

Web-Based Support of Crop Selection for Climate Adaptation

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Abstract

Farmers must now consider climate adaptation amongst other variables when they select crops for the coming year. A changing climate means traditional crop choices may not perform well. Yet, it may be difficult to trust recommendations about new crop choices provided without extensive local knowledge. This paper describes the design and implementation of a prototype tool to support Canadian farmers in their crop selections. However, authoritative data about growing conditions that maximize crop performance has been difficult to assemble. Therefore, we propose an extension to the prototype system that would allow farmers to submit reports of crop performance along with data that describes their growing conditions. With many farmers contributing these experience reports, the data in these reports could be mined to provide localized information about the performance of different crops and the conditions which best support each.

1. Introduction

As climate variations impact local regions, farmers must adapt. Hewitt et al. [5] have indicated that these climate variations may significantly alter regional crop suitabilities in Canada. All farmers will need to consider shifting towards new crops that may perform better under the new growing conditions. In the present information age, a web-based decision support system is the most promising way to add consideration of climate adaptation to the crop selection process.

More and more crop information is being made available online. For example, Canada participates in the Germplasm Resources Information Network. However, the only available interfaces to this database¹ are accession queries, taxonomic queries, and research crops descriptor queries. It is possible to request

germplasm through the online system, but there is no coordinated additional information that would allow farmers to see whether such a crop might do well in a particular location with its own climate variabilities.

It is not sufficient to make information available. Rather, that information must be accessible in ways that support farmers in making effective crop selections to adapt to changing climates, which includes several dimensions.

Information that is available must be presented in such a way that its value is clear. One may think of information that is highly usable and satisfying format as having a strong *information scent* [18], which can facilitate navigation through a web-based support system. This element was the focus of the initial stage of the project: creating a satisfying interface to explore crop information.

Information that is available may, however, be incomplete to support the task at hand. Consider *growing degree days* (GDD) as an example. It has been observed that air temperature is an important factor that controls crop development, which is typically modelled using GDD. However, if a crop's allowable range for GDD matches the local climate, it represents a necessary but not sufficient condition for success. Furthermore, descriptions of candidate crops in terms of their GDD requirements may be difficult to obtain.

If it is possible to know the climatic conditions of other geographic regions and the crop selections made there, it would be possible and valuable to consider crops grown in "climate twin" regions (regions where the climate is very similar). Where such detailed information is not available, computer models may help to identify potential crop selections.

As experience is gained with different crops, high yield crops for a region can be identified. If each farmer reports his or her experience with a crop (which could include soil type, climate information, management practices, and inputs), over time a rich

¹ http://pgrc3.agr.ca/search_grinca-recherche_rirgc_e.html

and clear understanding of how to maximize localized crop yields in the face of climate variability can emerge. The potential validation of existing models and the development of new models to predict crop performance will increase the capacity for climate adaptation.

Spimes [21,22,23], a newly coined term for an historical entity with an accessible, precise trajectory through *space* and *time*, may be the most appropriate means to encapsulate information about a crop's performance in a given locality, while maintaining the global context that includes performance of different accessions in various other localities and all the accumulated knowledge collected in various databases, such as Species 2000² and TRY³, for example. A spime is an object whose informational support is so overwhelmingly extensive and rich that it is regarded as a material instantiation of an immaterial system. It is the tip of an iceberg that does not exist on its own: the wealth of information it represents is collected and shared by a community of concerned citizens. Wikipedia.org is an example of what is possible.

The rest of the paper is organized as follows. Section 2 provides a review of existing crop selection support tools, the design of the REAP system, including the selection of the metrics used in its crop database, and some of its outstanding issues. Section 3 describes the practical aspects of shifting towards experience reports from farmers as the primary source of crop performance data, including how climate data may be collected. Section 4 discusses progress to date and opportunities for future work.

