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McKeague

Expert Committee on Soil Survey

Comité d'experts sur la prospection pédologique

MINUTES FIRST ANNUAL MEETING

PROCÈS-VERBAUX PREMIÈRE RÉUNION ANNUELLE

March 20-23, 1979
Ottawa

20-23 mars 1979
Ottawa

NOTE: This report is an internal working document and does not necessarily reflect the views

Remarque: Le présent rapport étant un document de travail intérieur, il ne reflète pas nécessairement

Minutes

First Annual Meeting

Expert Committee on Soil Survey

Procès-verbal

la réunion annuelle

Comité d'experts sur la prospection pédologique

Editor J.H. Day Editeur

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CONTENTS

MINUTES OF THE ANNUAL MEETING OF THE
EXPERT COMMITTEE ON SOIL SURVEY

Chairman J.S. Clark, welcomed the members of the Canada Soil Survey Committee and as well as other participants attending the meetings. Visitors Dr. D.E. McCormack of U.S.D.A.; Beltsville Maryland, and Dr. R.W. Arnold of Cornell University, N.Y., were introduced.

It was brought to the attention of the Committee that one of the many purposes of the meeting was to restructure the Committee under the new committee structure developed by the Canada Agricultural Services Coordinating Committee. Under this new committee structure, the former Canada Committee on Soil Survey is now the Expert Committee on Soil Survey (ECSS) of the Canada Committee on Land Resource Services. This latter Committee has overall responsibility for all agricultural land related issues and includes Expert Committees on Soil Management (ECSM) and on Agrometeorology (ECA). The Expert Committee reports and recommends to CASCC through the CCLRS. The members of the Expert Committee are appointed by the Assistant Deputy Minister Research Branch on the Recommendation of the Chairman CCLRS for a three-year term.

The need for economy has been an important consideration in restructuring of the CASCC Committee for both the federal and provincial governments. Thus, the Expert Committee on Soil Survey has been encouraged to reduce its membership so that the financial support required is proportionately reduced.

It was emphasized that the Expert Committee have been encouraged to maintain their scientific and technical role. This is to be done through "working groups" which are assigned responsibility for providing recommendations or advice for the solution of problems. Financial support can be given if available for participation of university staff named to working groups. It was foreseen that the ECSS, through its members and working groups, could continue to provide scientific coordination for soil survey and classification in Canada in the same way as was done by the CSSC.

Expert Committee on Soil Survey

Members of the ECSS will be appointed by the Assistant Deputy Minister Research on the recommendations of the Chairman, CCLRS. In recognition of the need for provincial acceptance of recommendations regarding systems of soil classification and other technical aspects of soil survey, this was structured to provide provincial representation as follows:

1) Membership - Members appointed to the Committee should have high technical and scientific competence in the field of soil survey or a related discipline.

2) Members -

Chairman - Appointed on the recommendation of the Chairman, Canada Committee Land Resource Services.

Secretary - Appointed by Chairman, CCLRS from Ottawa region.

Provincial Representatives from each province to be nominated for appointment by:

a) the provincial Soils Advisory Committee established to advise on soil survey matters or;

b) the Provincial and Federal Soil Survey Heads and the Chairman Department of Soil or Land Science.

One Representative from each of the following:

Department of Fisheries and Environment
Department of Energy, Mines and Resources
Department of Indian and Northern Affairs

Ex Officio Members

Chairman, Canada Committee Land Resource Services
Chairman, Expert Committee on Soil Management
Chairman, Expert Committee on Agrometeorology

Other expert members as required.

3) Working Groups - On the recommendation of the Chairman, ECSS, working Groups will be established to deal with technical aspects of soil survey.

4) Terms of reference.

i) To advise the Canada Committee on Land Resource Services (CCLRS) of the adequacy of the services (research, regulatory, etc.) being provided in Soil Survey and Land Evaluation necessary for maintenance and development of an efficient agricultural production system.

ii) To encourage the establishment of a national system of soil classification and land evaluation by structuring working groups to recommend and encourage research on soil classification and land evaluation and to develop appropriate classification systems and operational procedures for use on a national basis.

iii) To recommend to CCLRS actions required for the improvement of services in the resource areas of soil survey and land evaluation.

iv) To carry out special tasks and studies and to perform other duties as may be required by CCLRS or other concerned agencies.

The Terms of Reference are to be reviewed by the ECSS for modification and approval if required after it has been appointed.

Canada soil survey committee

Concern was expressed that the historical technical role of the former CSSC would be lost under new arrangements. There was considerable discussion on the issue. There also was considerable support for continuing the Canada Soil Survey Committee within the present framework of the ECSS. The Chairman stated, however, that the present committee structure would allow continuation of the essential roles of CSSC by means both of the Committee itself and working groups, and that by scheduling working groups and committee sessions together, the technical aspects of the former survey committee would be maintained.

A resolution was received immediately after the meetings for the continuation of the CSSC and this will be considered by the ECSS. See Appendix 4.

Committee recommendations

Recommendations for research and development from the ECSS must reach the CCLRS by early November. A meeting of the ECSS was tentatively scheduled for mid-October to review the recommendations of the Committee and to assess and modify the terms of reference of the Committee, if required.

2) Membres -

Président - Nommé sur recommandation du président du C.C.R.T.

Secrétaire - Nommé par le président du C.C.R.T., doit venir de la région d'Ottawa.

La candidature des représentants de chaque province sera proposée par:

a) le Comité consultatif sur les sols de la province ou;

b) les chefs des bureaux de pédologie provinciaux et fédéraux et les présidents des Départements des sciences du sol des universités.

Un représentant des organismes suivants:

Ministère des Pêches et de l'Environnement
Ministère de l'Energie, des Mines et des Resources
Ministère des Affaires indiennes et du Nord

Membre d'office

Le président du C.C.R.T.
Le président du Comité d'experts en gestion des sols
Le président du Comité d'experts en agrométéorologie

Les autres membres experts peuvent être désignés au besoin.

3) Groupes de travail - Sur la recommandation du président du C.E.P.P., des groupes de travail seront formés pour traiter des aspects techniques de la pédologie.

4) Mission -

i) Donner son avis au C.C.R.T. sur la valeur des services (recherches, réglementation, etc.) fournis dans le domaine de la prospection pédologique et de l'évaluation des terres, nécessaires au maintien et au progrès d'un système de production agricole efficace;

ii) travailler à l'établissement d'un système national de classification des sols et d'évaluation des terres en organisant des groupes de travail chargés de recommander et d'encourager la recherche dans ces domaines et d'élaborer des systèmes du classification appropriés et des méthodes à utiliser à l'échelle nationale;

iii) recommander au C.C.R.T. les mesures nécessaires à l'amélioration des services dans les domaines de la prospection des sols et de l'évaluation des terres;

iv) s'acquitter de tâches et d'études spéciales et remplir d'autres fonctions suivant les besoins du C.C.R.T. et d'autre organismes concernés.

Ce mandat doit être revu par le C.E.P.P. qui, une fois constitué, pourra l'approuver ou le modifier au besoin.

Commission canadienne de pédologie

Certains craignent que ces nouvelles dispositions ne marquent la fin du rôle historique de consultation technique de l'ancienne C.C.P. La question a fait l'object de vifs débats et plusieurs membres préconisnet le maintien de la Commission à l'intérieur du cadre actuel du C.E.P.P. Le président a expliqué toutefois que la structure présente du Comité assurerait la continuation des rôles essentiels de la C.C.P.P. par l'entremise du comité lui-même et de ses groupes de travail, et qu'en convoquant simultanément les réunions des groupes de travail et du comité, on pourrait conserver les aspects techniques de l'ancienne commission.

Immédiatement après la réunion, une résolution a été déposée en faveur du maintien de la C.C.P. La résolution sera considérée par le C.E.P.P. Voir Appendice 4.

Recommandations du comité

Le C.C.R.T. devra recevoir d'ici novembre les recommandations sur la recherche et le développement émanant du C.E.P.P. Une rencontre de ce dernier a été provisoirement prévue pour la mi-octobre afin de revoir ces recommandations et d'évaluer et de modifier au besoin le mandat qui lui a été confié.

APPENDIX 1
DATA COLLECTION AND RESEARCH PRIORITIES

Province of Newfoundland

M.D. Sudom

The Newfoundland government is not involved in agriculture research, therefore the province depends on Agriculture Canada for most of its research needs. The CDA Research Station at St. John's West provides a very useful service and covers a number of aspects of research. However, much of the research for the Maritimes is done on a regional basis from other provinces and often is not applicable in Newfoundland. In addition, the Agriculture industry is relatively small and consequently has little or no capacity to undertake research on a contractual basis. The problem is further aggrevated because there are no colleges or universities in the province conducting agriculture research.

The province has an active program for data collection for farmer statistics, soil/land capability and land use information. Soil survey and land use staff have been increased several fold in the past few years. There is a very real need for accelerated research to keep up with data collection.

A recently signed 5 year cost-shared Agriculture Development Subsidiary Agreement (DREE) puts major emphasis on development and expansion of agriculture. This will mean increased demand for research services in the province.

Some priorities for agriculture research/data collection in Newfoundland follow.

Climate

- More detailed information on localized climatic conditions with emphasis on crop growth, development and yield.

- Frost probability; heat unit data.

- Soil temperature studies and the relationship to crop suitability and growth.

Soil

- Peatland fertility, drainage and equipment with particular emphasis on costs of production and long term effects of drainage and cropping.

- Productivity/performance of soils for various agricultural enterprises Variety trials.

- Feasibility of draining mineral soils.

- Effect of cemented and ortstein layers on productivity.

- Carrying capacity, nutrition, management and/o~ improvement of "barrens" (heathland) for livestock grazing.

- Correlation of soil testing to amendment applications. Provision for linking soil data bank, performance/management research and mapping information.

- Water regimes - oxidation/reduction potentials, hydraulic conductivity/seepage water movement.

- Land clearing - guidelines, cost-benefit.

Land Evaluation and Land Use

- Land values according to productivity.

- Developmental land values.

- Benefits/losses to society of preserving agricultural land.

- Optimum farm size by commodity.

- Land registration.

Ageconomics

- There are no Agriculture Economists in the province.

Province of Prince Edward Island

A. Raad
Department of Agriulture and Food

Following the completion of field work in the Soil Survey Project in Prince Edward Island, efforts are presently being made to complete the report write-up and mapping. The conclusion of the project in terms of producing the report and the soil map may take two or more years, depending, of course, on the line-up for cartography work in Ottawa and the priorities of the Land Resources Research Institute.

In the meanwhile, users of soil survey data in Prince Edward Island, including farmers, agricultural extension soil specialists, urban and physical resources planners, foresters, and soil research personnel are trying to find out the most effective and least costly means by which the soil survey information could be used to benefit the present management of land, water, and forest resources.

The interest of resource planners in the use of soil survey information has never been higher than it is at the present time. This is especially true if we consider the present and future plans of major urban centers and suburbs in Prince Edward Island to expand and develop additional urban services. Probably more important in this regard is the strongly expressed interest of farmers to know more about their farm land and other resources and how best to overcome land management problems which may have adversely influenced land productivity and limited it use in crop production.

The degree of appreciation by farmers for land resources services seems to grow proportionally with the increase in the price of land. This is what is happening now in Prince Edward Island. It is therefore our hope to develop and expand land resources services to the farming community in the Province. Some sucess has been achieved in this regard, under our present programs of land management, the family farm and the new farmers.

We are presently planning to strengthen the land resources services program to include the soil survey unit, effective April 1, 1979. Once this is accomplished, it is our intention to provide a land resource inventory and evaluation services to the farmers, especially new farmers. This service will provide interested farmers with a "Land Resources Record Book" to include a soil types map, erosion potential map, drainage map, frost risk probability map (iso-thermal lines), a yearly soil test map (fertility), and crop production potential rating. Farmers who participate in this service will receive more indivdual attention and field visitation by our soil specialists and district staff.

It is our belief that implementing basic land management practices such as drainage to remove excessive water from the soil, crop rotation to break disease cycles and condition the land, proper green and animal manuring to build up and maintain proper soil tilth and structure, proper tillage to control weeds and conserve topsoil, and addition of proper lime and fertilizer levels, will go a long way in overcoming crop problems such as common weed infestations, pest and disease infections, especially those caused by soil-borne or related disease, low yields and inferior quality. The significant financial loss to farmers and the expenditures used to research and develop solutions to overcome these stress-related problems could have been saved if basic land management practices, as those mentioned in this report and others, are implemented on farm land.

In order for the P.E.I. Department of Agriculture and Forestry and other concerned provincial and municipal agencies to be able to use soil survey information, we find it necessary to establish through research and experience practical solutions to the following problems:

Data Handling

Storage, retrieval, and analysis of soil survey and other bio-physical resource data seem to offer the biggest challenge to our ability to analyse and interpret land resources data at the decision-making level in the management of farms, forests, and other resources. The CanSIS system may offer some assistance in this regard. However, the general and broad nature of its present data base and the limited scope of its application to specific site levels are factors which influence the value of CanSIS in the short run.

What we need is a data handling system which lends itself to linking and simultaneous handling of different data bases such as those relating to: soil test, frost probability, moisture levels, slopes, erosion potential, specific fertility problems, drainage, compactness, soil types, texture, pH, and other resource parameters. The system will be able to accommodate application of data analyses and interpretation at the farm and specific site levels. Terminals of this data handling system will be established at the regional services centers in the Province.

Soil Compaction and Degradation

Investigation of the effect of compaction on agricultural land use, with specific reference to crop performance, needs to be done in Prince Edward Island. Cash cropping and expansive use of heavy farm machinery are practices which are common to Prince Edward Island Agriculture.

Management of land under these conditions will certainly require research into the practices which are capable of maintaining land trafficability and productivity. Degradation of land as exemplified by loss of top-soil, poor structure and tilth, reduced moisture and nutrient-holding capacity and other similar symptoms of degradation need to be better evaluated, especially in terms of its effect on land productivity and the level of economic returns per acre.

Drainage Classification and Effects

More specific delineation of drainage classes for common crop production and other types of land use should receive a high degree of priority in our research efforts.

Compact Subsurface Layer in Prince Edward Island Soils

It is essential to know more about the nature, extent (i.e., area, and thickness) and effect of the compact subsurface layers which have been confirmed to exist in many soils in the Province. This knowledge will help our soil extension specialists to properly interpret the effects of these layers on many parameters which are relevant to crop performance and land use in general, such as rooting depth, water storage, sewage disposal, drainage, erosion potential, and others. The use of seismic or resistivity (i.e., airborne E-phase) methods deserve consideration. The rate of subsoiling and the drains in resolving drainage problems which are related to the presence of these layers should be evaluated.

Finally, we support the soil research priorities which have been approved by the Atlantic Provinces Soil Survey Committee on December 11, 1978 under "site evaluation and improvement" and "crop selection".

Provinces of Nova Scotia and New Brunswick

G. Beke
Land Resource Research Institute

The research needs are summarized briefly as follows:

Soil Survey

- soil water regime classification and interpretive limits
- limits for ortstein and fragipan horizon
- compatibility in mapping and correlation procedures between provinces in the Atlantic Region
- evaluation of the organic soil component
- interpretive criteria, particularly for sylviculture, identification and evaluation

Agronomy

- improved varieties of winter wheat and fall rye that incorporate disease resistance, high yield, quality
- improved spring wheat and milling wheat varieties. 'Lennox' needs processing improvement, not more that 3 of the 6 European varieties currently under testing at five Valley sites have any hope of changing the need for an improved milling variety
- relationship between physical soil properties and yield or quality
- the emphasis on soil physical amelioration (eg. deep tillage) requires the reevaluation of varieties, of chemical treatments, of plant disease, and of pesticides, that brought about the changes in planting dates and plant-soil environment
- effect of soil loss (nutrients, structural deterioration, altered moisture regime) on plant growth.

Agroeconomics

- effect of soil loss on farm income
- cost-benefits of physical soil amelioration of new equipment, of improved soil moisture management by irrigation or drainage
- economics of self-sufficiency.

Agrometeorology

- climatic zonation based on temperature
- microclimatic evaluations of valleys
- location of weather stations, thus radius of representation
- agronomic forecasting
- improvement of available moisture factor in Thornthwaite equation.

Land evaluation

- improve the credibility of the data collected
- regional coordination and greater uniformity in source data
- need productivity data
- integrated information system. Happily, LRIS has been given a new look on life.

Province du Quebec

M. Tabi
Ministère de l'agriculture

Les rapports pour Rivière du Loup, L'Islet, les Iles St-Laurent sont soumis pour publication.

Pour les rapports de Arthabaska, Charlevois, et de Témisgaming, l'impression est prévue pour 1980.

Travaux en cours; par l'équipe provinciale dans les cantons de Mégantic, Beauce, par l'équipe fédérale dans les régions des Ste. Hyacinthe - Richelieu Verchêres.

Recherches sont en cour en phénologie (Dubé), collections des données (Isfan) micropédologie (Pagé), et étude des sols marginaux (Baril).

Province of Ontario

R. van den Brock
Ministry of Agriculture and Food

Introduction

Research or service needs have been solicited via various committees and institutions. The recommendations put forward by the Ontario Soil, Water and Air Research Committee are attached in Appendix 1a.

The Ontario Ministry of Agriculture and Food has hired six pedologists, two laboratory technicians and one draftsman to keep up with the growing demand for soil survey information. Also the Ontario Institute of Pedology is trying to work closely with the Ontario Ministry of Natural Resources, Ontario Ministry of Transportation and Communication and other departments which have not "traditionally" made use of soil survey information i.e. C.W.S., W.R.R.I. etc. Thus the view of types of information has been enlarging and we realize our response time with information will have to be shortened. With these conditions in mind we set about the identification of research and/or service needs seen by the present members of the Ontario Institute of Pedology. The procedure followed was as follows: firstly, each member of the Ontario Institute of Pedology was interviewed to identify items of research; secondly, each member was asked to estimate time, numbers of sites and numbers of samples required for the research of his interest; thirdly, using these estimates research activities of present members were identified and agreed upon, and fourthly, the following priority was agreed upon by the members of the Ontario Institute of Pedology.

The items identified by members of the Ontario Institute of Pedology are supportive of the four recommendations made to the Ontario Soil, Water and Air Research Committee. In the following pages we expand and further detail our reasoning for the four recommendations.

Priority 1

Proposal. Continued support for land evaluation research to enable testing of established methodology.

Details. The program leaders estimate that a funding level of at least $200,000 per year for a five year period would be required to produce an usable model of the comprehensive nature that is desired. The expected level of funding in 1979-80 is about half this amount.

Background. A land evaluation program was initiated in 1976 at the University of Guelph with contract funding from Agriculture Canada and support through Ontario Ministry of Agriculture and Food Program 39. In this program, land evaluation is regarded as a synthesizing technique that takes what is known about the capability of land for certain uses, about the availability of land and non-land resources, and about the needs that the land has to meet and indicates how important each area is to each use in the attainment of these objectives. A methodology for land evaluation has been developed. This methodology and the several components of the model require considerable refinement and further development before the system can be applied with confidence.

The land evaluation program involves an interdisciplinary group which includes Geographers, Agricultural Economists, Soil Scientists and Agrometeorologists. The social scientists are primarily responsible for the development and testing of the overall land evaluation model and the development of a prototype set of data for Ontario. The natural scientists are primarily involved with the development of land productivity models which will provide a better estimate of the productivity of our soils than is provided by the present C.L.I. land use capability system. Of particular concern is the estimating of the variability of production on different soils due to variability in climate and/or changes in the management or technological inputs.

A comprehensive approach such as the one being used at Guelph is necessary to achieve the goals that have been set for the land evaluation program. Major increases in level of support will be required if these goals are to be achieved.

Priority 2

Proposal. To increase support for further soil erosion research in Ontario.

Details. One professional, one technical man-year and operating funds should be made available to the Ontario Institute of Pedology, Guelph for this purpose. The approximate cost is $35,000 annually.

Background. Soil erosion and sedimentation research was recently initiated in Ontario as part of a much larger study designed to assess the impact of agricultral land use on the water quality of the Great Lakes. The results of these studies revealed that sediment and phosphorus derived from agricultural land contributed significantly to Great Lakes water quality (50 to 60% of the total stream delivered to the Lakes). Funds made available for this research (PLUARG) were terminated in 1978.

However, many questions remain to be answered with respect to: the impact of sediments and phosphorus on stream water quality, soil erodibility and erosion rates, soil erosional processes and remedial measures, and the location of stream sediment contributing areas within the agricultural landscape. Research projects on soil erosion and sedimentation that have particular significance to this Committee include:

a) the use of existing soil resource information for the planning and implementation of soil erosion remedial programs

b) the collection of additional soil resource information that could be obtained from ongoing soil inventory programs for improved soil conservation recommendations

c) the development of a soil erodibility index that is sensitive to both rainfall and runoff events throughout the year. It appears that some quantitative measure of soil structure will be an important component of a meaningful soil erodibility index

d) methods for delineating the sediment contributing areas of an agricultural landscape. The identification of stream sediment contributing areas is necessary to permit the cost effective application of remedial programs. The application of remote sensing techniques would seem to the most efficient manner in which to obtain this information.

Priority 3

Proposal. Research support for the soil survey program in Ontario.

Details. Funding for: 1 research assistant, 1 technician, 3 part-time summer support staff and operating funds. Total direct costs approximately $60,000.00.

Background. The soil survey activities have expanded and the surveyors are in need of research support from Carleton to Middlesex counties. The turn around time of field mapping results has to be shortened. To do this the laboratory has been geared to completing analysis in a shorter time. However, even though the methodology has been worked out the personnel are not in place to give a quick turn around time on micropedological data, soil variability studies or soil-landform relationships. This request would put two people into positions which would support (work cooperatively as team members with research scientists) the soil surveyors, on specific problems.

Specifically, within the next two years we visualize these new personnel working on some of the following problems:

1) Variability in mapping units and soil series to establish statistically sound estimates of the range of various soil properties used for interpretation.

2) Defining various soil-landform-vegetation relationships in various counties for mapping legend preparation and to aid in making interpretative maps.

3) To supply expertise on micromorphological analysis as requested by soil surveyors, land evaluation studies, erosion control studies, etc.

4) Quantification of soil survey information, i.e. on soil physical and chemical properties as required for land evaluation, productivity, erodibility research and for soil classification and mapping purposes.

Priority 4

Proposal. To operationalize a CanSIS retrieval system(s).

Details. Research funding is required to support a M.Sc. student in the Dept. of Land Resource Science, University of Guelph. The direct cost estimate is $12,000.00/year for two years.

Background. For several years through the leadership and co-ordination of Agriculture Canada, Soil Survey Information has put into the CanSIS data bank. The management language has been modified several times. In the last two years research has been undertaken to document user needs (i.e. M. McKnight's thesis re: Agricultural Representatives Needs). We visualize the development of a "Users Manual to CanSIS" for government, and private industry personnel as being very necessary in the near future. Upon development of the manual we will provide a laboratory exercise in various courses so that graduates would be familiar with the data available in the Data Bank.

Appendix 1a
Report to the Ontario Soil, Water and
Air Research Committee

By C.J. Acton, Chairman
Ontario Soil Survey and Land Use Research Committee

Committee Membership and Affiliation

The membership of the committee was unchanged in 1978, and includes the following:

L.J. Evans	- Land Resource Science, University of Guelph.
D.W. Hoffman	- Center for Resources Development, Univ. of Guelph, and Director, School of Urban and Regional Planning, Univ. of Waterloo.
B. MacDonald	- Land Resource Research Institute, Agriculture Canada, Ottawa.
R.S. Rodd	- Dept. of Economics and Extension Education, Univ. of Guelph, and Acting Director, Center for Resources Development.
K. Rutherford	- Dept. of Geography, Queens University, Kingston.
V. Spencer	- Food Land Development Branch, Ontario Ministry of Agric. and Food, Toronto.
C.J. Acton	- Agriculture Canada, Guelph.

