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**DEVELOPMENT AND EVALUATION OF A GIS-BASED AGRICULTURAL
ASSESSMENT FOR LAND USE PLANNING**

A Thesis

Presented to

The Faculty of Graduate Studies and Research

of

Carleton University

by

IAN EDGAR JARVIS

In partial fulfilment of requirements

for the degree of

Master of Arts

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**DEVELOPMENT AND EVALUATION OF A GIS-BASED AGRICULTURAL
ASSESSMENT FOR LAND USE PLANNING**

submitted by Ian E. Jarvis, B.A.

in partial fulfillment of the requirements for the degree of Master of Arts

Thesis Supervisor

Chair, Department of Geography

Carleton University
September 19, 1995

ABSTRACT

Most of Canada's prime agricultural land is in proximity to urban areas and is under stress from incompatible non-agricultural land uses. The Ontario government places a high priority on preserving agricultural land. However, policies have met with mixed success largely due to political considerations, but also in part due to the methods used to identify and prioritize agricultural lands. The objective of this research is to assess the feasibility of assembling a computerized database of information for agricultural land use planning and to compare results of the GIS-based agricultural assessment system against results of more traditional, non-computerized, subjective, expert assessment methods. The GIS-based assessment system uses a parallel approach by integrating physical suitability based on land resource data and a socio-economic suitability assessment within a Geographic Information System (GIS).

A recently developed computerized method of soil suitability rating, the Land Suitability Rating System (LSRS), was implemented and compared to the Canada Land Inventory soil capability ratings and the results of the LSRS were found to be generally consistent with the CLI ratings.

The results of the GIS-based agricultural assessment system were evaluated using criteria developed from government planning policy and they were compared to results of a manual expert assessment system developed by the Ontario Institute of Agrologists (OIA). The GIS derived zones were found to be consistent with government planning guidelines. Also, there was very strong correlation between the GIS zones and zones produced by the OIA. Although costs for personnel were similar, capital costs of the GIS exceeded capital costs for the manual approach. Overall, the GIS-based approach was an effective method for assessing agricultural suitability and developing land use planning zones.

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1. INTRODUCTION

1.1. Nature of Problem

The extent of Canada's prime agricultural soils is very limited and diminishing (Bentley 1981; Manning 1984; Richardson 1989). In Southern Ontario only 17 percent of the land area is considered prime (i.e. Classes 1-3 according to the Canada Land Inventory, Land Capability for Agriculture [ARDA 1970]). Of this only 6 percent is class 1. In addition, most of this remaining prime farmland is located on the fringe of major urban centres and is potentially vulnerable to loss from agriculture due to urban expansion, (Crerar 1962; McCuaig and Manning 1977). The conversion of agricultural land to other uses raises many issues including the potential instability of domestic food supply associated with an increased reliance on imported food (Ontario Institute of Agrologists 1975), foreign trade balance of payments (Bryant and Russwurm 1979), and the retention of agricultural land for its amenity value (Krueger 1977).

A healthy domestic agriculture industry is important to ensure a reliable and sustained food supply into the future (Bryant and Russwurm 1979; Smit et al. 1987). Locally the farm "community" has many positive social aspects and has a great influence on the rural way of life (Little 1979; Flaherty and Smit 1982). From an economic perspective, rural non-farm development results in increased municipal taxes for all landowners

(OMMA 1988). For these reasons the protection of agricultural land is a priority at federal, provincial and municipal levels of government. For example, government policies in Ontario, as identified by the Food Land Guidelines (OMAF 1978), place a high priority on the protection of good agricultural land, although there is some debate on the effectiveness of protection policies (Furusest and Pierce 1982; Johnston and Smit 1985). Globally the Food and Agriculture Organization (FAO) of the United Nations has placed a high priority on developing methods of rural land evaluation as a means to identify lands critical for agricultural production and to promote effective rural land use planning policies (FAO, 1976).

In Canada present federal agriculture policy is directed towards a 20 billion dollar a year agricultural export target and an increased share of the 80 billion dollar domestic market by the year 2000 (Goodale 1994). Federal policy also reflects the need for Canadian agriculture to be able to adapt quickly to foreign markets, requiring flexibility in the commodities produced and consequently flexibility in the land resources supporting production. If the present vision is realized it would result in 250,000 new jobs in the agri-food business, GDP would rise from 4 to 28 billion and net farm income would increase by over 25 percent by the end of the century (Goodale 1994). Consequently, there are also economic arguments for preservation of the agricultural land resource.

Central to the effort to protect agricultural land is the need to identify levels of land suitability for agricultural use, and to compare, or evaluate, this with the suitability for other non-agricultural uses (FAO 1976). In the context of this research, agricultural suitability is a

measure of the inherent physical capability of the land as well as the socio-economic infrastructure available to support agricultural activities. This definition strays from the common applications of suitability analysis, which usually focuses on the physical capability of the land alone (McRae and Burnham 1981) and the concept of integral land evaluation which extends physical land evaluation by analysing critical importance of land use as well (Beek 1978, Smit et al. 1984). Soil surveys are one option for physical capability assessment, and have been used to map the quality and location of the Canadian land resource (McKeague and Stobbe 1978). They contain basic data about the soil but require expert interpretation to determine the suitability of particular areas for specific uses.

The Canada Land Inventory (CLI) rating of land capability for agriculture has been useful for the assessment of land quality and the identification of lands which should be designated for agriculture (Environment Canada 1976). Clearly, the CLI has identified the limited areas of land with agricultural capability and, in particular, the relatively small areas of top quality agricultural land (Simpson-Lewis et al. 1979; Environment Canada 1989). The CLI requires expert knowledge and experience to apply and, to some extent, to interpret correctly for planning application (Cressman 1980; Richardson 1989). The CLI evaluation process is not all quantified which makes it difficult to replicate results, or implement using computerized techniques. Also, the number of pedologists who can develop, interpret and defend CLI assessments is decreasing due decreases in the number of qualified soil survey undergraduates produced by Canadian universities. Consequently, it has become important to consider alternative procedures for the assessment of land quality.

In addition to the CLI, there are a number of alternative suitability assessment techniques available for land evaluation (Beek et al. 1986). In Canada the most recent development in agricultural suitability assessment is the land suitability rating algorithm for spring seeded small grains (LSRS). The LSRS is based on detailed soils data, specific crop requirements and can be implemented using a computerized algorithm linked to the soils database (Agronomic Interpretation Working Group 1992). The LSRS is national in scope and was specifically developed to replace the CLI.

At a time when soil expertise is decreasing, the speed with which planning decisions are required is increasing. The volume of relevant information continues to grow, as does the range of societal objectives and the degree to which decisions must be documented and explicit. Traditional manual planning techniques relying on expert interpretation do not have the speed and flexibility for analysing large volumes of data and develop and test planning alternatives rapidly. Also, traditional methods do not have the level of explicit substantiation required by present day society. On the other hand, computerized systems offer speed and flexibility while still having the ability to incorporate traditional planning expertise in the analysis process.

Recent advances in computer technology and Geographic Information Systems (GIS) have provided planners and resource managers with a tool to store, manage, integrate and analyze land resource data (Burrough 1986). GIS offers a powerful tool to integrate soil-based assessments with socio-economic data to provide an alternative to traditional

agricultural assessment systems. The needs of today's land use planners are for assessments which are:

- Responsive to a wide range of economic and environmental needs.
- Data based so that they can be applied with minimum controversy.
- Relevant to the spatial units upon which decisions are made (i.e. lots and townships).

GIS offers the capability, flexibility and speed to meet planners' needs and the goals of government land use policy. Analysis can be performed on one spatial basis (e.g. soils units), then reorganized and presented on different spatial units (e.g. land ownership parcels) based on a set of rules. However, a GIS-based system requires a different set of capital overheads and personnel skills than traditional planning techniques. In times of fiscal restraint the benefits offered by using GIS must exceed the associated capital and human resource costs.

1.2. Research Objective, Scope and Outline

The objective of this research is to assess the feasibility of assembling a computerized database of information for agricultural land use planning and to compare results of the GIS-based agricultural assessment system against results of more traditional, non-computerized, subjective, expert assessment methods such as those employed by the Ontario Institute of Agrologists (OIA 1986).

The agricultural suitability assessment criteria are derived from current Ontario government policy as outlined by the Ontario Food Land Guidelines (OMAF 1978). The suitability assessment encompasses an integrated assessment of both the inherent physical suitability of the land for agriculture along with an assessment of the socio-economic support structure. The database used for the assessment is based on widely available information including soil survey, land use systems, cadastral and tile drainage mapping.

The evaluation of the GIS-based assessment is threefold. First it is based on an evaluation of its ability to meet provincial planning objectives as reflected in guideline policies. Second, the evaluation compares the GIS assessment with the results of the manual, expert assessment. Third, the evaluation encompasses a cost analysis of the estimated capital and personnel requirements for both assessment systems.

The research focuses on the townships of Rideau and Osgoode in the Regional Municipality of Ottawa-Carleton. This area was chosen because it has a complex mix of land resources, containing land ranging from the highest to the lowest agricultural potential. Also, the area contains biophysical conditions which are reasonably representative of a large portion of Eastern Ontario.

2. EVALUATING LAND FOR AGRICULTURE

2.1. State of the Agricultural Land Resource

The area of land suitable for agriculture is decreasing and this trend is accentuated in near-urban areas. For example, 84.9 percent of the land converted to urban uses between 1971 and 1976 in the Regional Municipality of Ottawa-Carleton was CLI Agriculture Capability class 4 or better (Warren and Rump 1981). The Ontario government considers class 1-4 lands as having a high priority for agriculture (Ontario Ministry of Agriculture and Food 1978). In Canada between 1966 and 1986 over 300,000 hectares of rural land were urbanized and 59% of this land had a high capability (CLI classes 1-3) for agriculture (Environment Canada 1989). Between 1981 and 1986 over 40% of the rural land converted to urban uses was at one time used for agriculture (Environment Canada 1989).

Provincial agricultural statistics indicate that there is a general trend towards intensification of agriculture as indicated by yield data (OMAF 1971, 1981; 1991). Also the Census of Agriculture indicates there was a 47 percent increase in area of cropped land in Ontario from 1941 to 1991, while total farm land has decreased by about 60 percent (Dominion Bureau of Statistics 1941; Statistics Canada 1991). The extension and intensification of cropping has largely taken place on high capability soils because lower class lands by definition are marginal or unsuitable for the production of field crops (ARDA 1970). This indicates agriculture has intensified on the best land while generally farm abandonment has occurred on lands of lower capability. Since much of the high capability

land is close to urban areas the implications of urban land conversion are greater than might be expected from the relatively small areas affected in terms of total farm acreage.

The impact of urbanization is felt far into the urban fringe (Krueger 1959; Bryant et al. 1982; Frink and Horsfall 1986). The actual amount of agricultural land converted to other uses is far in excess of the land area actually under direct urban expansion. Krueger (1959) notes that for every hectare of physical conversion to non-agricultural uses, two hectares were also converted due to indirect effects. As well, urban density has been decreasing. In the Regional Municipality of Ottawa-Carleton (RMOC) urban population density has decreased by more than 20% since 1959 (RMOC 1990). Overall this has resulted in an increased demand for the conversion of rural land to urban use.

There are several indirect effects from rural land conversion. These include the short and long term economic costs associated with non-farm development on the urban fringe (Furuseth and Pierce 1982b; James F. MacLaren Ltd. 1976; Ontario Ministry of Agriculture and Food 1978; Ontario Ministry of Municipal Affairs 1988). Problems such as escalating land prices, land use incompatibilities and land fragmentation all affect lands within the urban fringe, and are indirect negative effects of urban expansion. The Food Land Guidelines, the present Ontario provincial policy on planning for agriculture, indicate that servicing scattered rural residential development "sharply increases provincial costs" (Ontario Ministry of Agriculture and Food 1978, p19).

Despite the negative impacts stemming from agricultural land conversion, there has been a substantial increase in agricultural productivity (Census Bureau of Canada 1941;

Statistics Canada 1991). During the last half of the 20th century technology has increased the productivity of land at such a rate that the conversion of agricultural land to other uses may seem insignificant. Continuous productivity increases due to new technology and increased levels of inputs, however, are probably unsustainable and indications are that the rate of productivity increase is slowing (Gibson 1977; Latomell 1978; Jorling 1978; Plaut 1980; Census Bureau of Canada 1941; Statistics Canada 1991). Inputs are energy intensive, and as such are subject to the variability of world energy markets, resulting in a potential increase in economic instability. In addition to purely economic considerations, modern farming practices have resulted in reduced natural fertility in crop intensive farming systems (Coote et al. 1981).

Technology driven intensification has negative implications for the sustainability of agricultural land. Many modern farm practices decrease resource quality and may be unsustainable in some situations (Coote et al. 1981; Senate Standing Committee 1984). Best management practices (BMPs) have been developed to move agriculture closer to sustainability (Agriculture Canada and OMAF 1993), but there has been little work to collect statistics on BMP adoption rates in Canada. The use of low capability soils to replace urbanized higher capability soils may not be sustainable since low capability soils are generally much more susceptible to all forms of degradation (Jacobs and Timmons 1974).

Residues from many pesticide and fertility inputs are putting soil and water quality at risk (Senate Standing Committee 1984), although recent statistics demonstrate that

pesticide application is decreasing and the materials used are less persistent and toxic (OMAFRA 1994).

