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# Mapping Soil and Climate Suitability for Specific Crops

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## **I. Introduction**

This project forms part of a larger study aimed at evaluating possible alternatives to traditional farming systems in east-central Saskatchewan. As part of these objectives, the Land Resource Centre has undertaken to explore the agronomic potential of six 'non-traditional' crops for District ADD boards 18 and 19 in east-central Saskatchewan.

## **II. Scope of the Project**

All crops have specific growth requirements and a first step towards evaluating the potential of a 'new' crop is to match its particular requirements with the soil and climate characteristics of the area. This potential has been presented in the form of maps in which all land areas are rated in terms of their suitability for the production of each of the six crops. The maps and the report attempt to serve two specific uses. First, it is intended that farmers will be able to locate specific land areas on the maps and obtain reasonable estimates of the long-term production potential for each of the 'non-traditional' crops. Second, it is intended that the maps will provide regional views of production potentials and contribute to decision-making about support for handling and/or processing facilities.

Six 'non-traditional' crops have been selected for consideration: fababean, winter wheat, timothy, meadow brome, canary seed, and flax. The crops were chosen by a committee composed of local agronomists, U. of S. researchers, and representatives of PFRA and Saskatchewan Agriculture and Food. The crops are 'non-traditional' in the region, however the potential to produce them on a larger scale may exist. As well, all are crops that may have strong economic potential in the future. They have pre-existing markets, or, in the case of meadow brome, can be used as feed for livestock, for which there are established markets.

### **III. Suitability Evaluation**

Discussion of crop suitability requires a context that is specific to the area in question. Agricultural production, in all parts of the world, demands management activities that are particular to the region but common to most crops. For example, in areas of high rainfall, some sort of drainage must be undertaken as prerequisite to annual cropping. This is part of the management context of the location and is not factored into a suitability evaluation of a particular crop. On the other hand, where a specific crop is susceptible to significant yield reduction due to diseases associated with high humidity, high rainfall might be factored into a suitability evaluation. Suitability rating assumes knowledge, on the part of producers, about the conditions which affect agriculture in general. It also assumes good management practices that deal with these conditions. A calculated suitability rating always includes this idea of sound management for a particular region. A high suitability rating for the study region, east-central Saskatchewan, depends on proper handling of previous crop residues, the maintenance of fertility, control of pests and proper timing of operations.

### **IV. Agricultural Production in the Project Area**

ADD boards 18 and 19 are in Crop District 5B. This district receives more precipitation than areas to the south and west. For traditional crops, such as spring wheat and barley, moisture is adequate in most years and drought is not considered the greatest hazard. As a consequence of higher rainfall, fields may be slow to dry in spring and seeding may be delayed. Similarly, fall rains may delay harvest or cause reduction of quality in crops that remain in fields for extended periods of time. The frost-free period may be short in the project area and the problems of a short season are often compounded by delays associated with excess precipitation. Cool, wet conditions tend to exacerbate disease problems. Fungal diseases, generally, and cereal rust, in particular, are common. In general, the soils of the area are high in organic matter and very fertile. In conjunction with high moisture, this provides a good cropping environment. However, high seed yields are also associated with high straw production. Large quantities of crop residues may create problems when seeding the next crop. In the past, residues have often been burned. This practice is detrimental to the maintenance of soil organic matter levels and the long-term sustainability of soil fertility, and adoption of alternative techniques for managing residues is encouraged. Another consequence of good growing conditions is large and healthy weed populations. Weed control is essential to obtaining high yields for all crops and particularly important where markets demand low levels of weed seed in the product.

This analysis of suitability of 'new' crop begins by assuming that the above-mentioned factors are inherent to farming in ADD boards 18 and 19. Precipitation may occur in sufficient quantity or be distributed in the growing season so that

planting and harvest may be delayed. Similarly, frosts may occur late in summer or early in fall and reduce seed quality. These risks will be expressed, in the long-term, as lower yields and lower quality. Conditions of high moisture and high fertility will create weed and disease problems. It is assumed that these problems are completely managed and that projected yields will not be reduced.

Although it is understood that managing pests costs money, these costs are not treated explicitly in the soil and climate suitability analysis. It is assumed that they are part of doing business in ADD boards 18 and 19.