Meetings

One meeting of the Ontario Soil Survey and Land Use Research Committee was held during the past year, on January 26th, 1979, for the purpose of establishing priority recommendations. Other matters were dealt with by correspondence.

Research Priorities

Suggestions on research priorities were received from a Research Subcommittee of the Ontario Institute of Pedology, as well as from the Coordinator of Ontario Ministry of Agriculture and Food Program 39, University of Guelph. The final decision on priority recommendations was made by the Ontario Soil Survey and Land Use Research Committee.

Summary of Action Relating to 1978 O.S.S.L.U.R.C. Recommendations

1) There was no continuation of support for soil erosion research following termination of the PLUARG contract at the University of Guelph.

2) No progress has been made in the preparation of supplement soil survey reports for county soil maps being reprinted.

3) Some progress has been made on the preparation of a generalized report on the Soils of Ontario, through use of a small amount of Ontario Ministry of Agriculture and Food Program 67 funds.

4) Research on development of an evaluative procedure for designating land for agricultural use has progressed favourably.

5) There has been no increase in support for soil genesis, characterization and correlation research.

6) Support for Ontario Ministry of Agriculture and Food Service Program 67 (Soil Survey Support Staff) has continued.

7) Support for the program involving the collation of current and historic soil resource, soil productivity and soil management data has continued.

8) A program is underway through Agriculture Canada to complete the reprinting of out-of-print soil maps in Ontario by 1980-81. A number of out-of-print county maps again will be available early in 1979.

Underlying Assumption Relating to 1979 O.S.S.L.U.R.C. Recommendations

No recommendations are forthcoming relating to the need for continued support for the soil inventory program in Ontario. It is assumed that it will continue at least at its present level of support. It should not be construed that the recommendations which follow are of higher priority than the on-going inventory program. Because there is a continuing demand for more soil inventory data to serve increasingly specific uses, the needs for supporting research to provide an improved soil data base in Ontario is apparent. Most of the research priorities which follow have been identified with this objective in mind.

Recommendation, Priority 1

To: Agriculture Canada, and the Agricultural Research Institute of Ontario.

Proposal. To continue support for land evaluation research to enable testing of established methodology.

Details. To continue the Agriculture Canada contract to the University of Guelph for the 1979-80 fiscal year in the amount of approximately $117,000 and support through Ontario Ministry of Agriculture and Food Program 39.

Background. Research on the development of an evaluative procedure for designating land for agricultural use has proceeded through an Agriculture Canada contract to the University of Guelph, and Ontario Ministry of Agriculture and Food Program 39.

There is need for continuation of the current program through 1979-80. The program would involve refining, testing and demonstrating the application of land evaluation models developed during the current phase of the program for a limited set of conditions, using the prototype data sets for Ontario. Included is the analysis of relevant climatological data to validate the corn and forage yield prediction models at a farm and regional level. This aspect of the program is identified as priority 3 of the Agrometeorology Research Committee. Soil and crop yield data also will be collected to evaluate the utility of the models at a broader scale.

There will be a further need for continuing the program in 1980-81.

Recommendation, Priority 2

To: Agriculture Canada, Central Region

Proposal. To increase support for further soil erosion research in Ontario.

Details. One professional, one technical man-year and operating funds should be made available to the Ontario Institute of Pedology, Guelph for this purpose. The approximate cost is $35,000 annually.

Background. Soil erosion and sedimentation research was recently initiated in Ontario as part of a much larger study designed to assess the impact of agricultural land use on the water quality of the Great Lakes. The results of these studies revealed that sediment and phosphorus derived from agricultural land contributed significantly to Great Lakes water quality (50 to 60% of the total stream loads delivered to the Lakes). Funds made available for this research (PLUARG) were terminated in 1978.

However, many questions remain to be answered with respect to: the impact of sediments and phosphorus on stream water quality, soil erodibility, soil erosional processes and remedial measures, and the location of stream sediment contributing areas within the agricultural landscape. Research projects on soil erosion and sedimentation that have particular significance to this Committee include:

a) the use of existing soil resource information for the planning and implementation of soil erosion remedial programs.

b) assess the need of additional soil resource information that could be obtained from ongoing soil inventory programs for improved soil conservation recommendations

c) the development of a soil erodibility index that is sensitive to both rainfall and runoff events throughout the year.

d) methods for delineating the sediment contributing areas of an agricultural landscape.

Recommendation, Priority 3

To: Agriculture Research Institute of Ontario

Proposal. To increase funding for research in support of the soil survey program in Ontario.

Details. Increased funding is required in Ontario Ministry of Agriculture and Food Program 39, University of Guelph to provide support for 1 Research Assistant, 1 Technician, 3 part-time summer support staff and operating funds. Total direct costs are estimated at approximately $60,000.

Background. In view of the expansion of the soil survey program in Ontario in recent years, and the increasing demand for more specific and precise information on soil resources as a basis for land-use decision making, the need for increased research in this area is strongly recommended. The scope of the research projects is very broad, but they are all related to improving the quality and usefulness of soil survey information. They include projects such as the following:

1) Variability of soil mapping units and soil series to establish statistically sound estimates of the range of characteristics to be encountered in naturally occurring soil groups delineated on a soil map.

2) Soil - Landform - vegetation relationships to improve predictive capability and hence efficiency of soil mapping.

3) Quantification of soil survey information. Provision of quantitative data on such things as soil physical properties, erodibility, productivity, drainage, etc. is required. In some cases much greater characterization of soil properties are needed; in others, methodology research for quantification is required. This type of data provides a more objective basis for interpretations in terms of capability, suitability or limitations for a given use. Information interpreted in this manner is more easily utilized by planners, land managers, etc.

Recommendation, Priority 4

To: Agriculture Canada, Central Region

Proposal. To support funding to operationalize CanSIS (Canada Soil Information System) retrieval systems.

Details. Research funding is required to support one M.Sc. student in the Dept. of Land Resource Science, University of Guelph.

Background. Through leadership and coordination by Agriculture Canada, soil survey data has been put into the CanSIS data bank for several years, however, data retrieval systems are not yet fully operational. Methodologies need to be established for data retrieval, and assessments made of users needs for land resource base information, in order to make soil survey information fully accessible and most useful on a provincial or regional basis.

Province of Manitoba

R.H. Hedlin

Department of Soil Science, Universityof Manitoba

Existing Data

There is a good deal of data available which is of value in assessing soil productivity. In order of increasing usefulness, the data available is as follows:

1) Statistics Canada data on summerfallow and stubble acreage and yields. These are published by provinces. They are also available by crop reporting districts.

2) Data from the files of crop insurance agencies. Manitoba probably has the longest records of this type. Yields are reported by farmers and some information on inputs such as use of fertilizer is included. Where crop damage occurred this is also recorded.

3) Data from Soil Testing Laboratories. Here again, farmer reported yields and information on management and various inputs such as weed control and fertilizer use, as well as crop damage, if any, is recorded.

4) Yield data from crop variety trials. These data are specific as to location and the yields have been measured accurately. Historically, fertilizer has not been used and nutrient levels by soil test have not been established. In general, weed control and general plot management have been excellent.

5) Yields from small plot fertilizer experiments. In these, measured yield data is available, there are commonly different levels of fertilizer application, and information on soil nutrient levels. Here again, plot management has generally been good.

Considerable progress has been made on putting information into the standardized soil performance and management file of CanSIS. To date, the information from the small plot fertilizer trials from the Department of Soil Science, University of Manitoba, have been encoded. In addition, about 60 percent of the Manitoba Crop Variety Zonation Trials have been encoded.

Data from the Provincial Soil Testing Laboratory and the Manitoba Crop Insurance Corporation, although not in CanSIS file, is available in a computerized form.

Use of Existing Data for Land Evaluation

In Manitoba, Dr. Kraft has made some progress in evaluating the Canada Land Inventory classes and sub-classes by using data from the Crop Insurance Corporation and Soil Testing Laboratory. His data indicate that yields are higher on class 1 land than on class 2 land and on class 2 land than on class 3 land. There is no real difference between classes 3 and 4 in productivity. His analysis also indicated a difference between crops in the way they are affected by land class. Rapeseed appeared to be influenced more by land class than wheat, oats and barley and flax less so. The supply of soil moisture - whether an excess or a deficit - was always an important factor influencing productivity.

Further work needs to be done relating the various kinds of data available to the classification systems in use for evaluating agricultural land, i.e., soil capability for agriculture, soil productivity groupings in use by the Manitoba Crop Insurance Agency and the indices used for tax assessment purposes.

Determination of Current and Potential Productivity

A year ago the outline plan for a very ambitious program for land evaluation was developed. The objective was to get estimates of potential productivity and current productivity.

Potential Productivity. Dr. G.J. Racz has developed equations relating the yields of wheat and barley to available soil nitrogen, fer tilizer nitrogen, degree days and water deficits (water available to the plant from stored soil water and seasonal precipitation minus potential evapotranspiration). The information required is all available or quite readily obtainable, except the water supplied to the crop by the soil (available soil water in spring less available soil water in fall). As initially planned, soils were to be sampled for moisture four times during the summer - at seeding, about 50 days after seeding, just before harvest and just before freeze-up. This would provide information on soil moisture used by the crop and also indicate whether moisture stress occurred during the growing season. Soil nutrient levels would be determined on the spring and fall samples. Forty-eight combinations of regional climate, soil properties and drainage were to be sampled.

Current Productivity. This would be a part of the study referred to above, i.e., information would be obtained from the same fields. The farmers selected would be clientele of the Provincial Soil Testing Laboratory. Hence, data on soil chemical properties would be available from samples submitted by the farmer (as well as from the potential productivity portion of the study referred to above).

The farmers would also provide information on management practices and also on yield for a field of at least 80 acres in size.

While this program will not be undertaken as originally outlined, there are plans in progress for getting some information which would be useful in land evaluation in 1979. This will consist of obtaining information on the soil moisture status at seeding time and throughout the summer on all variety trial and soil fertility plots. If not already available, information on soil nutrient status and weather data (precipitation and temperature) will be obtained. This information together with yield data will provide a basis for testing the yield model referred to above.

Land Degradation

During the past year, letters have been received from two soil conservation districts requesting information on the amount of soil loss actually taking place by wind and water erosion. The request was for work to make existing soil loss equations more applicable to Manitoba conditions. This is an aspect of soil research that requires further support. Measurements of actual soil loss by wind and water erosion merit consideration.

We hope to undertake a study which would supply some information on land degradation. This would involve a follow up to a study conducted by in the period 1963 to 1965 when about 6000 surface soil samples received by the Provincial Soil Testing Laboratory, were analyzed for organic matter. In this study, there were 14 mapped soil units from which 100 to 670 samples were received. A repeat of this study with soil samples to 670 samples were received. A repeat of this study with soil samples currently being received would provide an indication of the change in organic matter content, if any, which has occurred in the last 15 years.

Another aspect of land degradation is the problem of soil salinity. The monitoring of the nature and distribution of salinity has been a continuing concern of soil survey. However, the impact of salinity on productivity has never been assessed. There is also a need to consider the changes in salinity, if any, which are occurring.

Research into Climatic Requirements of Crops Grown in Manitoba

Support is needed for analysis of existing climatic data for research to establish quantitatively the climatic requirements of Manitoba crops. Climatic requirements for the optimum growth of most crops grown in the province is not known. Current studies show, for example, that the corn heat units used in Onrario to classify regions for corn production are not an accurate indicator of corn maturity in Manitoba. In other crops, e.g., sunflowers, virtually no data is available as to climatic requirements.

Soil Survey

There continues to be a demand for more inventory work than can be undertaken in the short term. The most pressing demands include request for:

a) Agriculture - particularly where agriculture is becoming more intensive and/or where there is high soil variability.

b) Urban planning - This occurs particularly in the periphery of the larger urban centres such as Winnipeg and Brandon and also in towns and villages within easy driving distance of these centres.

c) Parks and recreation - information is requested where development of this type is planned.

Province of Saskatchewan

R.J. St. Arnaud
Dept. of Soil Science University of Saskatchewan

In January, the Canada Committee on Land Resource Services considered a strategy paper prepared by the Expert Committees on Soil Fertility and Soil Survey. At that time, while the Committee was in general agreement with the strategy paper, it was felt that it reflected primarily Agriculture Canada's Research Branch Program. It was decided that as a follow-up, each province should prepare its own strategy paper on Land Resource Research by May 15 of this year. This was to be done by the provincial representatives in consultation with their own appropriate provincial authorities.

Don Rennie was the Saskatchewan rep. on the Canada Committee on Land Resource Services and is presently involved in preparing a provincial outlook paper on this matter. Since the deliberations with provincial authorities are only in the initial stages, it is not possible for me to outline exactly what our future plans will be in terms of soil resource research, and even less to anticipate what the long-term expenditures might be in this particular area. However, I believe I can very briefly itemize the priorities which we foresee and which the Saskatchewan Institute of Pedology would hopefully carry out.

We would envisage that this work would continue under the banner of the S.I.P. which provides an integrated approach involving federal, provincial and university personnel.

The Basic Soil Inventory

In Saskatchewan our basic resurvey program which provides more detailed and updated soil information for the settled parts of the province is about one-half completed. We foresee the need to complete this inventory and likely to increase the detail of survey on the remaining map sheet areas in order to provide the greater detail of soils information required by user agencies in the province.

At the same time, we realize the need for soils information on a broader scale for the rapidly developing northern areas of Saskatchewan (N of 55°). It is worth noting here that the Saskatchewan Research Council is presently preparing a surficial geology map of northern Saskatchewan--such a map should greatly reduce the intensity of effort required to document on a broad scale the nature and occurrence of soils of that region.

Land Quality Research

There are two major areas of concern with regard to land quality which require immediate and continuing attention. One is soil salinity--the other is the decreasing fertility levels of our cultivated soils. Both problems are to some extent related to past cultural practices and to inefficient use of water from precipitation. The increased salinization of our soils over the last decade is well documented. Also, we can attribute the loss of up to 50% of the soil humus from our soils as the result of intensive tillage, high frequency of summerfallowing and both water and wind erosion. High priority must be given to research aimed at further substantiating and documenting the processes involved and in developing remedial measures. A soil nitrogen research program with the dual objective of providing guidelines for the rebuilding of the "active soil organic matter" and evaluating the role of asymbiotic and symbiotic nitorgen fixation under the soil, climatic, and cropping conditions in the province can be expected to result in major dividends for agricultural production.

Land Evaluation

The wise and judicious use of our land resources requires that we have a thorough understanding of their potentials and limitations. Soil inventory interpretations, and in particular the prediction of yield potentials are fundamental to the wise use of land and to the selection of cropping alternatives. While Agriculture Canada, through the Land Resource Research Institute has initiated a national land evaluation program, we feel the need for a much stronger provincial input into this type of program.

Soil Information Systems

A few years ago the Saskatchewan Institute of Pedology initiated the development of a modest Soil Data Bank, primarily in support of the Soil Testing Laboratory's operation. In recent years with funding from federal sources three of the files in this data bank, the pedology, soil productivity (or performance) and soil management files, have been gradually updated. We feel the need for a cartographic file as well.

A number of other provincial agencies, in particular the Municipal Assessment Branch, D.M.A., the Land Bank, and Crop Insurance, are in the process of developing soil data banks to meet their specific objectives. We recognize the need to integrate these numerous data banks to provide a soil data storage and retrieval system for all provincial users. We also adhere to the concept of integrating the provincial data banks with the Canada Soil Information System (CanSIS).

Province of Alberta

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Department of Soil Science
University of Alberta

I believe the following comments are representative of the concerns of Pedologists in Alberta. In preparing this I have consulted several people but accept full responsibility for the content.

I would like to briefly touch upon some research activities in Alberta and then discuss data collection and research goals.

What is Being Done?

Land Utilization Studies. In general there is more emphasis on studying varying treatments than soil properties. These studies relate to the technical aspects of Land Utilization and do not deal with the broader issues of land use:

- general fertility (fertilizer) studies
- engineering uses
- zero tillage
- a few rotational studies
- a few forestry related site characteristics studies
- a few studies on waste disposal on land, i.e. manure, sewage effluent, sewage sludge and fly ash.
- recreational suitability studies
- concern and documentation on irreversible non-primary production related uses.

Land Degradation Studies.

- industrial pollution
- saline seeps
- acidification

Land Reclamation Studies.

- tar sands are
- coal mining sites (2-3)
- deep ploughing
- wetland drainage - practised but not studied.

Land Evaluation.

- crop yields-climate-soil characteristics compilations
- soil temperature and moisture monitoring
- nutrient cycling models on some soil-plant systems
- some watershed hydrological modelling

Research and Data Collection Needs

General Conceptual Framework. Land is a resource with value. Soil is a component of that resource and influences its value. In addition to extrinsic variables such as location, and distance to market etc., the intrinsic value of soil is a function of two things:

i) what the soil is as a material, and
ii) what soil does.

Soil must be carefully and thoroughly described as a material. Current efforts are mainly in that direction. The need will continue to grow and such information should be continually available.

The greatest immediate need for new research direction is number (ii), "what soil does" or "how do soils function?". Soils have, to borrow a phrase from the biologists, "function as well as form". Just as Botonists are becoming more aware of the dynamic functioning of plant communities and Geologists are studying geocycles of elements and the functioning of the earth's crust; so must Pedologists, charged with linking the two, vigorously prosecute efforts to characterize soil as a functioning naturally occurring three dimensional body in the landscape.

Specific Suggestions. In pursuing this theme to more specific suggestions, three levels of abstraction must be separated.

a) Global scale - develop models of the role of soils in transferring materials between the various ecospheres (atmosphere, lithosphere, hydrosphere and biosphere). Example: some pertinent problems are:

  - water percolation rate through soils
  - what profile characteristics control it?
  - what mutual effects are there on the soil and water?
  - what are the rates of C entry to and loss from soils?
  - how do soil characteristics control them?
  - what are the soil characteristics and the quantitative measures of them that control gas exchange?
  - what are the rates of gas exchange between soil and atmosphere, which are characteristic of various soils under defined moisture and temperature regimes?
  - what are the rates of mineral weathering in soils and to what extent do they vary with soil properties?

b) Value of soil as an immediately exploitable resource (survey extrapolation):

i) intrinsic soil characteristics and functions as they affect exploitation.

ii) interaction between intrinsic soil properties and extrinsic management (or exploitation) techniques.

re food and fiber: On the one hand, substantial areas of soils have been described and on the other much money has been spent conducting management trials (say fertilizer trials) on sites where the soil profile has not been described or referred to. These two sources of information must be integrated. Secondly, whereas our past efforts have been to examine the effect of various management techniques on the same soil, we must now examine similar management on different soils. Both parameters (soil and management) must be controlled and varied independently. Example:

1) How do intrinsic soil characteristics influence and control (quantitatively) nutrient, water and O_2 supply to plants, root penetration through soil and hence crop growth?

2) HOw do soil characteristics quantitatively control effectiveness of added amendments, or movement through the profile of metals added in sludge?

Probably soil physical properties since they change slowly and influence so much of what soil does should be examined first.

c) Loss of the resource:

How much, where, and which soil characteristics influence it?

- erosion
- nutrient depletion by non harvest mechanisms
- salinity and acidity
- irreversible non-primary production uses

The above comments (especially (b) and (c)) relate to interpretation. Interpretation is possible only if good information and survey data is available to begin with. Interpretation is also user-focused and the type of future land use cannot always be predicted. Therefore, research is needed into ways of conducting soil surveys to provide the greatest amount of information possible on soil parameters controling soil function.

Summary

1. Soil must be treated in terms of <u>function</u> as much as <u>form</u>. Models of where soils fit into various ecosystems will help here.

2. Integration of information on intrinsic soil properties and their interaction with extrinsic management variables is needed. This will permit effective extrapolation and collection of both survey and management data. Intrinsic soil parameters that may be most profitably examined immediately are physical properties, especially through controling water, gas and heat exchange and movement.

3. There are immediate problems of resource loss that must be documented in terms of how much, where and why. Of most concern to use would be erosion, non-harvested nutrient loss and irreversible land loss.

4. Research into survey techniques must continue. Survey techniques should be developed to permit concentration on function as well as form. It follows that soil parameters controlling soil function must be identified and measured routinely.

Province of British Columbia

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University of British Columbia

In British Columbia, six lead committees were formed by the B.C. Agriculture Services co-ordinating committee (BCASCC) which in turn reports to the Canada Agricultural Services Coordinating Committee (CASCC). The terms of reference for these lead committees are:

1. To act as advisory committees to the B.C. Minister of agriculture if he so wishes;

2. To consider all items involving research, teaching or extension, referred to them by BCASCC with the understanding that they would make recommendations with the help of such scientific subcommittees as may be necessary;

3. To keep under regular review the scientific areas allotted and to report or recommend improvement of a reasonable and practical nature that would in time bring about significant progress in British Columbia Agriculture.

The six lead committes are in the areas of animal, engineering, food, plant, social and soil science. I expect that the reason I was chosen to prepare this statment is that I am Chairman of the B.C. soil science lead committee.

In respect to this statement it is therefore important to have some understanding of the nature and agency representation on the lead committee, which for the past year was:

Agriculture Canada	- Soil survey unit and research stations(2)
Environment Canada	- Forest service
B.C. Ministry of Agriculture	- Soils division
B.C. Ministry of the Environment	- Resource analysis branch, land commission and lands branch
B.C. Minister of Forests	- Forest Service
University of British Columbia	- Faculty of forestry and department of soil science.

Representatives from the 5 other lead committees.

It is evident from the committees composition that it includes a wide range of data collectors and users. The names of the organizations represented give some indication of this and although time does not permit elaborating on their activities in this statement; there are representatives of a number of the organizations present who may be consulted.

The committee at the present time has two sub-committees that report to it, one on soil fertility and the other on agrometeorology. These subcommittees have representatives on the Canada expert committees on soil management and agrometeorology.

Some of the lead committees activities also relate to this Canada expert committee on soil survey. In this regard, the committees reviewed and gave general approval and support to the report dealing with strategy for land research prepared and circulated by Drs. Halstead and Clark, March, 1978, and the committee agreed that the data it would generate was needed greatly. The committee also noted the two projects: Collation of historic and current soil resources, soil productivity and soil management data in British Columbia and crop yield model in the Peace River District of British Columbia, related to land evaluation are underway.

The lead committees report annually to BCASCC under the headings general, research and non-research. The soil science committee, in its annual report, January 1979, identified the following areas of priority which appear to relate to the expert committee on soil survey:

Soil Surveys and Related Research

The need to update, provide greater detail and fine tune soil surveys in areas of critical importance and expecially with regards to the agricultural land reserves. In addition, increased effort is required to update the Canada Land Inventory Data Base to prepare specific climate-soil-plant suitability ratings.

The need to obtain additional basic information concerning the physical, chemical and biological properties and management of major soils. In this regard special consideration should be directed to soil physical characteristics including soil temperature and water relationships.

Agrometeorology

The subcommittee on agrometeorology reviewed research needs and identified the following areas as requiring attention:
Soil temperature, Soil water balance, Weather and crop growth, remote sensing techniques, instrumental research. The subcommittee also identified the non-research areas requiring attention noted below:
Improved solar radiation network, additional frost risk mapping, consistent inclusion of soil and climatic data in crop yield studies, better utilization of archival data.