Globally, changing climate may slow or reverse increases in productive capacity. Global warming aside, in recent decades we have gone through a period of relatively stable climate and are now appearing to be entering a time of greater climate variability, which is the more "usual" nature of our climate (Schneider 1989). Many of the present climate change scenarios paint a very pessimistic picture for the future of agriculture world wide. The majority of the literature indicates that the general trend will be towards warmer and drier continental climates (Smit 1987; Schneider 1989; White 1990). Most major food producing regions of the world will experience harsher climates (Land Evaluation Group (LEG), U. of Guelph 1985). However, Canada could experience an increase in productive land area and productive capacity (LEG 1985). Should the Canadian proportion of the world's food production capacity increase, then it can be argued that Canada would have a moral duty to play a larger role in world food production. In the face of climatic uncertainty however it would be wise to protect our agricultural resource to ensure flexibility for future land use decision making.

The realization that the land resource and land use alternatives are limited underscores the need for planning measures to ensure appropriate land allocations which are sustainable. It also indicates a need for planning to maintain flexibility in agricultural land use options so as to maintain the potential for less intensive or different agricultural

practices in the future. A primary requirement for developing and meeting these objectives is the assessment of land capability for sustained agricultural use.

2.2. Agricultural Land Use Planning Policy in Ontario

North American society has viewed agricultural land from many perspectives. Historically it has been viewed as a residual use, left over after all other 'higher' uses have been designated, a by-product of the "free" land market (Furuseth and Pierce 1982). This perspective still prevails in some parts of North America, with farmland being viewed simply as land available for conversion to "higher valued" economic uses. In the past Canada has been viewed as having a huge storehouse of land resources (Manning 1984). This perception brought rise to the attitude that farmland is just a reserve of land waiting to be developed and land use planning decisions have focused on urban needs. Consequently, agricultural land use policies were few and rural land use was determined primarily by market forces.

The planning community has recently argued that rural land use planning should be modified to consider all potential land uses in a comprehensive fashion. Planning deliberations should consider the long term costs and benefits of alternative development strategies for all land uses rather than servicing just the needs of urban centres (Bryant and Russwurm 1982). The needs of agriculture should not be considered in isolation from the needs of other competing uses.

During the mid 1970s, the government of Ontario recognized that good agricultural lands were being converted to urban use at an alarming rate. In light of the importance of the agricultural sector to the provincial economy and concerns for future food supply the government made the preservation of good agricultural lands a priority. These concerns were outlined in a government statement paper titled: A Strategy for Ontario Farmland, March 1976 (Ontario Ministry of Agriculture and Food 1976).

The Food Land Development Branch, later to be renamed Food Land Preservation Branch and presently the Land Use Planning Branch, was created to address the government's concerns and to implement policies intended to create a framework of rational agricultural land-use planning. As a result, the Food Land Guidelines (OMAF 1978) were drafted as a policy statement of the Government of Ontario on planning for agriculture.

The assumptions, goals and intentions of the Guidelines were that the province of Ontario must protect high quality lands on a long-term basis by encouraging the development of land use zones where agriculture can occur with a minimum of disruption from competing and/or incompatible land uses (OMAF 1978).

Within the land use planning process as established through the implementation of the Planning Act, the Ministry of Agriculture and Food and Rural Affairs interests are protected using indirect police power measures, using the traditional land use planning system, tax relief and provincial influence on Official Plans and zoning bylaws (Furuseth and Pierce 1982). Through the Ministry of Municipal Affairs, representatives of the Ministry of Agriculture and Food are permitted to comment and request changes to

municipal official plans and planning amendments. During the review the Ministry ensures that Guideline policies are incorporated into municipal planning policy. Any disagreements between the municipalities, land owners or interest groups are often initially mediated by the Ministry of Municipal Affairs, and eventually, if dissent remains, may be referred to the Ontario Municipal Board for arbitration.

The system of land use planning in Ontario is hierarchical, with the top level represented by provincial policies, followed by the regional level and finally the township level. The policies and designations developed for each level must conform to the level above it. The level of planning determines the scale of analysis required for a planning application and effects the way planning policies (i.e. Food Land Guidelines) are interpreted.

One of the most important objectives of the Food Land Guidelines (FLG) has been to define and delineate high priority agricultural lands that should be protected and made available for food production over the long term. These lands are then subject to the agricultural preservation policies in the guidelines. Section 3.4 of the FLG (OMAF 1978, p 9) defines what should be considered as high priority agricultural lands. Section 3.4 reads as follows:

1. All lands which have a high capability for the production of speciality crops due to special soils or climate.
2. All lands where soils classes 1 to 4 predominate as defined in the Canada Land Inventory(CLI) of Soil Capability for Agriculture.

3. Additional areas where farms exhibit characteristics of ongoing viable agriculture.

4. Additional areas where local market conditions ensure agricultural viability where it might not otherwise exist.

The guidelines also contain policies which direct that "the objective (of agricultural designations) is to create areas of predominantly high priority agricultural lands which are as large as is practical and are uninterrupted by non-agricultural designations" (OMAF 1978, section 4A.1, p 14). Any land assessment method used in Ontario should strive to meet the requirements of the FLG policies. Consequently, these government guidelines represent criteria which can be used to evaluate the effectiveness of alternative land assessment systems. Analysis of these benefits, along with the cost (labour and capital) of implementing the assessment presents an appropriate measure to compare suitability assessment techniques.

2.3. Suitability Assessments Based on Soil Mapping

Any application of soils data, like the CLI or the Land Suitability Rating System for small grains (LSRS), must consider the concepts used to develop the soils map. The date, scale and methods used to collect soils data have implications as to how the data should be interpreted. Due to variability in mapping methods, interpretations cannot be handled

uniformly across the province. The knowledge required for this type of interpretation is generally lacking in the rural planning community (Cressman 1980; Richardson 1989).

Central to the development of capability assessments is the need for basic soil inventory information (Barnes 1949; Kellogg 1955; and Anderson 1971). Assessments of soil capability have been made since the early days of soil survey (Ruhnke 1926; McKeague and Stobbe 1978). Soil survey delineations are based on intrinsic soil criteria, while soil capability classifications are extrinsic, based on an external objective (Williams and Lance 1965). The way in which soil properties correlate to soil capability is subjectively defined and the relationships between intrinsic soil properties and overall soil capability are difficult to quantify. As such, capability assessments are usually based on subjectively defined criteria. Consequently, classifications like the CLI represent broad, non-crop specific generalizations based on a general understanding of the relationship between crop behaviour and the limitations imposed by intrinsic soil properties. Also, the method used to determine the intrinsic soil properties can have a considerable effect on the resultant capability ratings.

2.3.1. Soil Mapping In Ontario

The first soil survey in Ontario began in 1914 (McKeague and Stobbe 1978), and published in 1926 (Ruhnke 1926). The survey was initiated by A.J. Galbraith of the Ontario Agricultural College, Department of Chemistry, under the guidance of G.N. Coffey, a U.S. trained soil scientist. The purpose was to map the major soil types in Southern Ontario.

Early mapping concepts reflect the U.S. approach of the time which incorporated a three tier hierarchical structure of soil province, soil series and soil type. The map accompanying the 1926 report showed the distribution of soils at the soil series level. There were nine series identified in this initial survey. This contrasts with over two hundred named soils in the same portion of Southern Ontario at present.

These early mapping concepts were based on landscape characteristics such as parent material, texture and drainage and the focus was on "detailed" half inch to a mile (1:126,720) scale county surveys. Maps of Kent, Norfolk, Elgin and Middlesex were among the first produced at this scale. After the 1920s there was a long period of inactivity until 1945 in which year the National Soil Survey Based Committee was established. The creation of this expert committee led to the development of a national survey methodology, and eventually to a Canadian taxonomic system in 1955, the Canadian System of Soil Classification (CSSC).

By the mid-forties, soil mapping concepts had changed considerably. A stronger relationship to taxonomy was implied and the major focus was put on soil profile characteristics rather than landscape. The mapping scale was one inch to a mile and the use of soil series complexes began (Acton 1980). The 1945 to 1965 period marked the most active period of soil survey. During this time the soils of most Ontario counties were mapped. These surveys represent the majority of county surveys in use today.

In the surveys of the 1945 to 1965 period, pedon data were restricted to the survey reports (where available) and typically the layer descriptions consisted of colour, comments

on structure, texture class, and pH. No laboratory data were maintained to support these surveys and there was no attempt to correlate these with earlier surveys, even though the same soil series' names often occurred over a wide geographic area in several county surveys.

During the mid 1960s the focus of Ontario soil survey again changed to more detailed mapping (1:20,000). Many of the resurveys were of counties with older, one and two inch to a mile (1:63,360, 1:126,720) inventories. Also, during this period the CLI mapping was initiated (ARDA 1970). The mapping concepts evolved to reflect the more detailed scale of mapping. These concepts reflected the state of soil survey knowledge during this era. Representative detailed pedon descriptions with chemical and physical analyses were derived for each unique series-phase combination (Acton 1980). Once again there was insufficient effort directed towards spatial and conceptual soil correlation, other than to add county identifiers to the detailed data, thus making them unique from identical series-phase occurrences in other counties.

In the early 1970s the number of survey staff employed by public agencies in Ontario was reduced and field activity stopped until the mid 70s when concern about depletion of the agricultural resource base arose. At this time soil survey was revitalized, the concepts again evolved and mapping scales were 1:25,000 and 1:50,000. This period saw increased use of air photography for preliminary classification of soil and landscape units. The major conceptual change was the use of soil associations to represent various drainage combinations on similar parent materials. Instead of the soil code representing the soil series

it represented an entire catena. A soil series is determined by the properties which can be observed within a single pedon, whereas a catena represents a series of landscape positions (usually three) on similar parent materials with different drainage characteristics. Soil properties can vary widely within a catena because of the pedogenic influence of drainage and landscape position. Of course this conflicted with the earlier surveys in which the soil code was equivalent to soil series. There is little evidence of any effort to correlate the older surveys with the new.

Recent mapping efforts have been directed towards completing and publishing a number of surveys, most at scales of 1:25,000 and 1:50,000. Soils mapping in some of these counties was initiated in the 60s, but the mapping concepts are consistent with recent survey methodology. These areas include Haldimand-Norfolk, Brant, Kent and Middlesex, with survey upgrades in Oxford and Waterloo counties.

The major thrust of soil survey in the last two decades has been the development of digital data products. The evolution of the digital database has been led by the Canadian Soils Information System (CanSIS) of the Centre for Land and Biological Resources Research (CLBRR), Research Branch, Ottawa. The availability of digital data has improved the type of analysis which can be performed. Of particular note is the use of GIS technology to store, manage and manipulate soil survey and other related data for land use planning.

The artefacts of soil survey generally last for long periods of time, even though mapping concepts change fairly regularly. Most of the county surveys created in the 1945 era still represent the state of soils information for those areas today, leaving a legacy based

on past methods, not necessarily representative of present day knowledge. The problems associated with this are compounded since no effort has been made to relate the former methods to present day concepts. Incongruity of concepts, methods, scale and data collection has created problems for the present day user. An example of this is the Lanark County survey, published in 1967 and the recent revision of the Ottawa-Carleton survey (Schut and Wilson 1987). The border between these two regions illustrates the disparities caused by incongruities of scale and mapping concepts and efforts to upgrade just a small portion of Lanark (Ramsey Township) to the modern standards and concepts have proven costly and difficult (Gregory Geoscience 1993).

2.3.2. Soil Survey of The Regional Municipality of Ottawa-Carleton

The current soil survey data for the Regional Municipality of Ottawa-Carleton (RMOC) comes from a resurvey done in the early 1980s at 1:50,000 scale (Schut and Wilson 1987). The survey is based on morphological properties of the soil. The conceptual mapping unit is the soil association, and the map reflects landscape units, a subclass of the association, along with landscape criteria for slope and stoniness (Schut and Wilson 1987). Map units may be composed of one or two landscape units. At the map level the only criterion for determining proportions of landscape units is that the first landscape unit must represent at least 40 percent of the polygon and the second unit is between 20 and 40 percent of the area.

Soil attributes are linked to the soil map by attaching a soil map unit file (SMUF), which in turn provides linkages to the detailed soil name (SNF) and soil layer data (SLF). This data structure is based on standards of the Canadian Soils Information System (CanSIS). A diagram of the CanSIS structure is provided in Figure 2.1. The links to detailed pedon data provide for up to three soil types within soil map units, with each soil type identified by a unique soil code-modifier key. The key links the map unit to the detailed pedon database. The first soil identified in the SMUF is the predominant soil found in the dominant landscape unit on the map. The second soil, if it exists, is usually the dominant soil of the second map unit, or the subdominant soil in the first landscape unit if there is only one landscape unit. In the RMOC, a third soil is rarely present. Each soil has its extent indicated as a percentage of the total polygon.

2.3.3. The CLI Capability For Agriculture

The detailed descriptions of soils derived from soil surveys, along with soil surveyor experience provides the basis for the CLI ratings. The CLI ratings are usually derived by the surveyors who created the soil map. Since there is a high degree of subjectivity in the CLI interpretations and the surveyors are often not available to represent their assessments, it is left up to others less familiar with the data to interpret, challenge and defend the ratings for land use planning applications.

Figure 2.1 CanSIS Detailed Soil Map - Database Structure
(Smith and MacDonald 1990)

Within the planning community, a common use of soil survey information is for determining agricultural potential. In almost all instances this involves the use of CLI agricultural capability interpretations of soil survey data (Cressman 1980).

