) - 5W(3) - 6MD(1)	4D(6) – 5(3) – 6MD(1)
		763001	5MD(7) - 5W(2) - 3W(1)	5MD(6) - 4M(2) - 5W(2)	5MD(6) - 4M(2) - 5W(2)
		849009	2W(6) - 5W(4)	2W(6) - 5W(4)	3W(6) – 5WV(4)
		854002	1(6) - 2(3) - 5W(1)	3H(9) – 5W(1)	3H(9) – 5W(1)

Table 5 continued

Prov.	area	SL#	LSRS – Small Grains	LSRS – Brome-timothy	LSRS – Alfalfa
ON	Chatham	565022	3(5) – 5W(5)	3(5) - 6W(5)	3(5) – 6WV(5)
	Guelph	564005	4TP(5) - 7WVB(3) - 4VT(2)		
	Ottawa	545001	6VWT(7) – 2T(3)		
	Ottawa	543005	3M(4) - 4M(3) – 7WV(3)		
	Ottawa	543009	6WV(7) – 2TM(2) – 4MT(1)		
	Ottawa	545004	3DW(9) – 3TM(1)		
QU	Montreal	541011	3W(10)	3W(10)	3W(10)
	Quebec City	540102	4PT(7) - 3(3)	4P(7) - 3(3)	5VP(7) – 7V(3)
	Chicoutimi	441007	3HDT(10)	3HDT(10)	4HD(10)
	poorly drained	540098	5W(7) - 4DW(3)	5W(7) - 4DW(3)	6WV(7) – 6VDW(3)
	Imp. drained	540074	3DW(6) - 5W(4)	3DW(6) - 5W(4)	4VDW(6) – 6W(4)
	Organic	541053	7WVB(10)	7WVB(10)	7WVB(10)
NB	Caribou	494001	2T(6) - 5DW(2) - 6WT(2)	2H(6) – 5DW(2) - 6W(2)	3HV(6) – 6VDW(2) – 7W(2)
	Siegas	493002	2(6) - 3W(3) - 7W(1)	2H(6) - 3W(3) - 7W(1)	6V(7) – 3V(2) – 7WV(1)
	Thibault	486011	3HT(8) - 3TW(1) - 7WTJ(1)	3H(8) – 3HWT(1) - 7W(1)	5V(9) –7W(1)
	Belldune	485001	3WT(6) - 6W(3) - 3M(1)	3W(7) - 6W(3)	6V(7) – 7WV(3)
	Tormentine	504033	3W(9) - 6W(1)	3W(9) - 6W(1)	6V(9) – 7WV(1)
	King	503024	5DTW(6)-3TD(3)-6WTD(1)	Missing climate data	Missing climate data
NS	Kentville	518004	4MT(8) - 6MDT(2)	3M(8) - 6MD(2)	6MDV(8) – 4V(2)
	Kentville	518005	3T(9) - 7W(1)	NO SOIL DATA	NO SOIL DATA
	Truro	517006	6W(7) - 3WTD(3)	Missing climate data	Missing climate data
	Truro	507003	3DT(8) - 6WD(2)	Missing climate data	Missing climate data
	Sydney	523003	4DTW(10)	4DW(10)	6VD(10)
	Sydney	523004	6W(9) - 3DT(1)	6W(9) - 3D(1)	7WV(9) – 6V(1)
PE		535001	3DT(8) - 5DV(1) - 7WD(1)	3D(8) - 5DV(1) - 7WD(1)	7VD(8) – 5V(1) - 7WVD(1)
		536003	3DT(7) - 6W(2) - 5DV(1)	3D(7) - 6W(2) - 5DV(1)	7VD(6) – 5V(2) – 7WV(2)
		537003	3T(6) - 3DT(4)	2(6) - 3D(4)	6V(10)
NL	Codroy Valley	463013	4TVP(10)	4HVP(10)	7VPT(10)
	Codroy Valley	463011	5TVP(7) - 7WT(3)	NO SOIL DATA	NO SOIL DATA
	Central	471012	4HTV(6) - 7WT(4)	NO SOIL DATA	NO SOIL DATA
	Central	466043	4TVP(6) - 7WV(4)	4VPT(6) - 7WV(4)	7VPT(6) – 7WV(4)
	St Johns	475007	4DTV(10)	4DVT(10)	7VD(10)
	St Johns	471017	5HPV(10)	Missing climate data	Missing climate data

Table 7. Comparison of climatic and selected soil ratings for small grains, brome-timothy and alfalfa for selected SLC polygons across Canada.

SL#	Crop	EGDD		Climate		Surface pH		Soil	
		value	deduct	rating	Class	value	deduct	rating	Class
Kentville, NS 518004 (soil 1)	Small grains	1609	0	100	1	5.9	0	34	4
	Brome-timothy		28	72	2H		0	34	4
	Alfalfa		33	67	2H		22	14	6V
Ridgetown, ON 565022 (soil 2)	Small grains	2242	0	100	1	6.5	0	55	3
	Brome-timothy		0	100	1		0	55	3
	Alfalfa		0	100	1		0	55	3
Saskatoon, SK 736008 (soil 1)	Small grains	1375	21	71	2H	7.3	0	61	2
	Brome-timothy		47	53	3H		0	61	2
	Alfalfa		47	53	3H		0	61	2
Prince George, BC 982044 (soil 3)	Small grains	1100	50	50	3H	6.1	0	56	3
	Brome-timothy		59	41	4H		0	56	3
	Alfalfa		61	39	4H		15	43	4V
Demmit, AB 610002 (soil 2)	Small grains	817	76	24	5H	4.95	17	62	2
	Brome-timothy		69	31	4H		17	62	2
	Alfalfa		71	29	5H		73	10	6V

EGDD = effective growing degree days (GDD for general crop season modified for daylength)

4. CONCLUSIONS

1. The LSRS program has been modified to accommodate a legume (alfalfa) crop model.
2. New climatic parameters related to a longer growing season (mean daily temperature > 5^{o}C) have been added to the SLC climate file.
3. It is clear that the forages, with potential for more than one "crop", should not be directly compared to the cereal and oilseed crops.
4. A new "Install" CD for LSRS 3.0 was created to support suitability testing for the two forage models as well as for canola, soybeans, corn and small grains.
5. All procedures are documented

5. ADDITIONAL COMMENTS

- The LSRS 3.0 test program, as presently implemented, only operates with NSDB data (associated with the national SLC ver.3 map)
  - i.e. it does not run on AGRASID or site data
- The LSRS 3.0 program can operate in batch mode (with an SLC link) or interactively with national SLC map.
- Again, this modified LSRS program appears well positioned to evaluate agricultural responses to climate change and it is suggested that a specified agency (perhaps the National Agroclimatic Information Centre) should be asked to take responsibility for the development and maintenance of the climate databases.

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7. APPENDICES

Appendix 1. Timothy Yield Reduction vs P-PE

Using the FORYLD database (Bootsma and Boisvert 1991) supplied by A. Bootsma, a comparison was made of % yield reduction of vs P-PE (May-Aug) for 1 and 2 cuts of timothy. The result (Figure 11) indicates a fairly good positive correlation with $R^2 = 0.663$.

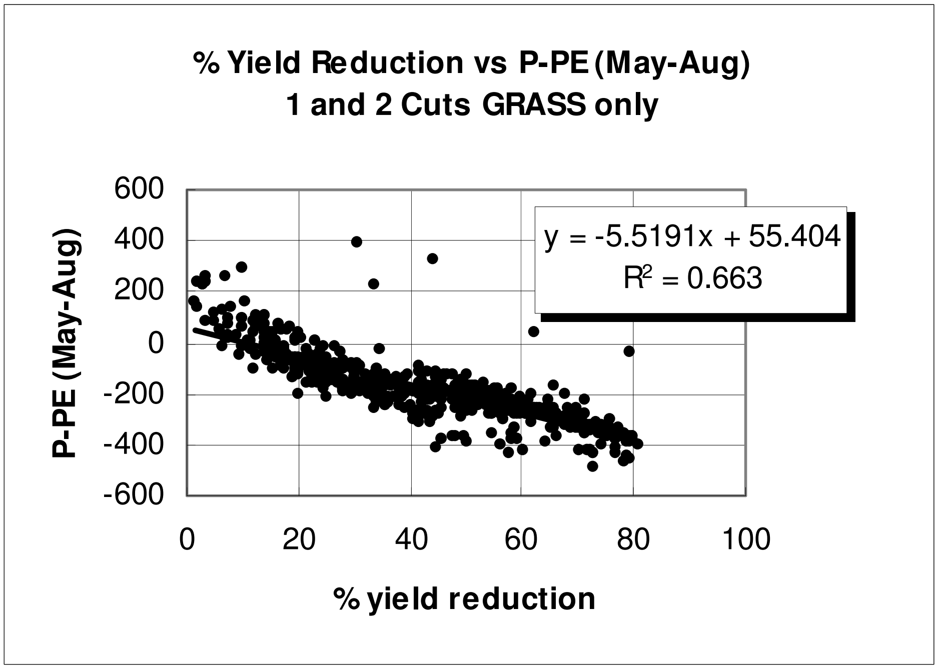


Figure 26. Percentage yield reduction of grass vs P-PE (May-Aug).

This relationship, using nearly 600 map units from across Canada provides some confidence for using a limited dataset to compare a set of expanded comparisons that include:

a) an expanded May to September growing season,

b) P-PE vs the LSRS M factor.

Appendix 2. Conversion of NSDB Stoniness Rating to Annual Removal Values

1.The Proxy Table.

The Stoniness Class types presently noted are those found in the NSDB-SLC map unit file.

Also included in this table are the Classes that are present in the regular soils map unit files in CanSIS as they will be needed at some time.

SLC Stoniness Classes

If "nothing" then stoniness "Annual Removal" value = 0.00
If StoneClass == "-" then stoniness "Annual Removal" value = 0.00
If StoneClass == "N" then stoniness "Annual Removal" value = 0.00
If StoneClass == "S" then stoniness "Annual Removal" value = 0.20
If StoneClass == "U" then stoniness "Annual Removal" value = 0.00
If StoneClass == "V" then stoniness "Annual Removal" value = 1.00

CanSIS Stoniness Classes

If StoneClass == "1" then stoniness "Annual Removal" value = 0.01
If StoneClass == "2" then stoniness "Annual Removal" value = 0.20
If StoneClass == "3" then stoniness "Annual Removal" value = 0.40
If StoneClass == "4" then stoniness "Annual Removal" value = 1.00
If StoneClass == "5" then stoniness "Annual Removal" value = 1.60

It is the "stoniness Annual Removal values" from this proxy that are used in the formula for Figure 6.4 in the LSRS manual.

2. The Percent Deduction Table (for small grains) (Figure 6.4 in manual)

It was felt that the Class 2-3 boundary should be nearly a 1 Class deduction (suggest 20 point/percent). This is set at an annual removal value of 0.3. Also, the 3-4 boundary, an annual removal of 0.6 should be a 2 Class (40 point/percent) deduction. The stoniness Class 4-5 boundary, at an annual removal rate of 1.2 should marginal or the LSRS 4-5 boundary (a 70 point/percent deduction).

Appendix 3. Temperature Proxy Requirement / Rating

Initially the climate database did not include the longer forage growing season or growing season length. Therefore the relationship to the present (EGDD) database was reviewed to determine its value as a proxy.

As mentioned in the introduction, the growing season for forages is longer than that for annual crops. The forage season, or GDD Sum1, is defined as > 5°C = growing season = < 5°C while the small grains growing season, represented as EGDD, is defined as > 5°C + 10 days = growing season = first frost. A comparison was made of 61-90 climate data (about 1200 stations across Canada) for GDD Sum1 and EGDD values. The resulting correlation (Figure 12) was very good with an $R^2 = 0.9802$. It was therefore considered reasonable to convert GDD Sum 1 values to EGDD and use the present index that was calculated for small grains and attached to Soil Landscapes of Canada polygons.

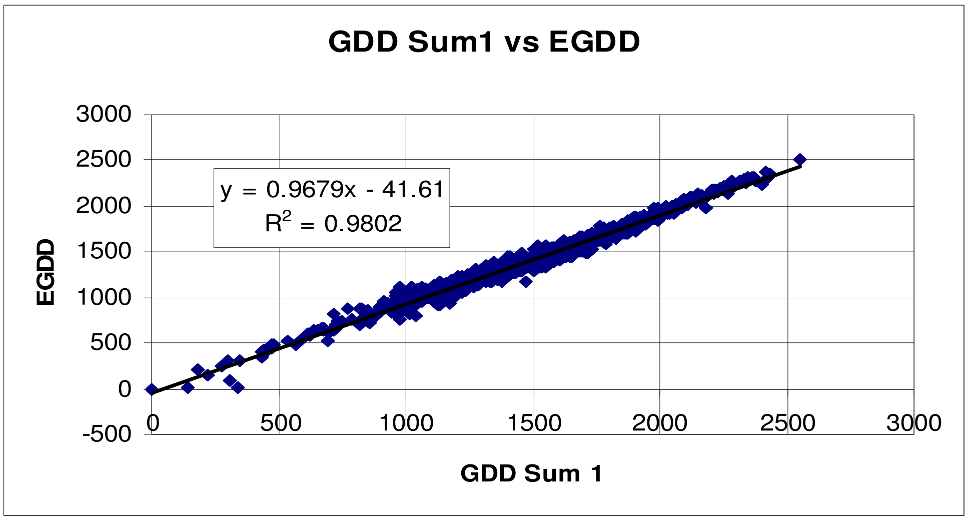


Figure 27. The relationship of GDD Sum1 (forage growing season) to EGDD (small grains growing season.

Using the relationship in Fig 4 (EGDD = 0.9679 (GDD Sum1) – 41.61), the above key limits become 858 EGDD (vs 930 GDD Sum1) and 1788 EGDD (vs 1890 GDD Sum1). These were rounded to 850 and 1800 respectively. Comparable values for the small grains are 900 and 1400 EGDD. The other values of 480 GDDs for one cut with no carryover and 1410 GDDs for two cuts became 423 and 1323 EGDDs which were rounded to 425 and 1325 respectively.

The above values, as representative of the bottom of Class 5, the bottom of Class 4, the lower part of Class 3 and the bottom of Class1, were assigned LSRS deductions of 80, 70, 50 and 20 points respectively. Graphing the assigned values (Figure 13), the alfalfa climatic temperature factor becomes:

Point deduction = 82.078 + 0.0041(EGDD) - 0.00002(EGDD)(EGDD)

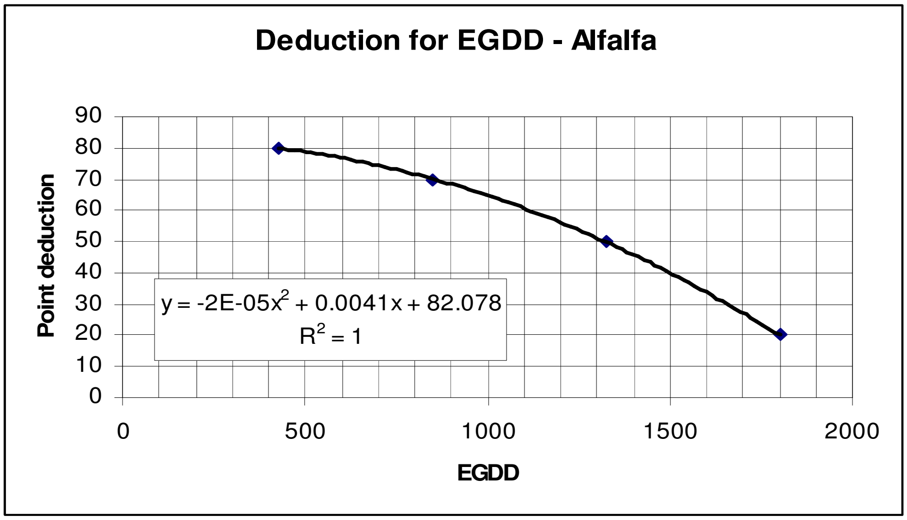


Figure 28. Point deductions for EGDD values for alfalfa.

APPENDIX 8. BROME – TIMOTHY CROP MODEL CONSIDERATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDMENTS

The author would like to acknowledge and thank the many people who offered frank comments and advice at various stages of the forage initiative: particularly Jane Thornton, Manitoba Forage Specialist, and Dr. Bruce Coulman, University of Saskachewan.
Thanks also to J.A. Brierley for expediting and supporting the project.

GENERAL REPORT INTRODUCTION

There were four aspects to this phase:

1. Reviewing the climate, soil and landscape requirements for grass (brome and timothy) forage production.
2. Adding to the climate database Growing Degree Days over $5^{O}C$ (GDD) and a Growing Season Length defined by the time greater than $5^{O}C$ (GSL).
3. Modifying the LSRS program to reflect brome-timothy requirements.
4. Testing to ensure the modified program operated properly in response to the above modifications.

The program will be limited to operations using the national Soil Landscapes of Canada (SLC) - National Soils Database (NSDB).

It should be noted that the testing referred to here is the operation of the program and not necessarily the correctness of the capability rating for alfalfa and brome-timothy. The latter will more properly be evaluated by the LSRS Sub-project Working Group (AAFC and Provincial partners)

Note:
1. Since this report was written, the forage ratings were converted to a new climate base.
   - using a longer growing season (GDD>$5^{0}C$ and growing season length)
2. The test results in this report were based on an EGDD proxy (see Appendix 3.)

1. INTRODUCTION

Both grasses and legumes are used as forages (McCartney and Horton 1997). The various species are adapted to such a large range of climatic and soil conditions that a single rating would be rather meaningless. On the other hand, to attempt to accommodate all the represented niches would result in an irresponsible number of specific ratings that would not support general land use planning. It is recognized that a general rating would not address the concerns of a forage specialist who deals with site-specific conditions (J. Thornton[7] pers. comm..), however it was felt that the main objective of a suitability rating that was initially to use the 1:1M soil Landscapes of Canada database (or 1:100,000 regional data) should be to support regional land use planning rather than site-specific decision making.

With the above arguments in mind, it was decided that two general categories of forages with somewhat different climatic and soil requirements should be recognized; namely legumes and grasses. Alfalfa (Medicago sativa L.) which is the most widely grown legume in Canada was chosen as a surrogate for that group. For the grass group, timothy (Phleum pretense L.) was chosen as the surrogate for eastern and central Canada and brome (Bromus inermis Leyss.) for western Canada.

It should be noted that the LSRS system could be modified to address any number of site-specific situations. It is the presumed objective of a general lands use objective that predicates the present decision of two categories.

Many annual crops (grains and pulses) are also used for forage, but the emphasis here is on the perennial crops. The main difference is that the perennial crops, with no concerns for annual seeding or for frost damage to grain, have a longer growing season. This extended season is assumed to be the period with mean daily temperatures above 5^{o}C (Bootsma and Boisvert 1991)

Another critical difference is that forages are not restricted to a single “harvest”. Depending on the season length, there can be one, two or even three or four cuts. This makes the forage rating fundamentally different from those for single-crop grains and oil seeds and they should not be directly compared - especially at a regional or local level. For example, at the west coast, long seasons and adequate moisture commonly allow for three cuts of forages but may not have the heat requirements for corn and soybeans.