Items from the Committees' Annual Report for 1978.

The following priority areas for sustained research were identified:
- soil deterioration (degradation)
- municipal and industrial waste application on soil
- classification, fertilization and management of wetlands.

With respect to soil deterioration, it should be noted that the soil science lead committee itself, or in cooperation with other lead committees, periodically sponsors workshops. In this regard, the committee proposes to sponsor a workshop on soil deterioration in the coming year. I would anticipate that such a workshop would consider such matters as the nature, extent and seriousness of soil deterioration in B.C., soil erosion and control measures on agricultural, forest and other lands, soil acidification, heavy metals and physical characteristics such as compaction and structure changes. In this regard it may be noted that the most recent workshop sponsored by the soils committee in 1977 was titled energy, water and the physical environment of the soil.

It should be noted that comments and recommendations made to BCASCC must be considered and priorized with respect to those provided by the five other lead committees for its report to CASCC. Also, the B.C. Land Resource steering committee which reports to the environment and land use technical committee also developes priorities and recommendations that relate to the land resource. I expect that some members of that committee are present and may wish to comment on and add to this brief regional statement.

Taxonomic Classification

(G.J. Beke, C. Wang, R. Baril, C.J. Acton, R.E. Smith, R.J. St. Arnaud, W.W. Pettapiece, T.M. Lord, J.A. Shields, J.L. Nowland, J.H. Day and J.A. McKeague)

Since the 1976 CSSC Meeting in Guelph this Subcommittee completed the rewriting of the Canadian System of Soil Classification and it was published in 1978. The Subcommittee thanks the many pedologists who criticized drafts of the system, contributed photographs, suggestions etc. I thank the members of the Subcommittee who together provided the essential "at-the-site" knowledge of the known soils in this vast country and a "down-to-soil" wisdom in resolving contentious issues. Their constructive criticism of several drafts of the system was responsible for much of what is good in Publ. 1646.

The need for updating the system began in October 1976 when a draft of the revised system was sent to the editors. New surveys and research both in Canada and elsewhere are providing new knowledge of the properties of soils and new concepts on their genesis, conservation and classification. For these reasons, the Subcommittee on Classification should remain active even though the priorities of the CECSS have moved on to more urgent matters such as mapping systems.

This report includes the following items:

A. A list of errors, ambiguities, etc. in The Canadian System of Soil Classification contributed by several pedologists. Please note other errors and inform the new chairman of this subcommittee.

B. A list of research needs related to soil taxonomy; these suggestions were made by members of the Subcommittee.

C. Recommendations of minor changes in the system that might be adopted at this meeting.

D. Recommendations on the role of this subcommittee.

Errors, ambiguities and other problems

p. 24. Aeg definition. Many Ae's have low chromas and hence would meet the definition of Aeg. Also line 29 "..set for fg, hfg, tg..." (Nowland).

p. 115. Skeletal particle-size classes (Lord).
Loamy-skeletal and clayey-skeletal definitions state, "particles 2 mm - 25 cm; "sandy skeletal" states, "particles coarser than 2 mm". The sandy-skeletal definition conforms with the U.S. family p.s. classes, but the others do not.

p. 128. Stoniness classes. No upper limit is placed on size of stones. CanSIS manual states, "stones 15-30 cm in diameter". At what diameter do stones become boulders? Also, why is the lower limit of stones 15 cm? CLI limit was 25 cm (Beke)? Why the gap between very stony (1-2 m apart) and exceedingly stony (0.1-0.5 m apart) (Beke)?

p. 144. Loamy - definition is wrong (same as clay). The definition should be: An accumulation of particles of which the fine earth fraction contains (by weight) less than 35% clay (<0.002 mm), and less than 70% of fine sand and coarser particles. Particles coarser than 2 mm occupy less than 35% by volume. (Is this o.k. Don Acton?).

p. 145. Hummocky (generally 9-70% slopes) vs undulating (dominantly 2-5% slope). Beke suggests there should be no gap in slopes between the two.

p. 146. Fig. 46 was by K. Michalica not J.L. Nowland (JLN).

p. 163. Q comes before P in the index (a case of failure to mind our p's and q's) (Beke).

Buried soils (Pettapiece) taxonomy is ambiguous.

Example 1. LH (10-0), Ck1 (0-10), Ahb (10-13), Ck2 (13-70), Ahb2 (70-73), Aeb (73-75), Bmb (75-90), Ck3 (90-100 cm +). A B horizon occurs in the control section but in principle, its a Regosolic soil, not Brunisolic. The "system" states on p. 19 that "a soil covered by a surface mantle of new material at least 50 cm thick is considered to be a buried soil." Presumably we classify the material above the buried soil in such cases, but this is not stated clearly. In example 1 the sequum with the Bmb begins at a depth of 70 cm so, I assume, we classify the material above as a Regosolic soil. If the Bmb had occurred at a depth of 30 cm, the soil would be classified as Brunisolic according to my assumption.

Example 2. Irrigated area, cut and fill. Apk (0-15), Ck (15-25), Ahb (25-40), Bmb (40-60), Ccab (60-75), Ckb (75-100 +). The deposited material is only 25 cm thick so the soil would be classified (according to the above assumption) on the basis of properties of the lower sequum, hence Orthic Dark Brown (depending on color of Ahb). The problem of classifying such soils needs consideration by the Subcommittee.

Gleyed Subgroups (Nowland, C. Acton, Baril and others).

Differentiation of Gleyed subgroups from soils of the Gleysolic order continues to be a problem. The present criteria are reasonably precise but, if followed to the letter, result in illogical classification. Nowland suggested modification in the definitions of 'g' etc. as follows:

Change the definition of Bg as follows "..accompanied by common or many prominent mottles, and more than in the C horizon."

Change the definition of g as follows "...grey colours, or common or many prominent mottles, or both,".

Define gleyed subgroups as "having either common to many distinct mottles indicative of gleying within 50 cm...or common to many prominent mottles at depths of 50 to 100 cm (but neither include the Aeg)".

p. 69. "Prominent grey or brown mottles in materials of reddish colour..". Suggest we stipulate 5YR.

Cliff Acton sent a copy of material used in Ontario for estimating "soil drainage" in the field. Although soil drainage classes and soil taxonomic classes do not have the same limits, they are related.

p. 72. Differentiating criteria of Humic Gleysols and Gleysols (Baril).

The present criteria require both low color value and more than 2% organic C for Humic Gleysols. Though this is not ambiguous, Baril prefers to base the separation on color value and add, "usually have more than 2% organic carbon". This should be considered by the Subcommittee.

pp. 50 & 51. Gleyed Sombric and Dystric Brunisols (Baril). Suggested the following change in wording "...faint to distinct and sometimes prominent mottles within 50 cm...". (According to the present criteria, prominent mottles within 50 cm would necessitate classification of the soil as Gleysolic).

Add Bfjgj and Bfjg as possible subhorizons (Again, by present criteria Bfjg would indicate Gleysolic order if the horizon is within 50 cm of the surface).

p. 71. French edition, under Gleysol humique. Instead of 'une couleur de matériau" state "une luminosité de couleur..".

Podzolic order - (Lord).
Some Ferro-Humic Podzols in B.C. have B subhorizons (in some cases immediately above a duric horizon) that contain more than 17% organic C. Should these be designated as H even though they have the properties of a podzolic B?

(Wang) p. 17 and elsewhere.
Delete the requirement that the texture of a podzolic B be coarser than clay. The pyro (Fe & Al)/clay ratio takes care of this.

Bt criteria (C.J. Acton).
Suggest that the ratio of 1.2 (times clay in Ae) be applied to soils with more than 40% clay. Thus Ae 60% clay, B - 70% clay; the B would not be a Bt even if there were evidence of illuviation of clay.

Phases (D.F. Acton). Consider addition of surface expression and erosional modifiers from the landform classification as soil phases (This is open now, I believe).

The Subcommittee should consider these proposals and develop specific recommendations.

Research needs related to soil taxonomy

1. Better characterization and definition of the limits of fragipan and ortstein.

2. Better definition of gleyed subgroup - Gleysolic limits (see above).

3. Investigation of ways of improving the usefulness of the family category. John Nowland has suggested the following:

   a. Delete soil climate. Classify pedoclimate separately from soil.

   b. Change mineralogy classes, nearly all Canadian soils have mixed mineralogy. Beke suggested adding depth to 'hardpan' classes.

4. Investigate the bases for establishing limits for soil series. The higher categories of the system have been defined reasonably precisely but the series category remains quite loose.

5. Investigate the relative merits of continuing to revise and develop the Canadian system and working with U.S. pedologists toward incorporating the superior aspects of our system (Cryosolic order, podzolic B definition, etc.) into Soil Taxonomy. Baril suggested that the first step is to adopt the same number of categories (add suborder to our system), and then fit our series into the system.

6. Investigation of physical attributes of soil: structure, consistence, hydraulic conductivity, water retention, etc. with a view to incorporate into taxonomic and interpretive classification more criteria based upon physical characteristics of soil.

7. Investigate the application of nature and amount of soil organic constituents to firming up some of the taxonomic classes (Shields).

Recommendations of Minor Changes in the Canadian system.

1. Add Fragic subgroups of Sombric and Dystric Brunisols. The definitions would parallel those of Fragic subgroups of Podzolic soils etc. Wang, Nowland and Beke have descriptions and data for such soils. They missed being incorporated into Publ. 1646 by a month or so.

2. Change skeletal particle size classes to conform to U.S. family particle size classes (this was the intention initially). It simply involves allowing fragments coarser than 25 cm to be included in the skeletal fraction.

These changes were agreed upon at the meeting I believe. However, the initial proposal was to add Fragic subgroups of Brunisolic soils, thus implying such subgroups of all great groups. Fragic subgroups of Melanic and Eutric Brunisols are not known to occur. Thus, these two changes are in effect for those who are aware that they have been made.

Proposed roles of subcommittee

1. To consider current ambiguities in the 'system' and current problems in soil taxonomy; to receive new suggestions of problems; and to develop solutions for proposal to the CECSS.

2. To consider research needs related to soil classification and to suggest priorities for such research at CECSS meetings.

3. Depending on the collective wisdom of the Subcommittee, to undertake the task indicated in part 5 under Research needs. In my opinion, working toward an international system that incorporates good aspects of our system is a task of high priority.

Having had the honor of chairing this Subcommittee for some years, I wish to thank all contributors to the work of the Subcommittee and request the Chairman of CECSS to select another chairman.

Soil Degradation in Canada - Summary Discussion and Research Needs

D.R. Coote
Land Resource Research Institute

Introduction

The L.R.R.I. soil degradation activities are part of the Land and Environmental Degradation program designed to meet, in part, the Research Branch goal of Resource Protection.

Why is soil degradation of concern at this time? Table 1 present a perspective of trends in agriculture and forestry over the last, and the next, 100 years. Soil degradation is clearly a problem as it can only aggrevate a situation (Table 1) which should be of concern to agriculturalists and foresters even if degradation were not happening. Information is needed on all aspects of assessment and control of soil degradation in Canada.

Problem Areas

A provisional listing of ten types of soil degradation has been prepared (Table 2). They are based on more or less distinct chemical or physical processes. Two additional soil degradation problems have been added to the ten principal processes of Table 2, - biochemical incompatibility and slope instability. These will require additional investigation.

Urbanization has not been included in the listing of Table 2. The program, at present, considers urban sprawl to be a separate political decision area, and soil degradation side effects such as contamination, drainage deterioration, compaction etc. can be covered in the items already listed. "Inherited" soil problems (natural), such as solonetzic soils, soils with compact subsoils and poorly drained soils, are not considered "degraded", so are not included in this review.

Table 3 presents a listing of some of the major environmental problems which are derived, at least in part, from the processes of soil degradation listed in Table 2. These impacts must be considered when soil degradation is evaluated.

Table 4 attempts to present a simple distribution of the ten principal soil degradation processes across the ten provinces of Canada. The table includes only the highlights, hence many small problem areas are not listed. Included in this table is a purely subjective rating, based on values from zero to five, of the "severity" (combination of aerial extent and degree of soil impairment) of each problem area in each province.

Table 1: Factors to consider in creating a perspective of soil degradation in Canada

The last 100 years	The next 100 years
1. Improvements in crop varieties, fertilizers and management giving continual crop yield increases.	1. Yield benefits from variety and fertility improvements may have reached their peak.
2. Increasing inputs of inexpensive energy - tillage, pesticides, fertilizers.	2. Energy costs rising rapidly - some sources discontinued.
3. Heavy reliance on native soil fertility and structure to resist abuse from continued highly intensive cropping.	3. Soil organic matter levels declining to reach new equilibria with cropping practices - lower fertility and soil structure less able to resist tillage abuse.
4. Marginal land abandoned in favour of better soils and climatic zones.	4. Marginal land may need to be returned to agricultural use because of lower yields on other land and demand for food.
5. Logging carried out in virgin forests.	5. Logging in previously logged and regenerated forests.
6. Urban pressure absorbed by combination of 1 and 2 above.	6. Urban pressure harder to absorb - land lost to urbanization must be replaced by lower capability soils.

Table 2: Preliminary separation of soil degradation types by principal processes

1. Soil erosion by water

2. Soil erosion by wind

3. Soil organic matter loss as related to structure and fertility

4. Soil structure deterioration from tillage and traffic (compaction)

5. Salinization and alkalinization - both dryland and irrigation

6. Accelerated soil acidification from fertilizer use and oxidation of natural and atmospheric-pollution sources of sulfur and nitrogen

7. Soil contamination from pesticides, waste-water sludges, atmospheric pollution, etc.

8. Soil disturbance and mixing by surface-access mining, pipeline installation, etc.

9. Drainage deterioration from microbial deposits (e.g. iron ochre), declining soil hydraulic conductivity, etc.

10. Subsidence of organic soils by oxidation, erosion and compaction

Miscellaneous

11. Biochemical incompatability (e.g. organic toxins from crop residue decomposition)

12. Slope instability - "earthflows"

Table 3: Environmental Degradation associated with soil degradation

1. Water pollution - surface water;
   - Eutrophication - N, P from erosion and runoff
   - Contamination - pesticides, heavy metals from erosion and runoff.

2. Water pollution - ground water;
   - Contamination - pesticides, heavy metals, nitrate in groundwater.

3. Sedimentation - from soil erosion;
   - Wildlife - destruction of fish habitat, filling of ponds, sloughs, etc.

4. Air pollution - from wind erosion.

5. Wildlife contamination - from plants and insects contaminated by uptake of pesticides, heavy metals, etc. in soils.

6. Desertification - from wind erosion, soil contamination.

7. Flooding - from excess runoff, drainage deterioration, sedimentation, land-slides, etc.

Table 4: Distribution of principal soil degradation problems in Canada.

Province	Erosion by Water	*	Erosion by wind	*	Soil o.m. loss (structure, fertility)	*	Structure loss (from tillage); compaction	*	Salinization (and alkalinization)	*	Acidification (fertilizers, atmospheric SO_2)	*	Contamination (heavy metals, pesticides)	*	Soil disturbance and mixing	*	Drainage deterioration	*	Subsu orga
B.C.	River Valleys - esp. Peace R. All logged forest land.	4	Interior plateau - recreation vehicles, exploration, overgrazing	2	Logged forest soils Peace R. valley	3	Logged forest soils, Interior plateau-recreation and exploration vehicles. Lower Frazer R. valley	3	Very localised	1	River valleys - esp. Okanagan	2	Near smelters in forested regions, excess manure disp., pesticide residuals in Okanagan V.	2	Some coal exploration in alpine regions, logging access roads	2	Lower Frazer valley	1	Lower Fr (no wate control)
Alta.	Peace R. valley. Milk R. ridge. Foothills. Widespread localized spots. Poor irrigation practice	4	Widespread - summer fallow, knolls, winter-bare soil.	4	Summer fallow, burning, overgrazing	4	Not general	1	Widespread seeps (summer fallow) irrigation seeps, canal leakage	5	Downwind of foothills gas plants, Fertilizer N in central and north Alta.	2	Oil Spills	1	Coal under solonetzic soils Oil sands extraction	3	None	0	None
Sask.	Localized spots only	1	Widespread - summer fallow, knolls	4	Summer fallow	4	Not general	1	Widespread seeps, (summer fallow)	4	Not general	1	Oil spills, potash plants	1	Very little	1	None	0	None
Man.	Localized spots only	1	Localized spots only	2	Summer fallow, burning. Organic Soils	3	Not general	1	Localized spots only	2	None	0	Very little-municipal	1	Very little	1	None	0	cultivat organic Central
Ont.	Southern Ontario - intensive cropping areas	4	South west - contin. row - cropped land	3	Southern Ont. - intensive cropping areas	4	Southern Ont. intens. cropping, pipeline installation	4	None	0	Localized in Southwest fert. N., general atmospheric fallout	2	Municipal and indust. sludges, atmos. fall-out, excessive manure disposal, pesticide residues	[illegible]	Gravel and sand extraction, extensive Pipeline and drainage installation	2	Iron ochre in some locations, intensive cultivation-soil hydraulic conduitivity problems	2	All devel soils
Québec	St. Lawrence lowlands Lac St. Jean, intensive cropping areas	3	Localized	1	St. Lawrence Lowlands - corn, potatoes	3	Intensive cropping on clay soils, land clearing in sandy soils, pipeline installation	3	None	0	Problems for rotations where potatoes grown	1	Atmospheric near smelters, Pesticide residues	1	Pipeline and drainage installation	1	?	1	All devel soils
N.B.	Saint. John R. valley, esp. potatoes	5	Localized	1	Potatoes	3	Potatoes	4	None	0	Naturally acid soils	1	Near smelters, pesticide & top-killer residues	1	very little	1	?	1	Not sig.
P.E.I.	General - Potatoes, Tobacco, corn	4	Localized	1	Potatoes, corn, tobacco	3	Potatoes, corn, tobacco	3	None	0	Naturally acid soils	1	Pesticide and top-hilder residues	1	very little	1	?	1	None
N.S.	Localized - corn, canning vegetables - North shore, Annapolis Valley, Hants, Colchester	3	Localized	1	corn	2	corn, vegetables	2	None	0	Naturally acid soils some acid-sulfate soils	1	Near smelters, pesticides residues	1	very little	1	Some local iron ochre problems, dykeland drainage failure	1	All deve organic
Nfld.	Localized		?		? —		?		None	0	?		Near industrial works, pesticides in organic soils.		?		?		All deve organic

* Subjective preliminary rating of severity on a scale of 0-5

Research Needs

The Inventory of Canadian Agricultural Research (ICAR) has been used to identify research projects active at federal and provincial research stations and universities during the 1977-78 fiscal period. From these, an indication can be obtained of the extent of research (man-years) allocated to each of the major soil degradation processes. Table 5 summarizes these data and compares them with the subjective ratings of Table 4. While this comparison is not completely up to date, nor does it include all of the many concerned individuals in extension services across the country, it does provide an indication of soil degradation processes which appear to have been neglected. For example, accelerated soil acidification and soil mixing from disturbances appear not to have been the subjects of any research programs in 1977-78. Furthermore, soil erosion and soil organic matter loss appear to have been researched at a low level compared with the national extent of these problems.

Data needs are extensive for all of the degradation problems listed above:

- Soil erodability data, together with monitored soil losses from experimental plots, are needed for all of Canada - with special emphasis, perhaps, on areas such as the Peace River Valley which appear to be particularly vulnerable to this problem;

- Soil organic matter data, by which to assess fertility and structure loss, are needed throughout Canada. Many research plots used for long term rotations in the past could be sampled before they are greatly modified by present users, and before their locations and histories are lost. Provincial soil testing services could be a source of valuable time-series data on soil organic matter levels.

- Data can be obtained by which to assess the extent of land currently degraded by saline seeps. However, data are needed to determine those sites which are in the process of salinization so that control measures may be instituted before crop yields are seriously affected.

- Better methods and techniques are needed by which to assess soil structure deterioration. Long-term rotation experiments could be used to obtain comparative soil data on soil compaction under different cropping practices.

- Acidification can also possibly be assessed by examination of soils under long term cropping and rotation experiments, many of which have been discontinued by research stations in recent years.

- Contamination must be monitored by maintaining records of sewage sludge disposal activities and the quality of sludges used, by sampling soils to which contaminants have been added in the past, and by monitoring atmospheric pollutant movement.

Table 5: Comparison of subjective rankings of "severity" of soil degradation processes with ICAR[1] research inventory (professional and technical man-years)

Degradation Process	Σ subjective rankings (1)[2]	Σ total man-years (2)	Ratio: (2)/(1)
1. Water erosion	30	5.65	0.19 *
2. Wind erosion	19	0.93	0.05 *
3. Organic matter loss	29	8.59	0.30 *
4. Structure loss, compaction	22	12.88	0.59
5. Salinization	12	15.80	1.32
6. Acidification	11	0	0 *
7. Contamination	13	11.43	0.88
8. Disturbance-mixing	13	0	0 *
9. Drainage deterioriation	7	3.05	0.44
10. Subsidence of organic soils	8	1.8	0.14 *

[1]Inventory of Canadian Agricultural Research, 1977-78, Can. Agric. Res. Council.

[2]From Table 4.

*Below average.

- Techniques are available to measure subsidence of organic soils. Data need to be gathered across the country to assess this resource depletion.

- Many other activities need to be undertaken to measure and assess the impact of mining, gravel extraction, drainage deterioration, etc. on soil degradation problems for which few data exist at this time.

Conclusion

Soil degradation is a widespread and serious problem in Canada which manifests itself in many forms and processes. A great deal needs to be done to: i) identify and describe the processes involved; ii) assess the locations and extent of each occurence of soil degradation; iii) determine causitive factors in each situation; iv) develop management alternatives to reduce, eliminate or reverse these degradation processes; and v) convince farmers and other land users to adopt necessary control measures. The task is a challenge to the entire soil inventory, research and extension community in Canada.

Soil Surveys and Correlation

J.A. Shields

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Soil surveys present factual information about our most important component of land. They also provide information on how that component, the soil, will perform under different conditions. The value of these surveys for land resource inventories depends on what interpretations can be made from the soil map and accompanying report.

Interpretations are dependent on the data collected and the research assigned to its analysis. Present priorities for data collection and research needs for soil survey and correlation are arranged in the following groups:

Group 1 - Marketing Research

Soil surveys are made to provide adequate information for a wide range of users. At the onset it is important to determine who are the prime users of the proposed survey project and their interpretation priorities. Contact with user groups must be made during the project planning stages and should continue throughout the project thereby providing them with sufficient familiarity of the project to confidently interact and interpret the product.

Establishment of interpretation priorities necessitates the compilation of soil-landscape properties and their limits definitive of each interpretation. This not only serves as a check on the adequacy of soil characterization and mapping but also provokes the mapper to making mental interpretations during the course of the survey.

Group 2 - Taxonomy and Mapping

Soil taxonomy. The present Canadian System of Soil Classification uses various chemical properties (extractable Fe+Al, pH, total C etc.) to distinguish between horizons. Although the importance of soil organic constituents in influencing soil properties has long been recognized, little use has been made of organic matter composition and nature in soil taxonomy. This is largely due to lack of data characterizing these constituents on a wide range of soils.

Soil organic matter analysis of ISSS samples, while indicating the need for standard methodology, has also provided some very positive results. Thereby, renewed interest has been generated in soil organic matter studies relative to taxonomy which is most encouraging and a most deserving research requirement.