## **V. Methods**

### **i) Analytical Method**

Evaluation of suitability, for each crop, involved a two-stage process. First, a profile of requirements and vulnerabilities was assembled using published sources as well as consultation with researchers and agronomists. From these profiles, the factors that were known to vary within the region were selected. If no part of the project area provided adequate conditions for successful dryland production, the crop was not considered for further analysis. If all of the area provided adequate conditions with respect to a particular parameter and distribution of that requirement in the project area would not be reflected in yield differences, the parameter was not included in the rating process. Second, the suitability criteria were applied to each of the units in the soil maps of the project area. This was done as two operations: a recoding of the soil inventory data base, followed by a GIS overlay of climate parameters.

### **ii) Databases**

#### **A. Soils**

The first level of interpretation uses the 1:100,000 soils maps of each rural municipality in the project area. Each soil map area has a set of data attributes or characteristics stored in electronic databases. The suitability rating criteria were checked against the attribute data for each unit and a soil suitability rating created for the unit. These ratings were displayed on a derived or interpretive map. Common boundary lines were removed between adjacent soil areas with identical suitability ratings. The new map could have fewer, but not more, units than the original. The soils databases contain a great deal of information. Only some of it was used in this analysis. The following soil attributes were considered: slope, salinity, stones, surface texture, and drainage. Additionally, some mapped soil series were considered unsuitable for cropping.

#### **B. Climate**

Three types of climate maps have been produced and used as overlays on the soil suitability interpretive maps. The maps are: total annual precipitation, growing degree days (5 degree base), and frost-free days. Monthly averages for

weather stations in and adjacent to the project area, from the thirty year period, 1961 to 1990, were used. First, a latitude/longitude grid of points was generated for the project area and imported to a GIS. Using a weighted average modelling procedure, a surface was interpolated. This assigned an elevation value to each pixel. In this manner, each latitude/longitude location had an elevation value attached. Using data from the weather stations, both in and in close proximity to the project area, regression equations were then developed for each of the climate parameters. Latitude, longitude and elevation were all used as independent variables in regressions of precipitation, growing degree days and frost-free days. The derived equations are all significant at the 90% confidence level and the equation for growing degree days is significant at the 95% level. The equations were then solved for every pixel on the climate maps and contours were created based on predetermined values corresponding to the requirements of each crop. The results were maps of the project area containing climate suitability polygons. Each climate map is uniquely contoured to reflect the determined requirements of each crop.

### **C. Merging Soil and Climate**

The final step was the overlay or superimposition of the climate map on the soils map. The method adopted for rating suitability was essentially a penalty system. At the outset, all units in the soils database were assumed to have high suitability. The application of limitations based on soil characteristics reduced the suitability of some units. The climate overlay continued this process. The soil suitability interpretation of each polygon was matched to the climate suitability polygons. Suitability ratings could be downgraded, but never upgraded, by this procedure. Where more than half the area of a soil polygon was intersected by a lower suitability climate polygon, the lower rating was applied to the whole soil unit. The end result was an interpretive map containing the original soil polygons with a single suitability rating attached. Lines between adjacent soil areas with identical ratings were then dissolved to produce the final map. The rating system used, contains three classes:

High Suitability- no to slight limitations.

Moderate Suitability- one or more moderate limitations.

Low suitability- one or more severe limitations.

Limitations may be due to soil/landscape factors, climate factors or both. Within the moderate suitability classes, the reason for the limitation is given. This information is included on the assumption that producers may consider that some negative soil characteristics can be overcome by particular management practices. The reasons for limitation to suitability are indicated on the maps by shading. The maps also distinguish areas of unclassified land such as gravel pits, steep valleys, urban land and water bodies.

## VI. Agronomy and Suitability Criteria for Fababean

The project considered the potential of six crops. However, for the purposes of describing the methodology, only the example of fababean is included in this presentation.