Season length is correlated fairly well with accumulated Growing Degree Days (GDDs) for the range of 800 to 1600 GDD (Figure 1) with an R^2 of 0.63 (not shown). However in the coastal regions with extended growing seasons, the relationship breaks down. This situation requires the introduction of season length as an independent climatic variable.

[7] J. Thornton, Government of Manitoba Forage Specialist. Brandon, MB.

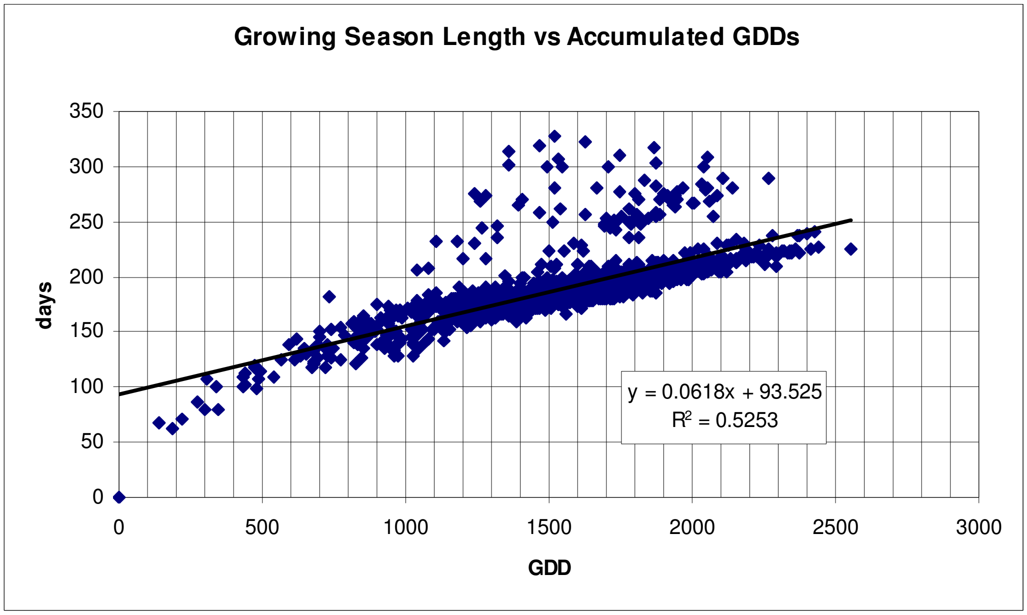


Figure 29. Growing season length vs accumulated GDDs (based on 61-90 station data).

Note: all stations with growing season >230 days are located on the west coast.

2. ACTIVITIES

2.1 Grasses – Brome-Timothy Crop Model

2.1.1 Introduction

Nearly all the cool season C3 grasses have similar growth requirements (Moser et al. 1996). Timothy is the usual forage grass where moisture is not limiting. However, brome is more tolerant of moisture stress and salinity and is the grass of choice on the prairies. It seemed appropriate to recognize the principal regional forage crops hence the title. As with alfalfa, the growing season is taken as the period with mean daily temperatures over 5°C but in the case of the grasses, the length of growing season becomes even more critical as a control of the number of cuts. The constraint free (potential) yield suggested by Bootsma et al. (1994) shows a maximum in the southern boreal climates of the northern prairies and northern Ontario with a decrease to the cooler more northerly climates and also a decrease into the hotter summer climates of the southern prairies and southern Ontario. However, in practice it is not so simple. A review of yield data in Ontario (www.omafra.gov.on.ca/english/stats/crops/ctyhay01.html) for the years 2001 through 2005 suggests that maximum yields are in the south as long as moisture is not limiting.

With respect to soil characteristics, these forages have the same requirements as the C3 small grains.

2.1.2 Climate Requirements/Ratings

2.1.2.1 Heat Requirement / Rating

According to Bootsma and Boisvert (1991) it requires about 480 GDDs (Growing Degree Days > 5°C) to produce a first cut of timothy and one should allow for about 400 GDDs for crop carryover requirements (slightly lower than that for alfalfa). The carry-over requirements are perhaps not too critical for the grasses (Coulman pers. com.) but, as the LSRS is a comparative rather than absolute rating, the concept was maintained to be consistent with alflafa. Therefore the minimum heat requirement for grasses is about 880 GDDs. This was considered the “marginal” requirement or the Class 4-5 boundary. Using the same approach, the ability to support two cuts per year should be (2 x 480) + 400 = 1360 GDDs and that for three cuts should be (3 x 480) + 400 = 1840 GDDs.

Deductions are assigned using the same argument as for alfalfa (Table 1).

From solely a GDD perspective (Figure 2) the climatic temperature factor then becomes:

Deduction = 89.28 + 0.0085(GDD) – 0.000016(GDD)(GDD)

Table 8. Point deductions assigned to GDDs for brome-timothy

GDD	Class description	Point deduction
480	Class 5-6 boundary	80
880	Class 4-5 boundary	70
1360	Lower part of Class 3	50
1840	Bottom of Class 1	20

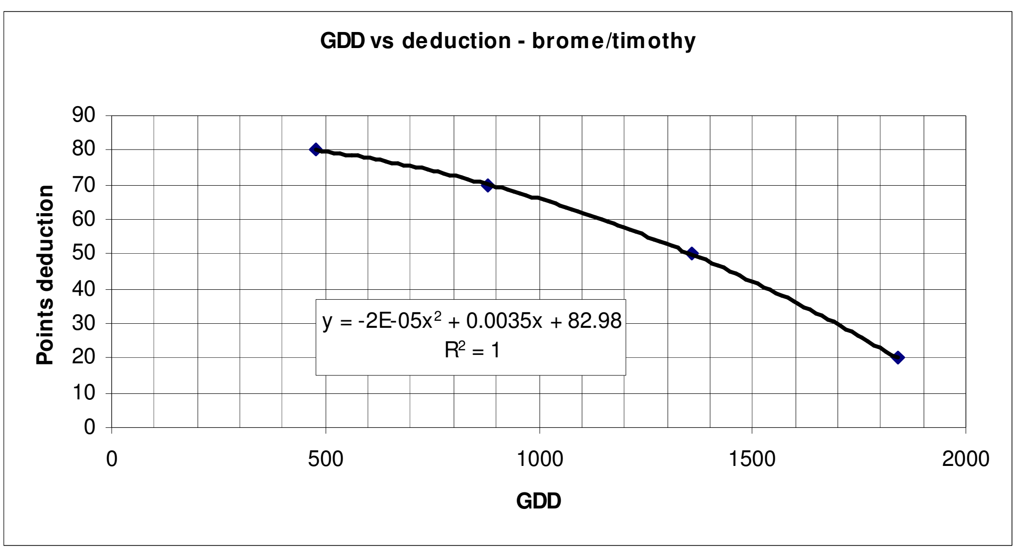


Figure 30. Deductions for GDD>5°C limitations for brome-timothy.

However, in the case of grasses, it is the kind and length of growing season that determines the maximum dry matter production.

2.1.2.2 Length of Growing Season Requirement / Rating

The C3 grass crops are known to perform best at temperatures around 20^{o}C (Moser et al. 1996). At higher temperatures, particularly over about 25^{o}C, there is reduced growth. Therefore, while higher temperatures accumulate GDDs, they do not contribute as much to dry matter production. It is also possible that higher temperatures initiate flowering more quickly and thus reduce the amount of dry matter production relative to a slightly cooler temperature - as long as the season length is not limiting. However, this is apparently not a clear cut issue. Bootsma and Boisvert (1991) assumed that an ideal length of time between cuts, recognizing optimum heat requirements and regrowth potential, is about 55 days. Others (Coulman per. com.) suggest lower values. The decision was taken to use a value of 50 days between cuts.

Using 61-90 monthly climate data and the above considerations, length of season requirement for one, two and three cuts of brome-timothy were established Table 2).

Table 9. Estimated days for brome-timothy cuts

Cut	GDD	Est. days
1	480	65
2	480	50
3	480	50
carryover	400	55

Note again that the beginning and end of season, spring and fall, take longer to accumulate heat units due to lower temperatures. Coastal British Columbia, with lower temperatures, particularly in the winter season, takes up to 20 days longer for both spring and fall but more than compensates with the longer growing season so is not limited in this respect.

From a suitability perspective, and based on the above, the number of days per cut are estimated as follows:

- One cut = 65 + 55 = 120 days
- Two cuts = 65 + 55 + 55 = 170 days
- Three cuts = 65 + 55 + 55 + 55 = 220 days

Using the same considerations as for temperature requirements, the season length was assessed (Table 3).

Table 10. Point deductions assigned to growing season length for brome-timothy.

Cut	days	Class description	Point deduction
1 – no carryover	65 days	Class 5-6 boundary	80
1 - carryover	120	Class 4-5 boundary	70
2	175	Lower part of Class 3	50
3	230	Bottom of Class 1	20

It should be noted that, with Class 1 defined as a minimum growing season of 220 days, Class 1 is mainly restricted to the coastal (and some interior) areas of B.C.

The growing season factor for brome-timothy becomes (Figure 3):

Deduction = 76.01 + 0.194(GSL) - 0.002(GSL)(GSL)

(where GSL = growing season length in days)

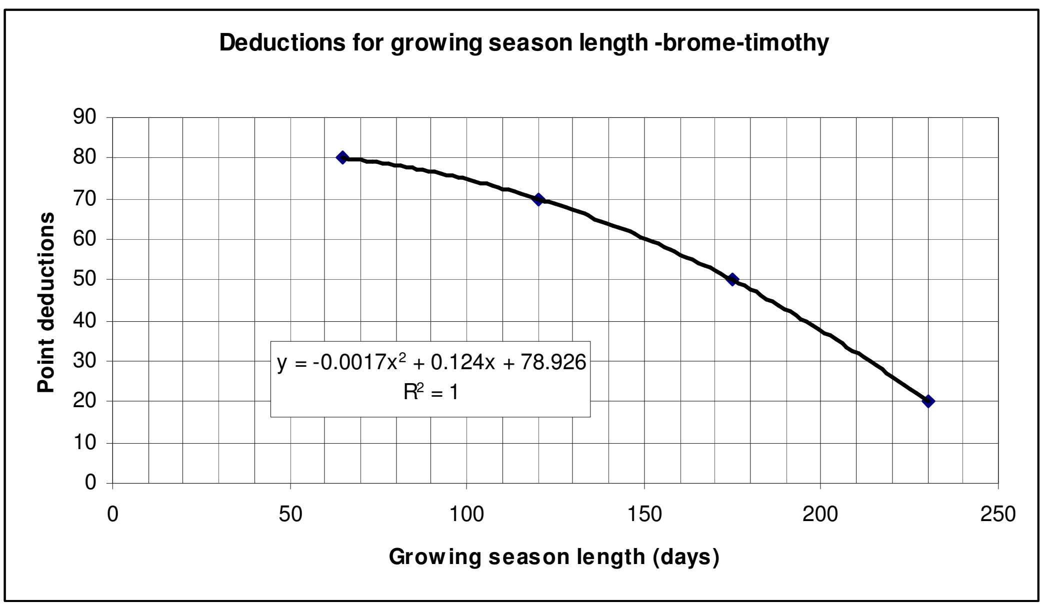


Figure 31. Deductions for growing season length for brome-timothy.

The heat rating or temperature factor (H) will be the most limiting of the GDD and GSL. For brome-timothy, these two values are fairly close in the shorter season and cooler areas (<1600 GDD) with the controlling factor generally being GDD. However, in the longer season and or warmer areas (>2000 GDD), the values diverge and GSL becomes the controlling factor.

The above is the recommended approach for temperature requirements for brome-timothy. However, this requires new climatic parameters that are not in the present database: namely GDD for the period >5°C and the growing season length represented by that period. It is felt that evaluations of climate change will consider a Biometeorological Time Scale (BMTS) which will use the >5°C growing season. When the BMTS approach is ready for implementation, the above characteristics can be included in the LSRS program. In the meantime, it was felt that a proxy using present climatic parameters should be attempted.

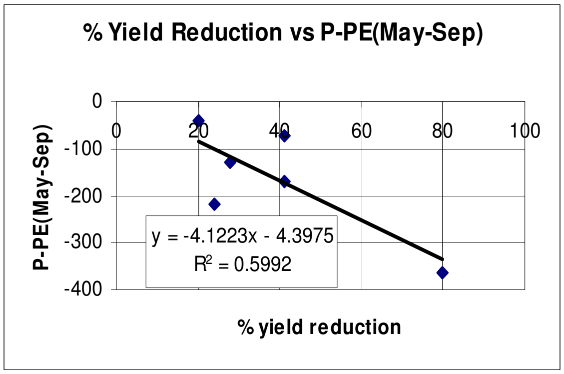
2.1.2.3 Moisture Requirement/Rating

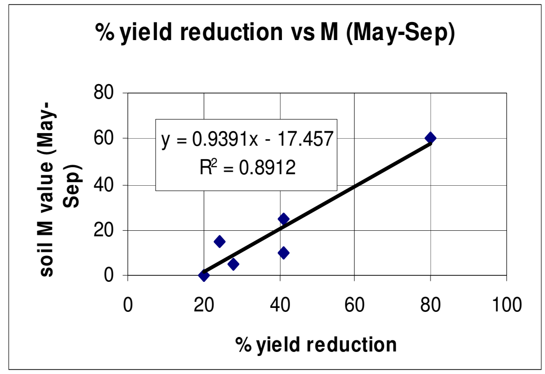
This assessment followed the same procedure that was used for alfalfa. An assessment of yield reduction related to moisture stress (Table 4) resulted in very similar correlation relationships (Figure 4) to those for alfalfa (Figure 5). In fact, the May-Aug correlation (R^2 = 0.6817 and 0.9272) was slightly better than the May-Sep correlation (R^2 = 0.5992 and 0.8912).

Table 11. Potential and actual brome-timothy yields and selected climatic parameters for several research sites.

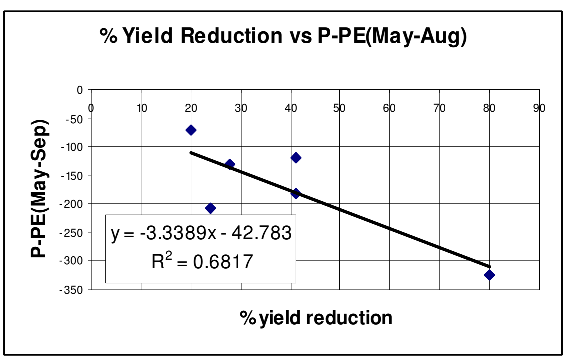
	Brome-timothy yields[1]		% yield reduction	P-PE May-Sep [2]	Soil AWC [3]	LSRS M factor [4]	P-PE May-Aug [2]	LSRS M factor [4]
location	potential	rain fed						
Charlottetown	12.4	10.0	20	-39	150	0	-72	0
Ottawa	12.8	7.5	41	-171	130	10	-182	12
Ridgetown	12.5	9.5	24	-220	200	15	-208	12
Swift Current	14.0	2.9	80	-362	150	60	-325	45
Truro	12.1	8.8	28	-128	100	5	-131	6
Kapuskasing	11.7	6.9	41	-71	50	25	-120	20

[1] [3] from Bootsma and Boisvert (1991)
[2] from 51-80 climate data provided by A. Bootsma
[4] determined from the LSRS manual

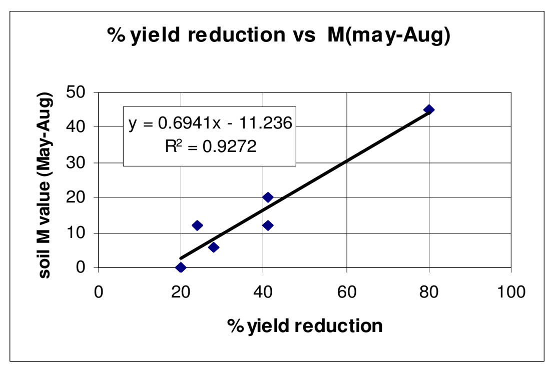




b)



c)



d)

Figure 32. The relationship of brome-timothy yield reduction to P-PE and LSRS-M values.

It was therefore felt that, as with alfalfa, that the present P-PE relationship used for small grains would be appropriate for the brome-timothy climatic moisture requirement.

2.1.3 Soil Requirements/Ratings

There are no recommended changes for soil requirements for the brome-timothy forage model. This is reasonable considering that these forages, like the small grains, are C3 grasses.

2.1.4 Landscape Requirements/Ratings

Landscape parameters are not as critical for forages as for annual crops. Erosion is much reduced with the continuous cover of perennial crops so slope steepness is important only as a limitation for haying (and silage) machinery. Stoniness is still a concern from a machinery perspective though perhaps not as critical at the lower stoniness classes. Gravel is not an issue from a landscape (management) perspective.

With the above in mind, the following relationships are suggested (Figures 5 and 6).

2.1.4.1 Basic Landscape Rating (slope steepness) (LSRS Section 6.1, Figures 6.2, 6.3)

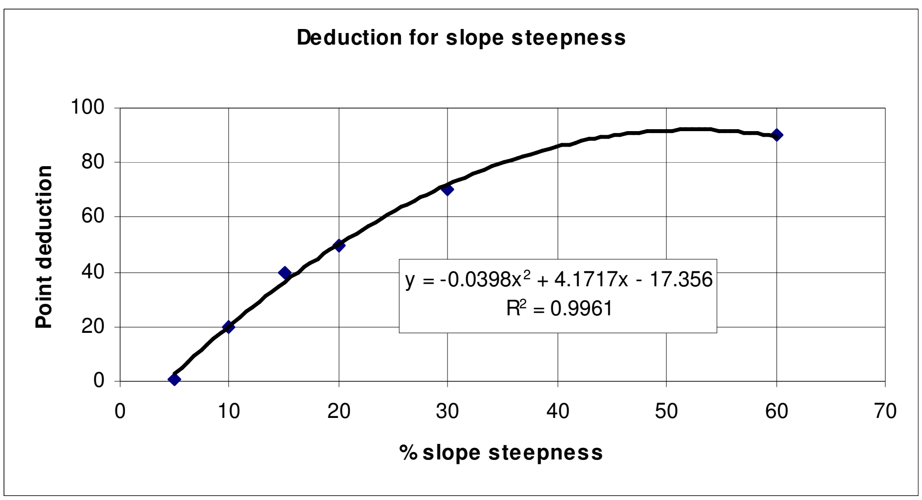


Figure 33. Point deductions for slope steepness.

Point deduction = – 17.356 + 4.1717 (% slope) -0.0398(% slope)(% slope)

This should apply to all regions and landform types.