The second research need relative to soil taxonomy centres on soil morphology. In particular, compound soil structures must not only be described in the field, but must also be viewed and characterized under stereo binoculars, in thin section and by the microprobe. This information must then be related to water flow and retention characteristics. Research on these aspects coupled with the nature of organic constituents will undoubtedly supplement existing criteria definitive of argillic horizons.

Thirdly, research is required to firm up the soil moisture regime. This research requirement applies not only to soil taxonomy but is also important for:

- soil mapping and correlation
- crop growth models and yield predictions
- engineering interpretations
- other alternative use evaluations.

It is important that relationships be developed between soil texture and moisture retention. The distribution of moisture on different soil-landforms must also be studied. Obviously, research on soil moisture as part of the overall hydrological regime is critical.

Soil series differentiae. Limits of physical-chemical properties definitive of soil series have not been adequately defined. Documentation would greatly increase the efficiency of survey operations by providing guidelines necessary to avoid confusion and frustration experienced during mapping.

Soil mapping systems. This topic has been successfully tackled to the point of documenting the methodology involved. Although there has been significant accomplishment in the past 18 months, it requires a continued research thrust. This topic will be subject to discussion at two subsequent sessions.

Soil mapping accuracy. Accuracy of soil mapping must be considered as a number of linkages commencing with the ability of the mapper to portray the distribution of soils over a given landscape on his mapping board. A second linkage exists between the map and the legend and a final linkage between the legend and the report. Accuracy is also required in registering the manuscript soil map to a suitable base.

Discussions of mapping accuracy are many but resolutions are few. Methodologies range from subjective spot checks to objective random or grid checking of varying intensity. As the intensity of checking increases, the time differential between the actual mapping and the checking becomes less. A method which provides the maximum cost benefit ratio has not yet been devised or duplicated.

Persistence of those advocating research inputs on mapping accuracy stems from the argument that it is necessary to assess what was done in order to know what was done wrong. An alternative to hindsight is foresight. Mapping accuracy is an integral part of all levels of soil correlation. It should be checked at scheduled intervals during the mapping process. To achieve this, it is important that correlation procedures are prescribed and adhered to. As the methodology on mapping systems winds down and is put into an operational mode, correlation procedures in tune with available resources must be prescribed for the various mapping projects.

Group 3 - Soil Interpretations

Interpretation of soil delineations for different uses serves to focus attention not only on the mapping accuracy but also the limits of variability permitted within a soil series or within a map delineation. Soil descriptions are reported for the dominant soil, occassionally for significant soil inclusions occupying 15-20% of the area, but rarely for minor inclusions. This raises two questions. 1) Does this information lend itself to interpretations required for particular site locations within a delineated area i.e. a septic filter field? 2) Can interpretations be made for areas delineated on the map or only for the soil series components occurring within the delineated area?

Soil survey interpretations for agricultural purposes have been made for many years. However, the last twenty years has witnessed an increased scope of soil interpretations to the disciplines of engineering, forestry, recreation, wildlife and more recently for urban planning. In the past these non-agronomic interpretations were done by the resident soil surveyor because resource personnel for a particular discipline were either not available or lacked pedological expertise at that time. This may no longer be the case.

Presently there are disciplines such as Forestry who have pedologists on staff with competence to make their own interpretation and are hesitant to have resident soil surveyors making interpretations from cook book recipes. In contrast, interpretations by resident pedologists for recreational purposes have been requested and well received by Parks Canada. Obviously, interpretive requirements will reflect, to some extent, the state of the art in user disciplines. Consequently, the need for different kinds of interpretations must be periodically reconsidered.

In view of the above discussion, I will confine my remarks to research needs on soil interpretations for agricultural activities:

1. Soil-climatic suitability indexes for different crops on different soil landscapes. Of necessity this must encompass interactions of soil moisture storage capacity, weather and plant (evapotranspiration) integrated to form soil bio-climatic areas. Cooperation among pedologist, agrometeorologist and plant scientist is essential for the success of this project.

2. Production input requirement on different farm systems on different soil landscapes. This research need has a very wide scope because it entails the major components of the Land Evaluation Program:

- Farm Systems Characterization
- Crop Growth Models,
- Land Use System Maps
- Productivity Ratings,
- Recurrent Cash Costs,
- Managerial Inputs.

Productivity ratings for map units while beneficial, do not tell the whole story. Different map units may have similar crop yields. However, although the yields may be similar, the inputs required to achieve these yields may be quite different. Previously, there was practically no data available for the various input requirements. Fortunately, this is slowly changing. Thanks to the Land Evaluation Program, a limited amount of data has now been collected and synthesized for the Ottawa area and for an area near Melville, Sask. The results are most enlightening and add a new exciting dimension to the interpretations of map units. This will be the topic of one of the following presentations.

Conclusions

During this period of budget and man-year restraints we must use our expertise wisely. We must foresee future data requirements and respond quickly to them. The continuing focus on land and the evaluation of productivity in terms of economic, energy and managerial inputs may well necessitate the collection of this kind of data at the sacrifice of traditional laboratory analysis. It is important that we address ourselves to the fact that we can no longer afford to analyze non-definitive properties solely to occupy space in soil reports and computers. Nor can we continue to spend time attempting to map subtleties among soil parent material, calcium carbonate levels or slope classes.

Crop Information Systems

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Introduction

Information on agricultural production - at regional, national and global levels - is presently collected and used by diverse agencies. The quality of this information, especially at the global level, has frequently been questioned. The Research Branch, Agriculture Canada, has been working on the development of a Crop Information System designed for improved accuracy of assessment of the current crop situation and applicable at any of the levels of interest. The System integrates -

i) remotely sensed imagery of the earth's surface (especially satellite data) for assessing acreage, general growing conditions and type of growth.

ii) global meteorological data used in agrometeorological modelling for the prediction of crop yields and meteorological satellite information for information on the spatial occurrence of the meteorological data and weather systems.

iii) a data bank of soil and land resource, and

iv) historical crop and climatic data.

Earlier work conducted in the Agrometeorology Section, now in the Land Resource Research Institute, concentrated on development of weather-based yield predictions of cereal crops. Currently, attention is being given to the application of these to the estimation of grain production in other wheat producing countries. System development will see the incorporation of these equations for wheat with other crops for domestic applications.

The Land Resource Research Institute brings together the main professional disciplines involved in land studies within Agriculture Canada. Emphasis is on the integration of information on weather/climate, soil and land-use in view of growing demands on Canadian soil resources. In addition to the activities carried out by five sections (Administration, Soil Classification, Land-Use and Evaluation, Agrometeorology and Soil Survey and Correlation), Management and staff members of the Institute are also responsible for two important Research Branch Programs: Land Evaluation and Crop Information Systems. The two Programs are integrated with ongoing research and development work in the Land Resource Research Institute as well as with the activities in the field of crop information conducted by other institutes and departments, especially the Policy and Economics Branch and the Food Production and Marketing Branch of Agriculture Canada.

Development of a Crop Information System

The goal of the Crop Information System Program of the Research Branch is to develop and integrate research knowledge, data sources and assessment of technology into operational systems which meet the requirement for current information on agricultural production in Canada and abroad. The requirement is for a coordinated Canadian capability of acquiring, processing and evaluating relevant satellite, airborne, meteorological and ancillary data (land resources, climate, agronomic and statistical crop data) supported by a research program for improving the accuracy and efficiency of the data required in the production and marketing of Canadian crops.

The final objective of an operational Crop Information System is as follows:

> To provide near real-time information on crop and weather conditions from satellite, airborne and meteorological data for forecasting crop production and assessing the supply aspects in the domestic and international marketing of Canadian crops.

Data sources

The Crop Information System requires data from several sources for development and assessment of procedures and for providing crop information in analog climatic zones on a near real time basis:

i) historical soil, agricultural crop and climatic data,

ii) near real-time (current) meteorological data, and

iii) near real-time (current) remote sensing processed information for earth satellites (eg. LANDSAT), meteorological satellites (eg. NOAA, Meteosat) and other airborne sensors.

iv) reference and verification data from test sites.

The flow of data and their interaction is shown in Fig. 1.

Major studies in progress

Current studies are concerned with the collection of ground-truth data and their processing into information on areal distribution of crops (Fig. 2, Table 1). Research into spectroscopic properties of crops and soils, new sensor techniques and soil-climate interpretations are in progress at several universities at research establishments across Canada (Table 2). Thus a back-up research program is being developed to ensure continued improvements and introduce new developments as needed. Test areas are strategically located in the various soil-climatic subzones for acquiring reference data for testing and evaluating of new concepts.

Contribution from the Agrometeorology Program

The Agrometeorology Program of the L.R.R.I., especially through its agrometeorological data bank and crop-weather modelling activities, provides an essential input to both the Crop Information System and Land Evaluation Program of the Research Branch. The Agrometeorology Program features a combination of unique characteristics:

i) Research, experimental development and agrometeorological data processing services are fully integrated and provide continuous feedback to each other.

ii) The program has a strong supporting function for other Branch projects. It has significant input to two Research Branch Programs: Land Evaluation and Crop Information System.

iii) Research support and services are also provided to other Federal Departments, Provincial establishments, universities and the private sector.

iv) The scope of the Agrometeorology Program is quite broad and includes: Crop Weather Modelling, Agroclimatic Resource Analysis, Crop Yield Estimations, Climatic Variability and Food Production, Climatic Aspects of Plant Winter Survival, Farm Planning and Operational Management.

v) The Research applications are oriented within programs directed towards practical requirements in agriculture and the results have been recognized departmentally, nationally and internationally.

The Program provides the framework for 9 research projects and related agrometeorological data processing activities (Table 3).

Development of a Land Resource Reference Data-Base

Landsat 1 which was launched in July 1972 started a stream of data flowing back to earth which was received with great optimism. Among the optimistics were the pedologists and nearly every province had several remote sensing projects related to soil survey activities. Six to seven years later the initial flurry of these survey oriented projects subsided. Many frustrations were encountered due to the hardware and software being unable to provide image compatibility with other soil information sources. In addition, resolution capabilities were not properly understood or utilized. In most cases approaches were not suitable and few benefits were obtained using the traditional approaches.

During the last few years there has been a shift from remotely sensed soil survey projects to those dealing with spatial distribution of crops. These latter studies evolved from establishment of the Canadian Spring Wheat Program in 1973 which subsequently co-operated with the LACIE Project. These programs focused initially on the identification of spring wheat areas and yield estimates. This in turn provided production estimates within administrative boundaries ranging from Crop Reporting Districts to the Prairie Region. More recently, studies have been conducted on the winter wheat growing areas of the USA (Kansas) and will eventually expand to other wheat exporting nations. The same period of time witnessed the development of studies focusing on rangeland and special field crops such as rapeseed.

One of the prime difficulties experienced with early procedures of identifying crops from Landsat data was due to variation in light reflected from different soils which then interfered with the spectral reflectance from the plant canopy. Obviously, this interference varied on different soil landscapes, particularly if the crop canopy was sparse.

The above problem which was recognized in Canada for many years, has now been resolved to a considerable extent. The first step was to establish a broad framework of selected attributes representing soil and agro-climatic properties. This framework was derived by overlaying a map of agro-climatic subregions (from CLI maps) on a map showing soil zones (from soil survey maps). The resulting relatively large areas are referred to as soil-climatic subzones. Within these subzones, natural soil and landform features were then used to establish boundary conditions of landscapes with similar spectral reflectance and degree of spatial variability. This was achieved by compiling maps of land systems at a scale of 1:250,000. The land system delineations were characterized by a recurring pattern of soils occurring within defined classes of slope, surface form (ie. landform), genetic parent material and soil texture. These components of land systems represent the non-seasonal, relatively permanent characteristics of the landscape thereby differing from Biophysical Land Systems in that vegetation was not used in a definitive role. However, this concept does permit the subsequent preparation of overlay maps showing the seasonal effects of weather, vegetation cover types and cultivation practises.

To further develop and evaluate the procedure, the Wynyard area was selected as it contained in one map sheet many of the problems encountered. The Land Systems Map for the Wynyard map sheet occurring in the central agricultural area of Saskatchewan was assembled and later digitized by CanSIS. It was then registered onto a geometrically corrected Landsat image. This registration procedure facilitated both convenience and accuracy of locating oneself on Landsat. It also provided a systematic analysis of digital reflectance data which served as a basis for grouping one or more land systems that appeared similar to Landsat. For example, hummocky knob and kettle areas with slopes of less than 5% appeared similar to those with 5-10% slopes but differed from those with 10-30% slopes. Areas of loam and clay loam textured lacustrine parent materials also appeared similar but differed from those of sandy loam.

Having grouped the individual land systems which appeared similar to Landsat, the next step in the procedure is to overlay the current seasonal weather pattern. This will give rise to areas of relatively uniform productivity for each growing season. Thereby, boundary conditions can be established from which crop classifier data sets derived from small ground truth training sites may be sensibly extrapolated.

As indicated earlier, these land systems maps have become an integral part of the crop information system. They have been prepared for Saskatchewan south of 53^{o} North latitude. A follow-on program must now be implemented to collect this information for the rest of the Prairie crop producing area. It is anticipated that this concept will materially increase the accuracy of extrapolating crop data from small training sites.

Other data and research requirements

In the recent past, data and research requirements concerning the application of remote sensing technology have been focussed primarily on providing information on spring-seeded cereal crops. However applications of remote sensing should also be oriented to providing information on:

1. Land Use System Mapping
- Seasonal changes from year to year
- Temporal changes within a growing season

2. Recurrance of fallow as an indication of susceptability to spread of soil salinity.

3. Seasonal susceptability to wind erosion.
- Present vs recommended strip widths
- Areas with high probability of occurrence of winds with erosive forces

4. Soil Mapping
- Firming up soil zonal boundaries.
- An overview of areas which are drained externally (disected) or internally (hummocky knoll and kettle).
- The occurrance and distribution of Gleysolic soils in small internally drained depressions (kettles).
- The persistence of small water bodies.

These requirements extend beyond those of the crop information system to encompass activities in soil survey, land evaluation and agrometeorology. To achieve the desired results within a credible time frame, continuing communication efforts and careful planning are required among these disciplines.

Outlook

In the past, the research and development work on crop information systems as described has been carried out through in-house projects and contracts under the Research Branch Crop Information System Program. Pilot projects have demonstrated the feasibility to apply remote sensing and ground information to the assessment of crop production in Canada. Plans are at hand for the development of an operational system which provides near real-time information on crop condition and potential yields of selected crops in Canada and other major food exporting/importing countries in support of marketing decisions. Such a retrieval system would involve several departments, agencies and private enterprise concerned with the use of soil-crop production information in long-term planning and day-to-day decision-making.

Figure 1 - DATA SOURCES

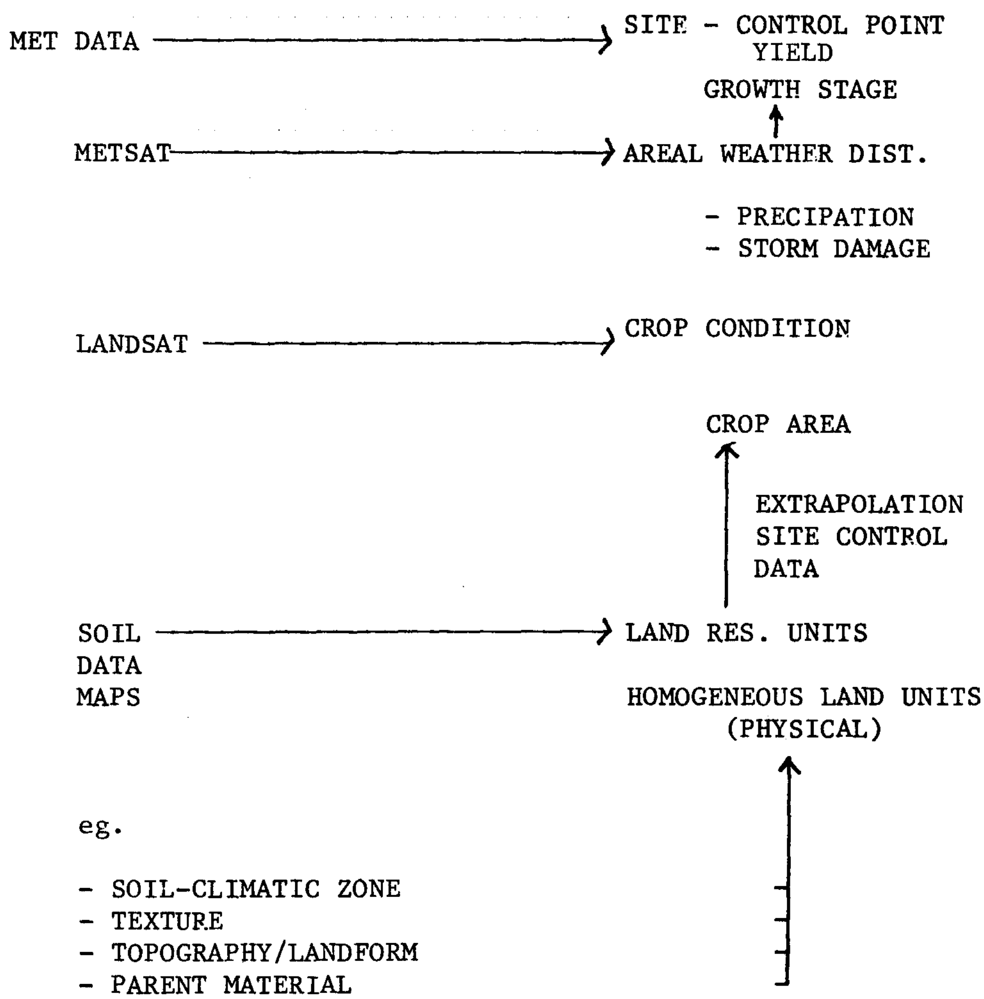

Fig. 2

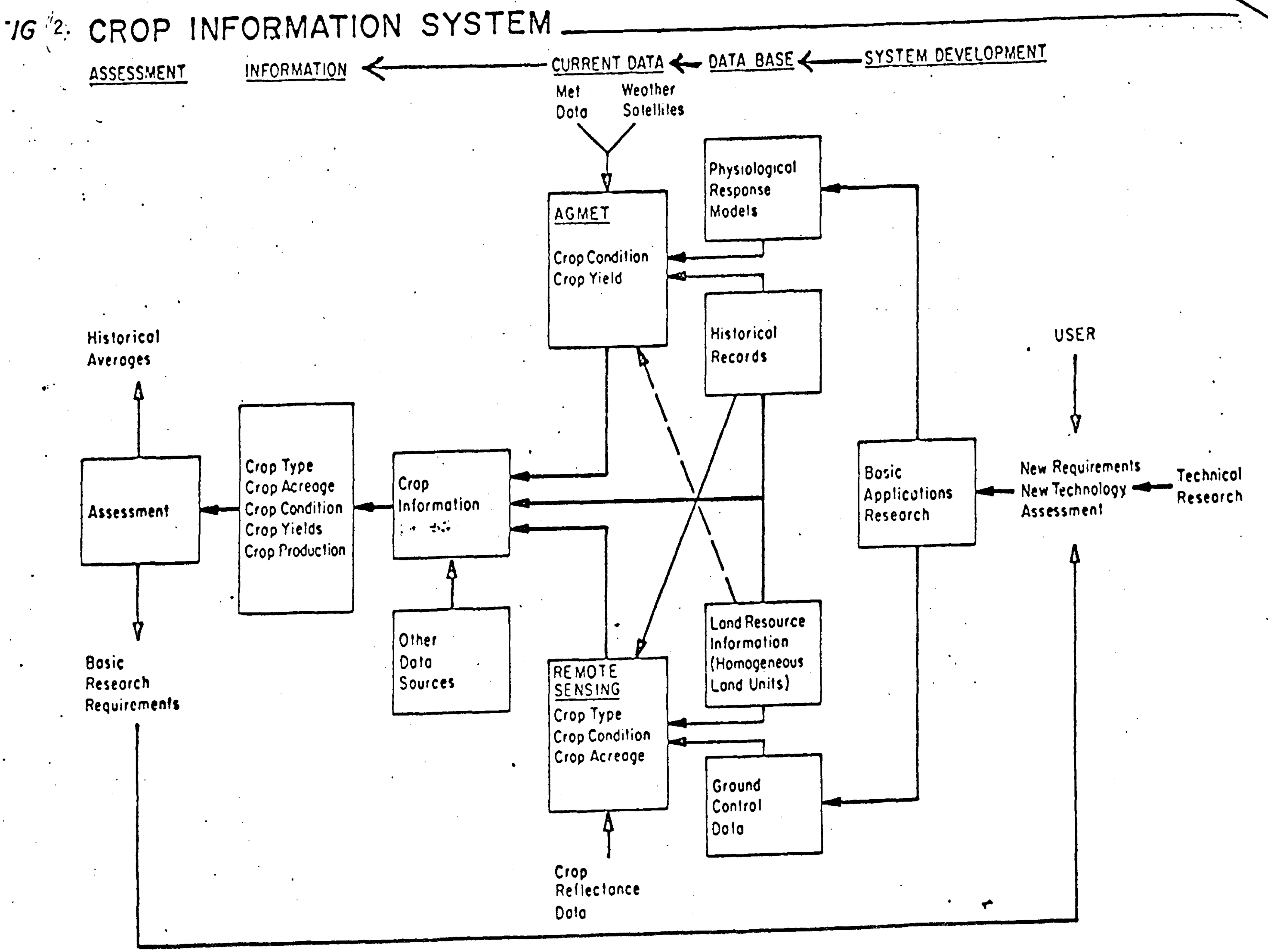
FIG #2: CROP INFORMATION SYSTEM
ASSESSMENT
INFORMATION
CURRENT DATA
DATA BASE
SYSTEM DEVELOPMENT
Met Data
Weather Satellites
AGMET
Crop Condition
Crop Yield
Physiological Response Models
Historical Records
Land Resource Information (Homogeneous Land Units)
Ground Control Data
REMOTE SENSING
Crop Type
Crop Condition
Crop Acreage
Crop Reflectance Data
Other Data Sources
Crop Information
Crop Type
Crop Acreage
Crop Condition
Crop Yields
Crop Production
Assessment
Historical Averages
Basic Research Requirements
Basic Applications Research
USER
New Requirements
New Technology Assessment
Technical Research

Table 1. - MAJOR STUDIES UNDERWAY
Remote Sensing

I INFORMATION ON AREAL DISTRIBUTION OF CROPS

a)	Cereal Crops	
	Spring Seeded	
	Fall Seeded	
	Research Sites	11 Western Canada
		4 Kansas
	Verification Sites	30 Saskatchewan
		Kansas
b)	Special Crops	
	Rapeseed	34 Western Canada
	Miscellaneous	
	(beans, potatoes, corn, alfalfa)	S.Ontario/N.B./Quebec
c)	Rangeland	
	Research Areas	Southern B.C. Foothills, Alberta North-eastern Sask. (Kamloops, Lethbridge, Melfort Res. Stn.*)
		* New proposal
d)	Salinity - Lethbridge	

Table 2 - MAJOR RESEARCH STUDIES

(Remote Sensing)

II Special Research Studies

a) Spectroscopic Properties
University of Manitoba

b) Species Classification
University of B.C. - Kamloops

c) Microwave (Radar)
University of Guelph
Spring Wheat Test-Sites
C.E.F.

d) Photographic Quality
University of Toronto
NRC

e) Laser Fluorescence and Bioluminesence
University of Manitoba

f) Soil Water (Geological Survey of Canada)
/LRRI
University of Saskatchewan

g) Soil Interference
LRRI - Dr. Shields

h) Soil-Weather-Remote Sensing
LRRI-Contracts

Table 3- LRRI AGROMETEOROLOGY PROGRAM

	PROJECT	PROJECT LEADER
1.	Plant productivity	R.L. Desjardins
2.	Physiologically-based Crop Models	D.W. Stewart
3.	Modelling Soil-Water-Plant and Atmosphere Interrelations	H.N. Hayhoe
4.	Agroclimatological Data Interpretation	S.N. Edey
5.	Agroclimatic Resource Analysis	G.D.V. Williams
6.	Site Suitability Zones for the Winter Survivial of Forage Crops	C.E. Ouellet
7.	Crop-Weather Relationships	W. Baier
8.	Agroclimatological Applications	R.B. Stewart
9.	Development and Application of Remote Sensing in a Crop Information System	A.R. Mack
10.	Agrometeorological Data Processing Support and Services	D.A. Russelo

APPENDIX 2
LAND EVALUATION

Land Evaluation for Soil Survey

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Introduction

The land evaluation program was started in a very small way in 1976. Initially some time was spent in developing methodology proposals, in experimentation on computer assisted climate mapping and on quantifying the agricultural capability scheme of the Canada Land Inventory (C.L.I.). Beyond this two pilot studies on methodology were established, one at the University of Guelph for central Canada and one at the University of Saskatchewan for the Great Plains.