2. Crop Selection Support Tools

Simon [20], who described the bounds on our abilities to fully rationalize decisions, and Norman [14], who described our unaided mind as being highly overrated in the decision-making process, have highlighted the opportunity for our activities to be augmented by the use of technology.

The World Wide Web has played a fundamental role in the development of tools to augment our decision-making abilities. Berners-Lee [3] described the next web as making the transition from linked documents to linked data, which is raw data in a standardized web format. The notion of linked data encourages opening access to all kinds of raw, unbiased data and information in relation to all kinds of things.

² www.sp2000.org/

³ <http://www.try-db.org/>




These general concepts provide a solid foundation for development of a framework for web-based support of crop selection for climate adaptation. However, also of interest is the data contained in such systems. The question of understanding what farmers need to know poses a challenging problem. Farmers, in general through their own unique experiences, have a good grasp of the growing conditions within their specific regions and which crops are likely to do well. However, this understanding may be invalidated as new growing conditions are introduced through climate change.

Key to the foundation of decision support tools is the collection of attributes that can accurately characterize growing crops. To better understand which attributes may be of interest and importance, two previously implemented systems: the Otago Polytechnic Crop Database (<http://crops.orc.govt.nz>, accessed June 2011) and the Alternative Crop Suitability Map database project, based on an implementation by researchers at the University of Illinois (<http://www.isws.illinois.edu/data/altcrops>, accessed June 2011). We created a number of scenarios [4] to explore interaction with those extant systems (problem scenarios) and design opportunities to be exploited with the new system (design scenarios). This process fills a role similar to that advocated by Peffers et al. [17].

2.1 Problem Scenario: Otago System

Search result: Suitable Crops

The following 30 crops are ranked in order of suitability:

 Suitable  Unsuitable  Not compared

			Apples and Pears	Detail	
			Apricots	Detail	
			Cherries	Detail	
			Grapes	Detail	
			Strawberries	Detail	
			Walnuts	Detail	

Figure 1: The results display of the Otago system. The cherries on the left indicate the suitability ratio as based on the six crop/land attributes.

Interested in finding alternative crops that are suitable to be grown on her land, Sally utilizes the

online tool. She selects her local region in the drop box and notices that the typical growing conditions are automatically populated for six attributes: GDD, drainage, fertility, cool season chilling, early first frost, and late last frost. She notices that the drainage in her individual land quality does not match typical conditions so she alters the value accordingly and then hits the search button. On the proceeding page is a listing of all suitable crops based on her query. She notices there are also other display icons and interactive links on the page. However, at first glance they do not make much sense to her. For example, beside each listed crop are six cherries, some coloured all red, some are coloured a combination of red, grey, and white. She makes the assumption that these cherry icons are representative of the six attributes on the previous page. However, she does not know which cherry icon corresponds with which attribute, or what the colour coding means. Leaving this for a moment, she notices that the crop name is a link so she clicks on the top crop assuming it will take her to a detailed analysis of how it fits within the region. However, the landing page from her click linked to a page describing the crop in detail, not how it related to her search attributes (just general information about the specified crop). Clicking back, she notices that there is a link beside each listed crop with the text “detail.” Clicking this link takes her to a page with a detailed analysis of the crop and how it related to her search.

2.2 Problem Scenario: Illinois System

John logs on to the system, as he is interested in growing a particular crop on his land that he has no experience growing and he is interested in seeing what is required for the crop to grow. Viewing the clickable regional map of his area, he zooms in to his specific region. Not sure how to view the suitable crops for his region he stops a moment to scan the interface. Eventually seeing the “see crop suitability” link he clicks on it but notices nothing happens to the interactive map. Again, stopping, he finally decides to maybe zoom in further so he clicks on the map again and to his surprise he is taken to a page which asks him what range of crop suitability he is interested in searching for: crops highly suitable, suitable, moderately suitable, slightly suitable, unsuitable based on the region he's selected. Selecting the check box to display crops that are “highly suitable” as this is what he is really interested in, he clicks the search button and on the proceeding page is a listing of highly suitable crops. At first glance he does not see the crop he was interested in and he wonders if the crop might appear on one of the other ranges of suitability so he clicks back and selects to view crops within the range