2.1.4.2 Stoniness (LSRS Section 6.2.1, Figure 6.4)

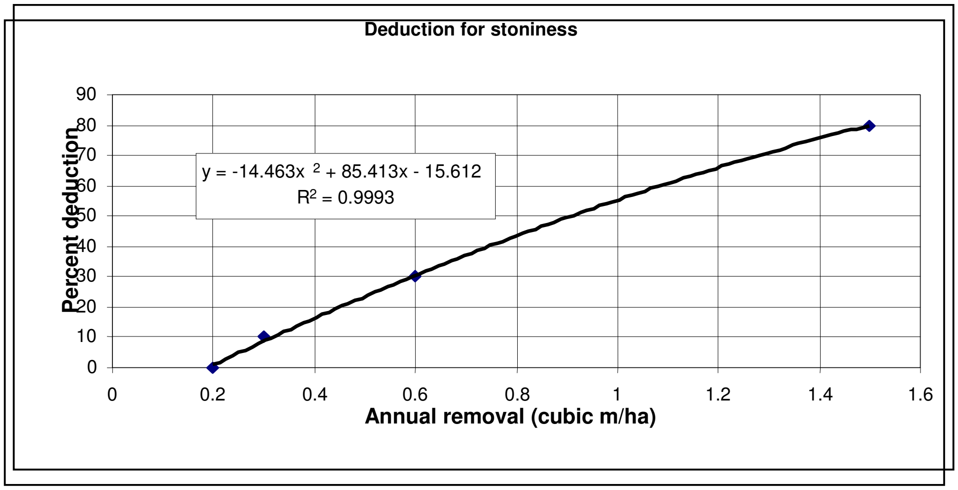


Figure 34. Percent deductions for stoniness.

Percent deduction = – 15.612 + 85.413 (annual removal) -14.463(annual removal)^2

See Appendix 2 for stoniness rating conversion to annual removal rate.

2.1.5 Organic Soil Requirements Ratings

Like the mineral soil requirements, the organic soil requirements should also remain the same those used for the small grains.

3. RESULTS AND DISCUSSIONS

In the introduction, it was stressed that forages are not directly comparable to single-harvest crops. However, comparisons are inevitable and can be useful for pointing out differences as well as concurrences. With this in mind, the small grains ratings were used to evaluate initial forage ratings.

3.1 Brome-timothy Crop Model

The standard SLC set used for testing previous crop models was also used for evaluation of the brome-timothy model (Table 5). The LSRS ratings from brome-timothy were very similar to those for small grains mainly in response to a dominant moisture deficiency limitation. However, there were some notable differences.

As expected, with the relaxed landscape constraints, the T limitation is often not noted for the forages ratings. In those instances where T is the dominant limitation for small grains, this could result in a higher rating for the forages. An example is PEI – 537003 where the brome-timothy rating is Class 2 compared to 3T for small grains.

With the different season/heat requirements it might be expected that there would be major climatic differences in the LSRS ratings for small grains and forages. This was not always apparent. Firstly, the shorter small grain season is situated in the middle of the longer forage season (900-1600 EGDD vs 800-1800 EGDD) and the extremes are not strongly represented in the test data set. Secondly, the heat parameter is often not the most limiting climatic factor. However, there are several examples where heat limitations alone have resulted in class changes. In most instances it was a rating decrease. Table 6, with selected examples from stations across Canada, clearly illustrate this point. In Table 5, other examples show the same result for the more usual cases: MB – 854002 went from a 20 point deduction for small grains to a 43 point deduction for brome-timothy (very bottom of Class 1 to the top of Class 3). Two other examples are AB – 729003 and SK – 705005 (both Class 2 to Class 3).

This does not mean that 854002 is "better" for small grains than for brome-timothy. Rather, it should be interpreted that, compared to the rest of Canada, there is no limitation for small grains but in the case of brome-timothy there are even better areas. That is, the relationship must be made on a national rather than local comparison.

It was also noted that there were several instances where the H limitation was missing from the LSRS roll-up.

The concordance between GDD and GSL requirements is not as good for brome-timothy as it was for alfalfa. It works well up to about 1600 GDD where growing season length is generally < 190 days (see Figure 1). That is, up to about the bottom of Class 2 which is defined as about 1550 GDD (see Figure 14) and 195 days (see Figure 13). The Class 1 distinction based on GDD alone is really not appropriate as it includes parts of southern Ontario (Table 3) with more than 1840 GDD but which does not have a long enough growing season for three cuts and may exclude a small portion of the west coast which has less than 1840 GDD but which has a very long growing season.

From a practical perspective this may not be overly serious. Firstly, southern Ontario will generally have a moisture limitation that will exclude Class 1 ratings. Secondly, both Class 1 and Class 2 are considered to be "very suitable" for the respective crops which is adequate for general planning. Therefore, as a first approximation, it is suggested that this rating will be adequate. However, it is strongly recommended that the new climatic parameters related to the longer forage growing season, be added to the database and incorporated into the LSRS forage models as soon as feasible.

3.2 Programming, Testing and Evaluation

The programming was completed and enabled.

Initial testing noted a couple of problems. These were successfully corrected before general model testing.

General testing was accomplished using both batch mode and individual SLC runs for alfalfa and brome-timothy as well as small grains. All worked as expected.

A new “Install” CD was created for comprehensive testing.

Table 12. Comparisons of LSRS ratings for small grains, brome-timothy and alfalfa for selected SLC polygons across Canada.

Prov.	area	SL#	LSRS - Small Grains	LSRS – Brome-timothy	LSRS – Alfalfa
BC	Fort St John	581008	7WV(10)	7WV(10)	7WV(10)
	Fort St John	585015	4DT(6) - 6W(4)	4DT(6) - 6W(4)	7VD(6) – 7WV(4)
	Prince George	982044	3HT(7) - 6M(3)	3H(7) - 6M(3)	4H(6) – 6MV(4)
	Prince George	982041	3HT(8) - 6MT(2)	Missing climate data	Missing climate data
	Penticton	1007020	6MT(5) - 7MTN(4) - 4W(1)	6M(6) - 7MTN(3) - 4W(1)	6M(6)-7MNT(3) - 4W(1)
	Penticton	1007019	6MTD(8) - 6MT(2)	6MTD(6) - 6MT(4)	7MTD(6) – 7MT(4)
	Lower Fraser	959004	6W(10)	6W(10)	7WV(10)
	Lower Fraser	959011	7WV(10)	7WV(10)	7WV(10)
	Lower Fraser	959019	2T(4) - 3M(4) - 7V(2)	2(4) - 3M(4) - 7V(2)	3V(4) – 5V(4) – 7VW(2)
AB	Foremost	828012	4MT(9) - 6M(1)	4M(9) - 6M(1)	4M(9) - 6M(1)
	Vulcan	793001	2M(10)	2M(10)	3HA(10)
	Neutral	771005	3MT(9) - 5W(1)	3MT(9) - 5W(1)	3MT(9) – 5W(1)
	Wetaskiwin	727011	3H(5) - 3HM(4) - 5W(1)	3H(5) - 3HM(4) - 5W(1)	4HM(5) – 4H(4) – 5W(1)
	Lloydminster	729003	2HM(8) - 5W(2) - 5M(1)	3HM(8) - 5W(2) - 4M(1)	4HM(8) – 5W(2) – 4M(1)
	Camrose	731002	3D(9) - 5W(1)	3HD(9) - 5W(1)	4VD(9) – 5W (1)
	La Corey	680002	3H(9) - 5W(1)	3H(9) - 5W(1)	4H(6) – 4V(3) - 5W(1)
	Grande Prairie	599001	3H(8) - 4N(1) - 5W(1)	3H(8) - 4N(1) - 5W(1)	4H(8) – 4V(3) – 5W(1)
	Clairview	591027	3H(9) - 5W(1)	3H(9) - 5W(1)	3H(9) - 5W(1)
	High Level	586001	3(8) - 6W(2)	3(8) - 6W(2)	7V(6(- 3H(2) – 6W(2)
SK	Regina	792004	3M(9) - 5W(1)	3M(9) - 5W(1)	3M(9) – 5W(1)
	Saskatoon	736008	2M(9) - 5W(1)	2M(9) - 5W(1)	3HM(9) – 5W(1)
	Melfort	705005	2(9) - 5W(1)	3H(9) - 5W(1)	3H(9) – 5W(1)
	Meadow Lake	680012	3H(9) - 4MV(1)	3H(9) - 4MV(1)	4H(9) – 7V(1)
	B topo	820002	4MT(10)	4M(10)	4M(10)
	C topo	810003	4MT(9) - 5W(1)	4MT(9) - 5W(1)	4MT(9) – 5W(1)
	Sandy (Black)	742002	5M(8) - 3M(2)	5M(8) - 3M(2)	5M(8) – 3HM(2)
MB		709007	3(5) - 2H(4) - 5W(2)	3H(9) - 5W(2)	3H(9) - 5W(2)
		717004	7WB(6) - 4DMP(4)	7WB(6) - 4DP(4)	7WB(6) – 4DP(4)
		724008	4DW(6) - 5W(3) - 6MD(1)	4DW(6) - 5W(3) - 6MD(1)	4D(6) – 5(3) – 6MD(1)
		763001	5MD(7) - 5W(2) - 3W(1)	5MD(6) - 4M(2) - 5W(2)	5MD(6) - 4M(2) - 5W(2)
		849009	2W(6) - 5W(4)	2W(6) - 5W(4)	3W(6) – 5WV(4)
		854002	1(6) - 2(3) - 5W(1)	3H(9) – 5W(1)	3H(9) – 5W(1)

Table 5 continued

Prov.	area	SL#	LSRS – Small Grains	LSRS – Brome-timothy	LSRS – Alfalfa
ON	Chatham	565022	3(5) – 5W(5)	3(5) - 6W(5)	3(5) – 6WV(5)
	Guelph	564005	4TP(5) - 7WVB(3) - 4VT(2)		
	Ottawa	545001	6VWT(7) – 2T(3)		
	Ottawa	543005	3M(4) - 4M(3) – 7WV(3)		
	Ottawa	543009	6WV(7) – 2TM(2) – 4MT(1)		
	Ottawa	545004	3DW(9) – 3TM(1)		
QU	Montreal	541011	3W(10)	3W(10)	3W(10)
	Quebec City	540102	4PT(7) - 3(3)	4P(7) - 3(3)	5VP(7) – 7V(3)
	Chicoutimi	441007	3HDT(10)	3HDT(10)	4HD(10)
	poorly drained	540098	5W(7) - 4DW(3)	5W(7) - 4DW(3)	6WV(7) – 6VDW(3)
	Imp. drained	540074	3DW(6) - 5W(4)	3DW(6) - 5W(4)	4VDW(6) – 6W(4)
	Organic	541053	7WVB(10)	7WVB(10)	7WVB(10)
NB	Caribou	494001	2T(6) - 5DW(2) - 6WT(2)	2H(6) – 5DW(2) - 6W(2)	3HV(6) – 6VDW(2) – 7W(2)
	Siegas	493002	2(6) - 3W(3) - 7W(1)	2H(6) - 3W(3) - 7W(1)	6V(7) – 3V(2) – 7WV(1)
	Thibault	486011	3HT(8) - 3TW(1) - 7WTJ(1)	3H(8) – 3HWT(1) - 7W(1)	5V(9) –7W(1)
	Belldune	485001	3WT(6) - 6W(3) - 3M(1)	3W(7) - 6W(3)	6V(7) – 7WV(3)
	Tormentine	504033	3W(9) - 6W(1)	3W(9) - 6W(1)	6V(9) – 7WV(1)
	King	503024	5DTW(6)-3TD(3)-6WTD(1)	Missing climate data	Missing climate data
NS	Kentville	518004	4MT(8) - 6MDT(2)	3M(8) - 6MD(2)	6MDV(8) – 4V(2)
	Kentville	518005	3T(9) - 7W(1)	NO SOIL DATA	NO SOIL DATA
	Truro	517006	6W(7) - 3WTD(3)	Missing climate data	Missing climate data
	Truro	507003	3DT(8) - 6WD(2)	Missing climate data	Missing climate data
	Sydney	523003	4DTW(10)	4DW(10)	6VD(10)
	Sydney	523004	6W(9) - 3DT(1)	6W(9) - 3D(1)	7WV(9) – 6V(1)
PE		535001	3DT(8) - 5DV(1) - 7WD(1)	3D(8) - 5DV(1) - 7WD(1)	7VD(8) – 5V(1) - 7WVD(1)
		536003	3DT(7) - 6W(2) - 5DV(1)	3D(7) - 6W(2) - 5DV(1)	7VD(6) – 5V(2) – 7WV(2)
		537003	3T(6) - 3DT(4)	2(6) - 3D(4)	6V(10)
NL	Codroy Valley	463013	4TVP(10)	4HVP(10)	7VPT(10)
	Codroy Valley	463011	5TVP(7) - 7WT(3)	NO SOIL DATA	NO SOIL DATA
	Central	471012	4HTV(6) - 7WT(4)	NO SOIL DATA	NO SOIL DATA
	Central	466043	4TVP(6) - 7WV(4)	4VPT(6) - 7WV(4)	7VPT(6) – 7WV(4)
	St Johns	475007	4DTV(10)	4DVT(10)	7VD(10)
	St Johns	471017	5HPV(10)	Missing climate data	Missing climate data

Table 13. Comparison of climatic and selected soil ratings for small grains, brome-timothy and alfalfa for selected SLC polygons across Canada.

SL#	Crop	EGDD		Climate		Surface pH		Soil	
		value	deduct	rating	Class	value	deduct	rating	Class
Kentville, NS 518004 (soil 1)	Small grains	1609	0	100	1	5.9	0	34	4
	Brome-timothy		28	72	2H		0	34	4
	Alfalfa		33	67	2H		22	14	6V
Ridgetown, ON 565022 (soil 2)	Small grains	2242	0	100	1	6.5	0	55	3
	Brome-timothy		0	100	1		0	55	3
	Alfalfa		0	100	1		0	55	3
Saskatoon, SK 736008 (soil 1)	Small grains	1375	21	71	2H	7.3	0	61	2
	Brome-timothy		47	53	3H		0	61	2
	Alfalfa		47	53	3H		0	61	2
Prince George, BC 982044 (soil 3)	Small grains	1100	50	50	3H	6.1	0	56	3
	Brome-timothy		59	41	4H		0	56	3
	Alfalfa		61	39	4H		15	43	4V
Demmit, AB 610002 (soil 2)	Small grains	817	76	24	5H	4.95	17	62	2
	Brome-timothy		69	31	4H		17	62	2
	Alfalfa		71	29	5H		73	10	6V

EGDD = effective growing degree days (GDD for general crop season modified for daylength)

4. CONCLUSIONS

1. The LSRS program has been modified to accommodate a grass (brome-timothy) crop model.

2. New climatic parameters related to a longer growing season (mean daily temperature > 5°C) have been added to the SLC climate file.

3. It is clear that the forages, with potential for more than one "crop", should not be directly compared to the cereal and oilseed crops.

4. A new "Install" CD for LSRS 3.0 has been created and is included to support suitability testing for the two forage models as well as for canola, soybeans, corn and small grains.

5. All procedures are documented

5. ADDITIONAL COMMENTS

- The LSRS 3.0 test program, as presently implemented, only operates with NSDB data (associated with the national SLC ver.3 map)
  - i.e. it does not run on AGRASID or site data
- The LSRS 3.0 program can operate in batch mode (with an SLC link) or interactively with national SLC map.
- Again, this modified LSRS program appears well positioned to evaluate agricultural responses to climate change and it is suggested that a specified agency (perhaps the National Agroclimatic Information Centre) should be asked to take responsibility for the development and maintenance of the climate databases.

6. REFERENCES

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McCartney, H and P.R. Horton. 1997. Canada's forage resources. Available from Western Forage / Beef Group, Agriculture and Agri-Food Canada, Lacombe, Alberta. 24p.

Moser, L.E., D.R. Buxton, and M.D. Casler, editors. 1996. Cool-season forage grasses. Agronomy series No. 34. Amer. Soc. of Agron. Madison, Wisconsin.

7. APPENDICES

Appendix 1. Timothy Yield Reduction vs P-PE

Using the FORYLD database (Bootsma and Boisvert 1991) supplied by A. Bootsma, a comparison was made of % yield reduction of vs P-PE (May-Aug) for 1 and 2 cuts of timothy. The result (Figure 7) indicates a fairly good positive correlation with $R^2 = 0.663$.

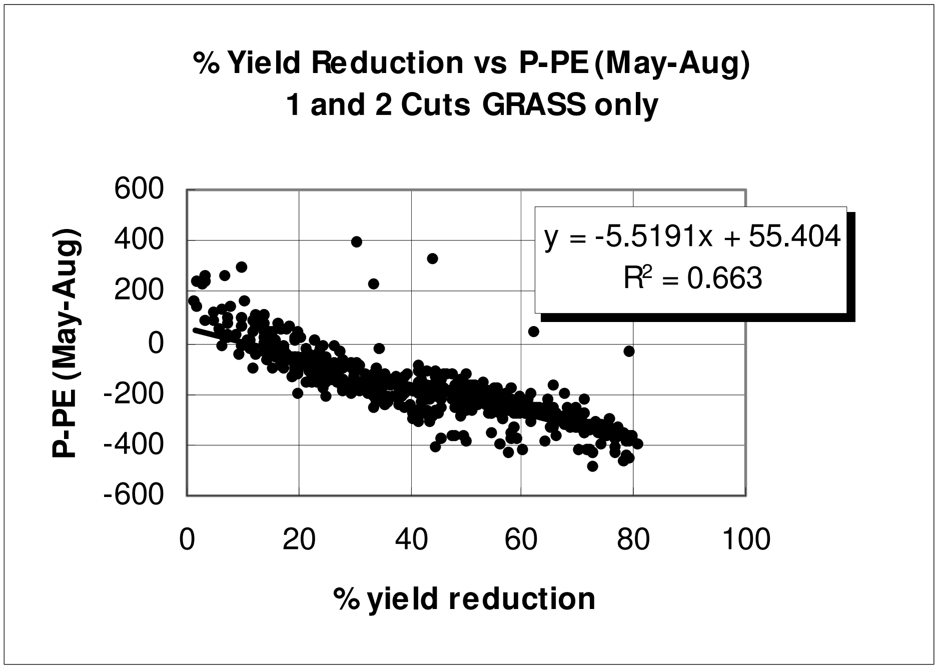

Figure 35. Percentage yield reduction of grass vs P-PE (May-Aug).

This relationship, using nearly 600 map units from across Canada provides some confidence for using a limited dataset to compare a set of expanded comparisons that include:

a) an expanded May to September growing season,

b) P-PE vs the LSRS M factor.

Appendix 2. Conversion of NSDB Stoniness Rating to Annual Removal Values

1.The Proxy Table.

The Stoniness Class types presently noted are those found in the NSDB-SLC map unit file.

Also included in this table are the Classes that are present in the regular soils map unit files in CanSIS as they will be needed at some time.