Fababean grows best in cool, moist conditions. Seed set is reduced by low humidity and high temperature. Yields are reduced by drought. The high moisture requirement limits production in the Brown and Dark Brown soil zones to irrigated areas. Non-irrigated production requires 350 to 400 mm of precipitation (Hebblethwaite 1983). A regression of dry matter yield versus depth of irrigation water applied has produced a straight line relationship with little annual variation (Krogman 1980). This however takes no consideration of the distribution of precipitation during the growing season. Krogman reports maximum yields where irrigation takes place at 70% of field capacity. Timing of drought influences which component of yield may be affected. Severe drought at the time of flowering may have a serious and irreversible effect on seed yield, however, *Vicia faba* is able to compensate for loss of pods due to a moisture deficit at the time of seed set by increasing the mean grain mass if more water is available later. (W. Day and B.J. Legg in Hebblethwaite 1983). In moister parts of the province, production is most likely to be limited by a short season. Immature seed is very susceptible to frost damage. Existing varieties of fababean require 114 to 122 days to mature. Where fertility is high, plants may not experience enough stress to induce maturity. Average seed yield in the Black Soil zone under dryland production range from 1000 to 2000 lb/ac (1112 to 2224 kg/ha). (Pulse Production Manual)

Fababean seedlings are very frost tolerant which helps to offset the problems associated with a short season. Crops should be sown in mid-April to early May. The seed remains underground during germination and the seedling may successfully emerge from soils at 5 C. A crop may be seeded on top of frozen soil which has thawed only to a depth that allows for seed placement. The seed may require as much as its own weight in water to germinate and may be sown up to 3 or 4 inches deep to ensure adequate moisture for emergence. Immature seed, however, is very susceptible to fall frost damage. Due to these differences in frost tolerance at the beginning and end of the season, energy requirements are put in terms of growing degree days (5 degree C base). A minimum requirement has been estimated as the energy requirement of spring wheat, 1100 degree days (Guide to Farm Practice, 1987) + 30% = 1450 growing degree days (Dr. A. Slinkard, personal communication). Areas having fewer than 1450 growing degree days are considered severely limited for production of fababean. Fababean has a limited tolerance to flooding, a very low tolerance to salinity and an optimum pH range of 6.5 to 7.5.

## SUITABILITY CRITERIA FOR FABABEAN

<b>Limiting Factor</b>	<b>Severe Limitation Level</b>	<b>Moderate Limitation Level</b>	<b>Reason</b>
Texture	GS,S,FS,GLS, LS,LFS,GSL, GL	SL,FL	-drought intolerance [SOIL]
Salinity	>20%very strong OR >40%strong OR >70% moderate	>3%very strong OR >10% strong OR >10% moderate	-salt intolerance [SOIL]
Stones	stone class 4 OR 5		-hindrance to cultivation [SOIL]
Slope	slope class >5 (>15%)	class 4 OR 5 (5- 15%)	-hindrance to cultivation [SOIL] -redistribution of moisture [SOIL]
Drainage	wetlands extent >4(>40%)		-poor drainage [SOIL]
Soil series/ associations	organic soils associations: -Alluvium -Swift Creek -Meadow -Marsh -Crooked L. -Whitesand	Gray Luvisols	-poor surface structure/ low fertility [SOIL]
Heat	<1450 growing degree days		-short season [CLIMATE]

Long-term average yield estimates:

High suitability areas - 27 - 30 bu seed/ac (1800 - 2000 kg seed/ha).

Limited suitability areas- 24 - 27 bu seed/ac (1600-1800 kg seed/ha).

## **VII. Results**

Coloured suitability maps for fababean and the other five crops have been produced at a scale of 1:170,000.

The total area of ADD boards 18 and 19 is 1,079,274 hectares (2,666,933 acres). Of this total, approximately 92,320 hectares (228,126 acres), or 10% is water or unclassified land. Proportions of land in each suitability class are expressed as fractions of the total area.

On the basis of the criteria used in this analysis, much of the study area is suitable to increased production of several of the six crops. It is emphasized that this analysis indicates physical suitability only. Economic returns depend on markets and the net costs of production. Successful production of some crops may require input costs that are not justified by the returns. Economic considerations require separate attention.

A significant portion of the study area, 21%, is considered highly suitable for fababean. Production of this crop in Saskatchewan is very limited at the present time. Provided that markets can be established for it, as either food for humans or livestock, production might be successfully increased in some parts of the study area. The attractiveness of fababean in rotations is enhanced by its superior nitrogen-fixing ability. Some of the risk associated with long term cultivation of this legume may be partially offset by the gains in soil nitrogen levels achieved by growing it prior to a high-value crop.

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