The widespread use of the CLI can be attributed to the inclusion of the CLI within provincial policy guidelines. The major uses of the CLI are identification of high and low priority agricultural lands and the development of statistical analysis of agricultural capacity (ARDA 1970; Environment Canada 1989).

The CLI ratings consist of a capability class and subclass. The seven class system indicates the general capability of the soil for agricultural use and the subclass defines the kind of limitations which exist. The class level represents the scale of information necessary for regional planning applications. Subclasses represent more specific management concerns and limitations that are usually addressed on a site specific or farm management basis.

CLI class 1 to 3 soils are considered suitable for sustained production of common field crops (ARDA 1970). Class four is marginal for sustained arable agriculture. Classes 5 and 6 are suitable for permanent pasture or grazing, with little potential for the production of field crops. Class 7 is unsuitable for agriculture.

The conversion of soil survey data to CLI ratings is based on unquantified expert interpretations of detailed soil data. The class and sub-class system of the CLI has been well documented (ARDA 1970), although, the process of creating ratings from soil data has

remained almost completely undocumented, relying on soil survey expertise (Schut 1994). Because of the undocumented nature of the CLI process, one surveyor's interpretation of criteria may vary from another's, resulting in inconsistency and presenting an opportunity for subjectivity. However, there is presently an effort to document the recommended analytical procedures for developing CLI interpretations in Ontario (Schut 1994).

The CLI classification system determines a soil's potential capability and not its present capability. Therefore, it assumes improvements which may be feasible at the farm level, such as tile drainage or stone removal, are in place and the soil is rated accordingly. Without those improvements, the productivity of a soil may be lower than that implied by the classification. The definition of what constitutes "feasible" is based on present knowledge and practices, and consequently can vary depending upon the date of the capability interpretation. The CLI classification does not address the economic viability of soils for cropping, or for improvements. Also, in some cases improvements are not physically possible. For example, tile drainage is dependent on natural drainage conditions. There is a requirement for an outlet and slope must be adequate.

A survey of upper tier municipal planners indicated that absence of an explanation of the rules of interpretation resulted in a lack of confidence in the overall approach, particularly when planners have to defend the CLI to politicians (Cressman 1980). Interpretation of soils mapping and the CLI for planning applications requires a high level of knowledge in mapping concepts and scale related issues. However, few people involved in the Ontario planning system have any base knowledge of soils or soil mapping

(Cressman 1980). So even though the CLI classification ratings are well accepted by pedologists and agrologists they are mis-used and mis-trusted throughout the planning profession (Cressman 1980).

Soils maps and the CLI were never intended to be used as agricultural planning zones. However, the CLI has evolved to be the dominant source of information used to identify agricultural land for planning purposes, and in some cases soil boundaries are used to represent planning zones. This application of soils information may be problematic. The inherent variability of soils results in mapped boundaries which are approximate and the size of the transition zone between soil units is related to survey scale. Depending on the nature of the area, a soil polygon boundary may represent a sharp division of land or a very wide zone of transition with inclusions of contrasting soils. As a result soil boundaries do not provide a good basis for planning zones. Soils maps contain boundaries which reflect biophysical conditions and do not reflect the political divisions on which land use decisions are made. Integrating soils data and land management units is difficult. When soil units are used for planning designations they result in fragmentation of the land base by presenting differing land use policies on different portions of the same land holding.

Scale related problems are a major area of interpretation error. This problem is not inherent in the CLI methodology, but rather it reflects the state of knowledge of the people producing the planning interpretations. CLI ratings are often applied to parcels of land which are smaller than the best resolution of the soils map (Cressman 1980). Generally the minimum resolution of a soils map is determined by the area represented by a box with

sides a half centimetre long (.25 cm²) at map scale (Monette and MacDonald 1992). For instance at 1:50,000 scale the minimum area would be 250m by 250m or 6.25 hectares. Since scale changes from survey to survey, CLI ratings cannot be uniformly addressed across county or regional boundaries.

Soil mapping provides the best available representation of the natural resource and as such an important source of information for land use planning. The CLI serves the needs of land use planning when used along with land use and other socio-economic indicators of agricultural viability. However, soil maps should not be translated directly into planning designations, as indicated by government policy and practised in some areas of the province. Soil conditions are usually highly variable and the direct use of soil-based capability ratings can result in agricultural designations which are fragmented by pockets of low capability land. This clearly does not meet the requirements of section 4A.1 of the Guidelines which indicates that areas defined as high priority for agriculture should be "as large as is practical and uninterrupted by non-agricultural designations" (OMAF 1978, Section 4A.1).

2.3.4. Alternative Approaches to Land Evaluation

The Soil Conservation Service of the United States Department of Agriculture has developed a system of agricultural Land Evaluation and Site Assessment (LESA) (Wright et al. 1983). The LESA system involves two distinct parts. The first is land evaluation which involves the evaluation of land suitability for agriculture based on physical land properties.

The second part involves site assessment based on factors other than soil which contribute to the overall suitability for agriculture (Wright et al. 1983). Non-soil factors include present land use, land use policies as defined by the Official Plan and zoning by-laws, distance from urban centres and the need for uses other than agriculture. The final site rating is derived by adding the weighted scores for each factor.

The adoption of LESA at the U.S. Federal level is assured since it was adopted into legislation in the 1981 Farmland Protection Policy Act. Recently a study of the status of LESA programs at state and local levels was conducted (Coughlin 1994). This study indicated that 138 local governments, mostly counties, and eight states are currently using the LESA system. The study also questioned users about their perception of the reliability ascribed to LESA. Results found that 79 percent of the respondents were satisfied with the results (Coughlin 1994). The 21 percent with less than satisfactory responses cited a variety of reasons including, "a poor LESA model, difficulty in using LESA, unsympathetic local political climate, lack of qualified and trained staff or simply the failure of the model to capture the complexity of all factors affecting a site" (Coughlin 1994, p10).

The LESA system was successful in integrating physical and socio-economic data. However, data were derived from many different sources and the integration of all the different databases was tedious and inefficient (Wright et al. 1983). The LESA system was designed for site-to-site evaluation and regional analysis was not feasible using manual techniques. Since these earlier attempts at comprehensive land evaluation there have been rapid and substantial improvements in computer hardware and GIS software (Burrough

1986; Goodchild et al. 1993). As early as the 1980's these developments have presented new opportunities to develop land assessment applications at the broader scale (Williams 1985). In addition new capability assessment techniques have been developed to replace the CLI. In Canada the development of the Land Suitability Rating System (AIWG 1992) is foremost of the efforts to replace the CLI.

2.3.5. Land Suitability Rating System Overview

Within the national soil survey community there has been increasing concern over the use of CLI agricultural capability ratings. When brought to the attention of the Expert Committee on Soil Survey in 1986 the Agronomic Interpretation Working Group (AIWG) was created (AIWG 1992). The working group examined a number of provincial CLI applications across the country and suggested the development of a new expert system approach to replace the CLI. The new system was defined well enough to allow for computerized implementation. The result of this process was the development of an algorithm for the rating of land suitability for a specified crop. Initially an algorithm calculating ratings for spring seeded small grains was developed (AIWG 1992). However, the system was constructed so that parameters can eventually be modified to match the requirements of any crop.

The Suitability Rating System (LSRS) was developed in response to several concerns regarding the CLI. These concerns were identified as follows (AIWG 1992, p x):

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

- * The influence of climate on land suitability for crop production was not adequately taken into account.
- * Nationally, organic soils were not included although some CLI applications do have survey specific ratings.
- * Lack of specificity in definitions and application guidelines had led to inconsistent ratings among land rating practitioners.

In concept, the LSRS is similar to the CLI. The LSRS rates soils based on their limitations to crop production. The major difference in the LSRS is the development of an algorithm which rigidly defines and quantifies the decision making process. A computer program for calculating the ratings has been developed (AIWG 1992), although the algorithm can also be applied manually.

The ratings are based on quantified but subjective assessments of individual parameters. The LSRS is interpretative and based on limitations to crop production. Limitations are divided into three separate categories. Each category can limit crop production independently from the other two categories. Consequently the final rating reflects the limitations imposed by the most limiting category. The final rating is calculated by subtracting from 100 the points of the most limiting category.

The three rated categories are climate, landscape and soils. Climate includes moisture and temperature factors. Landscape includes factors of topography, stoniness, landscape pattern and flooding. Mineral soil ratings are based on four factors; water supplying ability; surface factors such as structure, organic matter and depth; subsurface

factors such as structure, reaction and salinity; and drainage. The final rating for each of the three categories is based on a combination of all factors within the category.

The LSRS algorithm can accommodate soils data of various levels of detail. For instance the LSRS can be used for general level data such as those contained in the Soil Landscapes of Canada, published at 1:1,000,000 scale (AIWG 1992). As well it can be applied to published pedon data for regional scale assessments of soil suitability. However, for field scale applications a higher intensity collection of site specific pedon data is required. This detail of data is not widely available from existing, published data inventories.

The rating system is based on quantified parameters, and while the rating point deductions have not yet been scientifically tested they do reflect the present state of expertise in soil-crop relationships. Also, the ratings reflect actual conditions, whereas the CLI reflects potential conditions based on feasible land improvements. The reproducibility gives the LSRS a better scientific foundation than the CLI. However, the LSRS shares many of the characteristics of the CLI approach; it requires soils expertise to apply and the results are usually portrayed on the same spatial base as the CLI. Considerations such as farm infrastructure, critical mass of agricultural activities, land fragmentation and competing land uses are not addressed. The LSRS is still in the development phase, and at present there is only one published report comparing an application of the LSRS to the CLI (Cressman 1994).

2.4. Suitability Assessment Using Geographic Information Systems

A GIS may be defined as "an organized collection of computer hardware, software and geographic data, and personnel designed to capture, store, update, manipulate, analyze and display all forms of geographically referenced information efficiently" (ESRI 1992 p 1-2). A GIS must be able to fulfil the following tasks (Laurini and Thompson 1992):

1. Provide tools for data acquisition and encoding.
2. Handle and secure these encodings efficiently, by providing tools for editing, updating, managing and storing; for reorganization or conversion of data from one form to another, and for verifying and validating those data.
3. Foster the easy development of additional insight into theoretical or applied problems, by providing tools for analysis, simulation and synthesis.
4. Assist the task of spatial reasoning, by providing for efficient retrieval of data for complex queries.
5. Create user-friendly output in varied forms.

Geographic information systems (GIS) have evolved to a point where they are widely used for land management applications. GIS offers computerized tools to manage, integrate and analyze large and complex databases; a prerequisite to carrying out regional suitability assessments.

The tools provided by GIS permit rapid analysis of digital land resource, land use and land management data for suitability assessment. The speed of analysis offers a new dimension of flexibility to data analysis. Analysis can be carried out in an iterative fashion, using direct feedback from previous analysis to modify the query until an optimal result is found. The iterative nature also offers the potential to test scenarios. Analysis still depends on traditional expertise, but the GIS frees up the expertise to concentrate on the core problem and analysis, while data management and data manipulation are handled by the computer system.

In an early example of a GIS-based land assessment application, Williams (1985) undertook a case study to implement LESA on a geographic information system. Williams found that the digital database allowed rapid manipulation of the LESA factors and flexibility to model changing parameters. The use of GIS technology alleviated many of the data management and analysis problems found in manual applications of the LESA methodology.

2.4.1. GIS Within the Planning Process

A schematic of a typical planning approach to land suitability assessment is presented in Figure 2.2. Land use requirements are converted to policy goals by politicians and senior administrators. These goals provide direction to the planners who in turn develop research questions. Planning questions may be developed for a wide range of uses and scales, proper land evaluation requires that multiple uses be considered (FAO

1976). The answers to these questions will provide the basis for decision making. A typical question might be : Where are areas most suitable for agriculture?

Figure 2.2 Suitability Assessment Within The Planning Process

Once general planning questions are formed, the questions are divided into several land qualities and socio-economic indicators. The FAO framework for Land Evaluation (FAO 1976 p 12) defines a land quality as a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use. Based on the example cited land qualities could be: Where are the soil properties viable for crop production (i.e. nutrient availability or drainage)? Where are landscape factors viable for crop production (i.e. slope and stoniness)? and where is the climate viable for crop production (i.e. temperature and moisture, but not usually significant for intra-regional scale

studies)? In addition to land qualities, socio-economic indicators must be determined (FAO 1976). These are properties important to the specific land use, but external to inherent land characteristics. Indicators may include things such as: Where is there sufficient infrastructure for agriculture or where is agriculture on-going and economically viable.

In the planning process land qualities and socio-economic indicators are derived from maps, photos, statistics and field survey. The relevant information is manually obtained from the various data sources to undertake the desired analysis. The next step is to integrate these attributes to develop a single layer of information which presents a possible answer to the original research question. The integration relies on planning expertise to combine information in a manner appropriate to the research question and proper planning principles. Because the process of integration is manual it is tedious and labour intensive. Multiple iterations, and scenario testing are difficult because of the effort and time required. Planning departments are usually required to turn out answers in a timely fashion, precluding thorough analysis using slow manual techniques.

The integration of GIS into the planning process is presented in Figure 2.3. While the corporate structure remains intact changes are required in the types of technical expertise required to manage and use the GIS, data costs and the capital costs of the physical GIS components. Initial start-up costs may be higher, but in the longer term costs should not exceed those of traditional planning, as labour and data costs decline.