Table 1: Claims analysis of features identified in the Otago Problem Scenario

Feature	Possible pros(+)/cons(-)
Search by region using drop box	+ easy to home in on specific region of interest - if area is not well-known, names may be unfamiliar
Automatically populated regional attributes (after selecting region) within drop boxes	+ ease of access to regional growing conditions + can easily alter values for specified attribute variations - search takes user to another page: if the user wants to alter attribute values, they must click back and re-query the system
Listing of suitable crops	+ Clear and concise listing of suitable crops
Cherry icons representing suitability range	+ after users understand what the cherries mean, they give a visual of the suitability of the crop - cherry icons to represent suitability may confuse: what do the cherries (and their colourings) mean? [13]. +/- Users can click the cherries (unknown initially) to get to the detailed analysis but are required to leave the page: potentially distracting them from task and wasting time[19].
Detailed analysis link	+ detailed analysis available - forces the user to leave the page: having the user click back and forth may be distracting

of moderately suitable to highly suitable, clicking search again. Again on the proceeding page is a listing of crops within the range. To John's delight he sees the crop he is interested in but it is listed as moderately suitable. He starts to question how the system is coming up with these crops, what attributes they are using, as none are listed. On second glance he sees a “crop info” link and clicks on it for the crop he is interested in and is taken to another page with a detailed analysis. He immediately thinks this is great but on further inspection finds himself slightly overwhelmed as some of the attributes listed are confusing. He also notices that some of the attribute values slightly differ from those of his specific land characteristics but there is no way to re-evaluate and change these values to see if the crop would reside in a

higher suitability range more closer to his specific land characteristics.



Figure 2: The primary display of the Illinois system. Clickable regions are displayed where users refine their regional search accordingly.

The REAP (Resilience Enhancement of Agro-Ecological Production zones) system that was developed for Canada built on the designs of the two previous systems, with its focus tailored to Canadian regional crops (<http://reap.cs.uregina.ca>, accessed June 2011). In developing the user interface for the REAP prototype, we began building on the concepts featured in the Otago and Illinois systems (exposed through claims analysis of the problem scenarios in Tables 1 and 2). The following design scenario describes our envisioned system.

2.3 Design Scenario: REAP Prototype

Interested in finding alternative crops that are suitable to be grown on her land, Sally utilizes the online tool. Clicking on her specific region on the interactive map display she hones in on her region and is immediately taken to an advanced search page. On the left of the search page has listed the typical growing conditions, represented by six attributes: GDD, corn heat units, frost free days, annual moisture, drainage, and fertility, each with their corresponding values typical of regional characteristics. In the middle of the page is a listing of all crops matching all criteria (those highly suitable) for growing within her region.

Table 2: Claims analysis of features identified in the Illinois Problem Scenario

Feature	Possible pros(+)/cons(-)
Clickable regional map	<ul style="list-style-type: none"> + users have a visual representation of the region they are searching + good interactive learning tool - may seem redundant for those who know region
Separation of zoom function and crop suitability menu	<ul style="list-style-type: none"> - highly confusing: even once this interaction is known, it adds unnecessary steps
Ability to select range of crop search suitability	<ul style="list-style-type: none"> + users may also be interested in seeing what crops closely match so they can make informed choice + depending on size of database, most crops will not be highly suitable (meet all criteria) for specified regions, thus this gives “larger” picture of options - may confuse users into thinking that crops are suitable when they may are not. Even if the degree of suitability is listed, some users may overlook this information - users are required to click back and forth, changing the suitability criteria if they wish to view other crop options, providing a potential distraction and waste of time
Crop info link	<ul style="list-style-type: none"> + gives users the ability to see why the crops grow as they do in specified regions - moves the user from the crop listing page, forcing users to click back and forth - there may be confusing attributes being used: highlighting the importance of selecting appropriate search attributes/metrics

Finally, on the right side of the interface is an advanced search that enables Sally to alter values for the six attributes accordingly. She also notices that there is a button at the bottom allowing her to reset the attribute values back to the typical regional growing conditions. Noticing that the drainage value typical of her region does not match the characteristics of her individual

land, she alters the value accordingly, noticing that the page automatically updated to a new listing of applicable crops. As well, she notices on the left side under the typical growing conditions that there is an indicator informing her that the value for drainage does not match the typical growing conditions for the region.