SLC Stoniness Classes

If "nothing" then stoniness "Annual Removal" value = 0.00
If StoneClass == "-" then stoniness "Annual Removal" value = 0.00
If StoneClass == "N" then stoniness "Annual Removal" value = 0.00
If StoneClass == "S" then stoniness "Annual Removal" value = 0.20
If StoneClass == "U" then stoniness "Annual Removal" value = 0.00
If StoneClass == "V" then stoniness "Annual Removal" value = 1.00

CanSIS Stoniness Classes

If StoneClass == "1" then stoniness "Annual Removal" value = 0.01
If StoneClass == "2" then stoniness "Annual Removal" value = 0.20
If StoneClass == "3" then stoniness "Annual Removal" value = 0.40
If StoneClass == "4" then stoniness "Annual Removal" value = 1.00
If StoneClass == "5" then stoniness "Annual Removal" value = 1.60

It is the "stoniness Annual Removal values" from this proxy that are used in the formula for Figure 6.4 in the LSRS manual.

2. The Percent Deduction Table (for small grains) (Figure 6.4 in manual)

It was felt that the Class 2-3 boundary should be nearly a 1 Class deduction (suggest 20 point/percent). This is set at an annual removal value of 0.3. Also, the 3-4 boundary, an annual removal of 0.6 should be a 2 Class (40 point/percent) deduction. The stoniness Class 4-5 boundary, at an annual removal rate of 1.2 should marginal or the LSRS 4-5 boundary (a 70 point/percent deduction).

Appendix 3. Temperature Proxy Requirement / Rating for Brome-Timothy

Relationships to the present (EGDD) database as reviewed in Section 2.1 (alfalfa) were applied to the brome-timothy situation but some constraints were encountered. As mentioned earlier, season length is such that two cuts are usually the norm. An exception is the west coast where almost year around growth is possible and three cuts are common. However, these coastal areas do not have high summer temperatures and show maximum yields with about 1800 GDDs as compared to the >2000 GDDs of southern Ontario.

To accommodate the above issues, it was decided to set the upper limit at 1800 GDDs (>5^{o}C to < 5^{o}C). This recognizes the coastal situation and does not penalize the hotter areas where moisture will usually be the more limiting climatic component.

The two critical points of 880 and 1800 GDDs when converted to EGDDs (see Figure 4 and section 2.1.2.1) where they equated to 810 and 1700 EGDDs. These were rounded to 800 and 1700 and assigned limitations of 70 points and 20 points respectively. The brome-timothy climatic heat factor (Figure 8) then becomes:

Deduction = 81.507 + 0.0065(EGDD) – 0.00003(EGDD)(EGDD)

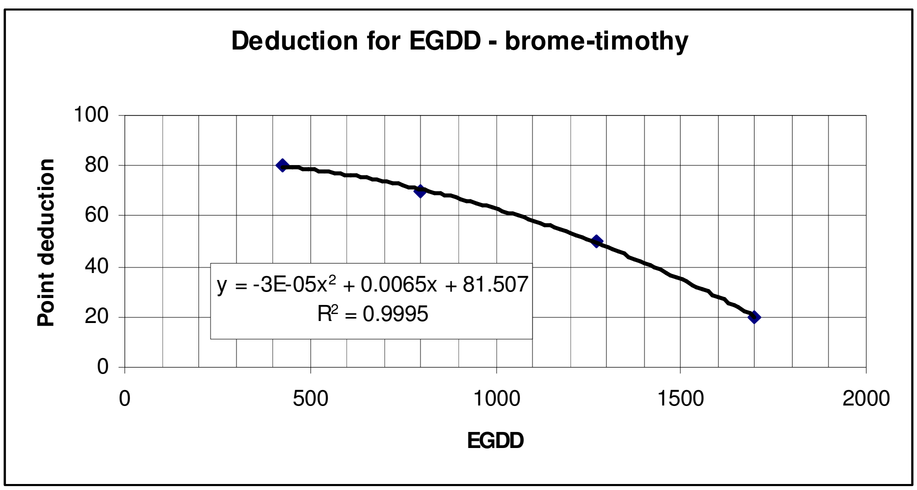

Figure 36. Point deduction of EGDD values for brome-timothy.

APPENDIX 9. COMMENTS FROM REGIONAL TESTING

9.1 British Columbia

LSRS Evaluation BC for Canola, Forages, & Soybeans

Canola

Climate: Appears to be logical: In BC canola is primarily grown in the Peace River which has capability classes 4 & 5. Canola is occasionally grown in other regions of BC.

Soil: The bedrock non soils such as $AR are getting a 7W Rating isn't W a water issue is a bedrock or depth to restricting layer issue!!!
The ALC (Alcan) in 2 polygons 583013 & 591019 soil class is rated at 3 but no sub class listed.
CNL (Cannel) a soil with bedrock at 50 cm in some cases soil class is 1. Do not believe this!
NIIvl (Nitanat very shallow lithic) a soil with bedrock at 45 cm in polygon 955037 is soil class is 2 with only M limitation no D.
PAGd (Page) I don't follow how this soil is a class 7 V. This soil has good pH values and also the texture % Si % C in calculation boxes don't follow with what is in the SLF. The V point is 248!!

Landscape: Appears to be logical:

Soybeans

Climate: Appears to be logical: In BC soybeans are not grown. Indeed they are not listed on the BCMAL web site listing BC Agricultural Commodities. Hardly surprising considering there is no better than class 3 climate rating which occurs in the Lower Fraser Valley. Also the climate rating for soybeans is extremely similar to that of corn so in BC corn is grown.

Soil: The bedrock non soils such as $AR are getting a 7W Rating isn't W a water issue is a bedrock or depth to restricting layer issue!!!
PAGd (Page) I don't follow how this soil is a class 7 V. This soil has good pH values and also the texture % Si % C in calculation boxes don't follow with what is in the SLF. The V point is 248!!

Landscape: Appears to be logical:

Brome

Climate: Appears to be logical: In BC forage is grown in all of the agricultural areas.

Soil: The bedrock non soils such as $AR are getting a 7W Rating isn't W a water issue is a bedrock or depth to restricting layer issue!!!

PAGd (Page) I don't follow how this soil is a class 7 V. This soil has reasonably good pH values and also the texture % Si % C in calculation boxes don't follow with what is in the SLF. The V point is 248 which when compared to a V100 deduction for alfalfa there appears to be a conflict. According to the interim report document alfalfa is more sensitive to pH.

Landscape: Appears to be logical:

Alfalfa

Climate: Appears to be logical:

Soil: The bedrock non soils such as $AR are getting a 7W Rating isn't W a water issue is a bedrock or depth to restricting layer issue!!!

PAGd (Page) I don't follow how this soil is a class 7 V. The calculation box is indicating a pH of 1.50. This soil has pH2 values ranging between 6 and 6.4, and also the texture % Si % C in calculation boxes don't follow with what is in the SLF. The V point is 100 which is less than that for brome a less pH sensitive crop.

Landscape: Appears to be logical:

Overall comments

Apart from the specifics mentioned above viewing the LSRS rating classes for climate, soil & landscape does not suggest concerns. Gleysols and organics as expected are down graded on W limitations. Where the landscape is steep there are severe T limitations. One would expect moisture limitations for the coarser textured soils in the drier interior regions, which is what occurs.

9.2 Saskatchewan

Mar. 23, 2007

Average CLI ratings were created by referring to the 1:100K soil inventory coverage used to delineate latest SLC ver 3.1 polygons.

CLI Soil Capability ratings for SLC ver 3.1 Polygons   Note: SL numbers & Soil Landscape areas (e.g Saskatoon Area) highlighted in Dark Blue were sent to W. Pettapiece Feb 22, 2006. Those in black were added July 2006.

Soil Landscape	SL	Physiographic Area in Prov / Soil Type(s) / Slope + Surfex	LSRS Rating Corn	LSRS Rating Small Grain	Soil Capability Rating
Regina Map area	782014	Good. Wr4 /4h, N. of M. Jaw	4MT(9)4HAT(9)5W(1)6MT(1)	3(9)MT4(1)MT	3T
	789007	Good. Ew + Wr + Br/3u -2u, N.W. of Moose Jaw	4M(10)	3(10)M	3M
	792005	Out 1 class (close) Aq:fl-sl, some silts & clay (Aq 4),Br(3),Ew(2),Tu(1) There should be no 6M coming out in LSRS.	4M(5)6M(5)	3(5)M6(5)M	4M (some 3M)
	792004	Out significantly, Dk. Brown HvC (heavy clay), Regina Plain. Ra/2u 3(9)M not, the 5(1)W is o.k. SKLAYER indicates Ap is HvC East of M. Jaw & S. and S.E. of Regina.	4M(9)5W(1)	3(9)M5(1)W	2C
	792001	Out 1 class. Mixture of Ra & Su N. of M. Jaw. Should be 2C.	4M(10)	3(10)M	2C
XXXX	792007	Poor correlation. Ru/1L, Gleysolic Vertisol. In SKSNF RUG is described as a Gleysolic Vertisol and a poorly drained soil, so problem is ours.	5W(7)5(M)3	5(7)W3(2)M5(1)NM	3(10)X
	782016	Out 2 classes Dk Brown gravel. Bg:sl/3 (Bg (80) Wr(15) south end of Last Mtn. Lake	6M(8)4MT(1)5WT(1)	6(8)M3(1)MT5(1)WT	4M
	756001	Good OxWr :L /4h mostly Black and Dk Brown till). N.E. of Regina	4HM(9)5W(1)	3(9)M5(1)W	3T
	754001	Out 1 Class. Ba: C/2u mostly. N.E. corner of Regina sheet. Probably no more Class 1 in Sask. re: LSRS	4HA(10)	2(10)M	1
	822005	Good Mixture of Aq sl/4h, Aq ls/3u, Vr. S. of M. Jaw. Dk Brown sands. 5M good estimate	6M(10)	5(10)M	5(9)M3(1)M
	789006	Out 2 Classes Dk. Brown. Bg: sl 50%, Aq fl 20%, Br. Scl 30%, mostly 3-2u. In SKLAYER, Ap = GCSL, Bm = GLCS, Ck = GCS	6M(7)5MT(3)	6(6)M4(4)MT	4(7)M3(3)M
Swift Current Area	816001	Out 1 Class. Brown. 60% Ec S.Solonetz, 25% KhAd, 15% AdKh on 3u. North of Chaplin Lake. This is significant difference. Most of the soils are solodized solonetz.	5M(10)	3(10)M	4(10)DM
	792003	Out 1 class. Ht ls & sl on 3-2u. Some Ap. N.E. of Chaplin Lake	6M(9)4M(1)	6(9)M3(1)M	5(10)M
	822001	Good. 60% 5h, 25% 6h. Am soils. 15% 5W. East of Chaplin Lake	5MT(9)5W(1)	4(9)TM 5(1)W	4(7)T5(3)T
	816007	Out 1 Class. Chaplin Lake complex: Ht Ch, most of which is saline. 5(10)MN would probably cover off most of this polygon. Much of this area is Ht 1 & Ht 2 so there are no series from which LSRS can extract info for salinity. In SKLAYER, Ap = GCSL, Bm = GLCS, Ck = GCS	6MT(9)5MT(1)	6(08)MT4(2)MT	5(10)MN
Swift Current Area	816014	Close. Brown. Mixture of Ad & Hr on 5h (70%) and 6h (20%). Missing some 5T in LSRS rating. South of Chaplin Lake	6MT(9)5W(1)	4(09)MT5(1)W	4(7)MT5(2)T

Soil Landscapes	SL	Physiographic Area in Prov / Soil Type(s) / Slope + Surfex	LSRS Rating Corn	LSRS Rating	Soil Capability Rating
	825007	Good Dk Brown. Thin loess/till + till. Wk, WkWr, WyAm on 3 topo. S. of Swift Current.	4HA(10)	3(10)M	3(10)M
	808015	Out 2 classes. Brown. Mostly Sc HvC with some Hr, some By and some Fx on 3 and 2 topo. Straight N. of S. Current and N. of Lake Dief.	5M(10)	4(10)M	2(5)C 3(2)M
	813009	Out signif. This is not a marginal (i.e. class 4) landscape. WW / T 50%, Sc 25%, By + Fx 20%. N.E. of 808015. Ww is clay, Sc is heavy clay lacust	5M(9)5W(1)	4(9)M5(1)W	3(5)M2(3)C4(2)M
	816004	Good LSRS. Ad L soils on 3-4 h topo. N.E. of Swift Current	5M(10)	4(10)M	4(10)M
Cypress Area	833006	Close. Domin Ec soils, some EcRo, some EcFr (domin. Brown Solodized Solonetz, some CL till). Not sure why LSRS is indicating some 5MT. Very S.W. corner of prov. Generally B slopes.	6M(10)	4(5)M5(5)MT	4(10)MD
	834001	Out 2 Classes. Brown. A mixture of FrEc & FrRo on 3-4 u, some steeper stuff. Fr is typically rate as 3M, Ec & Fr rated as 4MD. Large area in S.W. corner of prov.	6M(10)	5(10)M	3(7)M4(3)MD
	835001	Out 1 Class. Mostly FrEc with 10% EcFr. Slopes of 4-5H & HD, some 5H and some 6-5 HD. The LSRS is kicking out a little high. Why? S.W. corner of prov. Surface is L texture. 01-22-W3rd.	6M(7)6MT(3)	5(7)M 5(3)MT	4(5)MT3(3)M5(2)T
	834002	Out two classes. Brown. Domin Fr CL soils. There is a mixture here though of classes 4, 5 and 6 topo. , some 3u. 15-04-W3rd	6M(8)6MT(2)	5(8)M5(2)MT	3(4)M4(3)MT5(3)MT
	832004	Out 1 Class. Not too bad. This area is a combination of EeEx/6-7, JcEx/5-7, JcCy/5-7, Ea and Av soils. Class 5 & 6 CLI should dominate this area. 43% D slopes (16-30%), 20% B slopes. 05-15-W3rd	5M(5)6MT(3)6WT(2)	4(5)M5(3)WT6(2)WT	5(4)T3(3)M6(3)T
	827006	Out 1 Class. Ht 50%, HtHr and HrHt 20%, HtCh 20%, Ap 10%. N.W. of Maple Creek, 12-27-W3rd.	6MT(10)	6(8)MT4(2)MT	5(7)ME6(3)M
	827004	Good LSRS Rating. HtAp 60%, Ap 40% 14-21-W3rd Rm139	6M(10)	6(8)MT4(2)MT	Mostly 6ME
	827002	Out 1 Class. Duned area, moderate to strong slopes. What is considered Class 7 in LSRS. 15-17-W3rd RM138	7MT(10)	7(10)MT	6(10)ME
	824002	Good LSRS. Brown. 80% Ap with dunes, 20% Ht 14-24-W3rd. RM 110.	6M(10)	6(6)M4(4)M	6(8)ME5(2)ME
	825011	Good LSRS Dk Brown. Thin Loess/till + till. WkAm / 3-4U	4HAT(10)	3(10)MT	3(10)M
	825010	Good. Same soils and landscape as 825011, slightly diff LSRS.	4HA(10)	3(10)M	3(10)M
Prelate Area	819001	Out 1 Class: This area is dominantly Class 5. In SKCMP3_1, Ht makes up 57%. Mixture: mostly Ht (50%), some HtHr 10% , some ApHt & HtAp 30%. Quite a lot of LS and SL textures, hence 5ME Polygon is the outer rim around the Great Sand Hills, 19-24-W3rd, RM171, 230 etc	6MT(10)	6(8)MT4(2)MT	5(7)ME6(2)M4(1)M

Soil Landscape	SL	Physiographic Area in Prov / Soil Type(s) / Slope + Surfex	LSRS Rating Corn	LSRS Rating	Soil Capability Rating
	819002	Out 1 Class. Ap is always 6ME (or 6SE), If Ap map unit has Humic Regosols, then some 5ME. Can look at Ap soils as primarily 6ME. RM171, 230	7MT(10)	7(10)MT	6(10)ME
Prelate Area	815002	Out 1 class. Ap 40-50%, Ht 30-40%, By 20%. LSRS is recognizng the 20% By with CLI=4. There is approx 40% Ht & HtBy. Sand Hills area. R.M. 232	6M(10)	7(10)M4(2)M	6(4)ME5(4)ME 4(2)M
	808012	Out 1 Class. Approx 10% Class 4 (bits of By & FX), some Ht which is 5ME, however, entire polygon could be Class 6ME.	6MT(9)6M(1)	7(7)MT4(3)MT	6(6)ME5(3)ME 4(1)M
	820001	Good. Domin. Fx on 2-4U, some 4-5h. Fx normally 3M, this is arid area so 4M fits perfectly. 18-20-W3rd, RM 169	5M(10)	4(10)MT	4(10)M
	808009	Out 2 Classes. Brown. Sc 60%, Ww, WwSc, WwFx 40%. 3-2 u. 22-24-W3rd, Rm230 just below S. Sask River	5M(9)5W(1)	4(9)M5(1)W	2(6)C3(4)M
	808013	Out 2 Classes: Sc 90%, Ww & Fx 10%. 3-2u and 2u topo. RM228,20-18-W3	5M(10)	4(10)M	2(10)C
	821004	Good: Domin. HrVa Brown loam till & thin silts on B slopes (3-4u) with approx. 30 – 40% of HrVa on C and some D slopes. Rm230 23-18-W3	5MT(10)	4(10)MT	4(8)MT5(2)T
	808014	Out 2 Classes: Brown. 70% Sc (HvC) on 2-3u (domin.A slopes), 30% Ww (C)on 3 -2 u (B slopes)	5M(10)	4(10)M	2(7)C3(3)M
Kindersley Area	808004	Out 2 Classes: Sc (Brown hvc) /3u & 2u. 24-20-W3rd N. of S. Sask. River in RM259	6M(9)5W(1)	4(9)M5(1)W	2(10)C
	780003	Out 2 Classes: Ra (Dk Brown HvC)/2u, 2ud,3u 70%, Su (C)/2u 30%. South and S.W. of Rosetown	5M(10)	4(10)M	2(7)C3(3)M
	780004	Perfect fit. Ew (Dk Brown silts)/3u 32-16-W3rd,	5M(10)	3(10)M	3(10)M
	780001	Quite close, A lot of Ra & Su (hvc & c), 50% on B slopes & about 40% on C slopes, some silt and till. Quite a bit of B slopes are undulating so I would be a bit more generous in CLI than for h topo.33-20-W3rd.	5M(10)	3(10)M	3(4)TM4(3)T2(3)C
	778001	Out 2 Classes. 60% Aq (Dk Brown) soils on A & B slopes, 15% Dune Sand, 15 % Wr (till). Most Aq is SL (some is LS) so LSRS of 6(M) is hitting the area too hard. 34-16-W3rd. SKLAYER looks O.K. re: texture class.	5M(10)	6(7)M3(3)MT5(1)W	4(6)M5(2)ME6(2)ME
	803002	Out 1 class. LSRS= 6M vs. CLI of 5M. 70% Ht sl & ls on A and B slopes = 5ME, approx. 30% HtAp for 6ME would be O.K. LSRS is picking up a bit of salinity which is fine. 34-22-W3rd	6M(8)5MT(1)6WN(1)	6(7)M4(2)MT6(1)WN	5(7)M6(3)ME