Except for the attempt at quantifying the C.L.I. the results of these initial probes by-and-large have been successful. The climate mapping program has been expanded to cover all of the Great Plains and south western Ontario. Some prototype evaluation methods have been developed at the University of Guelph, and these are now being operationalized for Ontario conditions. In Saskatchewan, the first phase of the study is being completed but due to manpower and other restrictions this will not be carried further.

Development of the Land Evaluation Program

Many people have had an input into the land evaluation program over the last three years. Out of their efforts four underlying, complementary concepts have evolved.

a) Land evaluation is the procedure of interpreting basic inventories of soils, climate and other environmental variables in an effort to i) indicate possible land use alternatives, ii) indicate the relative worth, utility or importance of allocating a particular use, as opposed to all others considered, to an area, i.e. how important is it that a specific land use be allocated or preserved in a given area.

b) Inherant in the above concept is the notion of scarcity value (demand for, strategic improvement of, competition) i.e. land has value not only because of its natural characteristics, but also because of the demand for the produce or output of some particular land use given that there may be several potential uses for the same land area.

c) Land evaluation does not identify the "best" use for an area (which is land planning) but indicates the land use options (degree of flexibility) under conditions of changing economics, population, energy resources, climate conditions, societal demands, etc. (i.e. what are the land use options under various scenarios). The only fixed item in a land evaluation is the land itself, all other items are variable.

d) Land evaluation is an application and an extension of soil and land classification for purposes of land use planning and land use policy assessment and development.

Apart from the research which has gone into methodology development two other events have played major roles in the evolution of the program. The first of these was the 1977 CARC report to CASCC which identified five major areas of land resource research for the future. These were rural land evaluation, crop productivity, land use planning, rangeland classification and socio-economic research. At present a national "Strategy for Land Resource Research" is being prepared by the CCLRS, and this will be submitted to CASCC in 1980.

The second event was the national land evaluation work planning meeting held in 1977. This pooled the collective wisdom of about 75 scientists of many disciplines from across Canada. The major conclusions of this meeting were:

a) the initial focus in land evaluation should be on agricultural evaluations, not in isolation but within the context of various other uses competing for the same land area.

b) The program would be useful only if it was future oriented and evaluations were dynamic and time dependent. Also it should have a bilevel approach, i.e. one for broad scale needs (policies, economics, etc.) and other for more detailed needs.

c) The FAO principles for land evaluation apply for Canada (alternate use possibilities, economic and environmental effects of each land use, productivity evaluations), but the FAO methodology is deficient and too much oriented to suitability. More work is needed on development of methods.

d) The major land use problems in Canada at present are urbanization, land degradation relative to agricultural land use practices, land reclamation, new land development and infrastructures in the north, and the general void of information on how farmers are using their land (farming systems).

e) Presently the major data deficiencies for land evaluation are climate data, farming systems (socio-economic research) and yield/ performance data.

f) The greatest need at the national level is for a broad scale input/output model to assist in land use policy development. However since no specific land use policies are on the horizon, the program must be flexible and open ended, and it must be structured on sound scientific principles and focused on basic information.

In response to these and several other concerns, the major thrusts in the land evaluation program are i) regional climate assessment, ii) crop productivity modelling, iii) crop yield and economic input/output assessment and iv) economic land allocation modelling. Aspects of land degradation are being worked into the program where they are important and where data are available.

Land Evaluation and Soil Interpretations

Land evaluation and soil interpretations are somewhat similar in purpose but they differ in concept and procedure. According to Funk and Wagnall (1977), to interpret means to convey the meaning of, to explain or construe; to evaluate means to find or determine the amount or worth of. The central difference is the notion of scarcity value which is embodied in land evaluation but not in soil interpretation.

The two differ also in procedure. Traditionally interpretations have been done following one of three approaches: a) Interpretive schemes - the process of interpreting the elements embodied in a soil map for certain narrowly defined uses; usually of local application. b) Land Classifications (capability, suitability) - the process of identifying the quality of land (soils and climate) for various broadly defined land uses, or the fitness of land for general or specific land uses; generally of regional or national application. c) Soil ratings - the process of deriving comparative indices for the performance of soil for specific, generally narrowly defined uses; usually of local application.

All of the above are necessary, and all have their place in the field of applied land resource assessment. Their major drawbacks are that all are static classifications and as a consequence the results of each are difficult to interpret relative to changing situations and changing needs. Land evaluation utilizes the best of these where this is deemed to be advantageous but: a) it concentrates on dynamic procedures rather then static classifications in an attempt to provide a means of evaluating land under changing conditions and needs. b) computer modelling is a major focus of the program, but it is not the most important aspect. c) it requires large, relational data bases, either estimated or developed through research programs. d) it is always multidisciplinary.

The land evaluation program is still in an experimental phase. Most of the work is being done under the contract research program, by university personnel. Some progress has been made in the areas of crop yield modelling, development of relational data bases and land allocation modelling. The farming systems research is also showing promise. Although preliminary results from the various facets of the program are encouraging, much remains to be done to tie the elements together in an operational system.

Development and Testing of a Phenological Model
for Small Grains in Saskatchewan

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The principal objective of the recent modelling work in Saskatoon has been to make a comprehensive test of the model WHTMOD, previously developed by Walker (1977). Without adequate testing, much effort might be spent improving aspects of the model which are not important under actual growing conditions. Fortunately, the 1977 and 1978 data from the Palliser Wheat Production Project were available (Wilkinson et al., 1978; Wilkinson, 1979), and contained information sufficient for modelling purposes on field scale plots scattered over a wide area of Saskatchewan. To assess the predictions of the model during the growing season, and as a first step towards expanding the model to incluclude crops other than wheat, small plots of wheat and barley were also sampled at two-week intervals throughout the 1978 growing season.

WHTMOD is essentially an empirical model and may be described broadly in terms of its three major component sub-models: Robertson's biometeorological time-scale (Robertson, 1968), Baier-Robertson's soil moisture budget (Baier et al., 1972), and a (modified) dry matter yield equation of de Wit (1958). The time-scale is used to estimate the dates of emergence, jointing, heading, soft dough and maturity. The growth stage determines critical factors such as the optimum growth rate, susceptibility to stress, and root distribution. The soil moisture budget monitors the moisture available for transpiration and evaporation. The growth rate is reduced by the proportion of water actually transpired to that demanded by the atmosphere, and by a site-dependent nitrogen factor determined from previous site yields, Dry matter production is calculated daily, and summed to the end of the season. The equation used is: Y=(m)(f)(Ts/PE)(Nf) where Y is the daily production of dry matter, m is a crop production factor (kg/ha/day), f is a factor that varies with growth stage, Ts is the in cm, and Nf is a nitrogen factor.

A number of changes were made to the original WHTMOD to facilitate the testing procedure. Since values for field capacity, wilting point, and bulk density (formerly part of the input), are not generally available, it was decided to estimate them from the soil texture and soil zone. The method used is that of de Jong (1978). All environmental data were stored in resident disk files, rather than being read in from cards. Temperature data was stored according to the reporting meteorological station, rainfall by site (site data was available from the Palliser Project), and solar radiation and day length obtained from Russello et al. (1974) were stored by degrees of latitude. The biophotothermal time-scale for barley (Williams, 1971) and a separate barley m value were added to enable the model to make predictions for barley as well as wheat. Walker's method of estimating Nf was replaced by an approach based on standard soil test and fertilizer data. This was done in a very simple way, by assuming that all the soil and fertilizer nitrogen was in the NO_3 form, and uniformly distributed through the soil solution. In addition, from 1.67 to 2.5 kg/ha of mineralizable N was added for each centimeter of the A horizon, according to the soil zone. A nitrogen factor was calculated from the concentration of nitrogen and used to reduce the daily dry matter production, as in Walker's approach (Ward, 1979). This method is too simple to make accurate predictions of nitrogen uptake and plant protein, but it has the desired properties of predicting yields for different nitrogen treatments and utilizing readily available data.

The small plot data was obtained from 22 sites located on fields of farm cooperators near Saskatoon. There were 14 wheat sites (6 on summerfallow) and 8 barley sites (6 on summerfallow). The Palliser data consisted of approximately 30 10-acre plots of wheat in each of 1977 and 1978. Although 3 varieties were grown, only Glenlea sites were tested with WHTMOD because this variety was grown both years at all sites.

An initial run was made on all the data without significant further revisions to the model, to be used as a benchmark for future testing. A suitable value for the coefficient m was determined from the small plot data, before running the Palliser sites. It was observed that the moisture use and dry matter predictions were higher than the actual values during the early part of the season. Also, the final yield predictions for some northern sites of the Palliser data were higher than expected, probably because the model's predicted yield is an increasing function of growing season length. An attempt was made to solve these problems, by reducing the demand for transpiration duirng the early season, and by setting a maximum yield independent of growing season length. The sites were then run again. A comparison of actual and predicted yileds on the 22 small plots is shown in Table 1. Weeds caused a severe yield reduction on sites 1 to 4. The results of the 1977 Palliser predictions are presented in Figure 1. The 1978 predictions were less consistent, particularly with regard to summerfallow and stubble differences. A side effect of reducing transpiration demand is that moisture stress is also reduced causing some yields to be over predicted. This stress should be simulated by making available moisture dependent on the amount of live root dry matter.

Conclusions

The results show that the model does require some improvement, but at the same time some cautious optimism is justified regarding the basic approach. It is surprising that this model can predict as well as it does considering its early stage of development. Without repairing any of the apparent flaws in modelling moisture and nitrogen effects, predictions could be improved by altering coefficients. Further, there are examples in the data where a poor simulation of moisture use or nitrogen effects has been the cause of a faulty prediction. Corrections can be made within the existing framework of WHTMOD, but time and care are required to make them effective.

Table 1. Land evaluation field data and WHTMOD predictions.

	Wheat					Barley			
	Dry Matter kg/ha		Grain kg/ha			Dry Matter kg/ha		Grain kg/ha	
Site	Actual	WTHMOD	Actual	WHTMOD	Site	Actual	WHTMOD	Actual	WHTMOD
1	2675	6909	1101	2737	7	6810	8594	2918	3359
2	3245	6803	1343	2694	8	5485	8594	2223	3359
3	3670	6919	1306	2690	9	9480	8861	4086	3465
4	5730	6421	2113	2492	10	10240	9176	4690	3591
5	6750	7338	2605	2836	11	2285	6095	1005	2338
6	6840	7408	2520	2864	12	2265	6105	1036	2341
13	4300	5274	1508	1902	21	6520	7718	3071	2960
14	4480	5231	1777	1885	22	6220	7618	3105	2922
15	5150	5481	2390	2035					
16	4240	5388	2024	1950					
17	3830	5928	1619	2149					
18	5545	5900	2350	2139					
19	8380	6873	2754	2496					
20	5108	5869	1900	2120					

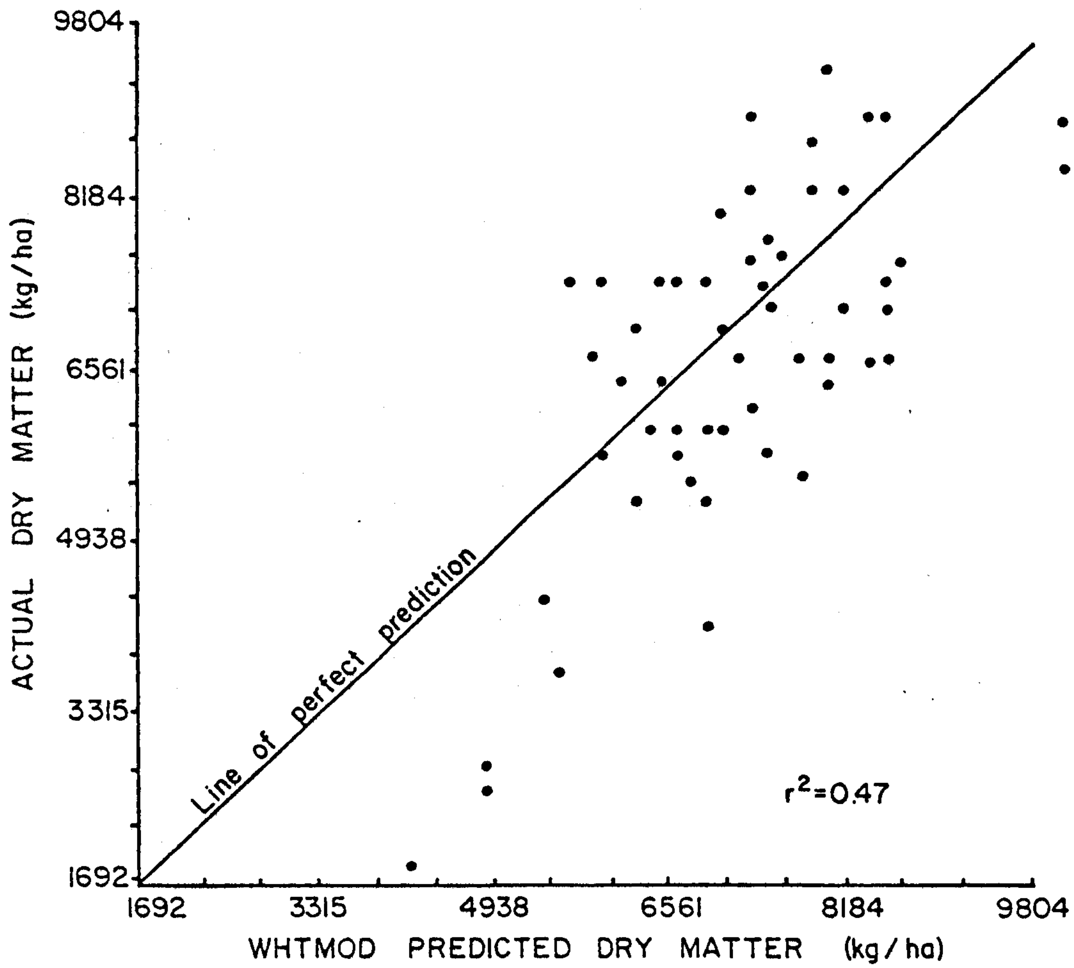

Figure 1. Relationship between actual and WHTMOD predicted dry matter production for the 1977 Palliser sites.

Land Productivity Models for Ontario - The Guelph Program

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Introduction

The productivity of land, in an agricultural context, is determined principally by the capability of the soil and associated climate to produce crops of economic importance. The Canada Land Inventory land capability system has classified land on a provincial basis according to this capability. Attempts have been made in recent years by Hoffman (1973) and others to determine quantitative values for the productivity of the different classes. While the CLI capability system has been used extensively, it has serious limitations for comprehensive land evaluation. The program at Guelph is designed to provide a system for productivity ratings that will overcome these deficiencies.

The relation of productivity to the land base should be expressed in a way that the impact of changes to the variables involved can be readily predicted. Of particular interest is the variability of production on different soils due to variability in climate and/or changes in the management or technological inputs. The system should also ensure comparability or results in all regions of Canada.

The CLI capability system includes climate as a subclass in the same manner as a soil limitation. The effect of climate is therefore static and estimates of capability are based on the climate that has existed during the past 10-15 years, the period during which most of the observations of yield were made. While climatologists differ in opinion as to whether the climate will become warmer or colder, there appears to be some agreement that it is becoming more variable. Extreme events are likely to occur more frequently than they have during the past 30 to 40 years. It is important that we develop a system to assess the impact of these changes on the productivity of our soil.

The CLI capability system assumes a high level of maangement but does not effectively consider the interaction of management with the soil characteristics. The level of management and the inputs required to obtain the potential productivity will vary with the soil characteristics and climate and therefore should be incorporated into the system.

The approach that we have adopted in our land productivity program is to develop a quasi-process oriented simulation model to predict yield of a crop as a function of climate, soil characteristics, and management inputs. Treating climate separately from soil characteristics, allows flexibility in dealing with climatic variability. The climatic component will permit the estimation of temporal variation in yield within a climatic region as climate varies. It will also permit comparison of yields from region based on long term climatic conditions. Thus, if one assumes optimum management and no soil limitations, an index value can be established for regions based on climatic differences. The soil and management components will indicate the reduction in yield within a climatic region due to soil or management limitations. The effect of a given degree of a soil limitation may vary with climate and management. Hence there must be an interaction among the three components of the model.

The major advantages of this approach over a strictly empirical or a regression approach are: 1) it provides much greater flexibility for change and development as new information becomes available and 2) it serves as a guide to further research by revealing those aspects to which yield variations are most sensitive or for which our understnading is inadequate. An empirical or regression approach is, to a certain extent, a snapshot and therefore static.

There are two major factors which must be continuously recognized in the development of the system. The first is that the application of the system will be based on the soils inventories that are available through the soil survey programs and the climatic data available from the standard climatological station network. Thus all inputs must be available in or derivable from these sources.

The second factor that must be kept in mind is the scale at which the system will be applied. We visualize that the land productivity models will be used for two somewhat different purposes. The first is to assign a productivity rating to each of the major soils in Canada under differing climate and management inputs. The second is to provide estimates of the productivity of given regions for use in the land evaluation model. The scale requirement of these two uses are somewhat different. Indeed, the scale requirement of the second use will change with the size of the region being considered. As the scale of application increases, the relative importance of the different components of the model will undoubtedly change. We believe, however, that both uses can be accomplished with the same model.

The approach that has been used in development and testing of the models is to calibrate them using detailed site-specific information and yields. The soils information used is obtainable from the soils inventory. Hence a set of soil characteristics that determine productivity can be assigned to each mapping unit in the inventory which is at a scale of 1:50,000. The land evaluation model will be used at a scale of about 1:1,000,000 with regions of 10,000 acres or more being considered homogeneous from the socio-economic viewpoint. Areas of this size may also be homogeneous from the climatic viewpoint. While it is not realistic to consider the soils homogenous, it will be possible to aggregate the productivity of the soil mapping units within a region to arrive at the productivity for that region using the models.

Although the general concepts of the models can be similar for all crops, specific models must be developed for each crop or group of crops. Alfalfa hay and corn have been selected for initial phases of the program. Alfalfa hay was selected because it is grown in all agricultural regions of Canada. Thus it will allow testing of the model as a means of comparison of the productivity in all regions. Corn was selected because if its major importance in southern Ontario. We believe it is desirable to develop similar models for soybeans and for cereal grains. This would allow extrapolation to most field crops. Specially crops such as fruits and vegetables are more specific in their requirements or are influenced to a greater extent by non-land factors. It is suggested that a different, more specific approach will be required for these crops.

Description of Models

Two plant growth and development simulation models have been used to estimate forage and corn yields for the purpose of land evaluation from an agricultural productivity standpoint. The forage model (SIMFOY) was developed by Selirio and Brown (1979) for a "dry weather-forage crop" insurance plan in Ontario, under contract with the Crop Insurance Commission of Ontario. The corn model (SIMCOY) was also developed by Selirio and Brown (1977) under contract with Agriculture Canada for land evaluation purposes. These models have been modified for use in the land productivity program.

Crop Growth. Both SIMFOY and SIMCOY assume that growth follows an idealized sigmoidal curve with time (Fig. 1). This idealized growth curve is broken down on a daily basis and as degree days or corn heat units accumulate growth progresses following the curve. Departures from the potential daily growth increment are due to limitations in soil moisture.

In SIMFOY the harvestable dry matter at the end of each growth cycle (each cut) depends on the accumulated daily growth increments and limitations in soil moisture. In SIMCOY, which is the more complex model, the final harvested plant dry matter depends also on accumulated corn heat units and limitations in soil moisture. The grain yield is estimated using the ratio of actual to potential evapotranspiration with a weighting factor for the relative sensitivity of grain yield to moisture stress in each of five growth stages.

Soil moisture availability. In both SIMFOY and SIMCOY, daily soil moisture is estimated in each of several soil zones starting with the profile at field capacity in the early spring (a realistic assumption for somewhat humid climates) by using potential evapotranspiration calculated from a modified energy budget approach and an extraction pattern that depends on soil moisture content and root distribution. The soil moisture is brought into both models by using a daily growth rate factor which decreases linearly from 1.0 (or 100%) of the potential growth when the soil contains 80% of more of the maximum available moisture than can exist in that particular soil to 0 when the soil is at the wilting point

(Fig. 2). This parameter "available moisture" must be determined for each soil profile in question for meaningful predictions.

In addition to the soil moisture holding properties of the soil, it seems realistic to assume that a reduction in root growth in a layer with a high bulk density would reduce the ability of the plant to extract water. Hence not all the "available" water in that layer would be accessible to the plant and the growth rate factor should be reduced. It was recognized that the ideal model would include a root growth component to estimate the density of roots in each layer (cm of root/cm^3 of soil). This however would require a very complex model. It was decided to use a more simple approach in which the standard root distribution is altered according to a relationship between root growth and bulk density (Fig. 3).

This function indicates that once the bulk density of a layer becomes greater than 1.3 g cm^{-3} the bulk density becomes a limiting factor in root penetration. This function deflates root content linearly with an increase in bulk density from 1.3 g cm^{-3} to 1.7 g cm^{-3} (assumed to be the upper limit of bulk density at which root penetration is completely inhibited). The decrease in root content results in a decrease in the daily growth rate factor for estimating the dry matter production. It also results in a decrease in actual evapotranspiration which is used in estimation of corn grain yield.

A special case of the bulk density deflator occurs with the existence of a restricting layer. In some soils, the bulk density at some depth will be such that no roots will penetrate. Hence the soil moisture in that layer and all layers below it will be unavailable.

The models will therefore, require values for the available moisture holding properties and the bulk density of the different horizons of the soil. Attention is currently being directed to the estimation of the upper and lower limits of available moisture in soils.

Validation Studies Conducted in 1978

The validation of a model requires that the output from the model be compared with measured values obtained under the range of conditions for which the model is to be applied. In the land evaluation program, we require prediction of yields obtainable under management systems that are used at the field level. Hence it is not realistic to validate the models against experimental plot data. Another reason for not using experimental plot data is that experimental plots are generally situated on the better classes of land. Rarely will experimental plot data be available from steeply sloping or eroded land for example. Yield estimates from these situations are required for proper validation of the models. It is not valid to use data from one source (experimental plots) for one situation and from another source (field data) for another situation.