Figure 2.3 GIS Within the Planning Process

The major advantage offered by GIS is the speed with which spatially referenced data can be handled. Land qualities and indicators are still developed by technical staff and on first iteration the analysis will be similar to the traditional system. However, with the GIS-based system data can be assembled and analysed much more quickly, allowing more time for analysis. A major advantage in using GIS is that once the data are compiled and registered, it is easy to test various alternatives through a series of scenarios and to refine and optimize the results iteratively (Jarvis and MacDonald 1993). GIS analysis does not easily support ad hoc or subjective analysis. The GIS offers a reproducible method for data

analysis which can be adopted for the development of land suitability assessments and land use planning applications. In addition, GIS techniques can be used to analyze data on one spatial basis and display it on another. For example analysis can be performed on soil mapping then summarized and presented on the basis of political units.

3. METHODS AND DATA

3.1. Research Objectives and Analysis Framework

The objective of this research is to assess the feasibility of assembling a computerized database of information for agricultural land use planning and to compare results of the GIS-based agricultural assessment system against results of more traditional, non-computerized, subjective, expert assessment methods such as those employed by the Ontario Institute of Agrologists (OIA 1986).

The agricultural suitability assessment criteria are derived from current Ontario government policy as outlined by the Ontario Food Land Guidelines (OMAF 1978). The suitability assessment encompasses an integrated assessment of both the inherent physical suitability of the land for agriculture along with an assessment of the socio-economic support structure. The database used for the assessment is based on widely available information including soil survey, land use systems, cadastral and tile drainage mapping.

Within this research, suitability is defined as the fitness of a given type of land for a defined use, where fitness is based on the inherent physical condition, major improvements to physical condition and existing infrastructure as indicated by land use intensity. The defined use is crop-based agriculture. This concept of suitability is more comprehensive than the definition proposed by either the CLI (ARDA 1970; Smit et. al. 1984), or the LSRS (AIWG 1992) in that it includes socio-economic criteria in addition to inherent physical condition. However, the definition falls short of integral land evaluation as defined in Beek

(1978) and Smit et al. (1984), or land evaluation as defined by the Food and Agriculture Organisation of the United Nations (FAO 1976), as it is specific to agricultural use only and does not address the critical importance versus other competing land uses other than as implied by government policy.

An analysis and evaluation framework has been developed to achieve these goals and is illustrated in figure 3.1. The following discussion briefly outlines the various stages of the framework.

Figure 3.1 Analysis and Evaluation

The framework assesses both physical and socio-economic suitability in parallel. The physical suitability assessment is derived from ratings generated by the LSRS

algorithm. The LSRS ratings are based on soil, climate and landscape data. The ratings indicate the suitability of the land for the production of spring seeded small grains. The socio-economic assessment is based on an analysis of major land improvements suggesting long term investment in agriculture and existing agricultural intensity which implies infrastructure. Data for the socio-economic suitability assessment are derived from Agricultural Land Use Systems mapping, cadastral and tile drainage mapping. The criteria used to develop this assessment are based on Ontario government planning guidelines.

Once the parallel assessments of physical and socio-economic suitability are complete they are generalized then combined to create a composite suitability assessment which can be used to develop agricultural land use planning zones. The composite assessment is spatially complex because it includes the spatial characteristics of the soil, cadastral and land use systems mapping. Ontario planning guidelines require that planning designations must be clearly defined, and the zones should be based on some land unit which is relevant and will permit easy enforcement of planning law. The fragmented and complex nature of the composite suitability assessment does not meet these requirements. Consequently, there is a need to generalise the composite suitability assessment to a scale and spatial unit which is relevant to regional planning needs.

Cadastral mapping provides the spatial basis for generalization and the rural lot (approximately 80 Ha in Ottawa-Carleton) represents the minimum unit size, or resolution of the analysis. Other than land ownership maps, rural lots are the most relevant spatial unit for rural planning application since they approximate the rural land management unit at the

regional planning scale. Cadastral mapping is readily available, whereas ownership maps are difficult to use and costly to obtain. The typical size of a rural lot is appropriate for regional scale planning applications. Generalization criteria were developed to summarize the database within each cadastral unit and then the cadastral based data and analysis was further generalized to meet provincial and municipal objectives for planning designations. To a great extent these planning objectives are based on the Food Land Guidelines (OMAF 1978, Section 3.2.1). Generally, the goal of generalization was to identify and delineate large contiguous agricultural designations of high suitability lands.

Once complete the final suitability assessment will be evaluated against criteria from the Food Land Guidelines to determine if the results conform to government policy. As well, the results will be evaluated against agricultural zones developed by the Ontario Institute of Agrologists (1986). This evaluation is based on a comparison of the GIS-based assessment to the manual expert assessment, as well as a comparison of the resources required to complete each assessment.

3.2. Planning and Evaluation Criteria

Suitability evaluation criteria were developed from the Ontario Food Land Guidelines (OMAF 1976). Identifying important agricultural lands and developing agricultural planning designations are the main policy areas of the guidelines which are applicable to this analysis. These policies are found in chapter 3 and 4 of the guidelines and are described in section 2.2 of this paper. This limited list is not exhaustive and represents

only the most significant policies with respect to this research. The following discussion lists the guideline policy (in italics); then criteria developed to meet the policies are identified:

1. Identification of high priority agricultural lands, derived from chapter 3 of the Food Land Guidelines. The resultant criteria will be used to assess the physical and socio-economic suitability of the land to support agriculture.

A) Policy:

- All lands with potential, or used for the production of specialty crops. These include areas where specialty crops are presently grown, or areas of organic soil with a high capability for specialty cropping (i.e. high suitability organic soils).

Note: Specialty crops include sod farms, fruits and vegetables.

Criterion:

- High priority is given to areas of specialty cropping as identified on the Agricultural Land use mapping of the RMOC and closely associated organic soils as identified by the RMOC soil survey.

Rationale:

- Generally specialty crops depend on unique soil and/or climatic and/or management conditions. The extent of these lands is limited and they usually produce crops which are not otherwise locally available. Due to the unique, valuable and rare nature specialty crop lands should be preserved wherever possible.

B) Policy:

- All lands with predominantly high capability for the production of common field crops.

Criterion:

- High priority is given to land with high suitability ratings according to the LSRS. High ratings are considered to be class 1 to 3 lands and some class 4 located in close association with class 1 to 3 lands.

Rationale:

- Class 1 to 3 soils are capable of supporting sustained production of common field crops. Class 4 lands can support perennial forage crops and when they occur in association with class 1 to 3 lands can be an important part of the farm operation, and these lands are generally used for pasture and/or hay production.

C) Policy:

- *Areas of lower suitability (i.e. CLI class 4-7) exhibiting characteristics of ongoing viable agriculture. As indicated by land use activities and investment in land improvements.*

Criteria:

- High priority is given to lands which support intensive agricultural activities according to the Agricultural Land Use Systems. High priority is given to lands supporting agricultural activities of moderate intensity with a significant portion tile drained. Moderate priority is given to lands with low soil suitability rating and is either tile drained or supports agricultural activities of moderate intensity.

Rationale:

- Most farming areas will be found on lands designated class 1 to 4 or specialty crop lands. However some areas of farming will fall outside of these areas on poorer lands. The reasons for this include the use of special management practices, unusual level of investment in improvements (i.e. drainage or stone removal), or an error in the soils map or LSRS rating calculation.

2. Development of agricultural designation. Criteria developed from these policies guide the conversion of the suitability assessment to an agricultural planning zone.

A) Policy:

- *Agricultural designations must be clearly identified. (i.e. The designations must be of appropriate size for the map scale presented and the boundary must be based on a tangible spatial unit.)*

Criteria:

- Boundaries of the agricultural planning zone will be based on legal boundaries from cadastral mapping.

Rationale:

- Planning decisions such as severances and plans of subdivision are made and implemented according to land ownership parcels. As a result it is logical that planning designations should reflect these spatial units to facilitate implementation and enforcement of planning policy while limiting fragmentation of the land base. Ideally, the land ownership map would provide the base for the planning designation, but the provincial land registry maps are complex and costly to obtain. Cadastral mapping provides an ideal alternative because rural lot and concessions were traditionally the land unit on which farms were based and as such cadastral maps approximate land ownership patterns in the rural area. As well, cadastral mapping is easily obtained or digitized.

B) Policy:

- *The designation should represent areas of predominantly high priority agricultural lands (based on 1 above). These designations should be uninterrupted*

by small pockets of non-agricultural designations. Alternatively, non-agricultural designations should not be interrupted by small pockets of agricultural designation.

Criteria:

- Small pockets of land with contrasting suitability will be eliminated by assigning them to the predominant surrounding zone. For example a pocket of low suitability land surrounded by high suitability land would be placed in the agricultural planning designation. The minimum pocket size for the agriculture and non-agriculture designation is 320 hectares, which represents approximately four rural lots in Eastern Ontario.

Rationale:

- The regional official plan represents fairly general, overriding land use policies. More specific and detailed policies are presented in the municipal (township) official plans and zoning by-laws. From a practical standpoint, when developing planning designations for regional planning it is important that the land use schedule reflect a spatial scale which is compatible with the policies. From the standpoint of agricultural land preservation, agriculture generally requires a land base which is not fragmented. There are several reasons for this including the fact that a minimum land area is required to support an economically viable farm unit, there is a need to maintain flexibility to meet changing economic conditions and/or changing crop requirements; and incompatible non-agricultural land uses (such as non-farm residential) within predominantly agricultural areas can create conflicts with agricultural practices. The minimum size criterion is not specifically outlined in government policy. The size selected (320 ha) was selected based on an analysis of the nature of agricultural activities, the distribution of soils and agricultural land use in the study area. The minimum size criterion is specific to the study area and may vary in other regions of the province. For instance the minimum size criterion for large areas of specialty crops could be expected to be much smaller (eg. Niagara fruit belt or Holland Marsh).

3.3. Study Area

The study area is Osgoode and Rideau Townships located in the eastern portion of Southern Ontario in the Regional Municipality of Ottawa-Carleton (RMOC) (Figure 3.2).

Figure 3.2 Location of Study Area

The study area is under the planning jurisdiction of the RMOC and all planning decisions must conform to regional policy. The area of Osgoode and Rideau Townships is 79,000 Ha which constitutes 28.6 percent of the RMOC land area. The study area is bisected by the Rideau River, separating Rideau and Osgoode Townships. The Rideau River also bounds the southern part of Rideau Township. Agricultural land use accounts for approximately 52.1 percent of the total land area and as such it plays an important role in the local economy.

Osgoode and Rideau Townships were selected for several reasons: First, the research area is under considerable pressure from the urban influence of Ottawa. Second, the area has been well documented in terms of data and previous research activities, including a relatively recent soil survey (Schut and Wilson 1987), Agricultural Land Use System mapping (Huffman and Dumanski 1977 and 1987), an expert assessment of Regional agricultural zones and planning policies (Ontario Institute of Agrologists 1986) and a recent Official Plan Update in the late 1980s (RMOC 1990). Finally, the study site presents a complex range of soil and land use conditions which are reasonably representative of the conditions in the RMOC and most of Eastern Ontario. The range of conditions represented in the study site were highly suited to test an agricultural suitability rating system for Eastern Ontario.

3.3.1. Physiography and Soils

The physiography of the Rideau-Osgoode site is a complex mix of clay, sand and limestone plains, intermixed with pockets of organic soils and drumlinized till plains (Chapman and Putman 1984). The complex physiography has developed from a combination of tills deposited during the Wisconsin glaciation which were reworked by the Champlain Sea and augmented by fine-textured marine deposits. Since the retreat of the Champlain Sea there has been further reworking and deposition from abandoned channels of the ancestral Ottawa River (Schut and Wilson 1987).

The soils are primarily differentiated by variations in parent material deposition. These differences encompass characteristics of texture, sorting and landscape. Consequently, the soils were mapped based on expression of landscape as observed through air photo interpretation, field mapping and detailed sampling (Schut and Wilson 1987).

3.3.2. Agricultural Land Use In The Study Site

The Census of Agriculture, produced by Statistics Canada, provides a snap shot of the state of agriculture every five years. The spatial reporting units are Census Consolidated Subdivisions (CCSDs) which coincide with township boundaries. The census provides a wide range of useful agricultural attributes, although the spatial and temporal resolution is rather poor. As such, the census is a valuable source of land use data for small scale study and overall trends. The following characterisations were compiled from selected land use

statistics selected from the 1941 to 1991 Census of Agriculture (Dominion Bureau of Statistics 1941, 1946, 1951, 1956, 1961, 1966; Statistics Canada 1971, 1976, 1981, 1986, 1991)

Between 1941 to 1991 the number of farms in the RMOC decreased by 63 percent, while average farm size increased by about 40 percent. A comparison of agricultural land use systems mapping (Huffman and Dumanski 1983) with CLI mapping (Schut and Wilson 1987) demonstrates that the abandonment of farmland has been heavily weighted towards poorer capability soils. Beef and hog farms are most numerous, but in terms of capital and farming intensity, dairy is the dominant farm type. The crops grown most extensively are grain corn, fodder corn and hay, indicative of a livestock-based crop rotation. Ten percent of the region's farms were cash crop operations in 1991, having risen from about 1 percent in 1966. The proportion of rented farm land has remained high relative to provincial averages, likely due to the rental of farmland owned by land development interests in proximity to the Ottawa urban area. Between 1960 and 1991 the proportion of land rented has increased from about 16 percent to 25 percent of total farmland.