Soil Landscapes	SL	Physiographic Area in Prov / Soil Type(s) / Slope + Surfex	LSRS Rating Corn	LSRS Rating	Soil Capability Rating
	771005	Fairly good. 45% Wr (Dk Brown till) on B slopes, 35% Wr on D slopes, other Misc. LSRS is picking up 10% gleysols which is good.	5MT(9)5W(1)	3(9)MT5(1)W	3(6)MT5(4)T
	807004	Good fit. 80% Hr + Va (Brown till & thin silt over till) on B and C slopes, 10% Gleysols.	5MT(9)5W(1)	4(9)MT5(1)W	4(9)MT5(1)W
	803001	Good. Brown. Kh, Kn, Kd 60% Solonetzic soils	5M(10)	3(10)M	3(6)M4(4)D
	805001	Out 1 Class. Kh, Ad, Kn 60% Solonetzic soils, B slopes. Not too much steep stuff to warrant 4MT.	5M(10)	4(10)MT	3(10)MD
Rosetown Area	770004	Fairly good fit. 60% Aq (Dk Brown sandy, sl-ls) best as 5ME. Dune sand is rated as Class 6. 32-13-W3rd	6M(6)7MT(4)	6(6)M6(4)MT	5(6)M6(4)SE
	770005	Fairly good fit. Dk Brown. 50% Vera (dune sand), 30% Aq, 20% saline gleysols. Aq could all go into 5ME, however there is about 5(2)WN to cover off Av saline gleysols. Could put the all the Aq in with Vera = 6(8)M or 6(8)SE and the rest into 5(2)WN. 32-09-W3rd, S.E. of Goose Lake.	6M(8)5W(2)	6(8)M5(2)W	6(6)SE5(2)WN
	770003	Good fit. Ew (Dk. Brown silts) Br (fl and vl lacust. Sands) on A slopes 34-10-W3rd. Approx 8% Aq (Dk Brown fluvial sands) on A slopes which should be Class 4M. Not sure why LSRS indicates 10% 6M.	4M(9)6M(1)	3(9)M6(1)M	3(9)M4(1)M
	810001	Close. Dark Brown loam till on B slopes. 27-10-W3rd	5M(10)	4(10)M	3(10)MT
	776005	1 Class out. Vera (dune sand in Dk. Brown Soil Zone) on primarily B slopes. 33-7-W3rd	7M(10)	7(10)M	6(10)SE
	776004	1 Class out. Vera (dune sand in Dk. Brown Soil Zone) on primarily C slopes. 33-05-W3rd (Dundurn Military Reserve)	7MT(9)6M(1)	7(10)M	6(10)SE
	782005	1 Class out. Rosemae and Trossachs, domin. solod. solonetz, in combin. with Wr l on B slopes. 27-03-W3rd	5M(10)	3(10)M	4(7)D3(3)M
	773009	Good fit. Although most of this area is dominantly solonetzic, Hy & Tu, the domin soil cap is 3(10)M with about 20% 4D. These solonetzic soils not as tough as the Rm and Tr soils in 782005. 30-04-W3rd.	4M(10)	3(10)M	3(08)M4(2)D
	782004	Out 1 class. Domin Wr on A slopes with about 20% Rm soils as a subdominant soil. 26-04-W3rd	5M(10)	4(10)M	3(10)M
	770010	Good. Most dune sand type soils, whether in Brown or Dk Brown zones are coming out as LSRS 7(10)M. LSRS for this polygon of dune sand rated different ?? 24-06-W3rd	7M(5)7MT(5)	6(5)M7(5)MT	6(7)SE5(2)M3(1)M
	789002	Good. Most dune sand type soils, whether in Brown or Dk Brown zones are coming out as LSRS 7(10)M. LSRS for this polygon of dune sand rated different. I put Aq into 5(2)ME because of association with dune sand material and some textures are light. 24-03-W3rd	7M(8)7MT(2)	6(8)M7(2)MT	6(8)SE5(2)M

Soil Landscapes	SL	Physiographic Area in Prov / Soil Type(s) / Slope + Surfex	LSRS Rating Corn	LSRS Rating	Soil Capability Rating
Saskatoon area	772002	Close. Bg (Dk Brown Gravel)+ Wr (Dk Brown till):sl/2-3u, Aq sl & some eroded areas. Bg(30) Wr(30) Aq(15) Br(15, fl texture) 38-05-W3rd	4M(6)6M(4)	3(6)M5(4)M	4M
	736008	Good Ox (Black till+ Cf (thin silt over till)/3u 40-06-W3rd	4HM(9)5W(1)	2(9)M5(1)W	2M
	770001	Good Br(Dk Brown fl generally): l – vl/3u Br(70) Aq(10) 37-11-W3rd	5M(10)	3(9)M5(1)W	3M
	776001	Good Vr (dune sand, Dk Brown): s/3-4h, Vr(80) Aq (2) 37-09-W3rd	7M(10)	6(10)M	$6M^7 5M^3$
	736006	Good CfOxHm /3u (Black loamy silt & till) 40-04-W3rd	4HM(8)5W(1)6M(1)	2(8)M5(1)W6(1)M	2M
	736008	Good Mostly Ox (Black till) and some Bb (black loam to silt loam) on A slopes. 40-06-W3rd	4HM(9)5W(1)	2(9)M5(1)W	2(9)M5(1)W
	733011	Good Mostly Bb L (black silty lacust) on A & B slopes. Approx 15% Hm FL & SL (Black sandy) 3M soils.	5HA(9)5W(1)	2(9)M5(1)W	2(8)M5(2)NW
	742002	Out 2 classes. Me some Bg, Black SL, FL and some LS fluvial sands. 41-10-W3rd	6M(8)4HM(2)	5(8)M3(2)M	3(6)M4(4)M
	733005	Out 1 class: Black till on mostly B slopes, with some A slopes, and minor amts of C slopes, some Gleysols.	5HMT(9)5HWA(1)	2(9)HMT5(1)W	3(5)T2(3)M4(3)T
Saskatoon area	701004	Out 1 class Dune sand soils in Black Soil Zone, Humic Regosols	6M(9)5W(1)	6(9)M5(1)W	5(10)ME
	736004	Good Bb (Black silts) Hm vl &fl on A slopes	4HA(8)4M(1)5W(1)	2(8)M3(1)M5(1)W	2(8)M3(1)M5(1)W
	701006	O.K. Em (dune sand in Black Soil Zone) Can be either 6ME or 5ME soil cap.	6M(7)6MT(2)6WB(1)	6(7)M6(2)MT6(1)WB	5(10)ME
North Battleford area	768002	Out Signif. WrSt: 70% of soils in SKCMP are on D slopes, so should have 5T for soil capability.		4(7)TM2(3)MT	5(8)T3(2)M
	768001	Out signif. Hardly any class 2 soils in this poly. Mostly B slopes with some D slopes.		2(8)MT4(2)TM	3(6)MT4(3)T5(1)T
	739003	Good Dune sand soils in the Dk Brown soil zone.	6MT(9)5W(1)	6(9)MT5(1)W	6(10)ME or 6(10)SE
	734003	Out 1 Class. Me 30, MeEm 30, Em 40	6M(6)5HMT(3)5W(1)	6(6)M3(3)MT5(1)W	5(8)ME3(2)M
St. Walburg – Shellbrook Area	711001	Out 1 Class. Domin. Orthic Gray Luvisol tills, with 60% SL and 40% L surface textures on B slopes. SKLAYER.DBF indicates SIL surf texture (too heavy) for Ap and/or Ae horizons, hence incorrect signal to LSRS.	6HAT(6)6W(3)7MT(1)	3(6)HT6(3)W6(1)MT	4(6)MD3(3)D6(1)W
XXXX	695004	Out 1 Class (close tho). Domin Me LS with subdom Em S, 10% Hm. SKLAYER indicates Ap texture of LFS (this is too light) for Me soils. 49-20-W3rd. I would say SKLAYER is giving LSRS wrong signal.	6M(8)5HM(2)	5(8)MT2(2)M	4(6)M5(4)ME
	687010	Out 1 Class. LzMt on A slopes, some B slopes. Dk Gray and Luv. tills 50-16-W3rd		3(9)HM5(1)W	2(6)M3(3))D5(1)W

	660008	Close. Gray Luvisols, loam till, on B and C slopes. 53-09-W3rd	5HTM(8)6WV(2)	4(8)TMP6(2)WV	3(6)D4(3)T6(1)W
Soil Landscapes	**SL**	**Physiographic Area in Prov / Soil Type(s) / Slope + Surfex**	**LSRS Rating Corn**	**LSRS Rating**	**Soil Capability Rating**
	680006	Out 3 classes. 60% is till with sandy over lay, and till; 40% is organics. 62-26-W3rd. N.W. of Meadow Lake. 62-26-W3rd	7WB(5)6M(4)6H(1)	7(5)WB4(4)M6(1) MP	4(6)MD0(4)
	680011	Out 1 class: LnBt complexes (O.G.Luv till + till with sandy overlay) mostly on B slopes, some A slopes. 61-26-W3rd	6H(5)6HMT(4)6HW (1)	3(5)HT4(4)MT5(1)W	4(9)MD5(1)W
	685005	Not too far out, all considered. Alluvium + organics Approx 60% is unusable. 59-15-W3rd		7(10)WV	5(4)W7(2)WO(4)
	682014	Out 2 Classes. 75% Pn Brunisolic and Regosolic sands on B slopes. 59-14-W3rd	7M(6)5HA(2)6W(2)	7(6)M3(2)H6(2)W	5MF
Melfort area	705002	Out 1 Class. Black lacust clay & HvC Mr/2-3u	4HA(9)5W(1)	2(9)HA5(10W	1
	705001	Out 1 Class. Ti (Dark Gray Lac Clays) & some Ed. (Luv. Clays)/2-3u , A slopes 46-14-W2nd	5HA(8)5W(1)	2(8)2(1)TM5(1)W	1(06)2(4)D
	705005	Out 1 Class. Black & Dark Gray Lacust clays/2-3u, A slopes. 45-16-W2nd	5HA(9)5W(1)	2(9)5(1)W	1
	706003	Out 1Class. Luv thick & thin silts,Dk Gray till on B & some C slopes 44-23-W2nd	5HAT(8)5W(1)5HM T	2(8)MT3(1)TM5(1)W	3(6)D2(4)M
	702006	Out 1 class. Mostly Go on A slopes, some Lc, Sb, Ka on B slopes Dk Gray & Luv fl lacust. Sands on gentle B slopes. 47-17-W2nd		2(8)MT3(1)TM5(1)W	3M
Meadow Lake area	680012	Good. Ln on A slopes, 322 & 321	6H(9)6MV(1)	3(9)H4(1)MV	3D (some 4D)
	680015	Out 1 Class. Ln, mostly A slopes	5HA(8)5HAW(1)5H W	3(8)H4(1)W5(1) W	4D
	685001	Mostly Md, some Bv & Ln		3(7)H3(2)M5(1)W	2(7)D3(3)D
Till on B slopes	820002	Close Hr + Fx /4h Brown till & silt	5MT(10)	4(10MT	3T
	729021	Good Mt + Mf/4h		3(10)MT	3TD
	783001	Good Wr /3-4h Dk Brown till	4MT(8)5W(1)6MT(1)	3(8)MT4(1)MT5(1)W	3MT
	756001	Good Ox/4h Black till	4HM(9)5W(1)	3(9)M5(1)W	3T
	749007	Good Ox + Yk mostly on 3, 3-4h		2(8)M5(2)W	2(07)M3(3)T
	782014	Good Wr L/4h Dk Brown till	4MT(9)6MT(1)	3(9)MT4(1)MT	3(09)MT4(1)W
Till on C slopes	748006	Mostly Black tills, 5-4, 5-6 topo, some 4-5h	4HAT(9)5W(1)	3(9)TM 5(1)W	4(7)T3(3)T
	810003	Good Wr/ mostly 5h		4(9)MT5(1)W	4T
	830010	Out 1 Class /mostly 5h	5MT(8)5M(1)5W(1)	3(8)MT4(1)M5(1) W	4T
	830011	Out 1 Class /mostly 5h, some 6h		3(9)MT5(1)W	4T
	830004	Out 1 Class /mostly 5H, some 4h		3(9)MT	4(7)T3(3)T

Till on D Slopes	822003	Out 1 Class. Am CL-L on 6h. North, N.E. and east of Old Wives. Incl. sign. GXX		4(8)TM5(2)W	5(10)TW
Soil Landscape	**SL**	**Physiographic Area in Prov / Soil Type(s) / Slope + Surfex**	**LSRS Rating Corn**	**LSRS Rating**	**Soil Capability Rating**
Black sandy soil	701009	Good. Hm + Me Black sandy	4HM(7)6M(2)5W(1)	3(7)M5(2)M5(1) W	3M
	701005	Out 2 Classes Me / Meota Ap horiz. in SKLAYER is LFS, too light, may give LSRS wrong signal.	6M(8)4HM(1)5W(1)	6(8)M3(1)M5(1) W	4M (some 3M)
	742002	Out 1 Class Me (minor Hm & Ws)/ Meota Ap horiz. in SKLAYER is LFS, too light, may give LSRS wrong signal.	6M(8)4HM(2)	5(8)M3(2)M	4M (some 3M)
	736009	Out 2 Classes Me / Meota Ap horiz. in SKLAYER is LFS, too light, may give LSRS wrong signal.	6M(8)4MT(1)5W(1)	5(8)M3(1)M5(1) W	3M
Gravelly soils	816015	Chaplin north end of Old Wives, 4h and 5h 50/50. Area extends to N.W. of Old Wives and contains Bg sl and Aq sl & fl surface textures with some eroded areas & Wc & Cn. Mixture of 5m and 4m. 14-29-W2nd	5MT(8)6MT(2)	3(6)MT6(4)MT	5(5)M4(5)M

Comments:

Note: The comments under "Physiographic Area in Province" have been left the same as for the last submission for LSRS Small Grains and do not refer to the LSRS Corn ratings.

1. Most of the LSRS ratings for corn from the SK_Corn.dbf are coming out fairly good, relative to LSRS ratings for small grains, and also in comparing LSRS corn ratings to CHU values from the database as supplied by Arnie Wadell. Reference has also been made to a Corn Heat Unit map available on the WEB from Sask. Agriculture and to a map from Sask. Crop Insurance that shows the area covered by insurance.
2. i) Regina heavy clay soils (Dark Brown) in west-central Sask. come out as 5M; Regina soils in Regina area come out as 4M.
   ii) There is an area of Sceptre heavy clay lacustrine soils in west Sask. That comes out as 6M; seems a bit harsh. Other areas nearby of Sceptre come out as 5M.
   ii) Luvisolic soils in northern ag. area come out as 5HA, 5HAT, some 6H, so seems reasonable.
   iv) Solonetzic soils seem to vary from 4M to 5M. In very Southwest of province, solonetzic soils are rated 6M for LSRS Corn.
   v) The same or similar soils (parent material, climatic zone) are usually being rated the same for the polygons that were reviewed, except as noted.
3. Steep slopes and areas of very sandy (dune sand) materials all seem to be handled appropriately.
4. There is an area around North Battleford and to southeast, south and southwest that have LSRS Corn ratings of 4HM, 4HAT. Around Humboldt and east a ways then south through Quill Lakes, there are areas rated as 4HM, 4HA, etc., and in relation to themed map of Average CHU Values (A. Wadell), fall just within the economic limit of 1900 – 2000. When comparing to the Accumulated CHU map from Sask. Ag. (90% confidence limit for Grain Production), these same areas would fall within the 1800-1900 CHU range.

9.3 Manitoba

Manitoba comments 10-12-07

1. Was the current LSRS testing done using SLCv3.1.1 data? In our April/07 SLC WG meeting, we indicated that all significant SLC CMP ag soils should have LU=A versions in the SNF and SLF. These should also have drained phases where the drainage has been significantly improved over native conditions, and the PHCA values of the Ap should be less acidic than the native versions of these soils, if liming is a common agricultural practice. Are there still many provinces that haven't done this for SLCv3.1.1? If so, perhaps this can be incorporated in the next SLC version.

2. MB sandy soils issue. As I recall, LSRS just looks at the total TSILT + TCLAY to evaluate the number of cm water per cm of soil. Adding 50% VFS to this total would increase the water holding capacity of fine sandy soils, and this simple modification is incorporated in the MB Foxpro LSRS program. If the AB LSRS program also doesn't use the KP values in the SLF to evaluate AWHC, then there should be no need to review whether %VFS was used in the KP pedotransfer functions or not. Would it be possible to make the change in a version of the AB program (or just run the MB program) and compare the LSRS ratings with and without VFSAND, to see if they change significantly? I think the ratings would improve for MB sandy soils.

3. Re: 3. It would be nice to see the actual 1960 to 1990 climatic data (P-PE, EGDD, and CHU) colour themed by itself. Many of our questions about the overall LSRS ratings maps may be due to problems with the underlying climate data.

4. Re: 7 Does LSRS make use of the SNF ROOTRESTR or RSTR_TYPE fields to identify impeding layers?

5. Haven't had time to review the MB maps in detail, but do recall some cases where Wayne's rollup method and a simple dominant method produced different results. Hopefully Glenn can provide some specific examples.

Wally Fraser

9.4 Ontario

Ontario comments 19-11-07

I have spent a bunch of time getting familiar with the Ontario SLC data and as well the LSRS interpretation output data. I have addressed the data issues thusly;

1. The inconsistencies between version 3.0 and 3.1 (1) and was able to realign the LU fields to match for all files
2. I created updated CMP, SNF and SLF files and created Drained phases (DR) and changed drainages to imperfect poorly drained lacustrine, marine and till soils.
3. I ran LSRS for Spring Seeded Grains, Corn, Soy and Alfalfa.

I have tried several different methods to compare the outputs to get a feel for appropriateness by climatic area, soil type and my knowledge of the agronomics of the areas.

1. I created an ArcGIS 'view' for each of the crops and visually evaluated the output by crop and comparisons between the crops. This was done by linking the PLY_SYMBOL to the SLC 3.1.1 map and mapping the resultant themed on first rating symbol (see attached jpg). I found this method useful and was able to then by looking at the output tables determine the differences between the rating by crop – based on climate, soil and topography.
2. I used the guidance that you provided and created unique tables by crop by processing the data through ACCESS and created output tables for each crop. I selected two polygons 7 regions in Ontario (Northern, Eastern, Bruce, Central, Niagara, Western and South-western) for each crop output. This allowed me to evaluate differences by region for each crop and determine the properties that changed the LSRS output. I was also able to do some comparison between regions to determine how suitability changed by crop between these regions. Please see attached table.

For the most part the most difficult for me to assess was the PLY_SYMBOL and how the classes were summarized and rolled-up. There appears to be some issues as to how things were summarized – not consistent. I could not find any real problematic areas – for the most part the output seemed to make pretty good 'agronomic' sense both where I knew the crops grow and ideas of relative yields. I had to do some thinking about the output for Alfalfa but for the most part things made sense.