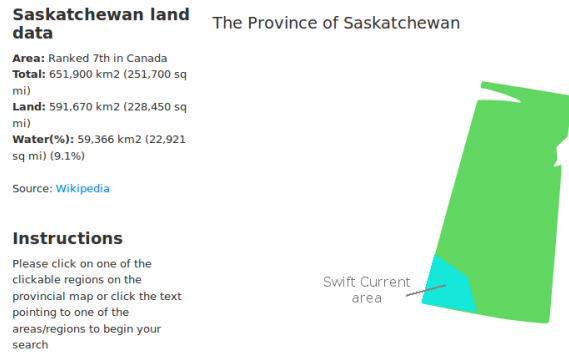


Figure 3: Provincial view page of the REAP project. Seen here is the view of Saskatchewan. The prototype only included the Swift Current area

As illustrated in the design scenario, we attempted to model the system design after many of the pros found in the Otago and Illinois tools, while refining the design to provide users with potentially more satisfying interactive experiences. Chosen crop search attributes included: growing degree days, corn heat units, frost free days, required (annual/regional) moisture, drainage, and fertility. Specifically with the Illinois system, we integrated the functionality that enables users to interact with a map view (Figure 3), allowing users to gradually hone in on a specific Canadian region while having the ability to visualize regions of interest. As with the other systems, we also displayed results in a textual view, allowing users to quickly identify applicable crops, as illustrated in Figure 4. Finally, having all search options on the same page limits the potential distraction and loss of information scent possible while searching interacting with the tool as users remain on the same page with all options available to them.

Although the user interaction is an important part of the system design, the data is of primary concern in this paper. The metrics selected for use in the REAP system are de facto standards in crop selection systems. Yet, are these 6 values able to capture all the necessary information to assess the suitability of a crop for a particular set of growing conditions?

Growing Degree Days (GDD) is a widely used means to express the accumulated heat units required

Table 3: Claims analysis of features identified in the REAP Design Scenario

Feature	Possible pros(+)/cons(-)
Clickable regional map	<ul style="list-style-type: none"> + users have a visual representation of the specified region they are searching + good interactive learning tool - may seem redundant for those who know region
Six defining attributes	<ul style="list-style-type: none"> + provides focus and standardization - may be too limiting: users may wish to compare other attributes
Advanced search page	<ul style="list-style-type: none"> + users have ease of interaction + users dynamically visualize changes in queries without flipping through pages
Reset to regional norms	<ul style="list-style-type: none"> + users can query alternatives while easily going back to typical regional norms
Indicator representative of typical growing conditions	<ul style="list-style-type: none"> + users can visually keep track if the current query matches regional norms
Listing only highly suitable crops	<ul style="list-style-type: none"> + users see only what typically grows under searched conditions + allows users to focus on specified search - may limit displayed results - may be "too strict"

for a crop to succeed. However, the base temperature used in the equation is an important parameter for which the choice is not always made explicit. Furthermore, as reported by McMaster and Wilhelm [12], the calculation is also subject to variation that can significantly change the results of the calculation. Wang's critique [25] of the heat unit approach, from 1960, would seem to support the idea that the GDD number does not preserve enough information, because the timing of the heat unit accumulation over the growing season may be an important determinant of yield.