3.4. Geographic Information System Development

The development of the GIS was undertaken in three stages. In the first stage the physical components of the system were established. In the second data needs were identified and third, a database was compiled in response to the data needs.

3.4.1. Physical GIS Components

Two commercial Geographic Information Systems were used. Initial database development and digitizing were done using PAMAP GIS, running on a 286 Zenith personal computer connected to a SUMMAGRAPHICS digitizing tablet. Subsequent analysis and output was produced on an ARC/INFO GIS running on a DEC ALPHA 3000 Model 300 workstation. Final output graphics were produced on a CalComp ColorMaster thermal laser printer. Some data management and analysis was performed on a 386 PC running DBaseIV and Quattro Pro software.

3.4.2. Data

Data characteristics and sources required to develop the suitability assessments are summarized in table 3.1.

Table 3.1 Data Requirements

RESEARCH COMPONENT	DATA THEME	SPATIALLY REFERENCED *	APPROXIMATE OPTIMAL SCALE REQUIRED
	Soil Survey	Yes	1:50,000
	Pedon Data	No	n/a
	Climate	Yes	1:5,000,000
	Agricultural Land Use Systems	Yes	1:50,000
	Artificial Drainage Mapping	Yes	1:50,000
	Cadastral Mapping	Yes	1:50,000
	Official Plan, Land Use Schedule	Yes	1:50,000
	Cadastral Mapping	Yes	1:50,000
	Ontario Institute of Agrolologists, agricultural planning zones	Yes	1:50,000

* Optimal Scale based survey intensity 3, county level planning application (Mapping Systems Working Group, 1984).

3.4.3. Database Development

Data were compiled from a variety of sources and integrated, in digital format, on to a standard Universal Transverse Mercator (UTM) projection. The standardized projection parameters are UTM projection, zone 17, source scale 1:50,000

The database is presented in greater detail within Table 3.2.

Table 3.2 Data Base

Layer Name	Definition	Scale	Source	Digital format	Scale	Appropriate to Source Scale.	Polygonal	Survey report 1987, digital map 1990
Soil Survey	High, although historically mapping concepts change over time	1:50,000	Digital format from The Centre for Land and Biologic Resource Research (CLBRR)			The map units are based on soil associations		
Modal pedon data for Ontario soils derived from field and laboratory measurements	Medium, data will change as additional soil sampling takes place	N/A	Ontario Land Resource Unit, CLBRR			varies depending on available field data and/or estimate methodology used	ASCII	Prepared in 1994
Land use, with an emphasis on agricultural land use systems	Medium, cropping patterns are fairly stable and change over periods of years to decades	1:50,000	Digital format from CLBRR			Based on air photo interp. cropping patterns over 2 years	Polygonal	Compiled and digitized in 1987, released in 1990
Tiled fields and municipal drains	High,	1:25,000	OMAF, Soil and Water Management Branch, digitized for this research			High	Hardcopy, polygonal	Updated annually, copy used 1992

Table 3.2 cont'd. Data Base

Layer Name	Scale	Source	Scale	Scale	Scale
Lot mapping for Rideau and Osgoode Townships	High	Digitized from hardcopy. Hardcopy obtained from the RMOC	1:100,000	High	Polygonal
Expert, subjective assessment of agricultural lands for land use planning	N/A	Ontario Inst. of Agrologists, Planning For Agriculture, 1986. Digitized for this study	1:100,000	High, based on expert assessment	Hardcopy, polygonal
					Current

3.5. Development of Physical Suitability Assessment

At present in Canada there are two major systems to evaluate physical agricultural suitability, the CLI and the LSRS. These systems were applied, compared and evaluated to determine which one was more appropriate for this application.

3.5.1. Canada Land Inventory Capability for Agriculture

CLI ratings were mapped for the study area, the ratings were derived from published CLI ratings found in the soil survey report (Schut and Wilson 1987). The ratings were mapped by linking the CLI rating files produced by the authors of the soil survey report to the dominant soil landscape unit identified in the map unit name located in the soil map unit file (SMUF). A capability map was produced based on the seven class system, with organic and non-mapped areas remaining non-rated. The CLI limitations were not included in the ratings since they are more detailed than required for a regional planning assessment.

3.5.2. Land Suitability Rating System For Spring Seeded Small Grains

The LSRS was applied to the dominant soil for each soil polygon. The minimum mandatory attributes required by the LSRS algorithm include:

- * Climate P-PE, moisture index for defined growing season
- * Climate effective growing degree days (EGDD)
- * Depths of soil horizons
- * Proportions of sand, silt and clay
- * Bulk density

- * Hydraulic conductivity
- * Depth to water table if less than 100 cm.

Properties of many of the soil series are described in detail in Volume two of the RMOC soil survey report (Schut and Wilson 1987), and in the CanSIS digital soil names file (SNF) and soil layer file (SLF). Where available the detailed data were extracted and manually entered in the LSRS program in conjunction with map unit data from the SMUF to derive the soil and landscape rating components of the LSRS. Where data were incomplete or totally absent, data from the Ontario representative soil layer and name file were substituted, although this only occurred for a few soils. The Ontario representative file consists of one set of modal data for each soil series described in Ontario. Climate data were obtained from 1:5,000,000 P-PE (precipitation minus potential evapotranspiration) and EGDD (effective growing degree days, above 5 C) maps distributed with the LSRS report.

The computerized procedure generated spurious results, particularly in areas of shallow soils over bedrock or on tile drained, heavy textured soils. The actual cause of these inconsistencies was difficult to determine since the programming code was not supplied with the LSRS software and the code was not otherwise accessible to the user. The ratings were repeated manually using the algorithm rather than the program. This method produced results which were more acceptable based on existing land use and experience with these soils. It appears that the programming code is in error for tile drained and shallow soils. The final LSRS results were based on a combination of program and manually derived ratings.

The ratings for the dominant soil were appended to the SMUF file and linked to the digital soil survey map in the GIS to produce rating maps.

The CLI capability ratings were statistically compared to the LSRS derived ratings to determine if the two procedures produced significantly different results. The areas for each rating were compared and the percent difference calculated. A Spearman rank correlation coefficient (Johnson 1980) was calculated to compare the results of the two rating systems. The correlation test was performed on all rated polygons. The formula is as follows:

$$r_s = 1 - [6 \sum(d_i)^2 / n(n^2-1)]$$

Where: r_s - Spearman rank correlation coefficient
 d_i - The difference in CLI and SRS rankings
 n - Number of pairs of data

3.6. Development of Socio-economic Suitability Assessment

In order to meet the government planning policies outlined in section 3.2.1 of the FLG, a suitability assessment of socio-economic factors related to agricultural land use was required. Based on the criteria developed the assessment includes identifying areas of specialty crops, areas of ongoing intensive agriculture and associated infrastructure and areas where significant improvement and investment in tile drainage have been made. In addition, areas of incompatible non-agricultural land uses such as towns and villages were

omitted from the study. The following table (3.3) summarizes the criteria, data sources and the selection criteria for each of the planning criteria identified in section 3.2.1.

Table 3.3 Socio-economic Suitability Assessment Criteria Development

PLANNING CRITERIA	SOURCE	SELECTION CRITERIA
	Agricultural Land Use Systems (ALUS) (Huffman and Dumanski, 1987)	Areas classed as Specialty Crops, Sod farms and Orchards in the ALUS
	Agricultural Land Use Systems (Huffman and Dumanski, 1987)	High- Monoculture or Corn ALUS Med.- Mixed, Hay Low - Pasture Grazing
	Tile drainage mapping (OMAF 1991)	Lots which are > 30% tile drained
	Agricultural Land Use Systems (RMOC 1990)	Incompatible, non-agricultural designations (Urban, recreation, extraction)

* This type of information should come from farm headquarters based census of agriculture data, however this data is not available due to confidentiality concerns. Huffman (1983) was able to demonstrate a strong relationship between Agricultural Land Use Systems classes and farm intensity/land use through the use of census data along with farm level surveys. Consequently, the ALUS provides an alternative to the census data.

** Criteria to determine farm infrastructure should be wide ranging (i.e. Farm input retailers, corn dryers, food processors, tile drainage, etc.), however this type of data was not readily available in digital form. Drainage provides a good surrogate for infrastructure because it represents a considerable level of investment, it is long term and it increases the suitability of the land resource to support agriculture.

3.6.1. Criteria For Assessing Suitability From Agricultural Land Use Systems and Official Plan Land Use Maps

The Agricultural Land Use Systems (ALUS) are important for three aspects of the suitability assessment; identification of specialty crops, identifying areas of intensive agriculture and identifying incompatible non-agricultural land uses. For this study the ALUS rating system was converted into five numeric classes, 1, 2, 3, -1 and -9. The positive numbers indicate the relative rank of agricultural intensity based on the land use system, with 3 being the class of highest intensity. Areas of specialty crops are also given a rating of three. A rating of -1 indicates a compatible non-agricultural land use and -9 indicates an incompatible non-agricultural land use. The absolute value of these rankings are not important. The positive numbers represent ranks and the negative numbers are flags to indicate non-rated, non-agricultural polygons. The rules by which values are assigned are summarized in Table 3.4. The actual allocation was done by a computer program which selects each type of ALUS designation and assigns the appropriate rating class.

Intensity is based on the proportion of corn production for each agricultural land use system. According to Huffman (1983) corn provides an appropriate surrogate for intensity as it requires a high level of management, inputs, yields and supplies a high net economic return. Huffman (1983) was able to demonstrate a correlation between this definition of intensity and socio-economic variables such as capital investment, annual income, annual expenses, farm labour and operator demographics using farm surveys. The estimated

proportions of land in corn were obtained from values published with the Agricultural Land Use Systems mapping report (Huffman and Dumanski 1983).

Table 3.4 Agricultural Land Use Systems Rating Method

CLASS	RATING	CRITERIA	LAND USE SYSTEMS
	3	Crop intensive, Greater than 30% of land area in corn or specialty crops	Monoculture Corn System Specialty Crops and Sod Farms
	2	Crop intensive, Less than 30% of the cropped land in corn	Mixed System Hay System
	1	Non-cropped, Improved grass for hay and native grass for pasture	Pasture System Grazing System
	-1	Compatible non-agricultural, non-agricultural uses which do not conflict with agriculture	Abandoned Farmland Forest Swamp or Marsh
	-9	Incompatible non-agricultural, Non-agricultural uses which conflict with agriculture	Extraction Urban Use Recreation

Lands with non-agricultural land uses which are compatible with agriculture are identified on the ALUS mapping as abandoned farmland, forest, swamp and marsh. These areas have little significant negative impact on adjacent agricultural operations but may provide many important services such as windbreaks, erosion control, groundwater storage and filtration. This class of land has a neutral impact on the land assessment. Compatible uses are listed in chapter 4 of the Food Land Guidelines (OMAF 1976). Lands which are

designated as incompatible to agriculture are lands which have land uses that may have an adverse impact on adjacent and nearby agricultural operations. The Food Land Guidelines indicate that all non-agricultural uses which are not listed as compatible (chapter 4) shall be deemed incompatible. In the study area these uses are identified as extraction, urban uses and intensive recreation on the ALUS mapping.

3.6.2. Criteria For the Assessing Suitability From Tile Drainage Mapping

Tile drainage is indicative of a significant level of investment in agricultural use and as such should be protected within an agricultural planning designation. The tile drainage map was digitized from the paper map by transferring the information to a digitized cadastral base. These maps show fields which are drained by systematic and random tile drains. Lots with at least 30 percent of the area tile drained were classed as artificially drained and entered into the digital map as such. The threshold of 30 percent of a rural lot typically represents about 24 hectares of land. This extent of drainage was selected because it is close to the minimum area of cropland required to support an intensive agricultural operation on a 80 hectare lot (i.e. corn system according to Huffman and Dumanski, 1983) and the average farm size in the RMOC is about 80 ha (Statistics Canada 1991).

Tile drainage will increase the suitability by one ranking over what would be expected based on land use alone, reflecting the importance of long term investment in agriculture. The procedure used is outlined in the following section.

3.6.3. Modification of Final Socio-economic Rating to Reflect Tile Drainage

The final socio-economic suitability rating represents a combination of the socio-economic factors integrated into one rating. An overlay was performed for the ALUS and tile drainage maps using the ARC/INFO intersect command. The resultant cover contains the spatial characteristics and the attributes of both maps. The methodology used to calculate the ratings for the combined socio-economic suitability assessment is as follows:

1. Non-rural areas such as towns are removed from further analysis.
2. Areas with a high or medium land use intensity rating and tile drained are given a high socio-economic suitability rating (class 3).
3. Areas with a low agricultural intensity rating, and tile drained are given a medium socio-economic suitability rating (class 2). The rating improvements are to reflect the long term investment in drainage improvements.
4. Areas with compatible non-agricultural land use and tile drained are given a low socio-economic suitability rating (class 1).
5. Areas with incompatible non-agricultural land uses and tile drained will remain unchanged (class -9).
6. Areas without tile drainage will maintain the same rating as assigned during the analysis of the ALUS map (section 3.5.1).

3.7. Generalization of Suitability Assessments to Cadastral Base

Socio-economic and physical suitability ratings were generalized to cadastral map units prior to integrating them into a final suitability rating. The generalization procedures are outlined in sections 3.7.1 and 3.7.2.