For these reasons, it was concluded that yields from farm fields were required for poper validation. Although field yields are available from a number of sources, the precision of these yield estimates was not thought to be adequate for validation. In addition, the soil and climatic inputs required are seldom if ever available for these yield estimates. Hence it was decided that a field program of data collection was essential for proper validation.

Another essential aspect of model validation is that each component of the model be validated rather than only the final output. This allows a clearer insight into the aspects that require improvement when the final output does not compare well with the measured values. In our models, this required that the soil moisture content and crop growth be measured periodically during the growing season.

The approach that has been taken in the validation is to select fields on farms that have a high level of management and that offer a wide range in soil and climatic variables. An area selected for detailed study within each field was instrumented with neutron probe access tubes for soil moisture measurement. The site was characterized thoroughly and the necessary soil moisture and crop growth measurements were made at approximately two-week intervals throughout the growing season. Rainfall was recorded on each farm and other climatic inputs were obtained from the nearest A.E.S. climatological recording station. The data from these sites allowed a detailed assessment of the functioning of the models.

Because of the importance of soil moisture in the two models it was important that we have as much variation as possible in available moisture holding capacity and in precipitation. To accomplish this, we selected farms in two widely separate regions; namely Brant and Carleton Counties. These regions were chosen primarily because of the detailed soils inventory information which was available.

Within each region, three locations were selected for each of two crops, corn and alfalfa hay. The three locations included a coarse textured soil, a fine textured soil with density limitation, and a medium textured soil. Two sampling sites having differing degrees of erosional damage were selected on the medium textured corn location in Brant Co. Two sampling sites varying in texture were selected at the coarse textured corn location in Brant Co. Thus a total of 14 sampling sites were used in the 1978 field program.

Examples of the simulated and measured dry matter production of forage are indicated in Figures 4 to 7. Figure 4 is from a loam site in Brant Co. at which the simulated growth was quite similar to the measured growth. The site represented in Figure 5 was a clay soil also in Brant Co. The simulated yield at this site was considerably lower than that at the loam site (Fig. 4) due primarily to the effect of the higher bulk density. The measured yields were below those simulated which is thought to be due to a less than optimum stand at this site. The poorer stand may be due to inherent soil characteristics or to management. The sites represented by Figures 6 and 7 are from the same farm in Carleton Co. on a loam and a clay soil respectively. The higher measured relative to simulated yield on the loam site (Fig. 6) is thought to be due to the presence of a perched water table which prevented a moisture stress. The model does not account for this situation. The measured and simulated yield on the clay site were quite similar and are much higher than those on the clay site in Brant Co. The bulk density of the clay in Carleton Co. was much lower than that in Brant Co. so the yield was not limited by bulk density.

To validate the models at the field level, a detailed soil survey of the field was conducted and the yields predicted by the models for each mapped soil unit will be aggregated to give a simulated yield for the field. This yield will be compared with the measured yield from the field.

The models will also be tested for application at the farm level. Management information has been collected and farmer estimates of yields of corn and alfalfa hay will be obtained for each field on each farm in Brant Co. The soil characteristics of each field will be determined from the soils inventory and the expected yield determined from the models for each soil mapping will be aggregated to estimate the total yield of the two crops on each farm. This will provide a preliminary validation of the models at the farm level as well as priving information on management and its incorporation into the land evaluation model.

The results of the 1978 validation trials have indicated a number of modifications that are required in the models. These are currently being made. In addition there are several aspects that have not yet been included in the models. These include fertility, excess moisture and management. These will be included as time and funding permit.

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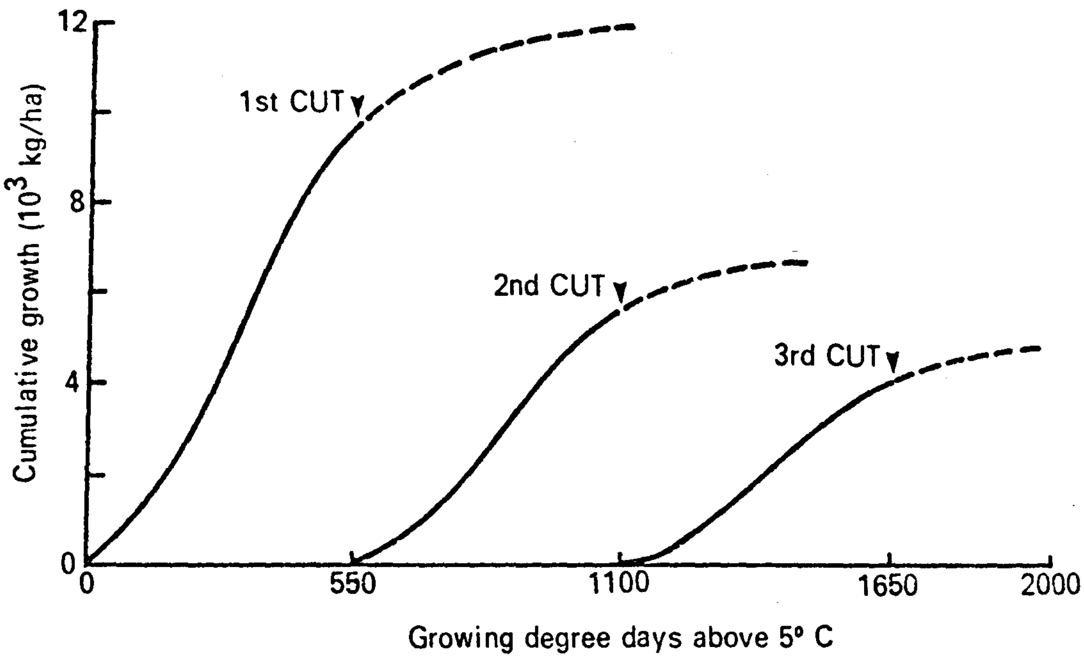

FIGURE 1 Idealized Growth Curves Used In Program SIMFOY.

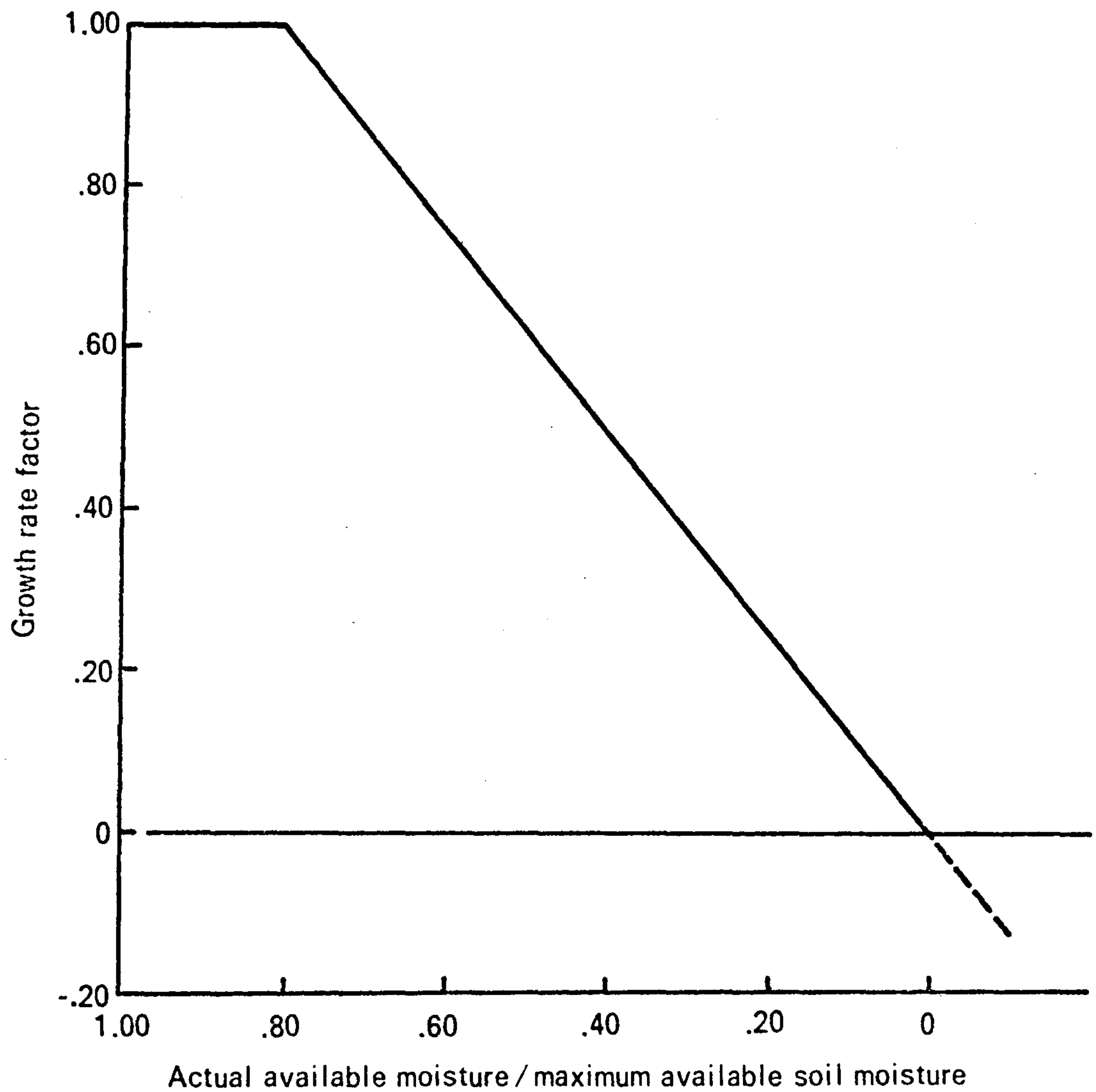

FIGURE 2 Assumed Growth Rate Factor-Available Moisture Relationship.

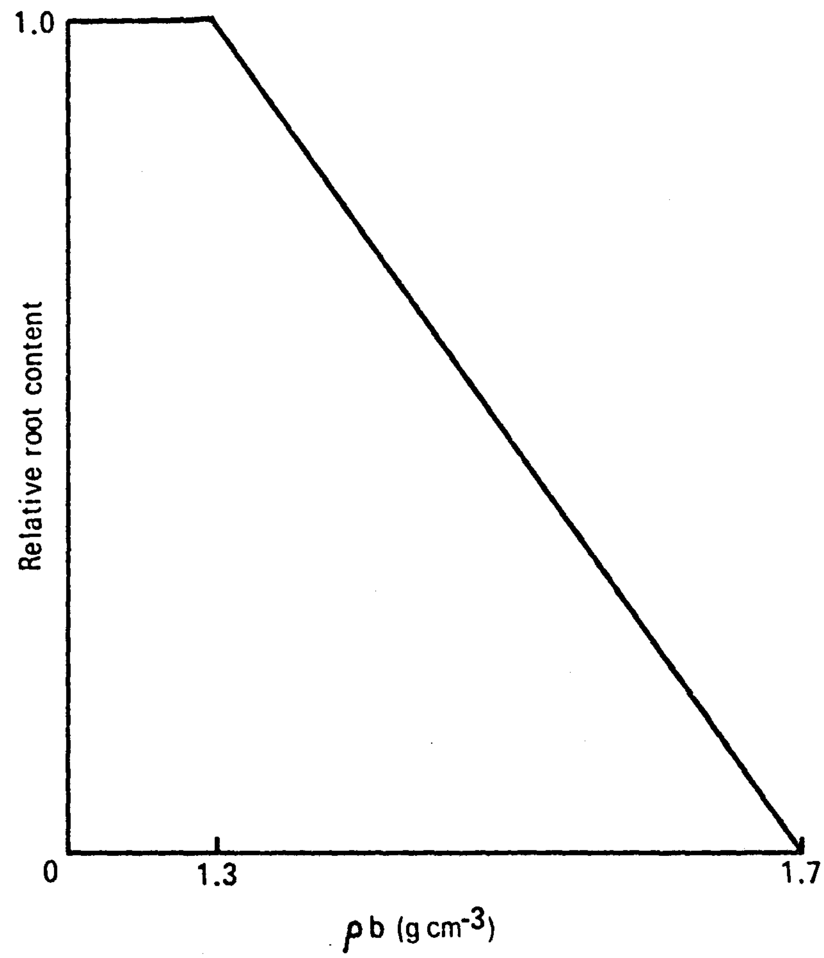

FIGURE 3 Relationship Between Root Content and Soil Bulk Density.

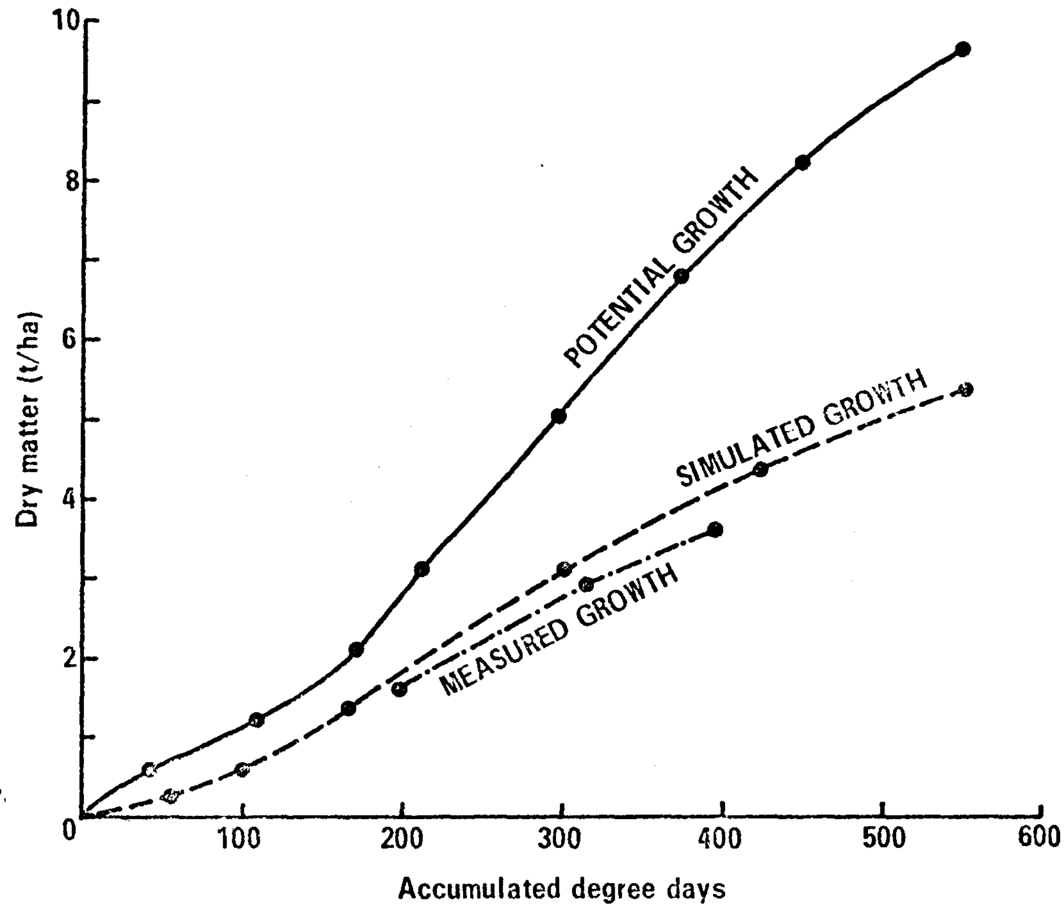

FIGURE 4 Comparison of Measured and Simulated Growth of Alfalfa Hay on a Loam Site in Brant Co. 1978.

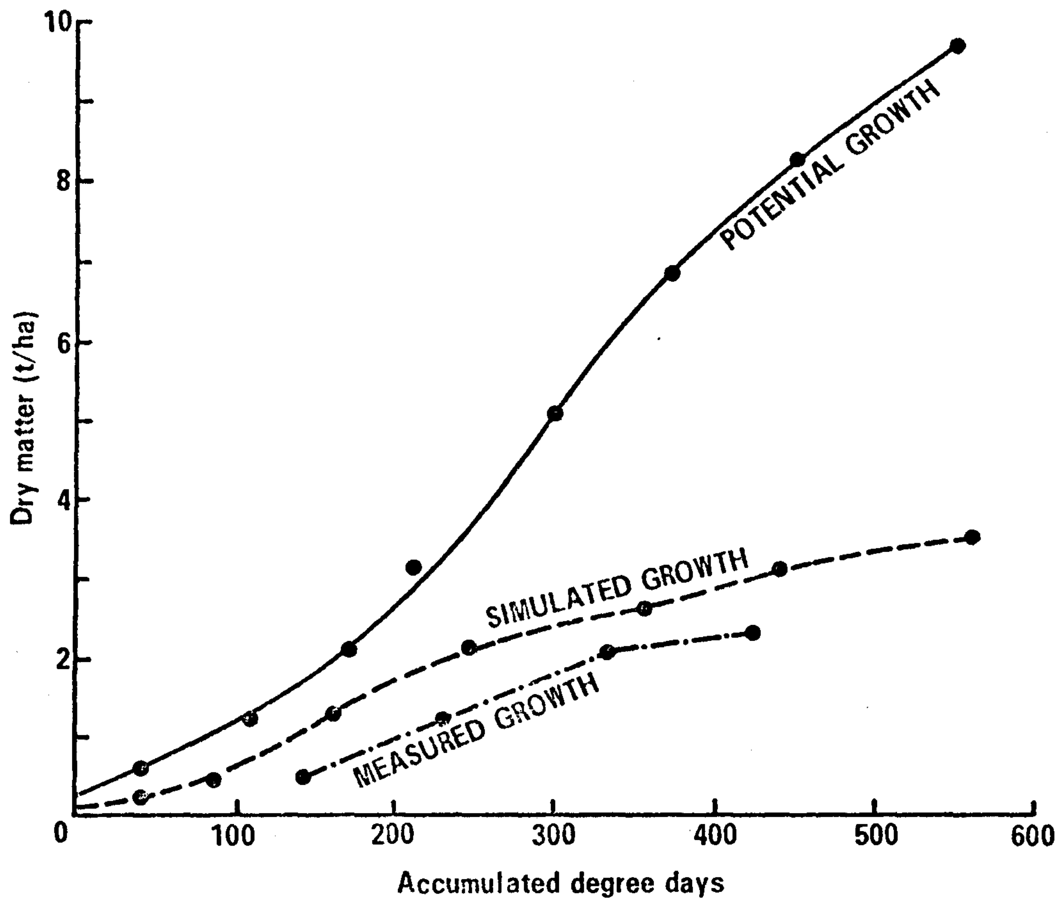

FIGURE 5 Comparison of Measured and Simulated Growth of Alfalfa Hay on a Clay Site in Brant Co. 1978.

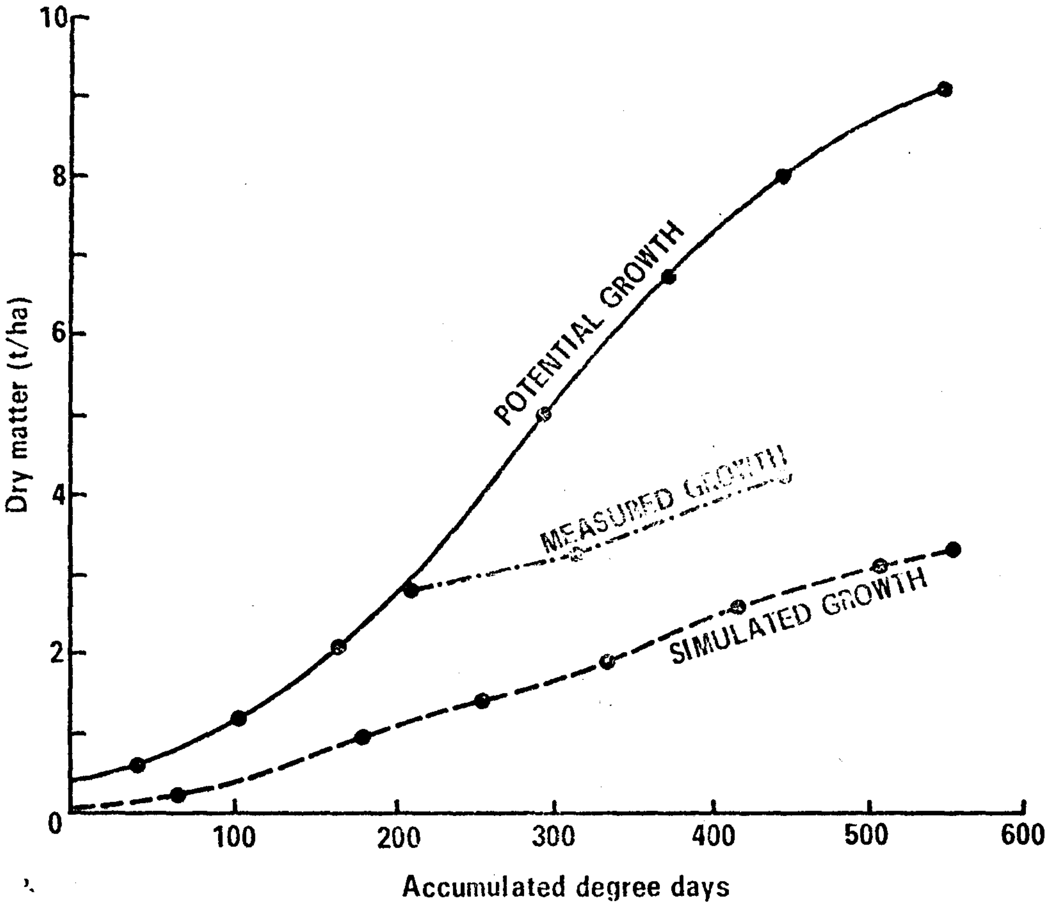

FIGURE 6 Comparison of Measured and Simulated Growth of Alfalfa Hay on a Loam Site in Carleton County, 1978.

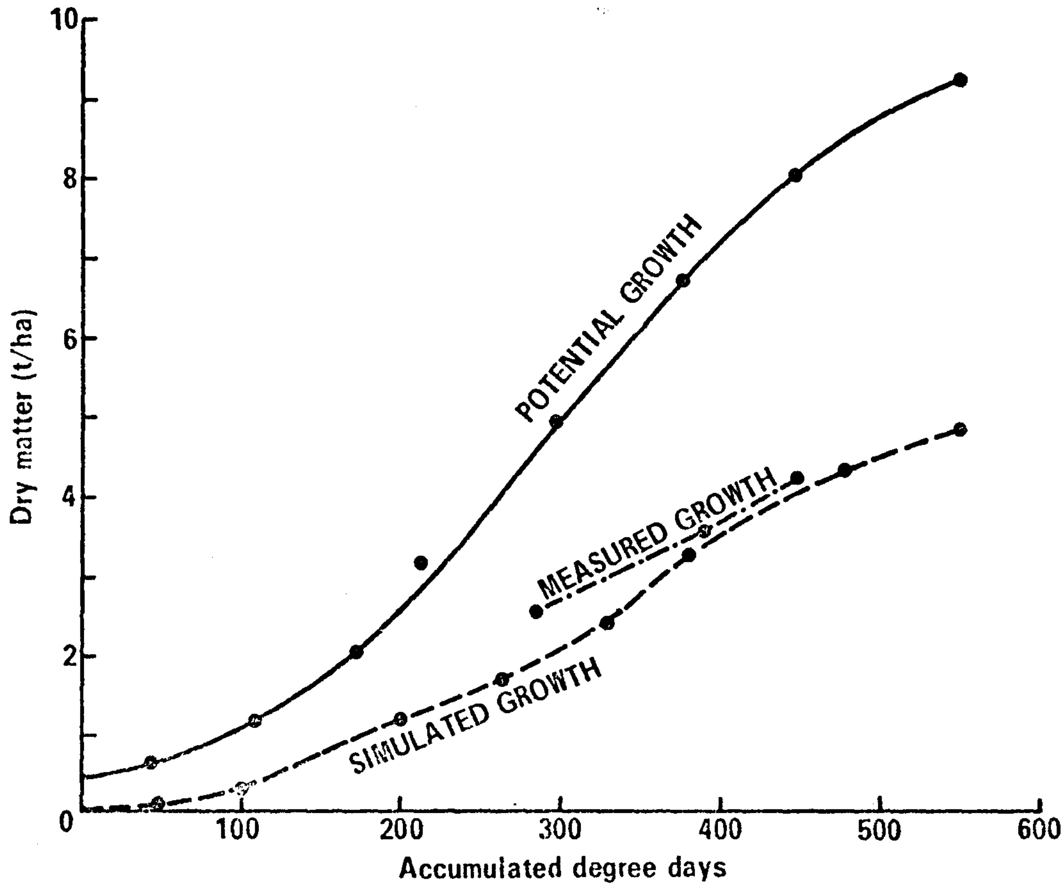

FIGURE 7 Comparison of Measured and Simulated Growth of Alfalfa Hay on a Clay Site in Carleton County, 1978.