Drainage is a qualitative attribute and therefore very difficult to quantify with any precision. Similarly,

Saskatchewan

Swift Current

General growing conditions:

- ✓ Growing degree days (above 0 Celsius): 2201-2350
- ✓ Corn heat units: 2201-2400
- ✓ Frost free days: 111-120
- ✓ Annual moisture (mm): 301-400
- ✓ Drainage: Well drained
- ✓ Fertility: Medium

✓ Current search attribute matches general regional growing conditions
⚠ Current search attribute does not match general regional growing conditions

Suitable crops matching the current search attributes

1	Spring Wheat
2	Winter Wheat
3	Oats
4	Barley
5	Peas (Field)
6	Chick Peas
7	Lentils
8	Canary Seed
9	Sunflower

Current search attributes

Growing degree days (above 0 Celsius)

2201-2350

Corn heat units

2201-2400

Frost free days

111-120

Required moisture (mm)

301-400

Drainage

Well drained

Fertility

Medium

[Reset to general growing conditions for Swift Current](#)

Figure 4: Advanced search interface for the REAP project. On the initial view users only see highly suitable crops.

Saskatchewan

Swift Current

General growing conditions:

- ✓ Growing degree days (above 0 Celsius): 2201-2350
- ✓ Corn heat units: 2201-2400
- ✓ Frost free days: 111-120
- ⚠ Annual moisture (mm): 301-400
- ✓ Drainage: Well drained
- ✓ Fertility: Medium

✓ Current search attribute matches general regional growing conditions
⚠ Current search attribute does not match general regional growing conditions

Suitable crops matching the current search attributes

1	Spring Wheat
2	Winter Wheat
3	Oats
4	Barley
5	Peas (Field)
6	Chick Peas
7	Lentils
8	Corn
9	Canola
10	Canary Seed
11	Mustard
12	Sunflower
13	Tomato

Current search attributes

Growing degree days (above 0 Celsius)

2201-2350

Corn heat units

2201-2400

Frost free days

111-120

Required moisture (mm)

501-600

Drainage

Well drained

Fertility

Medium

[Reset to general growing conditions for Swift Current](#)

Figure 5: Advanced search interface for the REAP project. Altering the current search attributes enables users to realize potential crops based on associated climate variability. Users can reset the current search attributes at any time reverting back to regional norms.

soil fertility assessments may be difficult to standardize.

The Otago, Illinois, and REAP systems all use crop data generated by crop experts. A main problem with this approach relates to scarcity of the data. All

possible crops appropriate for a particular climate have not been quantified according to the handful of commonly used metrics. It is difficult to find credible information about crops in these terms. It may be that an excellent choice of crop for the new climate in a region is one that is grown halfway around the world. In this case, an approach of finding climate twins[9] could lead to success.

Furthermore, assessment of the suitability of a crop may be more subtle and nuanced than can be provided by values associated with 6 variables. Variations in crops that have been developed to thrive in certain localities may have a unique profile, different from similar varieties.

An important aspect of adaptation to climate is selecting seeds that are adapted to localities and that thrive in new climates. Adaptation may not always require new crops, but the adaptation and selection from current crops. The emerging practice of participatory crop improvement [1] may help in this regard.

3. Experience Reports

It may be that farmers are best qualified to determine which crops are likely to succeed in a given region. Their experiences with crops in a particular environment are invaluable. Qualitative experience reports may be incredibly valuable to other local farmers contemplating new crop choices. However, development of a robust model will be facilitated by the collection of accurate information about the growing conditions of a crop, a job not well suited to farmers. Each farmer is conducting his or her own experiment, ultimately. Taken all together, these individual experiments can be valuable in modelling the crop in the local climate.