I still am not sure of fully robust method to 'evaluate' the LSRS output, short of presenting the results to my provincial colleagues which I have not done to date. I hope that these comments are useful and if there is further evaluation that you want me to perform please let me know.

Thank-you for all the effort that you and Glenn have put into this interpretation and thanks for your patience guiding me through how to interpret the interpretations.

Dave Kroetsch

Ontario test rating sheet

REGION	SL	PLY_SYMBOL	PLY_RAT	NUMB	CMP_AREA	CMP_RAT	CMP_CLAS	C_RAT	C_CLAS	C_SUB1	S_NAME	S_RAT	S_CLAS	S_SUB1	S_SUB2	L_RAT	L_CLAS	L_SUB1
	ALFALFA																	
NIAGARA	569001	3W(5) - 6VW(5)	36	1	35	50	3	90	1	-	LIC/DR	50	3	W035	-	100	1	-
NIAGARA	569001	3W(5) - 6VW(5)	36	2	24	14	6	90	1	-	HIM	14	6	V064	W035	94	1	-
NIAGARA	569001	3W(5) - 6VW(5)	36	3	16	59	3	90	1	-	BVY	59	3	W035	-	100	1	-
NIAGARA	569001	3W(5) - 6VW(5)	36	4	13	20	5	90	1	-	ALU	20	5	V070	W034	100	1	-
NIAGARA	569001	3W(5) - 6VW(5)	36	5	12	25	5	90	1	-	TLD/DR	25	5	V058	W035	100	1	-
	ALFALFA																	
NIAGARA	569005	5VW(5) - 5W(3)	34	1	42	25	5	90	1	-	TLD/DR	25	5	V058	W036	100	1	-
NIAGARA	569005	5VW(5) - 5W(3)	34	2	26	25	5	90	1	-	WUS/DR	25	5	W069	-	100	1	-
NIAGARA	569005	5VW(5) - 5W(3)	34	3	8	59	3	90	1	-	BVY	59	3	W035	-	94	1	-
NIAGARA	569005	5VW(5) - 5W(3)	34	4	7	66	2	90	1	-	MPW/DR	66	2	W027	-	100	1	-
NIAGARA	569005	5VW(5) - 5W(3)	34	5	7	37	4	90	1	-	WAM	37	4	M038	-	94	1	-
NIAGARA	569005	5VW(5) - 5W(3)	34	6	5	70	2	90	1	-	BRR	70	2	-	-	94	1	-
NIAGARA	569005	5VW(5) - 5W(3)	34	7	5	31	4	90	1	-	LOW	31	4	W067	-	100	1	-
	CORN																	
NIAGARA	569001	3W(10)	45	1	35	48	3	78	2	A022	LIC/DR	48	3	W035	-	94	1	-
NIAGARA	569001	3W(10)	45	2	24	38	4	78	2	A022	HIM	38	4	W035	-	68	2	T032
NIAGARA	569001	3W(10)	45	3	16	53	3	78	2	A022	BVY	53	3	W035	-	94	1	-
NIAGARA	569001	3W(10)	45	4	13	39	4	78	2	A022	ALU	39	4	W034	V033	94	1	-
NIAGARA	569001	3W(10)	45	5	12	48	3	78	2	A022	TLD/DR	48	3	W035	-	94	1	-
	CORN																	
NIAGARA	569005	3W(6) - 5W(3)	41	1	42	48	3	79	2	A021	TLD/DR	48	3	W036	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	41	2	26	25	5	79	2	A021	WUS/DR	25	5	W069	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	41	3	8	53	3	79	2	A021	BVY	53	3	W035	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	41	4	7	57	3	79	2	A021	MPW/DR	57	3	W027	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	41	5	7	22	5	79	2	A021	WAM	22	5	M053	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	41	6	5	59	3	79	2	A021	BRR	59	3	-	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	41	7	5	31	4	79	2	A021	LOW	31	4	W067	-	94	1	-
	SOY																	
NIAGARA	569001	3W(10)	48	1	35	51	3	85	1	-	LIC/DR	51	3	W035	-	94	1	-
NIAGARA	569001	3W(10)	48	2	24	40	4	85	1	-	HIM	40	4	W035	-	68	2	T032
NIAGARA	569001	3W(10)	48	3	16	56	3	85	1	-	BVY	56	3	W035	-	94	1	-
NIAGARA	569001	3W(10)	48	4	13	41	4	85	1	-	ALU	41	4	W034	V033	94	1	-
NIAGARA	569001	3W(10)	48	5	12	51	3	85	1	-	TLD/DR	51	3	W035	-	94	1	-
	SOY																	
NIAGARA	569005	3W(6) - 5W(3)	43	1	42	51	3	84	1	-	TLD/DR	51	3	W036	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	43	2	26	25	5	84	1	-	WUS/DR	25	5	W069	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	43	3	8	56	3	84	1	-	BVY	56	3	W035	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	43	4	7	62	2	84	1	-	MPW/DR	62	2	W027	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	43	5	7	24	5	84	1	-	WAM	24	5	M046	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	43	6	5	64	2	84	1	-	BRR	64	2	-	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	43	7	5	31	4	84	1	-	LOW	31	4	W067	-	94	1	-

REGION	SL	PLY_SYMBOL	PLY_RAT	NUMB	CMP_AREA	CMP_RAT	CMP_CLAS	C_RAT	C_CLAS	C_SUB1	S_NAME	S_RAT	S_CLAS	S_SUB1	S_SUB2	L_RAT	L_CLAS	L_SUB1
	SS																	
NIAGARA	569001	3W(10)	51	1	35	55	3	96	1	-	LIC/DR	55	3	W035	-	94	1	-
NIAGARA	569001	3W(10)	51	2	24	44	4	96	1	-	HIM	44	4	W035	-	68	2	T032
NIAGARA	569001	3W(10)	51	3	16	59	3	96	1	-	BVY	59	3	W035	-	94	1	-
NIAGARA	569001	3W(10)	51	4	13	43	4	96	1	-	ALU	43	4	W034	V033	94	1	-
NIAGARA	569001	3W(10)	51	5	12	54	3	96	1	-	TLD/DR	54	3	W035	-	94	1	-
	SS																	
NIAGARA	569005	3W(6) - 5W(3)	46	1	42	54	3	97	1	-	TLD/DR	54	3	W036	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	46	2	26	25	5	97	1	-	WUS/DR	25	5	W069	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	46	3	8	59	3	97	1	-	BVY	59	3	W035	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	46	4	7	66	2	97	1	-	MPW/DR	66	2	W027	-	94	1	-
NIAGARA	569005	3W(6) - 5W(3)	46	5	7	37	4	97	1	-	WAM	37	4	M038	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	46	6	5	68	2	97	1	-	BRR	70	2	-	-	68	2	T032
NIAGARA	569005	3W(6) - 5W(3)	46	7	5	31	4	97	1	-	LOW	31	4	W067	-	94	1	-
	ALFALFA																	
ESSEX	570007	5VW(9) - 2(1)	26	1	80	22	5	96	1	-	BKN/DR	22	5	V052	W034	100	1	-
ESSEX	570007	5VW(9) - 2(1)	26	2	10	24	5	96	1	-	TLD/DR	24	5	V058	W035	100	1	-
ESSEX	570007	5VW(9) - 2(1)	26	3	10	67	2	96	1	-	BRR	67	2	-	-	94	1	-
	ALFALFA																	
ESSEX	572001	2(8) - 6V(2)	53	1	30	68	2	98	1	-	BRR	68	2	-	-	100	1	-
ESSEX	572001	2(8) - 6V(2)	53	2	20	57	3	98	1	-	PLL/DR	57	3	W033	-	94	1	-
ESSEX	572001	2(8) - 6V(2)	53	3	15	69	2	98	1	-	FOX	69	2	M024	-	94	1	-
ESSEX	572001	2(8) - 6V(2)	53	4	15	18	6	98	1	-	HRW	18	6	V070	-	69	2	T027
ESSEX	572001	2(8) - 6V(2)	53	5	10	61	2	98	1	-	TUC	61	2	W033	-	100	1	-
ESSEX	572001	2(8) - 6V(2)	53	6	10	20	5	98	1	-	BUF	20	5	V070	-	89	1	-
	CORN																	
ESSEX	570007	4W(10)	42	1	80	40	4	76	2	A024	BKN/DR	40	4	W034	-	94	1	-
ESSEX	570007	4W(10)	42	2	10	47	3	76	2	A024	TLD/DR	47	3	W035	-	94	1	-
ESSEX	570007	4W(10)	42	3	10	56	3	76	2	A024	BRR	56	3	M021	-	68	2	T032
	CORN																	
ESSEX	572001	3M(8) - 3TM(2)	52	1	30	57	3	78	2	A022	BRR	57	3	-	-	94	1	-
ESSEX	572001	3M(8) - 3TM(2)	52	2	20	54	3	78	2	A022	PLL/DR	54	3	W033	-	81	1	-
ESSEX	572001	3M(8) - 3TM(2)	52	3	15	49	3	78	2	A022	FOX	49	3	M044	-	68	2	T032
ESSEX	572001	3M(8) - 3TM(2)	52	4	15	41	4	78	2	A022	HRW	53	3	M024	-	41	4	T052
ESSEX	572001	3M(8) - 3TM(2)	52	5	10	54	3	78	2	A022	TUC	54	3	W033	-	94	1	-
ESSEX	572001	3M(8) - 3TM(2)	52	6	10	54	3	78	2	A022	BUF	54	3	M023	-	58	3	T032
	SOY																	
ESSEX	570007	3W(10)	46	1	80	43	4	86	1	-	BKN/DR	43	4	W034	-	94	1	-
ESSEX	570007	3W(10)	46	2	10	50	3	86	1	-	TLD/DR	50	3	W035	-	94	1	-
ESSEX	570007	3W(10)	46	3	10	62	2	86	1	-	BRR	62	2	-	-	68	2	T032
	SOY																	
ESSEX	572001	2(8) - 3T(2)	57	1	30	63	2	88	1	-	BRR	63	2	-	-	94	1	-
ESSEX	572001	2(8) - 3T(2)	57	2	20	57	3	88	1	-	PLL/DR	57	3	W033	-	81	1	-
ESSEX	572001	2(8) - 3T(2)	57	3	15	59	3	88	1	-	FOX	59	3	M034	-	68	2	T032
ESSEX	572001	2(8) - 3T(2)	57	4	15	41	4	88	1	-	HRW	62	2	-	-	41	4	T052
ESSEX	572001	2(8) - 3T(2)	57	5	10	57	3	88	1	-	TUC	57	3	W033	-	94	1	-

ESSEX	572001	2(8) - 3T(2)	57	6	10	58	3	88	1	-	BUF	64	2	-	-	58	3	T032
REGION	**SL**	**PLY_SYMBOL**	**PLY_RAT**	**NUMB**	**CMP_AREA**	**CMP_RAT**	**CMP_CLAS**	**C_RAT**	**C_CLAS**	**C_SUB1**	**S_NAME**	**S_RAT**	**S_CLAS**	**S_SUB1**	**S_SUB2**	**L_RAT**	**L_CLAS**	**L_SUB1**
	SS																	
ESSEX	570007	3W(10)	50	1	80	47	3	94	1	-	BKN/DR	47	3	W034	-	94	1	-
ESSEX	570007	3W(10)	50	2	10	53	3	94	1	-	TLD/DR	53	3	W035	-	94	1	-
ESSEX	570007	3W(10)	50	3	10	67	2	94	1	-	BRR	67	2	-	-	68	2	T032
	SS																	
ESSEX	572001	2(8) - 3T(2)	61	1	30	68	2	96	1	-	BRR	68	2	-	-	94	1	-
ESSEX	572001	2(8) - 3T(2)	61	2	20	60	2	96	1	-	PLL/DR	60	2	W033	-	81	1	-
ESSEX	572001	2(8) - 3T(2)	61	3	15	68	2	96	1	-	FOX	69	2	M024	-	68	2	T032
ESSEX	572001	2(8) - 3T(2)	61	4	15	41	4	96	1	-	HRW	73	2	-	-	41	4	T052
ESSEX	572001	2(8) - 3T(2)	61	5	10	61	2	96	1	-	TUC	61	2	W033	-	94	1	-
ESSEX	572001	2(8) - 3T(2)	61	6	10	58	3	96	1	-	BUF	74	2	-	-	58	3	T032
	ALFALFA																	
WEST	560003	2(8) - 3W(1) -	62	1	57	73	2	75	2	-	GUP	73	2	-	-	89	1	-
WEST	560003	2(8) - 3W(1) -	62	2	16	66	2	75	2	-	HRR	66	2	-	-	89	1	-
WEST	560003	2(8) - 3W(1) -	62	3	10	61	2	75	2	-	CTG	61	2	W029	-	100	1	-
WEST	560003	2(8) - 3W(1) -	62	4	10	1	7	75	2	-	ZOR	1	7	W086	V048	100	1	-
WEST	560003	2(8) - 3W(1) -	62	5	7	57	3	75	2	-	PLL/DR	57	3	W033	-	94	1	-
	ALFALFA																	
WEST	568001	3V(8) - 3TM(2)	47	1	25	50	3	84	1	-	FOX	64	2	M029	-	50	3	T050
WEST	568001	3V(8) - 3TM(2)	47	2	24	65	2	84	1	-	CAD	65	2	M026	-	94	1	-
WEST	568001	3V(8) - 3TM(2)	47	3	23	14	6	84	1	-	BUF	14	6	V070	-	94	1	-
WEST	568001	3V(8) - 3TM(2)	47	4	11	19	6	84	1	-	ALU	19	6	V070	W033	100	1	-
WEST	568001	3V(8) - 3TM(2)	47	5	10	84	1	84	1	-	TEW	92	1	-	-	94	1	-
WEST	568001	3V(8) - 3TM(2)	47	6	7	68	2	84	1	-	GNY/DR	68	2	M025	-	94	1	-
	CORN																	
WEST	560003	3MT(8) - 3W(1)	48	1	57	55	3	58	3	H042	GUP	55	3	M031	-	58	3	T032
WEST	560003	3MT(8) - 3W(1)	48	2	16	48	3	58	3	H042	HRR	48	3	M024	-	58	3	T032
WEST	560003	3MT(8) - 3W(1)	48	3	10	53	3	58	3	H042	CTG	53	3	W029	-	94	1	-
WEST	560003	3MT(8) - 3W(1)	48	4	10	1	7	58	3	H042	ZOR	1	7	W086	V048	94	1	-
WEST	560003	3MT(8) - 3W(1)	48	5	7	53	3	58	3	H042	PLL/DR	53	3	W033	-	81	1	-
	CORN																	
WEST	568001	3M(8) - 4TM(2)	45	1	25	34	4	73	2	A027	FOX	44	4	M049	-	34	4	T066
WEST	568001	3M(8) - 4TM(2)	45	2	24	45	3	73	2	A027	CAD	45	3	M046	-	81	1	-
WEST	568001	3M(8) - 4TM(2)	45	3	23	48	3	73	2	A027	BUF	48	3	M030	-	68	2	T032
WEST	568001	3M(8) - 4TM(2)	45	4	11	38	4	73	2	A027	ALU	38	4	W033	V033	94	1	-
WEST	568001	3M(8) - 4TM(2)	45	5	10	72	2	73	2	A027	TEW	72	2	M027	-	81	1	-
WEST	568001	3M(8) - 4TM(2)	45	6	7	55	3	73	2	A027	GNY/DR	55	3	M039	-	81	1	-
	SOY																	
WEST	560003	3HT(8) - 3W(1)	52	1	57	58	3	58	3	H042	GUP	64	2	M021	-	58	3	T032
WEST	560003	3HT(8) - 3W(1)	52	2	16	52	3	58	3	H042	HRR	52	3	D021	-	58	3	T032
WEST	560003	3HT(8) - 3W(1)	52	3	10	57	3	58	3	H042	CTG	57	3	W029	-	94	1	-
WEST	560003	3HT(8) - 3W(1)	52	4	10	1	7	58	3	H042	ZOR	1	7	W086	V048	94	1	-
WEST	560003	3HT(8) - 3W(1)	52	5	7	56	3	58	3	H042	PLL/DR	56	3	W033	-	81	1	-

REGION	SL	PLY_SYMBOL	PLY_RAT	NUMB	CMP_AREA	CMP_RAT	CMP_CLAS	C_RAT	C_CLAS	C_SUB1	S_NAME	S_RAT	S_CLAS	S_SUB1	S_SUB2	L_RAT	L_CLAS	L_SUB1
	SOY																	
WEST	568001	3M(8) - 4TM(2)	52	1	25	34	4	74	2	H026	FOX	54	3	M039	-	34	4	T066
WEST	568001	3M(8) - 4TM(2)	52	2	24	55	3	74	2	H026	CAD	55	3	M036	-	81	1	-
WEST	568001	3M(8) - 4TM(2)	52	3	23	58	3	74	2	H026	BUF	58	3	-	-	68	2	T032
WEST	568001	3M(8) - 4TM(2)	52	4	11	40	4	74	2	H026	ALU	40	4	W033	V033	94	1	-
WEST	568001	3M(8) - 4TM(2)	52	5	10	74	2	74	2	H026	TEW	82	1	-	-	81	1	-
WEST	568001	3M(8) - 4TM(2)	52	6	7	61	2	74	2	H026	GNY/DR	61	2	M032	-	81	1	-
	SS																	
WEST	560003	2T(8) - 2W(1)	54	1	57	58	3	94	1	-	GUP	73	2	-	-	58	3	T032
WEST	560003	2T(8) - 2W(1)	54	2	16	58	3	94	1	-	HRR	66	2	-	-	58	3	T032
WEST	560003	2T(8) - 2W(1)	54	3	10	61	2	94	1	-	CTG	61	2	W029	-	94	1	-
WEST	560003	2T(8) - 2W(1)	54	4	10	1	7	94	1	-	ZOR	1	7	W086	V048	94	1	-
WEST	560003	2T(8) - 2W(1)	54	5	7	59	3	94	1	-	PLL/DR	59	3	W033	-	81	1	-
	SS																	
WEST	568001	2(8) - 4TM(2)	59	1	25	34	4	92	1	-	FOX	64	2	M029	-	34	4	T066
WEST	568001	2(8) - 4TM(2)	59	2	24	65	2	92	1	-	CAD	65	2	M026	-	81	1	-
WEST	568001	2(8) - 4TM(2)	59	3	23	68	2	92	1	-	BUF	68	2	-	-	68	2	T032
WEST	568001	2(8) - 4TM(2)	59	4	11	43	4	92	1	-	ALU	43	4	W033	V033	94	1	-
WEST	568001	2(8) - 4TM(2)	59	5	10	81	1	92	1	-	TEW	92	1	-	-	81	1	-
WEST	568001	2(8) - 4TM(2)	59	6	7	68	2	92	1	-	GNY/DR	68	2	M025	-	81	1	-
	ALFALFA																	
BRUCE	551028	3W(8) - 3VT(1)	51	1	71	58	3	75	2	-	EDS	58	3	W035	-	94	1	-
BRUCE	551028	3W(8) - 3VT(1)	51	2	13	17	6	75	2	-	CLY	17	6	W077	-	94	1	-
BRUCE	551028	3W(8) - 3VT(1)	51	3	7	20	5	75	2	-	ALU	20	5	V070	W034	100	1	-
BRUCE	551028	3W(8) - 3VT(1)	51	4	5	47	3	75	2	-	WTO	81	1	-	-	47	3	T050
BRUCE	551028	3W(8) - 3VT(1)	51	5	4	62	2	75	2	-	LTW	62	2	W033	-	89	1	-
	ALFALFA																	
BRUCE	556003	4TP(5) - 2(4)	43	1	53	33	4	71	2	-	PKL	86	1	-	-	33	4	T050
BRUCE	556003	4TP(5) - 2(4)	43	2	31	70	2	71	2	-	HRR	70	2	-	-	89	1	-
BRUCE	556003	4TP(5) - 2(4)	43	3	11	1	7	71	2	-	ZOR	1	7	W089	V048	100	1	-
BRUCE	556003	4TP(5) - 2(4)	43	4	5	71	2	71	2	-	HKY	88	1	-	-	89	1	-
	CORN																	
BRUCE	551028	3WT(8) - 5TM(1	45	1	71	52	3	56	3	H044	EDS	52	3	W035	-	68	2	T032
BRUCE	551028	3WT(8) - 5TM(1	45	2	13	17	6	56	3	H044	CLY	17	6	W077	-	68	2	T032
BRUCE	551028	3WT(8) - 5TM(1	45	3	7	39	4	56	3	H044	ALU	39	4	W034	V033	94	1	-
BRUCE	551028	3WT(8) - 5TM(1	45	4	5	29	5	56	3	H044	WTO	61	2	M029	-	29	5	T066
BRUCE	551028	3WT(8) - 5TM(1	45	5	4	55	3	56	3	H044	LTW	55	3	W033	-	58	3	T032
	CORN																	
BRUCE	556003	5TPM(5) - 3HT(	29	1	53	20	5	52	3	H048	PKL	66	2	M030	-	20	5	T066
BRUCE	556003	5TPM(5) - 3HT(	29	2	31	52	3	52	3	H048	HRR	54	3	-	-	58	3	T032
BRUCE	556003	5TPM(5) - 3HT(	29	3	11	1	7	52	3	H048	ZOR	1	7	W089	V048	94	1	-
BRUCE	556003	5TPM(5) - 3HT(	29	4	5	52	3	52	3	H048	HKY	72	2	-	-	58	3	T032