Multi-dimensional bases for Land Evaluation

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During the past two years, the Rural Land Evaluation Contract at the University of Guelph has been involved with the development of methodologies for a land evaluation system. This research involves three areas of focus: the specification and interpretation of allocation-evaluation models, the design and construction of multidimensional tables, and the development of crop productivity models. The latter two concerns pertain to the measurement or estimation of data required for the land evaluation procedure. This paper describes the design, construction and use of a multidimentsional table as a data base for a land evaluation system. This includes a brief overview of the land evaluation system as proposed at Guelph and an indication of the connections between the model, the multidimensional table and crop productivity modelling activities, a general outline of procedures for the design and construction of multidimensional tables, and a brief description of the prototype data base that was developed at Guelph.

The methodologies developed at Guelph have considered land evaluation as "a system which indicates the relative worth or utility of allocation a particular use, as opposed to all others considered, to an area" (Centre for Resources Development, Publication No. 82, 1977). This system attempts to indicate the strategic importance of land areas for certain uses if specific socioeconomic-environmental objectives for the use of land are attained. It can be regarded as a synthesizing technique that incorporates what is known about the capability or 'performance' of land for certain uses and the needs or objectives that the land has to meet (e.g. - production requirements of agricultural commodities, or the limitations of available resources, or perhaps desirable levels of pollution and erosion in the use of the land resource) and indicates how important each area is to each use in the attainment of these objectices.

The implementation of this system requires a wide range of research activities. Several general requirements for this procedure can be listed as follows:

1) the identification or definition of alternative combinations of land and land use: the "units for allocation" which are to be considered in the evaluation procedure. (These represent the variables in the mathematical specification of an allocation evaluation model). This requires the definition of land types and land use types.

2) the measurement or estimation of "performance characteristics" for each land/land use combination (e.g. - values of commodity production, resource utilization, gross returns, erosion levels, etc.). These

values are used as Left-Hand-Side (LHS) coefficients in the constraints of the model.

3) the specification of societal objectives for each aspect of performance for the entire land use system. These values represent the Right-Hand-Side (RHS) limits or goals in the formulation of constraints for the model.

4) the programming of an allocation-evaluation model using this information, the solution and interpretation of the model for the evaluation of land and land uses.

The construction of a multidimensional data base provides a convenient means to store data for land evaluation and represents an initial accomplishment or requirements 1 and 2 (above). The design of this table represents the same problem as the definition of land and land use types. Each typology of land and land use is represented by a separate axis in the table. The categories along each axis of the table represent the defined types of land or land use. In its simplest representation, the multidimensional table concept is a three-dimensional table with separate axes of land use types, land types, and commodity types or 'performance characteristics'. Theoretically there is no upper limit to the number of axes that comprise the table. Any degree of complexity can be represented in the definition of the land use system within the limitations imposed by computer storage facilities and by the specification of the models.

Several initial considerations are important prior to the definition of land and land use typologies. Attention must be given to the general objectives for a land evaluation system and to the nature of the questions that the system is expected to address. Factors which affect the extent and location of the use of land and factors which affect the 'performance' or capability of certain land for certain uses should be identified. Any '*a priori*' criteria imposed on the definition of these typologies must be identified - e.g., that particular economic regions or political boundaries be identifiable, or that typology definitions result in types with relatively homogenous characteristics and demonstrate significant differences between types.

Following thse considerations, the definition of land and land use typologies is constrained by limitations in the scale or completeness of coverage of the available data sources from which the multidimensional table could be computed. Clearly a data source must supply the criteria to enable the identification of the land and land use types in addition to supplying the data on various performance characteristics. Limitations in the specification of allocation models or in computer storage facilities may also constrain the potential typology definitions to describe very large and complex data bases (multidimensional tables) for land evaluation. It may also be important to consider the appropriateness of the typologies to the possible use of simulation models (i.e. - crop productivity models) in the estimation, imputation, or alteration of particular cell values in the tables.

It may be useful to consider an inventory of possible 'land units' and 'land use units' prior to the definition of land and land use typologies. These 'units' could be defined as basic spatial or functional units of land and land uses, for which data is available from various sources - i.e. - soil mapping units, fields, farms, Canada Land Inventory Units, Canada Geographic Information System polygons, Census divisions, provinces, etc. A consideration of various levels of aggregation of these units might provide a better idea of the compatability between data sources and between various definitions of land and land use typologies.

The actual construction of a multidimensional table involves programming the appropriate algorithms for each typology and computing the table from the selected data source. This enables a calculation of a 'performance' statistic:

q_{ijk} which represents the amount of characteristic k produced or used by land use type i on land type j,

for each cell of the table. Statistics of this type are readily formulated into constraints for the allocation-evaluation model. To demonstrate using a simplified example, if q_{ijk} represents the known production of wheat from use i on land j, and the variable X_{ij} represents the area of land type j allocated to use i, and given we have information on the societal requirement for wheat production Q_k, then a constraint of the form:

$$\sum_i \sum_j X_{ij} \cdot q_{ijk} \geq Q_k$$

forces the allocation of all land or land use combinations to meet this requirement in a solution of the model.

There is a potential application of the crop productivity models being developed at Guelph for the estimation of similar values for empty cells in the multidimensional table, or where alteration to existing values is required to replicate the conditions described by a particular scenario for the land use system. Also, due to the fact that any data source used in the construction of the multidimensional table will contain localized or temporary anomalies in the data, and that the evaluation system proposed is more appropriate to long-range planning, the use of crop productivity models (and the development of similar models for other characteristics) may be a more realistic means to compute values for multidimensional tables. Thus it may prove to be an important consideration that crop productivity models (and other simulation models) and multidimensional tables be developed with compatible or comparable scales and typology definitions.

Several initial considerations affected the design and construction of the prototype multidimensional table developed at Guelph. A prime intent was to establish a data base to use in the implementation of a land allocation-evaluation model within the contract time period. An attempt was made to maintain a relatively simple structure for this prototype data base and yet one that would serve as an adequate demonstration of some of the potentials and limitations of the land evaluation procedure. For these reasons, the typology investigation relied on reviews of current literature and initial research efforts that were at times cursory and somewhat expedient. An additional decision affecting the typologies was that the prototype land evaluation procedure would consider only agricultural lands and land uses. The final structure of the prototype data base resulted from the definition of typologies of land uses and land units. This structure is roughly demonstrated in Figure 1, which indicates an axis of land use types, an axis of environment zones, and an axis of land capability types. An additional axis of commodity types or 'performance characteristics' which is not apparent in the 2-dimensional view presented in Figure 1, describes a fourth "k" axis of the table.

In the prototype data base, land uses or farm types are identified on the basis of the combination of enterprises (or mix of commodities produced) on individual farms. Enterprises are loosely defined as major commodity groups (i.e. - grains, feeds, or dairy enterprise, etc). A farm is typed by comparison of its actual enterprise mix to farm types with various theoretical or ideal enterprise mixes and is assigned to the farm type to which it demonstrates the closest statistical similarity. This results in the identification of a possible 66 farm types, denoted by subscripts along the "i" axis of this table.

Land types are represented by two separate axes. Environmental zones denoted by subscripts along the "j1" axis, are identified as macro regions demonstrating homogenous characteristics of climate (defined by Corn Heat Unit Intervals), of urban influence (defined by population density and real land values), and of regional economy (arbitrary definition). Land capability types, denoted by subscripts along a "j2" axis, are identified as areas demonstrating homogenous characteristics of agricultural capability (Canada Land Inventory classes). The seven environmental zones and the six land capability types so defined combine to identify a potential 42 land types. Again, it should be noted that the criteria currently used in the definitions of categories for the axes of the prototype data base do not necessarily result in the most accurate or the most useful representation of the land and land use system.

The typologies of land use and land type which define the axes of the multidimensional table can identify a potential 2772 alternative land or land use combinations (see Figure 1). This final form of the prototype data base describes a structure for the land use system. It is of interest to note the distribution of land uses or farm types as they occur over the various land types in the prototype data base. The presence or absence of particular land use types on particular land types can be seen as an indication of environmental response in terms of the localization of particular land types for particular uses. Data on the distribution of major farm types on various land types presented in Table 1 provide some evidence to support such observations.

This kind of observation can provide a basis for an example of alternative applications for data in multidimensional tables. The calculation of coefficients of localization (after Isard, 1972) represents measures of relative regional concentration for each farm type. This type of statistic can also be presented in graphical form, as in Figure 2. This example indicates that whereas 'mixed' farm types are relatively evenly distributed across all environment zones, the 'grain-cattle-dairy' farm type is highly concentrated in zone 4, and demonstrates the use of multidimensional table data as a valuable source of information on the land use system in its own right.

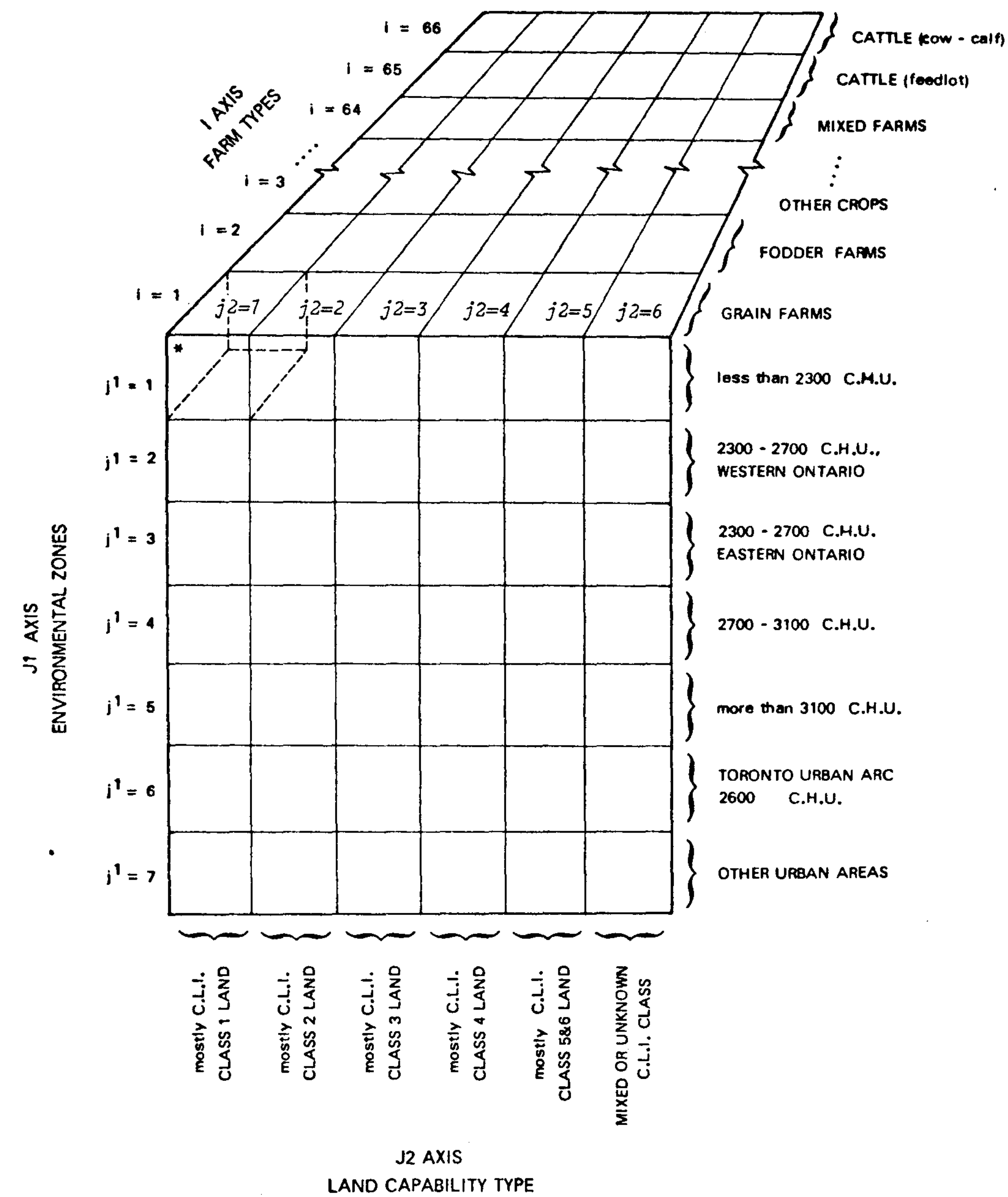
The major function of a multidimensional table, however, is the storage of data required by land allocation-evaluation models. The measurement of 'performance characteristics' for alternative combinations of land and land use types requires the identification of the defined land uses within each land type. As a source of these data, the 1971 Census of Agriculture was selected as it provides fairly comprehensive data for all farms. in Ontario. The Census enables a relatively easy tying of individual farms both to land use categories (on the basis of commodities produced and to environment zone categories (on the basis of Enumeration Area codes). The identification of land uses by land capability type, however necessitated the use of a sampling procedure. Approximately 22 percent of the Enumeration Areas in Ontario were identified as possessing relatively homogenous characteristics of land capability for agriculture. As a result, only 15 percent of the farms in Ontario could be identified to categories of land capability type.

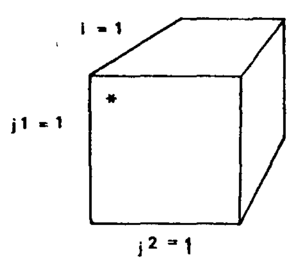
The Census of Agriculture provides data on 19 sales commodites, three resource inputs, and total sales. These 'performance characteristics' comprise the 23 categories of the "k" or commodity axis. Thus, the prototype data base consists of four major axes: land use (farm type), environment zones, land capability for agriculture and commodities (outputs and inputs). The performance of the alternative land/land use combinations defined by the multidimensional table is assessed by the measurement of the statistic:

$q_{i\ j1\ j2\ k}$ which represents the production or use of commodity k from use i on land in environment zone j1 of land capability type j2

If the variance associated with this value is also computed in the multidimensional table (as was done in the prototype data base), then analysis of variance and similar statistical techniques can be employed to suggest areas where further refinement and improvement is desirable to the typology definitions that comprise the axial categories in the table.

A more detailed description of the multidimensional tables constructed at Guelph is contained in : A Prototype Data Base for Land Evaluation in Ontario (Technical Report No. 2, published by the Centre for Resources Development, 1979). This report outlines the typology definitions, the procedures used in the construction of the table, and demonstrates some of the alternative applications for the data.





EACH 'CELL' IN THE MULTI - DIMENSIONAL TABLE, REPRESENTED BY INDIVIDUAL CATEGORIES ALONG EACH AXIS DEFINES A SET OF FARMS WITH RELATIVELY HOMOGENOUS CHARACTERISTICS OF LAND USE (FARM ENTERPRISE TYPE), ENVIRONMENT ZONE (CLIMATE, URBAN INFLUENCE AND REGIONAL ECONOMY), AND LAND CAPABILITY FOR AGRICULTURE. FOR THE CELL ILLUSTRATED, THESE ARE SPECIALIZED GRAIN FARMS IN AREAS OF LESS THAN 2300 CORN HEAT UNITS, OPERATING ON PREDOMINATELY C.L.I. CLASS 1 LAND.

AN ADDITIONAL AXIS OF COMMODITIES, OR PERFORMANCE CHARACTERISTICS WHICH IS NOT EVIDENT IN THIS 3 - DIMENSIONAL VIEW, MEASURES SALES PER ACRE DATA ON 23 COMMODITIES (INPUTS AND OUTPUTS) AVAILABLE FROM THE 1971 CENSUS OF AGRICULTURE, FOR EACH CELL OF THE TABLE.

TABLE 1

PRINCIPAL FARM TYPES BY ENVIRONMENT ZONES: FREQUENCIES AND PERCENTAGES

Farm Types	Zone 1 <2300 CHU Number	%	Zone 2 2300-2700 CHU WEST Number	%	Zone 3 2300-2700 CHU EAST Number	%	Zone 4 2700-3100 CHU Number	%	Zone 5 3100 + CHU Number	%	Zone 6 Urban Arc Number	%	Zone 7 Other Urban Number	%	Total No. of Farms
G	473	8	552	9	125	2	1988	34	2418	41	146	3	191	3	5893
F	375	23	372	23	397	24	276	17	105	6	96	6	16	1	1637
O	146	4	161	4	26	1	2938	77	489	13	35	1	17	-	3812
H	2160	33	509	8	175	3	1136	17	1801	27	712	11	123	2	6616
C*	3184	18	6509	38	2798	16	3409	20	472	3	735	4	187	1	17294
L	1300	17	2360	30	605	8	2403	30	673	9	445	6	118	2	7904
D	1146	13	1583	18	3263	37	1954	22	336	4	354	4	136	2	8772
G-F	137	17	196	24	110	13	215	26	107	13	45	5	18	2	828
G-O	15	3	8	1	-	-	230	40	312	55	-	-	6	1	571
G-H	34	5	13	2	5	1	143	21	458	68	7	1	14	2	674
G-C	163	8	355	18	107	5	940	46	358	18	54	3	48	2	2025
G-L	69	5	162	12	28	2	615	44	475	34	23	2	20	1	1392
C-L	1192	15	3895	50	463	6	1711	22	243	3	276	4	56	1	7836
C-D	799	10	2404	30	2468	31	1976	25	92	1	161	2	95	1	7995
L-D	72	8	402	42	124	13	321	34	12	1	12	1	6	1	949
G-C-L	60	5	199	17	26	2	640	53	237	20	34	3	12	1	1208
G-C-D	26	5	66	13	31	6	332	64	40	8	6	1	19	4	520
C-L-D	558	11	2562	52	471	10	1218	25	37	1	78	2	21	-	4945
MIX	1766	20	2112	24	1264	14	2243	25	898	10	470	5	128	1	8881
All others	573	14	563	14	330	8	1589	38	941	23	156	4	25	1	4177
Totals	14248	15	24983	27	12816	14	26277	28	10504	11	3845	4	1256	1	93929

Key: G - Grain; F - Fodder; O - Other Crops; H - Horticulture; C - Cattle; CA - Cattle feedlot; CB - Cattle cow-calf; L - Livestock; D - Dairy

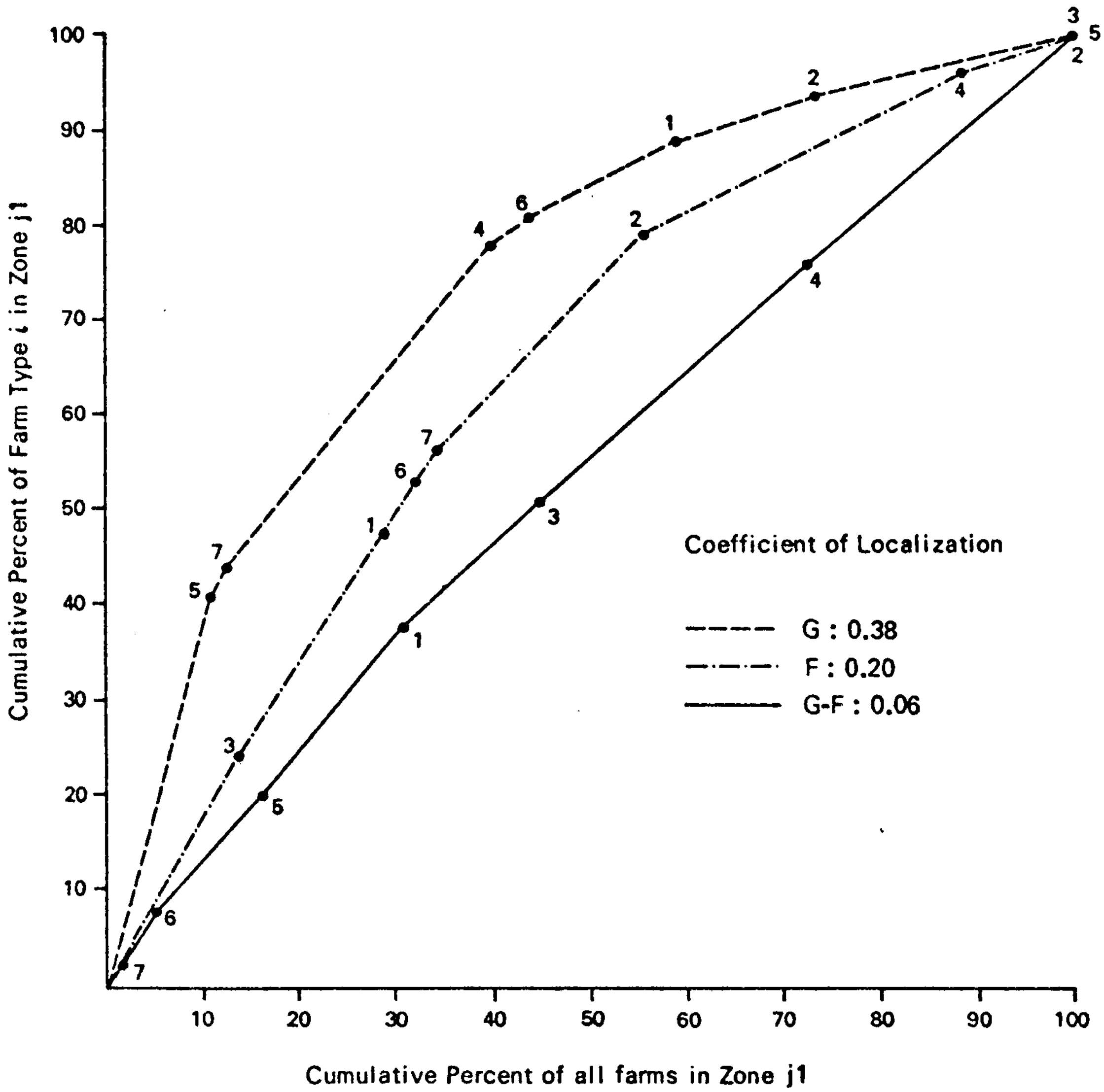
Note: C* = C + CA + CB

Note: this table represents a breakdown of the multi-dimensional table data by the farm type and environment zone axes only, and NOT by the land capability type axis.