3.7.1. Generalization of the Socio-economic Suitability Rating

An ARC macro language (AML) program was used to generalize the socio-economic suitability ratings to the cadastral base. The generalization procedure is based on an area weighted average. The methods are outlined as follows:

1. The Combined socio-economic suitability rating developed in section 3.6 was intersected with the cadastral map using ARC/INFO software
2. Based on the calculation of the interim suitability rating, lands with non-agricultural ratings had a negative value (-1 or -9), and areas with some agricultural suitability had a positive suitability rating (1, 2 or 3). Within each cadastral lot the area of non-agricultural and agricultural lands were summed and the respective proportions calculated.
3. If fifty percent or more of the lot had a positive rating it was placed into a preliminary agriculture class; otherwise the lot was determined to be non-agricultural.

4. Non-agricultural lots were given a final socio-economic suitability rating of -1 (compatible) or -9 (incompatible), which ever constituted the greatest proportion.
5. An area weighted final socio-economic suitability rating was calculated for lots with an agricultural interim rating. The area weighting algorithm is as follows:

$$S_t = \text{Sum}_{n1-nx} ([S_n * A_n] / A_t)$$

Where:

$n1-nx$ = All lot fragments with an agricultural suitability rating within the lot

S_t = Lot based, area weighted suitability rating

S_n = Suitability of polygon fragment

A_n = Area of polygon fragment

A_t = Total area of polygons with agricultural suitability ratings in the lot

Note: The term “*lot fragment*” refers to a polygon which is contained within, and comprises a part of a single lot. The sum of all fragments within a lot will equal the total area of that lot.

6. The area weighted socio-economic suitability rating was re-classified into high, medium and low based on the criteria outlined in table 3.5. In agriculturally dominated areas the classification criteria were selected so as to maintain a three class suitability rating schema.

Table 3.5 Socio-economic Suitability Assessment Generalization Criteria

CLASS	CRITERIA
	Weighted average of socio-economic suitabilities, 2.01 to 3.00
	Weighted average of socio-economic suitabilities, 1.51 to 2.00
	Weighted average of socio-economic suitabilities, 0.00 to 1.50
	> 50 Percent area non-agricultural, and compatible > incompatible
	> 50 Percent area non-agricultural, and incompatible > compatible

3.7.2. Generalization of Physical Suitability Ratings

The similar procedure was used to produce a generalized physical suitability map. The use of land resource data based on 1:50,000 soil mapping for a regional scale planning application permits a high level of generalization. In theory, the minimum area resolvable using 1:50,000 maps is 6.25 hectares (Monette and MacDonald 1992), while regional planning is done on considerably larger areas. Consequently use of the dominant soil component in terms of proportion of area within a lot is an appropriate level of generalization. This is based on the assumption that the dominant soil will have the greatest influence on overall agricultural suitability at a resolution appropriate for regional planning. This procedure also helps reduce the occurrence of contrasting pockets, a requirement of the Food Land Guidelines (section 4A.1). The methodology used is outlined as follows:

1. The soils map with the LSRS ratings was intersected with the cadastral map using ARC/INFO software. The resultant map had the combined spatial characteristics and attributes of both maps.

2. An INFO program was written which determined an area weighted average LSRS rating for each lot. Non-rated soils were exempted from this calculation.

3. The area of non-rated soils within each lot was determined. Lots with 40% or more of the lot classed as non-rated were classed as non-rated in the final assessment.

4. The lot based suitability ratings were further generalized and converted from the seven class rating schema to a three class system which was consistent with the classes used for the socio-economic suitability assessment. The criteria used for generalization are outlined in table 3.6.

Table 3.6 Physical Suitability Rating Generalization Criteria

CLASS	CRITERIA
	Average LSRS suitability rating of 1.00 or 2.00
	LSRS suitability rating of 3.00 or 4.00
	LSRS suitability rating of 5.00 to 7.00
	LSRS suitability of "non-rated"

3.8. Composite Physical and Socio-economic Suitability Assessment

Once the physical and socio-economic suitabilities were compiled on the cadastral base they were brought together to create one integrated suitability assessment. This

assessment was used to derive the final planning zones. The rating methodology weighted the physical and socio-economic assessments equally with the higher rating of either assessment used as the final rating. A least limiting approach was selected to reflect the “protectionist” bias of provincial government policies by placing the largest area of land in the high suitability class . Although, if policies or societal goals were to change, the decision process could be modified to rate based on the most limiting factor or a weighted average of both physical and socio-economic suitability. Such an approach would be consistent with the LESA procedures which rely on socio-economic weightings to be determined by committee (Coughlin et al. 1994). The rating matrix is outlined in Table 3.7.

Table 3.7 Composite Suitability Rating Matrix

	High Physical Suitability	Medium Physical Suitability	Low Physical Suitability	Non-Rated
High	High	High	High	High
High	High	Medium	Medium	Medium
High	High	Medium	Low	Low
High	High	Medium	Low	Non- Agricultura l
Non- Agricultural	Non- Agricultural	Non- Agricultural	Non- Agricultura l	Non- Agricultura l

3.9. Development of Land Use Zones

In order to produce a map appropriate for planning applications, the final suitability ratings had to be generalized to produce large contiguous land use zones of agricultural and non-agricultural designations. Contiguity is determined by size and shape. The minimum size criterion is 320 hectares (see section 3.2.1); as well, the shape of a planning zone should be developed so as to limit the length of shared border between designations (i.e. no jutting appendages from one designation into another). The grouping process involved using the GIS software to merge small pockets of contrasting suitability into large contiguous pockets representing the dominant suitability. The technique developed to do this is as follows:

1. The lot based suitability map was simplified by using the GIS to dissolve the boundaries between lots with the same suitability rating.
2. The GIS was used to identify polygons with areas less than 320 hectares. These contrasting pockets were then eliminated by merging with adjacent polygon sharing the longest common border.
3. The shape as well as the size of the zones was important to maintaining contiguity. Consequently, a manual check was performed to determine where single lots or sinuous features projected into a contrasting zone joined only by one narrow

edge. In such cases the surrounded feature removed and reclassified to the predominant surrounding class.

3.10. Evaluation of Land Use Zones

The effectiveness of the GIS-based suitability assessment was evaluated. First, an evaluation was performed based on criteria developed from the Food Land Guideline policies for developing agricultural planning designations. Second, an evaluation was performed comparing the results of the GIS assessment with the expert evaluation produced by the Ontario Institute of Agrologists (OIA 1986). The objectives of the evaluation were threefold:

1. To determine if the methodology was successful in meeting the requirements of government planning policy.
2. To determine if GIS techniques using readily available data can be used to produce results similar to those of a manual expert assessment.
- 3 To evaluate the cost effectiveness of the GIS approach compared to the manual approach in terms of labour and capital.

3.10.1. Evaluation Compared to Goals of Provincial Planning Guidelines

The methodology used to derive the suitability assessment and planning zone map was developed from the Food Land Guidelines to meet provincial agricultural land use planning objectives. Consequently, the objective of this evaluation is to ensure that the guideline policies were reflected in the final planning map. The guidelines for developing agricultural zones were reviewed in section 3.2.1 and are summarized as follows:

1. Visually verify that areas of specialty crops are included in the final agriculture designation.
2. Verify that areas of high capability soils are included in the final agricultural designation. A simple visual and statistical check using summary statistics was made to compare the area of agricultural designation with the area of high capability soils on the soils map.
3. Verify that areas of lower capability soils exhibiting evidence on ongoing viable agriculture were included in the final agricultural designation. This was checked by overlaying the ALUS mapping to ensure intensive ongoing farms are included in the agricultural designation. The check used visual analysis along with analysis of summary statistics.
4. The designations should be clearly identifiable (i.e. based on cadastral units).
5. Verify that the designations consist of large contiguous areas uninterrupted by small pockets of contrasting designation (less than 320 ha).

The final agricultural zone map was evaluated based on each of the five criteria listed above.

3.10.2. Evaluation Compared to Expert Manual Assessment

In the mid 1980s the Regional Municipality of Ottawa-Carleton undertook a review and update of their Official Plan, the blueprint for all planning matters in the region (RMOC 1990). As part of this review, input from the public and interest groups was solicited. The Ontario Institute of Agrologists, Eastern Ontario Chapter, responded by submitting a document which commented on rural land use policies and developed an assessment of regional agricultural resource lands (OIA 1986). The OIA assessment was based on the subjective expert application of CLI and land use data, using expert experience and windshield surveys to create agricultural designations.

The OIA approach built upon the use of CLI by considering not only biophysical soil capability but land use as well. An important aspect of their approach was that only large blocks of land would be considered, thus eliminating the effect of small pockets of contrasting soils. Similar to the approach of the GIS assessment, the OIA linked the biophysical soil resource and land use data to lot and concession mapping, thus integrating biophysical land resource with socio-economic considerations on the basis of land management units. The major difference was that the OIA assessment was produced manually, without the aid of computers. The OIA approach to agricultural land assessment

meets the policy requirements of the Ontario Food Land Guidelines. Because of the high level of expertise involved, the OIA agriculture zone map provides an independent test for the GIS planning zones.

The location and extent of the agricultural zone were evaluated by comparison to land use zones produced by the Ontario Institute of Agrologists (OIA) using the following methodology:

1. The objectives of the OIA mapping were identified and analysed to determine if they were consistent with government planning policy.
2. The OIA “Agriculture Exclusive” zone was intersected and merged with the zones developed in this research using the ARC/INFO intersect command.
3. Once merged the two agricultural zones were compared based on the extents of agricultural and non-agricultural designations and the spatial relationship between the two maps, including areas of agreement between the maps, areas which are exclusive agricultural, non-agricultural, and where there is disagreement.

3.10.3. Cost Evaluation and Data Availability

The costs of developing each of the assessments were estimated based on the time and personnel resources and the material resources required as well as the long term costs and advantages of each system of assessment. For the GIS assessment the time required for database development and analysis were tracked through this project development. For the OIA assessment no records of study costs were available; an estimate, however, of OIA

requirements were made based on the methodology outlined in the OIA report (OIA 1986), project length and number of persons employed.

4. RESULTS AND DISCUSSION

4.1. Physical Suitability Assessment

Two published soil survey based assessments of agricultural suitability were recreated using the study database. The first was the CLI agricultural capability ratings and the second was the LSRS developed by the AIWG (1992).

4.1.1. Canada Land Inventory Capability For Agriculture

The CLI agricultural capability map was produced digitally by establishing a link between published CLI ratings (Schut and Wilson 1987) and the soil polygons in the ARC/INFO GIS. The map was based on ratings for the dominant soil landscape unit for each polygon, presented in Figure 4.1.

The majority of the rated soils are classes 2 and 3 (44.7%), and low capability soils, classes 5 -7, comprise 25.5 percent and non-rated make up 15.4 percent of the area. The non-rated polygons consist of organic soils, water bodies and built-up areas. The soils are not uniformly distributed; some areas are dominated by high capability soils, while others are of lower capability. The majority of the high capability soils are located in north-east Rideau and east Osgoode townships, and the poorer soils are generally located in west Rideau, west and central Osgoode

The areas of each class were calculated and are presented in Table 4.1.

Figure 4.1 Canada Land Inventory, Capability For Agriculture

Table 4.1 CLI and LSRS Class Summary

Class	CLI Area (ha)	CLI % Area	LSRS Area (ha)	LSRS % Area	Difference in CLI - SRS
1	238	0.3	80	0.1	0.2
2	19,245	24.3	16,631	21.0	3.3
3	16,156	20.4	18,295	23.1	-2.7
4	11,167	14.1	5,623	7.1	7.0
5	7,128	9.0	7,524	9.5	-0.5
6	10,533	13.3	1,505	1.9	11.4
7	2,534	3.2	15,840	20.0	-16.8
8	12,197	15.4	13,700	17.3	-1.6

4.1.2. Land Suitability Rating For Small Grains

Suitability ratings were calculated using the algorithm developed by the Agronomic Interpretation Working Group (AIWG). The LSRS suitability ratings for the study site are presented in Figure 4.2. The LSRS algorithm produces a rating of 1 to 100. A correlation table to convert the LSRS rating to the CLI equivalent was created and is published with the LSRS report and is built in to the computer program. For presentation and discussion purposes the LSRS will be addressed in terms of the CLI rating equivalent.

The pattern of LSRS ratings is similar to the pattern exhibited in the CLI map and a tabular summary of the LSRS ratings is presented in table 4.1 along with a comparison of these results with the CLI ratings. Table 4.1 indicates that for classes 1 to 4 there is a

Figure 4.2 Land Suitability Rating For Small Grains

Figure 4.3 CLI - LSRS Comparison

variance between CLI and LSRS class extents of only 7 percent or less. This shows the similarity between the two rating systems for lands with the potential to grow crops. Overall the table indicates that the total extent of each capability class is very similar, with the exception of class 6 and 7 soils. The major cause of the difference is the way in which the CLI rates the Farmington soils compared to the LSRS rating. The Farmington soils are shallow, poorly drained soils, and they are concentrated in the west half of Rideau township and north east Osgoode. Almost all of the Farmington soils are class 6 in the CLI and 7 in the LSRS rating. Since the Farmington dominated soils comprise 19.8 percent of the study area, the minor discrepancy in ratings has a significant impact on the comparison. However, since class 6 and 7 soils have little or no agricultural potential, and the Farmington soils are isolated from areas of agriculture this discrepancy will have little impact on the development of an agricultural zone. A map showing the areas of discrepancy and agreement between the LSRS and the CLI is presented in figure 4.3. Approximately 50 percent of the area is in agreement and the majority of the remainder differs by only one class.