REGION	SL	PLY_SYMBOL	PLY_RAT	NUMB	CMP_AREA	CMP_RAT	CMP_CLAS	C_RAT	C_CLAS	C_SUB1	S_NAME	S_RAT	S_CLAS	S_SUB1	S_SUB2	L_RAT	L_CLAS	L_SUB1
	SOY																	
BRUCE	551028	3WT(8) - 5T(1)	48	1	71	55	3	56	3	H044	EDS	55	3	W035	-	68	2	T032
BRUCE	551028	3WT(8) - 5T(1)	48	2	13	17	6	56	3	H044	CLY	17	6	W077	-	68	2	T032
BRUCE	551028	3WT(8) - 5T(1)	48	3	7	41	4	56	3	H044	ALU	41	4	W034	V033	94	1	-
BRUCE	551028	3WT(8) - 5T(1)	48	4	5	29	5	56	3	H044	WTO	71	2	-	-	29	5	T066
BRUCE	551028	3WT(8) - 5T(1)	48	5	4	56	3	56	3	H044	LTW	58	3	W033	-	58	3	T032
	SOY																	
BRUCE	556003	5TP(5) - 3HT(4	29	1	53	20	5	52	3	H048	PKL	76	2	-	-	20	5	T066
BRUCE	556003	5TP(5) - 3HT(4	29	2	31	52	3	52	3	H048	HRR	59	3	D021	-	58	3	T032
BRUCE	556003	5TP(5) - 3HT(4	29	3	11	1	7	52	3	H048	ZOR	1	7	W089	V048	94	1	-
BRUCE	556003	5TP(5) - 3HT(4	29	4	5	52	3	52	3	H048	HKY	82	1	-	-	58	3	T032
	SS																	
BRUCE	551028	3WT(8) - 5T(1)	50	1	71	58	3	99	1	-	EDS	58	3	W035	-	68	2	T032
BRUCE	551028	3WT(8) - 5T(1)	50	2	13	17	6	99	1	-	CLY	17	6	W077	-	68	2	T032
BRUCE	551028	3WT(8) - 5T(1)	50	3	7	44	4	99	1	-	ALU	44	4	W034	V033	94	1	-
BRUCE	551028	3WT(8) - 5T(1)	50	4	5	29	5	99	1	-	WTO	81	1	-	-	29	5	T066
BRUCE	551028	3WT(8) - 5T(1)	50	5	4	58	3	99	1	-	LTW	62	2	W033	-	58	3	T032
	SS																	
BRUCE	556003	5TP(5) - 3T(4)	32	1	53	20	5	100	1	-	PKL	86	1	-	-	20	5	T066
BRUCE	556003	5TP(5) - 3T(4)	32	2	31	58	3	100	1	-	HRR	70	2	-	-	58	3	T032
BRUCE	556003	5TP(5) - 3T(4)	32	3	11	1	7	100	1	-	ZOR	1	7	W089	V048	94	1	-
BRUCE	556003	5TP(5) - 3T(4)	32	4	5	58	3	100	1	-	HKY	88	1	-	-	58	3	T032
	ALFALFA																	
CENT	553005	2(9) - 7WVB(1)	55	1	22	57	3	75	2	-	SMV	57	3	-	-	94	1	-
CENT	553005	2(9) - 7WVB(1)	55	2	19	68	2	75	2	-	OBE	68	2	-	-	69	2	T027
CENT	553005	2(9) - 7WVB(1)	55	3	18	60	2	75	2	-	SMC/DR	60	2	W034	-	100	1	-
CENT	553005	2(9) - 7WVB(1)	55	4	15	73	2	75	2	-	WPO	73	2	-	-	94	1	-
CENT	553005	2(9) - 7WVB(1)	55	5	12	1	7	75	2	-	ZOR	1	7	W085	V048	100	1	-
CENT	553005	2(9) - 7WVB(1)	55	6	8	46	3	75	2	-	SMF	46	3	W032	V023	94	1	-
CENT	553005	2(9) - 7WVB(1)	55	7	6	63	2	75	2	-	DUL	63	2	M024	-	94	1	-
	ALFALFA																	
CENT	553027	1(6) - 4MV(4)	65	1	52	86	1	86	1	-	NWC	87	1	-	-	94	1	-
CENT	553027	1(6) - 4MV(4)	65	2	21	29	5	86	1	-	BGH	29	5	M054	-	94	1	-
CENT	553027	1(6) - 4MV(4)	65	3	12	19	6	86	1	-	ALU	19	6	V070	W033	100	1	-
CENT	553027	1(6) - 4MV(4)	65	4	9	77	2	86	1	-	BDH	77	2	-	-	89	1	-
CENT	553027	1(6) - 4MV(4)	65	5	3	57	3	86	1	-	DGT	57	3	W026	-	89	1	-
CENT	553027	1(6) - 4MV(4)	65	6	3	61	2	86	1	-	LYS/DR	61	2	-	-	94	1	-
	CORN																	
CENT	553005	3M(7) - 4TM(2)	44	1	22	46	3	58	3	H042	SMV	46	3	M034	-	81	1	-
CENT	553005	3M(7) - 4TM(2)	44	2	19	41	4	58	3	H042	OBE	49	3	M038	-	41	4	T052
CENT	553005	3M(7) - 4TM(2)	44	3	18	54	3	58	3	H042	SMC/DR	54	3	W034	-	94	1	-
CENT	553005	3M(7) - 4TM(2)	44	4	15	58	3	58	3	H042	WPO	59	3	M027	-	68	2	T032
CENT	553005	3M(7) - 4TM(2)	44	5	12	1	7	58	3	H042	ZOR	1	7	W085	V048	94	1	-
CENT	553005	3M(7) - 4TM(2)	44	6	8	54	3	58	3	H042	SMF	54	3	W032	-	68	2	T032
CENT	553005	3M(7) - 4TM(2)	44	7	6	44	4	58	3	H042	DUL	44	4	M044	-	68	2	T032

REGION	SL	PLY_SYMBOL	PLY_RAT	NUMB	CMP_AREA	CMP_RAT	CMP_CLAS	C_RAT	C_CLAS	C_SUB1	S_NAME	S_RAT	S_CLAS	S_SUB1	S_SUB2	L_RAT	L_CLAS	L_SUB1
	CORN																	
CENT	553027	2TM(6) - 5M(4)	51	1	52	68	2	71	2	A029	NWC	71	2	M028	-	68	2	T032
CENT	553027	2TM(6) - 5M(4)	51	2	21	13	6	71	2	A029	BGH	13	6	M070	-	68	2	T032
CENT	553027	2TM(6) - 5M(4)	51	3	12	37	4	71	2	A029	ALU	37	4	W033	V033	94	1	-
CENT	553027	2TM(6) - 5M(4)	51	4	9	58	3	71	2	A029	BDH	58	3	M038	-	58	3	T032
CENT	553027	2TM(6) - 5M(4)	51	5	3	49	3	71	2	A029	DGT	49	3	W026	-	58	3	T032
CENT	553027	2TM(6) - 5M(4)	51	6	3	50	3	71	2	A029	LYS/DR	50	3	M031	-	81	1	-
	SOY																	
CENT	553005	3(7) - 4TM(2)	47	1	22	52	3	58	3	H042	SMV	52	3	M027	-	81	1	-
CENT	553005	3(7) - 4TM(2)	47	2	19	41	4	58	3	H042	OBE	59	3	M028	-	41	4	T052
CENT	553005	3(7) - 4TM(2)	47	3	18	57	3	58	3	H042	SMC/DR	57	3	W034	-	94	1	-
CENT	553005	3(7) - 4TM(2)	47	4	15	58	3	58	3	H042	WPO	67	2	-	-	68	2	T032
CENT	553005	3(7) - 4TM(2)	47	5	12	1	7	58	3	H042	ZOR	1	7	W085	V048	94	1	-
CENT	553005	3(7) - 4TM(2)	47	6	8	57	3	58	3	H042	SMF	57	3	W032	-	68	2	T032
CENT	553005	3(7) - 4TM(2)	47	7	6	54	3	58	3	H042	DUL	54	3	M034	-	68	2	T032
	SOY																	
CENT	553027	2T(6) - 4MT(4)	53	1	52	68	2	76	2	H024	NWC	81	1	-	-	68	2	T032
CENT	553027	2T(6) - 4MT(4)	53	2	21	19	6	76	2	H024	BGH	19	6	M064	-	68	2	T032
CENT	553027	2T(6) - 4MT(4)	53	3	12	40	4	76	2	H024	ALU	40	4	W033	V033	94	1	-
CENT	553027	2T(6) - 4MT(4)	53	4	9	58	3	76	2	H024	BDH	68	2	M028	-	58	3	T032
CENT	553027	2T(6) - 4MT(4)	53	5	3	53	3	76	2	H024	DGT	53	3	W026	-	58	3	T032
CENT	553027	2T(6) - 4MT(4)	53	6	3	55	3	76	2	H024	LYS/DR	55	3	M024	-	81	1	-
	SS																	
CENT	553005	2(7) - 4T(2) -	51	1	22	57	3	91	1	-	SMV	57	3	-	-	81	1	-
CENT	553005	2(7) - 4T(2) -	51	2	19	41	4	91	1	-	OBE	68	2	-	-	41	4	T052
CENT	553005	2(7) - 4T(2) -	51	3	18	60	2	91	1	-	SMC/DR	60	2	W034	-	94	1	-
CENT	553005	2(7) - 4T(2) -	51	4	15	68	2	91	1	-	WPO	76	2	-	-	68	2	T032
CENT	553005	2(7) - 4T(2) -	51	5	12	1	7	91	1	-	ZOR	1	7	W085	V048	94	1	-
CENT	553005	2(7) - 4T(2) -	51	6	8	61	2	91	1	-	SMF	61	2	W032	-	68	2	T032
CENT	553005	2(7) - 4T(2) -	51	7	6	63	2	91	1	-	DUL	63	2	M024	-	68	2	T032
	SS																	
CENT	553027	2T(6) - 4MT(4)	56	1	52	68	2	90	1	-	NWC	91	1	-	-	68	2	T032
CENT	553027	2T(6) - 4MT(4)	56	2	21	29	5	90	1	-	BGH	29	5	M054	-	68	2	T032
CENT	553027	2T(6) - 4MT(4)	56	3	12	42	4	90	1	-	ALU	42	4	W033	V033	94	1	-
CENT	553027	2T(6) - 4MT(4)	56	4	9	58	3	90	1	-	BDH	77	2	-	-	58	3	T032
CENT	553027	2T(6) - 4MT(4)	56	5	3	57	3	90	1	-	DGT	57	3	W026	-	58	3	T032
CENT	553027	2T(6) - 4MT(4)	56	6	3	61	2	90	1	-	LYS/DR	61	2	-	-	81	1	-
	ALFALFA																	
EAST	546005	2(7) - 7WVB(2)	58	1	29	75	2	75	2	-	GVI	81	1	-	-	94	1	-
EAST	546005	2(7) - 7WVB(2)	58	2	25	67	2	75	2	-	EMR	89	1	-	-	67	2	P033
EAST	546005	2(7) - 7WVB(2)	58	3	19	1	7	75	2	-	ZOR	1	7	W088	V048	100	1	-
EAST	546005	2(7) - 7WVB(2)	58	4	8	71	2	75	2	-	NGW/DR	71	2	W028	-	100	1	-
EAST	546005	2(7) - 7WVB(2)	58	5	7	67	2	75	2	-	WFD/DR	67	2	W025	-	100	1	-
EAST	546005	2(7) - 7WVB(2)	58	6	5	64	2	75	2	-	MTD	64	2	W027	-	94	1	-
EAST	546005	2(7) - 7WVB(2)	58	7	4	41	4	75	2	-	ERC	41	4	V042	-	50	3	T050
EAST	546005	2(7) - 7WVB(2)	58	8	3	50	3	75	2	-	KRS	50	3	M025	-	94	1	-

REGION	SL	PLY_SYMBOL	PLY_RAT	NUMB	CMP_AREA	CMP_RAT	CMP_CLAS	C_RAT	C_CLAS	C_SUB1	S_NAME	S_RAT	S_CLAS	S_SUB1	S_SUB2	L_RAT	L_CLAS	L_SUB1
	ALFALFA																	
EAST	547010	3D(8) - 7WVB(2	35	1	61	40	4	76	2	-	FRM	40	4	D052	-	100	1	-
EAST	547010	3D(8) - 7WVB(2	35	2	24	1	7	76	2	-	ZOR	1	7	W084	V048	100	1	-
EAST	547010	3D(8) - 7WVB(2	35	3	10	70	2	76	2	-	GVI	70	2	M023	-	89	1	-
EAST	547010	3D(8) - 7WVB(2	35	4	3	70	2	76	2	-	NGW/DR	70	2	W027	-	100	1	-
EAST	547010	3D(8) - 7WVB(2	35	5	2	54	3	76	2	-	TNY	54	3	M022	-	89	1	-
	CORN																	
EAST	546005	2M(7) - 7WVB(2	51	1	29	61	2	65	2	H035	GVI	61	2	M033	-	81	1	-
EAST	546005	2M(7) - 7WVB(2	51	2	25	57	3	65	2	H035	EMR	71	2	M022	-	57	3	P040
EAST	546005	2M(7) - 7WVB(2	51	3	19	1	7	65	2	H035	ZOR	1	7	W088	V048	94	1	-
EAST	546005	2M(7) - 7WVB(2	51	4	8	63	2	65	2	H035	NGW/DR	63	2	W028	-	94	1	-
EAST	546005	2M(7) - 7WVB(2	51	5	7	58	3	65	2	H035	WFD/DR	58	3	W025	-	94	1	-
EAST	546005	2M(7) - 7WVB(2	51	6	5	56	3	65	2	H035	MTD	56	3	W027	-	81	1	-
EAST	546005	2M(7) - 7WVB(2	51	7	4	34	4	65	2	H035	ERC	57	3	M035	-	34	4	T066
EAST	546005	2M(7) - 7WVB(2	51	8	3	30	4	65	2	H035	KRS	30	4	M045	-	81	1	-
	CORN																	
EAST	547010	4DM(7) - 7WVB(	27	1	61	31	4	65	2	H035	FRM	31	4	D052	M035	94	1	-
EAST	547010	4DM(7) - 7WVB(	27	2	24	1	7	65	2	H035	ZOR	1	7	W084	V048	94	1	-
EAST	547010	4DM(7) - 7WVB(	27	3	10	51	3	65	2	H035	GVI	51	3	M043	-	58	3	T032
EAST	547010	4DM(7) - 7WVB(	27	4	3	61	2	65	2	H035	NGW/DR	61	2	W027	-	94	1	-
EAST	547010	4DM(7) - 7WVB(	27	5	2	49	3	65	2	H035	TNY	49	3	M042	-	58	3	T032
	SOY																	
EAST	546005	2H(7) - 7WVB(2	52	1	29	65	2	65	2	H035	GVI	71	2	M023	-	81	1	-
EAST	546005	2H(7) - 7WVB(2	52	2	25	57	3	65	2	H035	EMR	80	1	-	-	57	3	P040
EAST	546005	2H(7) - 7WVB(2	52	3	19	1	7	65	2	H035	ZOR	1	7	W088	V048	94	1	-
EAST	546005	2H(7) - 7WVB(2	52	4	8	65	2	65	2	H035	NGW/DR	67	2	W028	-	94	1	-
EAST	546005	2H(7) - 7WVB(2	52	5	7	63	2	65	2	H035	WFD/DR	63	2	W025	-	94	1	-
EAST	546005	2H(7) - 7WVB(2	52	6	5	60	2	65	2	H035	MTD	60	2	W027	-	81	1	-
EAST	546005	2H(7) - 7WVB(2	52	7	4	34	4	65	2	H035	ERC	67	2	M025	-	34	4	T066
EAST	546005	2H(7) - 7WVB(2	52	8	3	35	4	65	2	H035	KRS	35	4	M035	-	81	1	-
	SOY																	
EAST	547010	4DM(7) - 7WVB(	30	1	61	35	4	65	2	H035	FRM	35	4	D052	M025	94	1	-
EAST	547010	4DM(7) - 7WVB(	30	2	24	1	7	65	2	H035	ZOR	1	7	W084	V048	94	1	-
EAST	547010	4DM(7) - 7WVB(	30	3	10	58	3	65	2	H035	GVI	60	2	M033	-	58	3	T032
EAST	547010	4DM(7) - 7WVB(	30	4	3	65	2	65	2	H035	NGW/DR	65	2	W027	-	94	1	-
EAST	547010	4DM(7) - 7WVB(	30	5	2	58	3	65	2	H035	TNY	58	3	M032	-	58	3	T032

REGION	SL SS	PLY_SYMBOL	PLY_RAT	NUMB	CMP_AREA	CMP_RAT	CMP_CLAS	C_RAT	C_CLAS	C_SUB1	S_NAME	S_RAT	S_CLAS	S_SUB1	S_SUB2	L_RAT	L_CLAS	L_SUB1
EAST	546005	2(7) - 7WVB(2)	60	1	29	81	1	97	1	-	GVI	81	1	-	-	81	1	-
EAST	546005	2(7) - 7WVB(2)	60	2	25	57	3	97	1	-	EMR	89	1	-	-	57	3	P040
EAST	546005	2(7) - 7WVB(2)	60	3	19	1	7	97	1	-	ZOR	1	7	W088	V048	94	1	-
EAST	546005	2(7) - 7WVB(2)	60	4	8	71	2	97	1	-	NGW/DR	71	2	W028	-	94	1	-
EAST	546005	2(7) - 7WVB(2)	60	5	7	67	2	97	1	-	WFD/DR	67	2	W025	-	94	1	-
EAST	546005	2(7) - 7WVB(2)	60	6	5	64	2	97	1	-	MTD	64	2	W027	-	81	1	-
EAST	546005	2(7) - 7WVB(2)	60	7	4	34	4	97	1	-	ERC	77	2	-	-	34	4	T066
EAST	546005	2(7) - 7WVB(2)	60	8	3	50	3	97	1	-	KRS	50	3	M025	-	81	1	-
	SS																	
EAST	547010	4D(7) - 7WVB(2	33	1	61	40	4	89	1	-	FRM	40	4	D052	-	94	1	-
EAST	547010	4D(7) - 7WVB(2	33	2	24	1	7	89	1	-	ZOR	1	7	W084	V048	94	1	-
EAST	547010	4D(7) - 7WVB(2	33	3	10	58	3	89	1	-	GVI	70	2	M023	-	58	3	T032
EAST	547010	4D(7) - 7WVB(2	33	4	3	70	2	89	1	-	NGW/DR	70	2	W027	-	94	1	-
EAST	547010	4D(7) - 7WVB(2	33	5	2	58	3	89	1	-	TNY	68	2	M022	-	58	3	T032

9.5 New Brunswick

Following your telephone call the same day after Sherif's email about LSRS, NB evaluation, I am providing you more details with specific examples on the evaluation. Should you have any questions about the next comments, please let us know.