We propose a system of experience reports that contain 2 sets of information: crops planted with yield results at harvest, and a collection of measurements regarding climate at the farmer's location (taken either from an existing sensor network, like the Canadian Wheat Board's WeatherFarm⁴ system, or by a standalone sensor unit). A functioning sensor unit with sufficient onboard storage will be able to give data about the entire growing season without requiring frequent maintenance visits. The data stored in the sensor unit would not be subject to external manipulation. One approach to the sensor data collection is through low-cost DIY (Do-It-Yourself) sensors built from kits. There do exist proprietary software tools with a variety of hardware options, for

example, there are a number of solutions available by Ambient Weather (<http://www.ambientweather.com/>) or ADCON Telemetry (<http://www.adcon.at/>), among others. However, many of these tools are limited in that only certain attributes are available/provided for use/evaluation by the tools. Another possibility is to use an existing mesonet to provide values for some or all of the attributes of interest. The Canadian Wheat Board has the WeatherFarm/WeatherBug network that could, for example, provide many of the desired pieces of data without specific on-farm intrusions. Automation of data collection is important because farmers are unlikely to make detailed data collection a priority amongst other pressing demands on their time.

Crop growing conditions could be captured in the following way:

- GDD: record and store the minimum and maximum daily temperatures (sampled appropriately during each day) during the whole growing season. The accumulation of heat units over the season may provide extra valuable information. Storage requirements for this data should not pose a problem in terms of storage capacity.
- Frost free days could be computed from the daily temperatures recorded.
- Moisture could be assessed with a rain gauge.
- Drainage could be calculated using a soil moisture sensor to determine when the soil is dry.
- Fertility of the soil could be assessed from a soil sample taken at the start of the growing season.

However, the farmers' reports of crop varieties planted on a particular date, and harvested on a particular date with a certain yield could be subject to manipulation. There are a few potential safeguards against this sort of behaviour: requiring a login to the reporting system that would associate an identifier with each report so that farmers understood the possibility that reports could be verified. Yet a collaborative (wiki) model might be used successfully. In general, wikis deal with quality through coordination [8] and the community. Judge and Schechter [7] suggest the use of Benford's Law as one means to safeguard against data entry problems.

Wikipedia[2], founded in 2001 (according to <http://en.wikipedia.org/wiki/Wikipedia>), is a popular and successful example of how current web technology can augment our capacity to design accessible repositories of information. In turn, knowledge is increased along with individual, community, and global capacity. On Wikipedia, thousands of web-enabled users collaborate in building a repository of knowledge about everything and enabling access to the

⁴ <http://weatherfarm.weatherbug.com/>

knowledge-creating content for anyone with access to the internet. Wikipedia has successfully modelled the development of web-based systems as a means for transfer of knowledge and the creation of web-based communities as a means for capturing of quality user-generated knowledge-creating content.

Wikipedia has been proven to provide a web-based system for successful knowledge transfer. Millions of users, both contributors, called Wikipedians and non-contributors, simply called Readers, contribute to and access Wikipedia on a daily basis. Wikipedia has also been proven to enable the creation of successful online communities as a means for capturing quality user-generated knowledge-creating content. Although some claim that the quality of user-generated knowledge, and user-generated content in general, is suspect the reality is that Wikipedia has achieved great success and continues to redefine the norm of providing access to quality knowledge-enabling content by continually building upon its successes [2, 15].

Wikipedia is an important model to guide the design of tools that aid in building the foundations of a knowledge society. Building from the Wikipedia model we consider the prospect of designing web-based (and mobile) tools to aid producers in better realizing their opportunities and alternatives for managing their crops and land.

4. Discussion

A web-based support system that enables producers to track the successes and failures of current crops and connect that tracking to climate information collected as the crops grow, could provide a wealth of information about crops' potential for adaptation to a changing climate.

Jiménez et al. [6] describe their work with producers of the Andean blackberry. They used reports from small-scale producers coupled with publically available climate information to derive a model that explained a great deal of the variability in production. They used that model to find areas that are best suited to Andean blackberries and to improve practices where productivity was low. This same approach can be adapted and expanded within the concept of crop spimes (providing the ability to track individual crop attributes and access crop data) to maximize productivity. Comparing derived models with more established ones, such as those from ApSim and CLIMEX, can help to improve our climate adaptation responses.