The Spearman rank correlation coefficient was calculated to quantify the agreement between CLI and LSRS ratings. The Spearman correlation is a non-parametric statistical test, but has an efficiency rating of 0.93 versus the parametric correlation test (Johnson 1980). Considering the large sample size of 840 soil polygons, the test results should be quite reliable. The Spearman rank correlation coefficient was calculated to be 0.99. A value

of one can be interpreted as a perfect positive correlation. Consequently this result indicates that there is a very strong correlation between the class ranks of the two soil suitability tests. The strong correlation would seem to indicate that the use of either the LSRS or CLI will produce similar results.

When the Spearman rank correlation test was performed it was noted that there were a considerable number of tied ranks. The presence of tied ranks slightly alters the sampling distribution and an alternate equation has been developed to accommodate ties (Ebdon 1987). The effect of the alternate equation is to increase the value of r_s . Since the test used has already established the strong correlation, the alternate test is not necessary.

The LSRS was developed to solve many of the problems of the CLI, while performing the same basic task. The algorithm provides a reproducible, subjective but quantified soil suitability assessment. The LSRS solves the inconsistency and confidence problems associated with the CLI by providing well documented procedures.

The LSRS was developed to assess suitability for small grains, while the CLI rates for non-specific "common field crops", or sometimes referred to as a "modal" crop. Small grains play a minor role in agriculture in the study site, comprising only 8 percent of the total crops grown (Statistics Canada 1991). In economic terms (net returns) the dominant crop in the study area is corn and in terms of area, hay. Other than heat requirements, the types of limitations for small grain production are similar to corn and other regionally important crops. However, the level of limitation varies between crop type. The study area does provide adequate climatic resources for corn production; consequently the small grain

ratings provide a good estimate of overall soil suitability in the RMOC. Also, based on the similarity of CLI and LSRS results, small grains likely approximate the conditions assumed for the CLI's common or modal field crop.

Overall, the CLI ratings are similar to the LSRS ratings. Because the LSRS system was much better documented and can be computerized the LSRS was selected over the CLI to develop the physical suitability analysis.

4.1.3. Generalized Physical Suitability Assessment

The LSRS ratings were intersected with the cadastral mapping and generalized to lots according to the criteria outlined in section 3.7.2 and the results are presented in figure 4.4. As intended the generalization procedure has significantly decreased the resolution of the suitability assessment, while maintaining the overall spatial pattern of suitability classes. By degrading the resolution many of the small soil polygons, inappropriate for regional scale planning, have been eliminated. Also, since planning decisions are usually made on the basis of land ownership units which closely correspond to rural lots, the generalized ratings are easier to interpret than soil polygon based ratings.

This seems to suggest that the generalization procedure was an effective approach to simplify soils information while still retaining an appropriate level of detail for regional planning applications.

Figure 4.4 Generalized Physical Suitability Rating

4.2. Socio-economic Suitability Assessment

4.2.1. Agricultural Land Use Systems

The GIS was used to recreate the Agricultural Land Use Systems (ALUS) map and is presented in figure 4.5. The ALUS map was based on the land use systems classes and boundaries supplied as part of the digital coverage of the Agricultural Land Use Systems of Ottawa-Carleton (Huffman and Dumanski 1987).

The land use systems were then reclassified into three agricultural groupings based on land use intensity as defined by area in corn, areas of specialty crops, compatible and incompatible non-agricultural use. The results of the reclassification are presented in figure 4.6.

The reclassification simplified the land use information, but maintained the aspects of land use which were most relevant for a socio-economic suitability assessment. The map gives a generalized indication of overall land use patterns. As well, it implies a level of investment and infrastructure associated with each land use system.

Figure 4.5 Agricultural Land Use Systems

Figure 4.6 Land Use Intensity

4.2.2. Artificial Drainage Mapping

A tile drainage map was produced based on the OMAF detailed Artificial Drainage Mapping (OMAF 1991). A map displaying lots with greater than 30 percent of the area tile drained is presented in figure 4.7. Generally there is a strong correlation between areas of highly rated soils and tile drainage. In particular, considerable areas of class three soils are tile drained. This suggests that although class three lands have moderate levels of constraint to crop production there is still considerable investment in improvements to sustain crop production.

Drainage improvements are dependent on soil conditions, but they also indicate a long term investment in agriculture which should be protected by land use policies. An assumption was made that a tile drained field is less likely to be removed from agriculture than a non-drained field. This assumption is substantiated by a comparison of the lot based land use intensity mapping to areas tile drained, which indicates only 4.8 percent of tile drained lots were mapped within non-agricultural land use classes produced for this research.

Figure 4.7 Lots With More Than 30% Tile Drained

Figure 4.8 Composite Socio-economic Suitability Rating

4.3. Composite Socio-economic Suitability Assessment

The tile drainage map was intersected with the interim socio-economic assessment based on the ALUS land use intensity and classified according to the criteria outlined in section 3.6.3. The results of this analysis represented the final socio-economic suitability assessment based on the ALUS and drainage mapping. This map is presented in figure 4.8.

The final socio-economic suitability assessment reflects the intensity of present day agricultural land use, long term investment in agriculture and areas of non-agricultural use which may have an impact on nearby agricultural activities. A comparison of the socio-economic suitability with the physical suitability indicates a clear correlation between the two. However, there are some areas where the socio-economic suitability exceeds or falls short of what might be expected based on physical suitability. These represent areas which would be excluded from the agricultural zone if it was based only on physical or socio-economic suitability alone. Since the government policies indicate that viable agriculture and high capability soils should be included, this suggests that a composite suitability rating is required to assess socio-economic agricultural potential.

The approach used will protect lands with either physical or socio-economic suitability or both. This policy resides on the side of caution as it protects some lands with low physical suitability as well as lands of high soil suitability which are not presently used for agriculture. The provincial government's approach seems to be an appropriate approach

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to maximizing areas available to agriculture in the long term. Since future land needs are not certain, and lands converted to incompatible non-agricultural use are generally difficult to convert back to agriculture, this approach seems prudent. It also maintains an optimal level of flexibility to accommodate changes in cropping systems and the types of commodities produced.

4.4. Integrated Physical and Socio-economic Suitability Assessment

The cadastral based physical and socio-economic suitability assessments were intersected to produce an integrated suitability rating. The resultant map was classified according to the least limiting of either the physical or socio-economic suitability. The least limiting approach was selected in order to meet government policies. If the most limiting approach was applied the final agriculture designation would be more fragmented and large areas presently in agricultural use would be placed in the non-agricultural designation.

Criteria for the classification were discussed in section 3.8 and the results are summarized in figure 4.9. The least limiting approach resulted in a final assessment map which overall has higher ratings than either the social-economic or physical ratings, reflecting present potential based on current land use and long term suitability based on inherent land resource suitability.

Figure 4.9 Integrated Suitability Assessment

The final assessment map is considerably more generalized than the land resource and socio-economic data used to create it. The cadastral based ratings are simplified but the map is still too fragmented and detailed to be used for regional planning applications and would not meet provincial planning guidelines for contiguity. Consequently, there is a need to generalize and smooth the assessment further to develop an assessment which can be directly used for planning applications.

4.5. Land Use Zones

The composite suitability assessment was simplified to develop land use zones which could be used for planning applications. The development of planning zones was a two stage process (section 3.9), and these procedures were required to meet the provincial guidelines for contiguity and planning zone size. The first stage was smoothing the areas by dissolving polygons with an area less than 320 ha. (figure 4.10). The dissolved polygons were joined with the dominant adjacent polygon as determined by length of shared perimeter. Next, large polygons with low or medium suitability ratings were merged with the dominant adjacent zone, producing a two class (agriculture, non-agriculture) rating system. This procedure eliminated the small pockets of contrasting designations.

Figure 4.10 Preliminary Agricultural Zones

The second stage was to smooth the boundaries. Although criteria had been applied to eliminate small pockets, there were cases where small slivers less than 320 ha protruded out of larger areas. These protrusions are surrounded on three sides by an incompatible designation. If left alone these areas of land could be adversely affected by the predominant surrounding land use. Government policy and research indicates that agricultural lands surrounded by incompatible uses are not viable (OMAF 1978, Furnseth and Pierce 1982b). These areas were visually identified and converted to the predominant surrounding designation. The final zone map is presented on Figure 4.11.

The final zoning map consists of three large, contiguous agricultural zones surrounded by non-agricultural lands. These final zones appear to meet all criteria outlined in section 3.4 of the Food Land Guidelines for identifying and designating agricultural land (OMAF 1978), and as such are appropriate for land use planning designations. The zones are evaluated against the guidelines in section 4.6.1.

4.6. Evaluation of Land Use Zones

The evaluation of the GIS derived planning designation was required to ensure government guidelines were met and the results were consistent with the manual expert assessment of the OIA. This evaluation was threefold, first, to determine conformity to government planning policy, second, determine the effectiveness of the GIS based approach to produce results similar to the labour intensive manual expert system, and

Figure 4.11 Final Exclusive Agriculture Zone

third, to compare the cost effectiveness of the GIS approach compared to the manual expert method.

4.6.1. Evaluation Compared to Planning Guidelines

The final planning zone map was evaluated against the policies of the Food Land guidelines. The purpose of this section is to determine if the criteria developed to meet the guidelines were effective. The criteria for evaluation were presented in section 3.10.1.

The first evaluation criterion is to verify that agricultural zones include areas of specialty crops and high capability organic soils. Although the LSRS can rate organic soils there was insufficient detailed data to carry out the ratings for this study area, and high capability organic soils were not identified. If these soils are used for agriculture they will be reflected in the socio-economic assessment and will be given consideration in the development of the final planning zones. However, most of the specialty crops are grown on parcels of land which are less than 320 ha. If the areas of specialty crop cultivation were less than 320 hectares they were placed in the non-agricultural zone when the planning map was created. Consequently most of the specialty crop lands were not included in the final designation, as required by government policy. This is not a failing of the assessment system but rather indicates that the scale of regional planning is not appropriate for identifying specialty crop lands.

Within the Ontario planning system regional official plans must conform to provincial policies and township official plans must conform to regional plans. In this sense the planning system is hierarchical and at each level of the hierarchy there is an inherent scale at which planning analysis and decisions take place. The scale implies a grain of observation which relates to the minimum size criterion. In application, for this assessment, the grain at the regional level is 320 ha. Moving down the hierarchy to the township level the grain becomes much finer. Consequently, in the township official plans most areas of specialty crops would be identified and zoned in agricultural designations, meeting government policy.

The second evaluation criterion is to verify that the agricultural designation includes areas of high suitability soils. Figure 4.12 is an overlay of the high capability soils and the final planning zone. The areas of high suitability soils in and out of the agriculture zones are summarized in Table 4.2 and are derived from Figure 4.12 using the GIS.

Table 4.2 Distribution of High Suitability Soils

	LSRS Class 1	LSRS class 2	LSRS Class 3	Total LSRS Class 1-3	Area
Agriculture Zone	500 Ha	12,600 Ha	12,100 Ha	25,200 Ha	
Non- Agriculture Zone	500 Ha	4,000 Ha	6,300 Ha	10,800 Ha	
Total Area Class 1-3 Soils	1,000 Ha	16,600 Ha	18,400 Ha	36,000 Ha	

Figure 4.12 High Suitability Soils Within Planning Zones

The agricultural zone is 30,200 Ha and 83% of the zone has a high soil suitability rating (class 1-3), while 17% have low suitability or are non-rated. In total, 70% of the high suitability soils in the study area falls within the agricultural zone, leaving 30% of the non-agricultural zone containing high suitability soils. However, it should be noted, of this 30%, 17.5% of the high suitability soils outside the agricultural zone are class 3. Also, as Figure 4.12 indicates, these areas of high capability soils in the non-agricultural zone occur as small pockets, isolated from larger areas of high suitability soils by large contiguous areas of low suitability soil. This analysis suggests that the criterion developed for the suitability assessment is effective at placing large contiguous areas of high suitability soils in the agricultural zone, meeting the evaluation criterion.

The third evaluation criterion is to verify that the agricultural designation includes areas of lower capability soils exhibiting evidence of ongoing viable agriculture. Figure 4.13 illustrates the location of areas with low suitability soils, compared to the zoning designations. These areas of low suitability soils with agricultural land use (land use intensity 1-3) are summarized in Table 4.3.

Table 4.3 Distribution of Agricultural Land Use on Low Suitability Soils

	High Land Use Intensity	Med Land Use Intensity	Low Land Use Intensity	Non- Agricultural
Agriculture	8,200 Ha	13,400 Ha	3,100 Ha	5,400 Ha
Zone				
Non- Agriculture Zone	2,600 Ha	7,100 Ha	5,400 Ha	33,500 Ha

Figure 4.13 Low Suitability Soils With Agricultural Land Use

There are 39,800 hectares of land in the study area with some level of agricultural land use on soils of low suitability. Of this area 62% are placed in the agriculture zone despite having soils of poor suitability. Of the 38% falling outside the agriculture zone over one third has a low agricultural land use intensity. In addition, these areas are generally small pockets of agricultural activity surrounded by non-agricultural use. This analysis suggests that the GIS-based system was effective at placing large contiguous areas of agricultural land use occurring with soils of low suitability within the agricultural designation, meeting the evaluation criterion.