You and Sherif

General comment:
1. The LSRS 3.0 works in NB, as mentioned in Sherif's email to you on Oct. 31, 2007. In the current use to generate land ratings based on the data and map of the Soil Landscape of Canada (SLC), the LSRS provides a clear image of where the good land is and what is the problem, which no doubt support policy making on land development. On the other hand, the rating results of LSRS 3.0 have limitations to support on-site land management decision with data input from the current SLC map. In the 1:1million SLC map, soil polygons of New Brunswick represent land areas ranged from 9 km2 to 900 km2. Most of the polygons consist of 2 or more soil series. It is not possible to locate the representing area of individual soil within the polygon. This limitation does not root from the methodology of LSRS itself, which is more suitable to on-farm managements given the detail soil data input, rather due to using the small scale SLC map. The shortcoming can be overcome if LSRS 3.0 works on a digital SLC map, which should have the capability showing meter by meter grid even on a 1:1 million scale map.

The LSRS 3.0 uses climate data from 1961 to 1990 to calculate the point deduction for climatic factors. It takes 30-year climate normals to avoid years with extreme weather, which is reasonable. I do not have the Maps 1-4, mentioned in the Technical Bulletin (1995. p. viii), thus the climatic factors are not considered in the evaluation.

Specific points:
1. Consistency: In the manual of Land Suitability Rating System for Agricultural Crops (Technical Bulletin, 1995), Moisture Factor (A) is considered as a climatic factor (p. 7). But, in LSRS 3.0, Moisture Factor (M) refers to a soil factor on mineral soil rating. This is contradicted and I was confused when referred to the manual (Technical Bulletin, 1995) for the meaning and definition of terms used in the LSRS 3.0 program. It would be more suitable by using text 'Water Supplying Ability (M)' in the LSRS 3.0 program, based on the information on how (M) was calculated (p. 13-15, Technical Bulletin, 1995).

2. Soil reaction (V) in the final ratings
SL # 495005, final rating 6VPM(5)-6WVP(3)-4MPV(2) for small grain. The rating result show soil reaction – pH (V) is a limiting factor for both natural land [6VPM(5)-6WVP(3)] and agricultural land [4MPV(2)]. The input data were collected or based on collected data years ago. Thus, when the rating results pointed out low soil pH is a limiting factor, one should note that soil pH might not be low at current time as it was years ago, due to the agricultural practices, e.g. liming the soil for crop production (as Gary Patterson mentioned in the response to Sherif's email on LSRS, NB evaluation, Nov.5, 2007). The LSRS 3.0

should advice the users to verify their soil pH before taking action to address the low pH problem. Fortunately, it is not complicated and not expensive to conduct soil pH test on site at current time.

3. Soil match in final ratings
SL # 484006, final rating: 3TP(5)-4VTP(5) for small grain and 4HTP(7)-6MVT(3) for corn. This is the polygon we discussed on the phone, but did not figured out which soil components the 3TP(5) or 4VTP(5) represents for in the small grain rating. There are 6 soil components within the polygon. By considering the area percentage and the rating score of individual component, I am not able to assign the soils to the final rating results for small grain as well as corn.

4. Rock (R) and Soil structure (D)
In several cases, LSRS 3.0 uses the bulk density (BD) of rock layer (R) to determine soil ratings. Here is an example, SL # 481007 final rating 7TPD(10) for small grain and corn:
In the polygon, the agricultural soil McGee with modifier 220 has the following layers:
BC 40 – 60 cm BD 1.4
R 60-100 cm BD 2.7
The LSRS picked up the highest BD within 100cm soil profile, which is BD 2.7 to rate this soil. I do not know this is correct.

5. Depth to impeding layer
In New Brunswick, shallow soil is common as pointed out in Sherif's email (Oct.31, 2007). It is not surprised that LSRS 3.0 generally downgrade the NB soil since it uses the same scale (7 classes) to measure national wide soils. A soil may be considered a good soil in New Brunswick, but LSRS 3.0 may rate it in a middle class. For example, SL # 484007 final rating 5TD(6)-4TDV(4) for small grain, the CBU/220 (area 30%) is rated at class 4 in LSRS, but this Caribou soil (CBU) in NB is a class 2 soil in Canada Land Inventory (CLI). There is nothing wrong with the rating results; however, the shallow soil nature should be reflected in the final ratings. In the LSRS 3.0, the deduction for the shallow nature (depth to impeding layer) is incorporated into BD and clay %. For example, SL # 481007:

In LSRS 3.0:
Subsurface Impedence
Highest BD value 2.70
%C (from above) 12 % deduction= 90
% Impedence Modification
Depth to impeding layer 60
P-PE (from above) -21 % modification deduction= 41
Final impedence % deduction= 37 (D)

The final impedence deduction (37%) may be reasonable for the soil. But, it is based on the BD 2.7 of the rock layer, as pointed out in the pervious comment (# 6). It would be convincing if the LSRS 3.0 chose the Highest BD from soil layers (in this case BD 1.4), which results in 0 % deduction from the BD, and deducted 37 % for the shallow nature - the Depth to impedence layer (60 cm), as suggested in the following paragraph. By separating the deduction of Depth to impeding layer from Highest BD, The users know the problem with their land is due to the Depth to impeding layer, most likely the depth to rock in New Brunswick, but not due to the soil bulk density.

Suggestion on rating calculation for the SL # 481007 polygon:
Subsurface Impedence
Highest BD value 1.4
%C (from above) 12 % deduction= **0 (D)**
Depth to impeding layer 60
P-PE (from above) -21 % deduction= **37 (Depth)**
Final impedence % deduction= **37 (Depth)**

You Jiao, Ph.D.
Pedologist

Hi Tony,

It has been a while since we corresponded, finally we can say we may be meeting the dead line date for responding to your request concerning LSRS, NB evaluation.
The evaluation was mainly for small grains, and we feel that:
- LSRS works well and makes good sense when applied using SLC for NB.
-Navigation through it is not difficult.
- We find that the verification of the rating output is tedious for the novice (one has to go back and forth to and from the KEY for the ratings.
- The ratings are very severe; downgrading the soil in question is the norm, of course it is based and dependent on the soil, climate and site data quality. For example; PH, OM, BD are all dependent on management, and may be the NB soils depth to the contrasting layer (compacted) is on the average between 40 – 60 cm.
We had hoped that the rating for potato production were ready for verification.

Please let us know if you have any questions concerning this matter.

Sherif

9.6 Nova Scotia

Comments on the Land Suitability Rating System (LSRS)
Dave Langille and Ken Webb, Nova Scotia, 2007-10-22

As an initial check I compared the ratings from the LSRS against those made for similar soils and crops in the Soils of Colchester and Pictou County (Co-Pi) reports.

Possible comparison

Co_Pi	**LSRS_Class**
Good (G)	**1, 2**
Fair (F)	**3, (4)**
Poor (P)	**4, 5**
Unsuitable (U)	**6, 7**

Overall the ratings are not bad. When comparing CLI ratings from the Colchester and Pictou county soils reports to the LSRS ratings there appears to be a stronger relationship between the two systems for small grains than there does alfalfa or corn.

Not Rated Polygons

There are still a great many polygons in NS, and other parts of the country, which are not rated. In NS, this is most likely because "Land Types" are components of the not (NR) polygons. If the LSRS program allowed these "Land Type" components to be ignored by recognizing the "U" (undifferentiated) class in the "KIND" field of the SLF it may allow a general rating for the polygon. (Similar to the SNLCHEK program).

Acidity

Because many of our soils have a naturally lower pH, lime application is standard practice for most crops. Soil reaction seems to play a much larger role in the assignment of ratings by the LSRS for alfalfa than it does for other rated crops. Alfalfa is a "prima donna" and requires near neutral pH as well as excellent physical soil characteristics to grow well. "That's why we grow more red clover here." (personal comm. Dr. N. McLean (NSAC)).

WOV3 is rated as class 4V LSRS for alfalfa based on pH. Increasing pH value in the SLF would help.

LSRS rates TUO3 as 3V for alfalfa and class 2 for small grains. This could be improved if we increased the pH values of our agricultural soils in the SLF.

WOB3/C is rated class 5VD in the LSRS for alfalfa and rated F in Co-Pi again pH and depth to restricting layer are the main issues. Revisiting the pH values and depth criteria for agricultural soils

Restricted Drainage

After reviewing the ratings for brome grass, I was surprised that NS had no class one soils. Brome grass has been successfully grown in NS on Queens (QUE) soils that have been tile drained, and on our Pugwash (PGW) soils. It can not tolerate prolonged periods of saturation within the root zone, so damp spring and fall seasons may hinder growth on imperfectly drained soils. Since the majority of brome root mass is within the top 50 cm, compact layers below this depth are not much of a problem (personal comm. Dr. Y. Papadopoulous (AAFC)).

Climate

Within the LSRS, climate does not appear to be a major limiting factor for crop production, in some regions of Nova Scotia (NS) except for corn. Historically NS had no CLI class 1 soils, as climate was the limiting factor. Along the Northumberland shore and in the Annapolis valley areas, climate is generally not a limiting factor for most crops. Corn varieties grown here are more suited to our climate (require fewer Corn Heat Units (CHUs)) and produce respectable yields. The majority of corn grown here is for silage but high moisture ear and grain corn varieties are grown successfully as well.

Flooding

It appears the LSRS is unable to assign meaningful flooding frequency and inundation period codes. All soils appear to be assigned 1 = rare frequency % and 1 = very brief inundation period. Significant flooding needs to be recognized on alluvial soils such as the Cumberland (CBR) and Stewiacke (STW). Maybe an algorithm interpreting the combined influences of WATERTBL (i.e., YG), MDEP (i.e., FLUV), and G_GROUP (i.e., *.R, *.HR, RG) would estimate some assessment of flooding. Adding the “active” process designation to FLUV might also help.

Stoniness

PLK1 is rated Upr in Co-Pi while the LSRS rates it 4PTD which is a border-line poor. The PLK soils are not suited to agriculture as they are stony 4. This problem is most likely due to a mixing of data between our 1:50,000 maps and the SLC. The SLC CMP file designates soils that are stony 3 and greater as V and the LSRS makes note of the soil as stony 3 not worse.

In the Co_Pi interpretations, Shulie (SUI) is rated Pp for alfalfa and small grains with stoniness as the limitation. LSRS rates SUI as class 6V for alfalfa and 4D for small grains. SUI soils are not well suited to agriculture as depth can be problem and stoniness is equally as bad on these soils.

Alfalfa

Based on the comments of Dr. McLean alfalfa is not well suited to most of our soils.

Brome-timothy

Based on the comments of Dr. Papadopoulous, it's possible that some of the ratings of class two and three soils could be improved one class. Depth may not be as restricting for brome production as the LSRS indicates. Some of the soils along the north shore of NS seem well suited for brome growth.

Corn

The three major limiting factors for corn production appear to be H, T, and D. Dairy farmers in NS grow a lot of corn and get pretty reasonable yields. Common practice is to leave the residue on the field after harvest and cultivating the field the next spring. Growing corn as part of a three year rotation with spring cultivation reduces the risk of soil erosion. I think a best rating of class three could be improved.

9.7 Newfoundland and Labrador

<u>Review of the LSRS Program and Associated Crop Suitability Ratings For NL</u>

First, I will deal with **canola**. Apparently there hasn't been any effort (either through field demonstrations or organized research) on growth of canola in NL. The general assumption, since 2000, has been 83% of the available land on dairy farms are used for forage production, of which more than 60% is used for corn production.

I went through several polygons covering the main agricultural areas on the island, following your demonstration to me, and came up with the following ratings as shown in the table below. These ratings are assessed on virgin soils.

The **corn** ratings limited by Heat, can certainly be moved to 1 or 2 classes better because of the use of plastic.

The Samco Integrated Crop System, introduced in the province in 2001, has assisted in 2,300 acres of corn being planted in this province that year. Photodegradable plastic mulch covers the planted area, creating a greenhouse effect which extends the province's growing season.

The Samco Integrated Crop System was developed and manufactured in Limerick, Ireland by Sam Shine, CEO of Samco. It was first introduced to Newfoundland and Labrador in 2001. The province is the first area in North America to use the technology successfully.

The system uses a plastic mulch to cover seeds, which encourages rapid early growth and allows for early seeding dates. The technique allows farmers to plant earlier than the province's climate normally allows. Seeds can go into the ground 30 days before the last spring frost. The system can increase corn plant population from 80,000 plants per hectare to 104,000 plants per hectare. The plastic is photodegradable and takes about six weeks to start breaking down.

All agricultural regions of the province have benefited immensely from this new growing technique especially in areas which are more susceptible to cooler temperatures. The system was introduced with the assistance of the provincial Department of Natural Resources and Agriculture and Agri-Food Canada and has resulted in a steady increase in corn yields in the province since 2001.

Ratings for **Brome** can also be increased by 1 class at least by liming, fertilizing, draining and removing stones.

Alfalfa ratings were poor in all regions except Central NL. However, under proper management Alfalfa grows well in most areas of the island except the Avalon Peninsula. Please see the notes below from two scientists with the Atlantic Cool Climate Crop Research Centre.

In summary, I guess what I am saying is that the LSRS is pretty well doing its job. We just have to develop a system to incorporate anthropogenic changes which will give more realistic Land Suitability Ratings in that particular area.

LSRS Rating

Poly. No	**Soil**	**Corn**	**Alfalfa**	**Brome**
476001	**Cr & Col**	**5HTV(6)-7WTV(4)**	**7V(6)-7WV(4)**	**4VT(6)-7WV(4)**
475009	**Bauline**	**6TPV(7)-7WTV(3)**	**7VTP(7)-7WV(3)**	**4TVP(7)-7WV(3)**
471015	**Victoria Pond**	**5HVT(10)**	**7VT(10)**	**4VT(10)**
468010	**Gdr & Kingford Harbor**	**5HTP(6)-7WTV(4)**	***5VPT(6)-7WVT(4)**	**4PT(6)-7WVT(4)**
466047	**Abn & MintPond Woodale**	**5HTP(6)-7WV(4)**	**7VPT(6)-7WV(4)**	**4PVT(6)-7WV(4)**
466061	**Birchy Ridge Cormack**	**5HPD(10)**	**7VDP(10)**	**4DPV(10)**
463014	**Little River Codroy**	***6HTP(910)**	**7VTP(10)**	**4TVP(10)**
463010	**Codroy & Harry's River**	**6HVP(7)-6HVT(3)**	**7V(10)**	**5VPD(7)-4V(3)**
461016	**Cdy**	***6WVP(10)**	**7VWP(10)**	***6WVP(10)**

Quote from Allan Kwabiah at the Research Centre

Hi Ed:

Attempts to expand alfalfa production on the Avalon have not been as successful as in central (Wooddale) and western NL (Cormack, Dear Lake, Corner Brook and Codroy Valley). Alfalfa is sown in spring or fall, and does best on well-drained soils with a neutral pH of 6.8 – 7.5. To maximize yield and nutritional quality, alfalfa will need to be supplied with a great deal of potash. Prior to seeding farmers usually fertilize with manure or inorganic fertilizer and apply lime to correct the pH. Usually a seeding rate of 13 – 20 kg/hectare is used. Most farmers cut alfalfa three to four times a year. Total yields are typically around 4-6 tonne/hectare. As expected the dry matter yields vary due to region and with weather (high heat units means better growth), and with stage of maturity when cut. Our studies show that later cuttings improve yield but reduce nutritional content.

Regards

Allan

Quote from Dave McKenzie also at the Research Centre

Hi Ed

- I haven't worked with alfalfa for ten years, but Allan Kwabiah is working on alfalfa rotations. Perhaps Rosalind Pound [tel 709 637-2046] might know alfalfa acreage in the province. Most arable land that could be tile drained and/or deep tilled to break up shallow hard pans could be put into alfalfa in the province.

Any farmer wanting to grow alfalfa is going to receive a recommendation to lime their surface soil to pH 7.0 before planting. Adequate phosphorus and potassium soil fertility levels are also important at planting. Farmers applying a lot of manure can grow alfalfa at slightly lower pH but we're not clear on how much lower it will survive winters and/or adverse cutting management. Alfalfa appears to be able to grow nicely on acid [pH 5 and perhaps lower pH? Gary Kirby did a field study to 2.00 metre root depth checking this out on alfalfa fields] subsoils as long as the surface soil pH is maintained above pH 6.5 during the stand life [perhaps 4 to 6 years]. Shallow soils may not be a problem if winter drainage is good, soil water holding capacity is adequate for plant requirements, and soil fertility is high – so minimum soil depth hasn't been worked out for this crop. Well drained soils are a requirement since winter waterlogged soils will kill alfalfa.

David B. McKenzie, Ph.D., P.Ag.