Some work has already been done in this regard in the form of a Google map, illustrated in Figure 6, highlighting local food producers in Saskatchewan. We

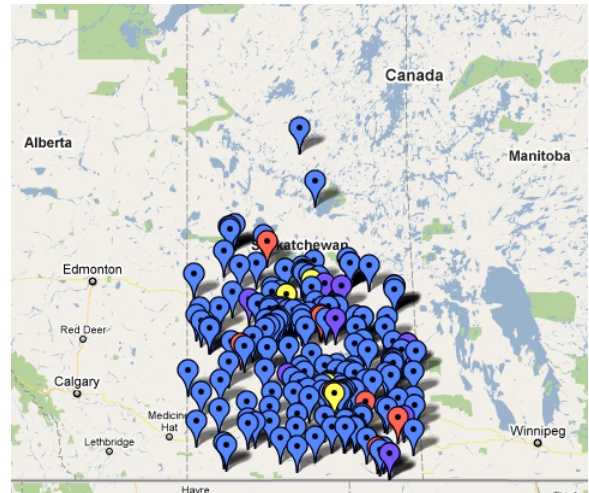


Figure 6: Screen capture of the Saskatchewan local food map (as of June 2011). The map is accessible online at: <http://bit.ly/lofosask>

are currently in the process of building more detail into the map and integrating specific crop information, including which crop alternatives are available in places other than Saskatchewan.

Another component of such a system could relate to *farm/land spimes*, providing the ability to track and monitor available farm resources, and the characteristics of the land in which the crops are grown.

Spimes[11] have many desirable properties, they:

- are designed within a network
- have a unique (digital) identity that is distinct from any other object in the world
- are physically fabricated from their virtual plans - meaning that spimes only come into physical reality when the information is accessed from the database
- can be tracked using real-time geo-location technologies
- can be searched
- are designed for disassembly, meaning they utilize cradle to cradle methods[10]
- have informational qualities that describe recapturing, recycling, and re-manufacturing of objects
- leave a historical trace that could be used for historical data visualization and in the creation of new spimes.

Along with linking producers to producers (producers relating their experiences growing certain crops), this type of system also has the capability to link producers to consumers. Many consumers are becoming more concerned about where their food comes from, the distance the food travels from producer to plate, and whether the local food that they

buy is best suited for local production (requires minimal inputs).

We hypothesize that in using this type of crowdsourcing [15] (Wikipedia) model that we more effectively open access to crop data and knowledge. Although the expert approach is still valid, by providing a usable method for producers to share their experiences and knowledge, we more effectively build awareness of regional and local crop suitabilities. As well, producers can gain awareness of what crops are being grown around them, and investigate opportunities for their own land.

Incorporating the notion of spimes, specifically crop spimes, may help structure the crop data and information in a format that is more usable and accessible, allowing producers to realize alternatives and opportunities more effectively.

Collection of data certainly facilitates better decision-making. The more that decisions are made on the basis of data, the higher the confidence in those decisions. However, transparency is an important part of decision-making and transparency [24] enables more ethical decision-making. Rather than base a crop decision on a single value of GDD required, it is better to examine the history of fluctuations in temperatures (as well as moisture and soil fertility) over the growing season along with yields obtained.

At present, discussions are being held with some key stakeholders about this project and what would be required of them. There is a great deal of interest already, but the extension of the underlying system to fully encompass the idea of “Experience Reports” is still in its very early stages. Nevertheless, there have been strong expressions of interest from various farmers who see the need and potential value of such an approach.

With sufficient numbers of farmers contributing experience reports and climate data from their farms, it will be possible then to apply techniques such as the rough set attribute reduction methodology [16] to mine and analyse all data for patterns, such that a smaller amount of data may be kept (reduced from the daily temperature measurements, for example) to enable predictions about the success or failure of particular crops in particular regions.

After multiple cycles of experience reporting, crop recommendation, and validation, this type of system could have enough data to become a very natural part of a farmer’s crop planning activities.

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