The fourth evaluation criterion indicates that designations should be clearly identified, based on cadastral units. The GIS-based system was effective at generalizing the suitability ratings to cadastral units. The data were smoothed in the process and the resolution was degraded. However, it remained compatible with the regional planning scale of analysis. The final zones consist of large blocky zones and boundary lines are consistent with lot lines and can be clearly identified, meeting the evaluation criterion.

The fifth evaluation criterion was to verify that designations consist of large contiguous areas uninterrupted by small pockets of contrasting designation (< 320 Ha.). The GIS-based system was very effective at developing large contiguous areas and eliminating small pockets. There are no areas of less than 320 hectares and the average size of each agricultural zone is over 10,000 hectares. The area to perimeter (A:P) ratio gives an indication of the size versus boundary length, which in this application reflects clustering of lots within the designations, which corresponds to some measure of contiguity. A perfect

circle will have the highest A:P ratio and a sinuous, elongated and dispersed area will have a low A:P ratio. The A:P ratio of the zoning designations are 1:7.9. Compared to a ratio of 1:60 for the soils mapping, it is evident that the agricultural designation is considerably more clustered than soil units and approaches the A:P ratio of a circle.

Overall the agricultural zones developed using the GIS met provincial policies as outlined in the Food Land Guidelines. The only policy which the analysis did not meet was the identification of specialty crops within agricultural designations because the areas of specialty crops were below of the resolution of analysis. At the regional planning scale the specialty crop policy appears to conflict with policies directed towards addressing the problem of small contrasting pockets. Analysis using a higher level of resolution at the township planning scale would likely place most of these areas within an agricultural designation.

4.6.2. Evaluation Compared to Expert Manual Assessment

The location and extent of agricultural zones derived by the GIS based procedures were compared to land use zones created by the Ontario Institute of Agrologists (OIA 1986). The OIA mapping is an independent subjective expert assessment based on the highest level of agricultural expertise available in the region. The objective of the OIA effort differed from this research in that they strove to develop a zone for exclusive agricultural use, which is buffered from the non-agricultural zone by areas of poorer agricultural

The personnel hours for the OIA study were estimates because precise figures are not available. The estimates are based on the number of summer employees hired for the project and an estimate of the professional time required to supervise and direct the study. The OIA study covered the entire RMOC, while the GIS-based assessment only considered about one third of this area. As a result the OIA figures have been modified to reflect only one third of the total time required for field checking and data assembly.

As Table 4.5 indicates the estimated resources required for the GIS database development greatly exceeds the requirements of the OIA study. The material costs for the GIS approach reflects a proportion of the cost of a workstation and an Arc/Info software license. If this study was produced in an environment with pre-existing computer and software resources this would not be required.

The estimated costs for the analysis stage of the studies are presented in Table 4.6.

Table 4.6 Cost Evaluation - Analysis

	Personnel Resources Professional (Hours)	Personnel Resources Technical (Hours)	Material Resources \$
	70	70	12,000
	40	200	
	14	67	1,000
Sub Total	54	267	1,000
Project Totals			
GIS Methodology	115	195	30,000
OIA Methodology	64	317	3,000

Figure 4.14 OIA Exclusive Agriculture Zone

Figure 4.15 OIA - GIS Agriculture Zone Comparison

Table 4.4 Comparison of GIS and OIA Land Use Zones

OIA Zone	GIS Agriculture Zone	Hectares	Percent of Total Area
Agriculture Zone	Agriculture	21,200	27
	Agriculture	9,000	11
	Non-Agriculture	2,100	3
Non-Agriculture	Non-Agriculture	46,600	59

The soils and land use data in the Manotick area suggest that it is agricultural in nature. The Manotick area has been the site of urban growth, particularly during the 1980's. In addition, the area west of Manotick has been fragmented by the construction of highway 16. Neither of these factors were in evidence on the Agricultural Land Use Systems (ALUS) mapping. The ALUS mapping was originally compiled in 1977 and the version used for this research was a 1987 revision. The 1987 version does not appear to contain the areas of urban expansion which occurred subsequent to developing the 1977 version. Consequently, the discrepancy in the GIS-based and OIA assessment systems can be attributed to data problems. It also points out the importance of field checking the digital databases.

The area of discrepancy near Metcalfe contains a fairly low level of agricultural land use according to the ALUS. However, the soil suitability for the area is predominantly high (classes 1-3). This suggests that the GIS-based system does a better job of assigning high suitability soils which are not used to their potential to the agricultural designation, as

compared to the OIA approach. It also underscores the need to scrutinize data and analysis using first hand knowledge, or field checking.

The remaining discrepancies consist of smaller areas on the margins of the OIA agricultural exclusive zone, and are generally classed as low priority agriculture in the OIA study. Overall, the GIS derived agricultural zone is consistent with the OIA zones, and this indicates that the GIS methodology is able to reproduce results similar to the manual expert system.

4.6.3. Cost Evaluation and Data Availability

The personnel and material costs of both assessment procedures were estimated and are presented in tables 4.5 and 4.6.

Table 4.5 Cost Evaluation -Data Assembly

	Personnel Resources Professional (Hours)	Personnel Resources Technical (Hours)	Material Resources \$
	5	35	17,000
	10	50	
	40	40	
	N/A	N/A	
	45	125	17,000
	Personnel Resources Professional (Hours)	Personnel Resources Technical (Hours)	Material Resources \$
	10	50	2,000
Total	10	50	2,000

The personnel hours for the OIA study were estimates because precise figures are not available. The estimates are based on the number of summer employees hired for the project and an estimate of the professional time required to supervise and direct the study. The OIA study covered the entire RMOC, while the GIS-based assessment only considered about one third of this area. As a result the OIA figures have been modified to reflect only one third of the total time required for field checking and data assembly.

As Table 4.5 indicates the estimated resources required for the GIS database development greatly exceeds the requirements of the OIA study. The material costs for the GIS approach reflects a proportion of the cost of a workstation and an Arc/Info software license. If this study was produced in an environment with pre-existing computer and software resources this would not be required.

The estimated costs for the analysis stage of the studies are presented in Table 4.6.

Table 4.6 Cost Evaluation - Analysis

	Personnel Resources Professional (Hours)	Personnel Resources Technical (Hours)	Material Resources \$
	70	70	12,000
	40	200	
	14	67	1,000
Sub Total	54	267	1,000
Project 4 Data			
GIS Methodology	115	195	30,000
OIA Methodology	64	317	3,000

Table 4.6 indicates that the total time required for the OIA study was 381 hours, and the GIS-based study took 310 hours. In addition, GIS-based assessment required 115 hours of professional time compared to only 64 hours for the OIA study. The major reason for this difference was that because the OIA study used published CLI soil ratings and the GIS study derived the soil ratings from the LSRS program and algorithm. Technical time for the OIA study was 317 hours compared to 195 hours using the GIS. This reflects the labour intensive requirements of data analysis and field checking used by the OIA, although a good knowledge of the study site replaced field checking for the GIS study. This level of expertise may not always be available and if the study was replicated in another geographic location field checking would be required. Considering the potential error for the OIA estimates and the difference in technical versus professional time requirements, the total personnel costs of the GIS and OIA studies were similar.

The GIS-based assessment would require an estimated 30,000 dollars for the computer and software compared to an estimated 3,000 dollars for the OIA study, a difference of 27,000 dollars. Since the computing and software resources were supplied, actual direct costs were near 0.

Overall, except for computer and software, project costs were similar for both study methods. Other than annual maintenance, the software and hardware costs are a one time expense. While the GIS analysis could be extended to the entire region with only a minimal personnel cost increase, the OIA analysis would require considerably more resources for data analysis and field work. The study area selected may have been too small to

demonstrate effectively that the GIS method is more cost efficient than a manual approach. However, the findings do suggests that the GIS assessment costs would likely be lower than costs for the OIA system, if the study area was larger. These cost savings would be predominantly a reflection of the substitution of computer technology for labour.

5. CONCLUSIONS AND RECOMMENDATIONS

A computerized database was established and analysed to produce an agricultural assessment for land use planning. The GIS-based agricultural assessment system was evaluated using criteria developed from government planning policy and compared to results of a manual expert assessment system in terms of material and personnel costs.

The assessment system used a parallel approach by developing physical suitability based on land resource data and a socio-economic suitability assessment based on agricultural land use and investment in tile drainage. These assessments used the best, most detailed data available and analysis was performed using a GIS then integrated to one overall assessment. The criteria used to develop the assessment were derived from Ontario government planning policies. The assessment was then generalized to cadastral mapping units using GIS software. Once generalized the physical and socio-economic suitabilities were combined to a single composite suitability assessment. The composite assessment was further generalized and smoothed to develop zoning designations appropriate for land use planning. The final agricultural zone was evaluated against government planning guidelines, an expert manual assessment produced by the Ontario Institute of Agrologists and a cost analysis comparing the GIS approach to the OLA manual method.

A new suitability rating algorithm, the LSRS, was implemented and compared to CLI ratings which have been traditionally used for rural land use planning. Analysis determined that these two methods produced results which were very consistent. In addition, the LSRS expert rules are well documented and can be applied more rigorously and consistently than the CLI ratings. The chances of two soil surveyors deriving the same

result is increased, and if they diverge the reason for the difference is recorded. As a result, the LSRS was used in place of the CLI to develop the physical suitability assessment. If widely adopted, the LSRS has the potential to be a significant improvement over the more traditional CLI rating approach.

The data used to derive the GIS based assessment were easily obtained or created and most became available in digital format during the research. Data not available in digital format were digitized from hardcopy. The computational power and data management abilities of present day hardware and software presented no limitations to the development of this research project. In the future the development of new software, computers, digital databases and lower costs will improve the potential for this type of assessment. In addition, the GIS offers the flexibility to change assessment objectives and investigate other land use options with a short turn around period.

The GIS derived zones were found to be very consistent with government planning guidelines. Also, there was very strong correlation between the GIS zones and zones produced by the OIA. The personnel costs associated with the GIS assessment were similar to the OIA Assessment. Since computers can handle large data sets as easily as smaller ones with little increase in the time needed, the personnel costs for the GIS approach can be expected to decline on a per unit area basis at a faster rate than the OIA manual method. Consequently, as the study area increases in size the GIS becomes more cost effective.

It can be concluded that the GIS system was able to manage and analyze the integrated database to produce a more comprehensive assessment of agricultural suitability for land use planning as compared to traditional, CLI, physical capability assessments. In

addition, the GIS-based assessment of agricultural land provided an effective alternative to manual assessment. This is an important finding and may present opportunities for similar applications to other areas of the province.

There were some difficulties in implementing the LSRS, and it required a high level of expertise in soils mapping and the specific soils data to which it is being applied. At present the LSRS assesses the suitability for spring seeded small grains only, although through comparison to the CLI it appears that the limitations for small grains are compatible with the "common field crops" rated by the CLI. This should be further tested, and the LSRS should be adapted to rate corn, hay and other regionally important crops. Compiling the database for developing the suitability ratings was difficult. No single set of data had all the data required for every soil. A combination of pedon data from the soil survey report and the representative digital soil layer and name file together provided most of the data needed, but these are not very accessible outside of the Ontario Land Resource Unit. If the LSRS is to be widely adopted, a considerable level of additional effort is required to compile, document and verify the Ontario soils database. The major limitation to adoption of the LSRS is likely to be the lack of basic land resource data, and at present the resources which support this type of data collection are limited. The LSRS should be tested using crop parameters from a variety of important crops such as corn and perennial forage.

It was found that the study's regional scale planning analysis was inappropriate for identifying areas of specialty crops, a requirement of government policy. Analysis indicates that this type of agriculture occurs on parcels of land which are too small to be recognized at the regional scale. Future research should be directed at modifying the suitability assessment

system to work at other planning scales. These scales include national, provincial, township and site specific levels.

In comparison with the OIA assessment a significant discrepancy was found in the GIS-based approach in the area of Manotick. Further analysis of the database indicated that this discrepancy could be attributed to outdated urban area mapping on the Agricultural Land Use Systems map. This suggests that the land use mapping must be kept current and that field verification of the GIS assessment is required to ensure the integrity of the database and data analysis.

While personnel costs were similar, the capital costs were substantially higher for the GIS assessment, reflecting the cost of computer hardware and GIS software. However, the capital costs are a one time expense and if adjusted to cost per unit area of analysis they will decline as study area size increases. The research suggests that if the GIS assessment was extended to the entire RMOC, the total cost would be far less than the cost of the OIA assessment.

While detailed digital pedon data was available for this study it has been produced for only a limited number of Ontario counties. This application has demonstrated the utility of digital county soil maps and the pedon database. It is recommended that development of this valuable data source should continue until complete for the entire agricultural portion of Ontario.

Once the LSRS program is finalized it is recommended that the Food Land Guidelines be modified to recognize the LSRS as the best available system of soil suitability assessment. Also, the guidelines should specifically address the need to include land use

systems and tile drainage mapping as indicators of socio-economic agricultural suitability for calculation of a final suitability rating.

Within this research rural lots provided the management units for integration. Lots represent the best approximation of land management units which were available at the time research was performed. Work is presently under way to digitize land registry maps. When available, these maps would present the ideal base for this type of application.

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