FIGURE 2

FARM TYPE LOCALIZATION CURVES :

GRAIN, FODDER, GRAIN-FODDER



NOTE: in this representation, a farm type with ZERO localization would be indicated theoretically by a line with a slope of +1.

A System for Rural Land Evaluation

Barry Smit
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In Canada there is a growing uncertainty about the ability of the land resource to meet all of society's future demands for goods, services and amenities. This is especially true in Ontario, where the bulk of Canada's food is produced and where urban-industrial development results in increasing land demands for housing, transportation, industry, recreation, gravel extraction, and so on. Concern has been expressed over the rate of conversion of agricultural land to alternative uses, the increasing dependence on imported agricultural products, and the increasing dependence of Canadian agriculture on intensive, high energy-consuming technology.

Whilst the amount of land in each land-based activity at any point in time reflects the prevailing market conditions of supply and demand, future levels of demand and future supply factors have been notoriously difficult to anticipate. Decision makers, with the responsibility to ensure that future demands for food and fibre are met, are faced with the problem of resolving these competing demands, not knowing how changes in population, energy supplies, climate or other conditions might affect the future land needs for agriculture. In the absence of new energy-saving technology, what are the implications for agricultural land needs of a decrease in energy inputs or of a drop in annual average temperature? Under such conditions, and recognizing land needs of other competing uses, is there enough land to meet all requirements? In order to meet these requirements, is it especially important that certain land areas be retained for particular land uses?

It would seem that any rational land use planning procedure should address such issues. This is where land evaluation (or, more accurately, land use evaluation) fits in. Land evaluation is concerned with indicating the importance of areas of land for particular uses.

Land evaluation and land use planning

In planning for the use of land it is necessary to know more than simply the capability or potential productivity of soils in various uses. One area of land may be equally suitable for many uses, whereas other land areas may be less than ideal for most land uses, and trade-offs must be made for land on which more than one use might be feasible. Whether it is important that an area of land be devoted to a particular use depends not only upon the capability of the land for the potential uses, but also upon the amount and nature of the land available and the various requirements society has for the use of land, such as concerns for the provision of food and fibre, the consumption of energy and other resources, and the provision of space to house and service the population. Land evaluation attempts to indicate the strategic importance of land areas to certain uses in the attinment of specific socio-economic-environmental objectives.

Land use planning decisions are often made for local areas without knowing whether it matters that a use be encouraged or discouraged in those areas if specific national or regional goals are to be met. Land evaluation is regarded as a synthesizing technique that takes what is known about the capability of land for certain uses, about the availability of land and non-land resources, and about the goals or needs the land has to meet, and indicates how important each area is to the attainment of these objectives. This would indicate to a decision maker what land use options are open, and how much flexibility there is in the use of given land areas. It would indicate where there is little choice and where there is more flexibility in order to achieve the objectives under given conditions. These conditions may pertain to future population, trading prospects, energy resources, climatic conditions and so on. Thus a comprehensive land evaluation system could be used as a simulation tool to indicate the importance or retaining certain land areas for specific uses in the future.

A methodological framework for land evaluation

The methodology and worked examples are described in detail in Development of Land Use Allocation-Evaluation Models for Ontario, Techn. Rep. No. 1, 1978.

The basis of the land evaluation procedure is a land-use allocation model. The variables in the model are the possible land uses that could occur in the defined land areas. All known information about productivities and input utilization for each land use in each land unit is incorporated in the constraints of the allocation model. These constraints specify the known or forecast limitations to land and non-land resources and known or expected requirements for commodities produced on the land. Thus, all known objectives for the land use system can be expressed as constraints, and will be satisfied by feasible allocations of land uses to land areas.

From the feasible solutions a particular allocation is chosen on the basis of maximizing or minimizing some objective function. Given that all relevant information (limitations, requirements, etc.) on the use of land is specified in the constraint set, the objective function needs to be very general, in that it has application for future conditions (when prices and costs are unknown) and for a range of land uses (for which prices and costs might not be comparable).

A possible objective function, and the one on which we have focussed, is to minimize land use change from the current land use pattern. Such a model can be expressed

$$\text{Min. } D = \sum_{ij}\sum /P'_{ij} - P_{ij}/ \quad \text{subject to the constraints}$$

where: $P'_{ij} \doteq$ the proportion of the total area currently in land unit j and land use i.

P_{ij} = the allocated proportion of total area in land unit j and land use i.

In essence, the model states: assuming all the requirements for a future land use system are expressed in the constraints, choose that system which, while satisfying those conditions, minimizes the change from the present land use pattern. Such an objective might be justified from two points of view:

i) a conceptual rationale: all the information we have on what will determine the future land use allocation is included in the constraints. Unless the constraints uniquely determine the solution (highly improbable), we are uncertain as to which of the feasible allocations is most likely. Selecting that allocation which minimizes change from the present system recognizes the inertia in land use patterns and is particularly appropriate for models that consider a diversity of land uses.

ii) an applied reationale: minimizing land use change might be interpreted as minimizing the costs of achieving the objectives stated in the constraints; that is, minimize adjustment costs (social and economic).

The output from the allocation model, the P_{ij}'s, indicate the proportion of the total area that needs to be allocated to each land use (i) in each land unit or area (j) in order to satisfy the conditions and achieve the objectives specified in the model. Two measures of importance or value of allocating a certain use to a particular land unit are readily calculated from this output, but only one is reported here.

The evaluation measure is given by the ratio:

$$W_{ij} = \frac{P_{ij}}{\sum_i P_{ij}}$$

This ratio indicates the importance of allocating land unit j to use i rather than to some other use. If the value of a W_{ij} is one, then, in order to satisfy the objectives, it is essential that land unit j be retained for use i, at the exclusion of all other uses. Such a result would indicate that, with the information given (production requirements from land, resource availability, input and output characteristics, etc), there is very little flexibility in the use of land unit j: it should be devoted exclusively to use i. Values of W_{ij} at or approaching zero would indicate that land unit is not important for that land use.

The evaluation measure W_{ij} has a particular interpretation. W_{ij} measures 'importance' if the objectives are to be achieved (given the input-output and other information contained in the constraints) <u>and</u> if we wish to minimize the change from the current land use pattern. In other words, to minimize land use disruption is an objective in addition to those specified in the constraint set (satisfy certain production requirements, recognize limits on resource availability, etc.).

The great advantage of W_{ij} as a measure of value is that it is dimensionless, in that it is independent of other units of measurements used in the analysis. It can be used in evaluations in which objectives refer to a variety of factors, measured in different ways. All these measures can be converted to one intuitively appealing measure of scarcity or value or importance. The importance of allocating to certain uses (or groups of uses) not only specific areas or land types, but also regions (aggregations of land units) can be determined.

Another noteworthy characteristic of the evaluation methodology is that the system makes it possible not only to measure the strategic importance of each unit of land for each use, but also to indicate the strategic importance of each land unit in the attainment of the objectives, and to measure how important each objective is to the land use pattern that is generated. The importance of each objective set for the system can be measured in terms of how much it affects the value of the objectives function. Those objectives that most influence the land use patterns will contribute more to changes in the value of the objective function. This is a very useful feature, since most attention should be focussed upon those objectives that have the greatest effect on the land use system. The methodology thus provides a means of evaluating objectives in terms of their impact on land and land use, as well as a means of evaluating land and the land uses in terms of their contribution to meeting objectives.

The system as an aid to decision making

The methodology outlined in the previous section confronts the difficult problem of combining objectives measured on different scales into one dimensionless measure of value or worth. In so doing, a useful tool is provided to guide research into future land use allocations as well as to plan for the rational use of land. The methodology assists in making the policy and planning problems more manageable for human decision makers but it does not replace decision makers. The model, besides giving measures of the strategic importance of allocating specific uses to areas permits the ordering of constraints in terms of their importance to the system. This can be useful information to guide policy making and planning to achieve some objectives, identifying the more crucial changes necessary in a system.

It should be apparent that such an evaluation system would have application to a wide range of land use and land use policy issues. The system permits the investigation of such questions as 'what is the value of putting this unit of land into a particular use if given objectives are to be met?', 'how critical is the supply of certain types of land?', 'what effect would a given increase in the demand for certain agricultural commodities have upon the land use system?', 'what adjustments in land use patterns would be necessary if the supply of certain resources was limited?', 'how necessary is it that a certain area of land is available to agriculture or forestry if given objectives are to be achieved?', 'what would be the impact on these objectives and on the land use sysetm given certain changes in the environmental-economic-technological environment?'

Operationalizing a land evaluation system

A multi-disciplinary team, co-ordinated through the Centre for Resources Development at the University of Guelph, has constructed a prototype land evaluation system for Ontario. A number of steps are necessary to operationalize such a land evaluation system (Figure 1). The scale and level of detail at which the procedure is to operate is established in the definition of land uses and land units. The land units should distinguish areas that are relatively homogeneous with respect to soil, climate, economy and other ecological variables. The prototype model identifies land units according to environment (climatic, economic, urban influence) zones and land capability types, together defining 42 distinct land units (the j axis) for Ontario. Land uses can refer to any categorization of land-based activities. In the prototype model agricultural uses are considered explicitly, although land requirements for other uses can be incorporated into the system via constraints on the supply of land. Land uses are defined for the protopype model in terms of identifiable farm systems (i axis), of which 66 are defined for the prototype model.

The definitions of the i and j categories have important implications for data; they define the basic structure of the data set. Data on productivities and input utilization levels need to be computed for each type of farm on each land unit. These input and output coefficients can be estimated for current conditions or for different climatic or technological conditions.

Once the units for allocation have been established, it is necessary to specify the constraints to the allocation system. The constraints state the limitations, capabilities and requirements (objectives) which the land allocation must meet, and upon which the evaluations are based. The prototype model includes constraints on the availability of land, on the availability of other input resources and on amounts of commodities that are required from the agricultural use of the land.

Additional data requirements follow from these constraints. Information needs to be gathered on land and resource availability and on commodity requirements. These values will vary depending upon the time period being considered and assumed conditions regarding population, consumption, trade, and so on.

In the development of land evaluation models, there is potential for the specification of many kinds of additional or alternative constraints. While some constraints may be considered to be logically necessary, others might represent specific policy objectives. Conceptually, any number of

As an example, a scenario that assumes reduction in the area of land available for agricultural uses might be implemented to assess the affects of a continued loss of farmland to other uses. A uniform 5 percent reduction in the area of land available for agriculture is assumed in this scenario, but the other constraints remain at the 1971 levels.

The value of the objective function for the model under this scenario is .0755, indicating that moderate changes from the current land use pattern would be necessary to accommodate the reduction in the farmland area and still satisfy the other conditions specified in the constraints. The nature and location of these changes can be determined by comparing the output with that from the test run, or by examining the change variables $(P'_{ij} - P_{ij})$ in the output. For instance, under this scenario of reduced land availability, the proportion of zone 5, land type 1 in 'horticulture' farms would need to be increased slightly at the expense of 'cattle', 'other livestock', and 'mixed' farms, if the specified objectives are to be achieved. The importance of selected farm types in this zone/land type are shown in Table 1. These results indicate that grain farms remain important in this zone/land type, while the importance of horticulture farms increases at the expense other farm types when the total amount of land available for agriculture is reduced by 5%.

The output pertaining to the land availability constraints indicates that increases in the amount of land available in zone 2, classes 1 and 2; zone 4 class 1; zone 5 classes 1, 2 and 3; and zone 6 classes 1, 2 and 4 would have the greatest effect in reducing the total land use changes. The results also indicate the likely effects of changing other conditions, such as commodity requirements.

Sensitivity Analysis

Given defined units, an appropriate data set, and a certain set of constraints, the evaluation procedures can indicate: the changes necessary in the use of land in order to achieve the stated objectives, the likely impact of changes in any objective on the land use system, the value of any land unit (or aggregation of units) to the attainment of the objectives, and the value or importance of any land unit for any use in order to satisfy the constraints. An important application of the procedures is to determine these values under different sets of conditions or scenarios. The comparison of results from different scenarios, indicates the sensitivity of the results to changes in some aspect of the model specification or data values. Different scenarios can be established by changing any or all of a number of aspects of the constraints: 1) the constraint set itself, i.e. add or remove constraints; 2) the right-hand-side values of one or more of the constraints; 3) the coefficients (e.g. productivities and input utilization) on the left-hand-side of one or more of the constraints. Constraints can thus be modified to reflect expected or assumed conditions influencing potential uses of land, or to reflect alternative objectives or policies pertaining to land.

Given the possibility of changing the constraint set, some or all of the RHS values (given certain policy objectives and assumptions regarding population levels, etc.), and some or all of the coefficients in the constraints (given conditions regarding climate, technology, etc.), the potential range of scenarios under which evaluations can be conducted is practically infinite. The system has the capability of incorporating new information regarding observed or expected changes in conditions which influence the use of land as this information becomes available. If there is uncertainty about future conditions, then evaluations can be implemented under several scenarios, covering a range of possible conditions. The evaluation system can then indicate the importance of certain areas of land for specified uses under this range of conditions. In this way, the land evaluation model serves as a tool to demonstrate possibilities in the use of land and to indicate which alternatives are desirable given objectives for the use of land.

Conclusion

The prototype model is outlined to demonstrate an approach to land evaluation and its potential applications. A comprehensive and reliable system requires development in a number of areas. Depending upon the applications and context, alternative land units would need to be identified, and alternative land use typologies can be employed. Additional constraints, recognizing interdependencies among different land uses, identifying economic implications of various scenarios, and incorporating land use policies, need to be specified for a comprehensive system. The mathematics of the system also require attention, and additional data are necessary to accurately specify constraints if evaluations are to be conducted for scenarios including different climatic and technological conditions. Another requirement is that the evaluation procedures are packaged in a form that permits ready use and interpretation by policy makers and analysts.

The approach outlined represents a flexible and workable tool which can provide information crucial to the rational use of land resources. We are not aware of any comparable method for synthesizing information on land productivity, resource utilization, and various objectives regarding the use of land such that the strategic importance of land areas for land uses can be evaluated. While further development, testing, and refinement of the methodology is necessary before a comprehensive, reliable and readily-usable tool is available, the prototype model demonstrates the approach and gives an indication of potential applications.

FIGURE 1

STEPS IN THE OPERATIONALIZATION OF A LAND EVALUATION SYSTEM

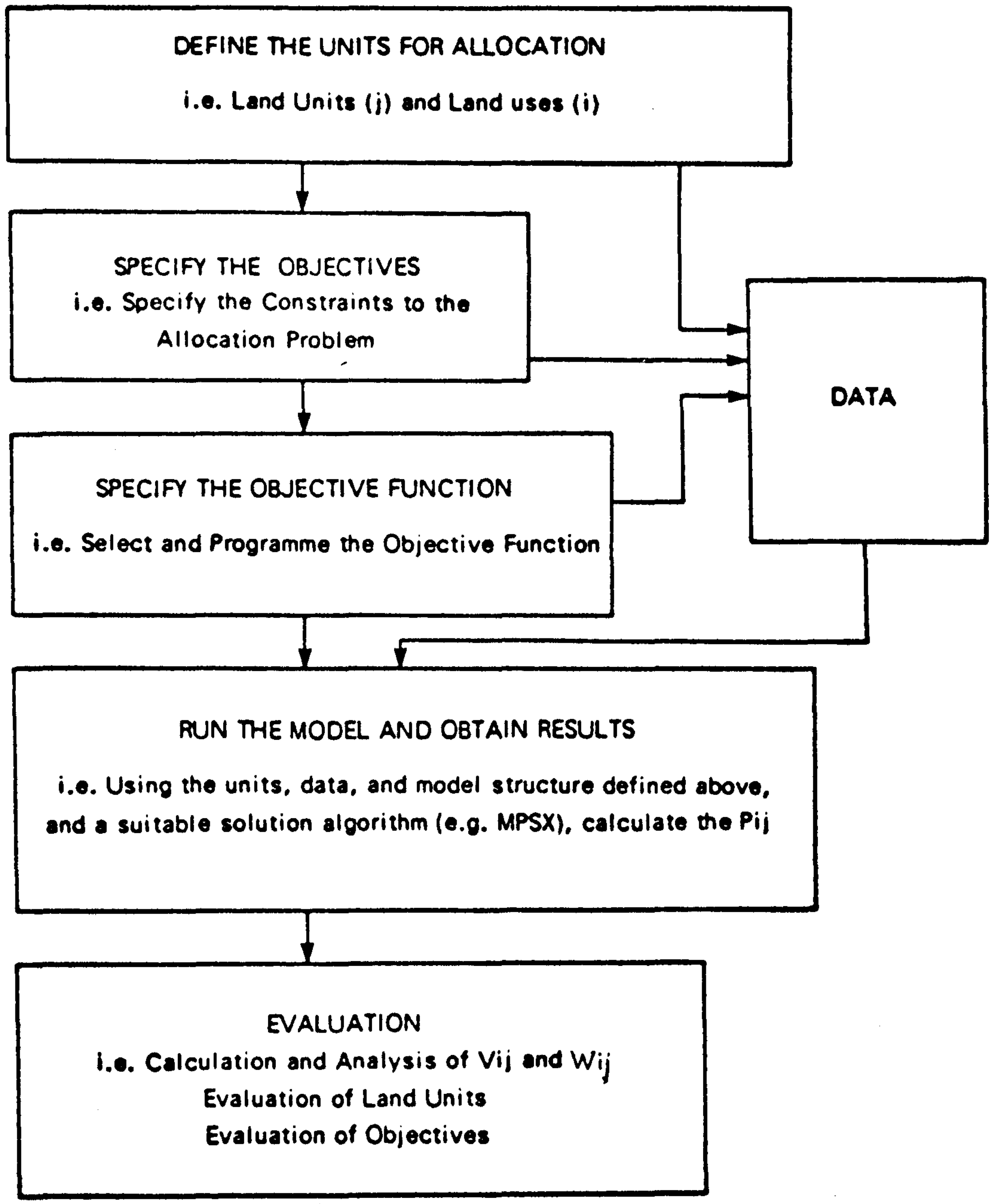


TABLE 1

Selected Evaluations (W_{ij}) for Zone 5, Land Type 1

Farm Type	1971 Conditions	Reduced Land Availability (5% across all zones and land types)
Grain	.626	.626
Horticulture	.324	.345
Dairy	.023	.023
Mixed	.011	.005
Other Livestock	.008	.000
Cattle	.004	.000

The F.A.O. Agro-ecological Zones Project: Methodology for Canada

R.B. Stewart
Land Resource Research Institute

Introduction

Present projections by F.A.O. estimate that to support the predicted world populaton in the year 2000 an increase in agricultural production of 60 percent will be required. The question posed today is whether there is sufficient global land resources to accomplish this increase, and as yet, little precise data exists upon which to base a reliable answer.

Recognizing the need for an answer to this question the F.A.O. in 1976 began a study involving the global potential land use by agro-ecological zones. The aim of this project was to obtain a first approximation of the production potential of the world's land resources, and so provide the physical data base necessary for planning future agricultural development.

Initially, the study dealt with the rainfed production potential for eleven crops in developing countries where virtually no data exists. With the methodology developed and preliminary estimates determined the F.A.O. in 1977 requested the cooperation of a number of developed countries, including Canada, in utilizing their methodology to evaluate production potential of various crops both as a test of the overall concept and to expand the overall global data base. In response to this request a project involving the assessment of the production potential of five crops, including wheat, maize, soybeans, potatoes and phaseolus bean, was begun in Canada in 1978. This paper briefly outlines the overall F.A.O. methodology employed in the potential land use suitability assessment.

The F.A.O. Methodology

The procedures involved in the assessment of potential rainfall production are illustrated in Figure 1. As shown, the project encompasses:

1) determining and inventorying the various climatic and soil requirements for each individual crop;

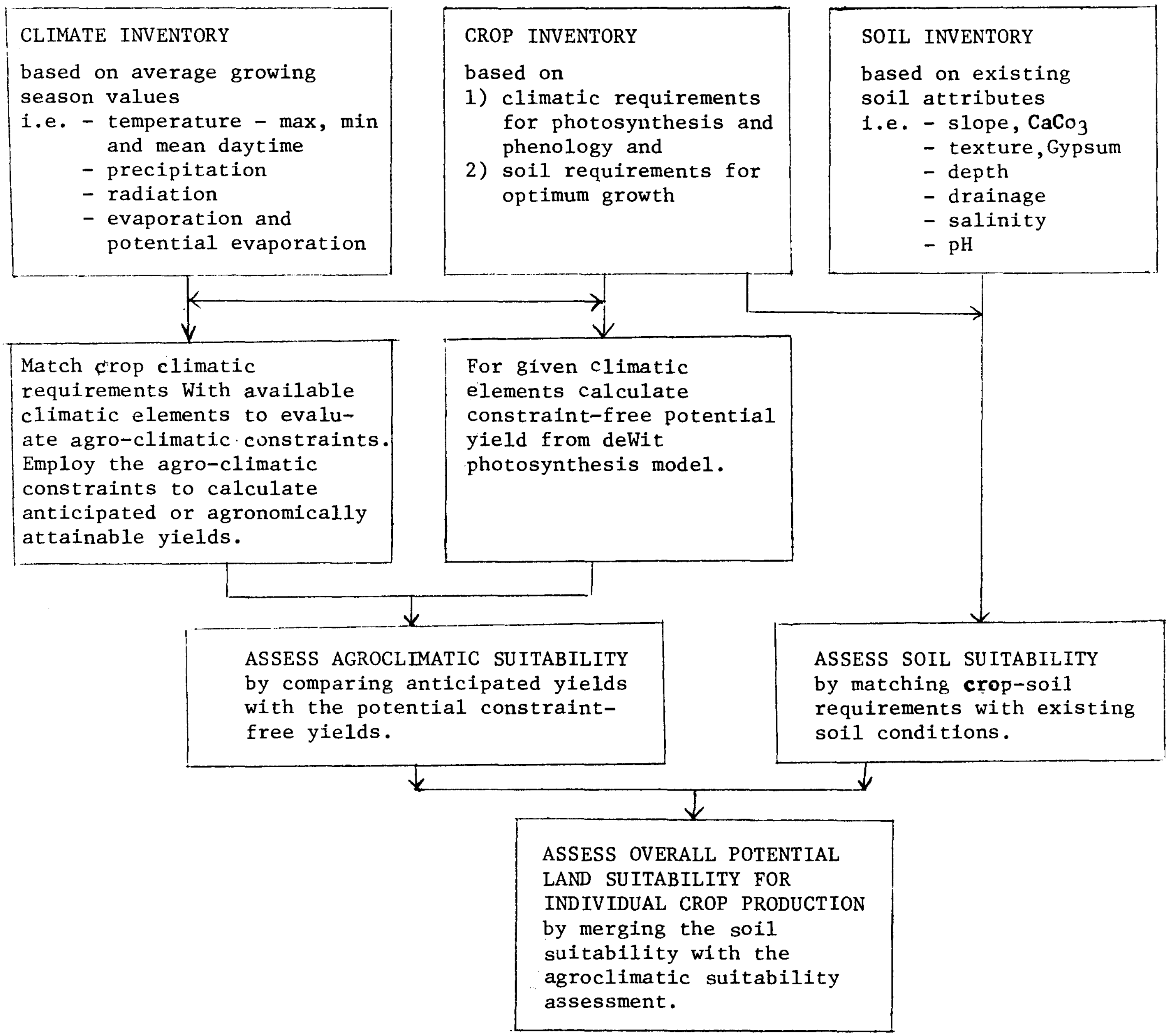
2) Inventorying the available land resources for all soil units of Canada including (i) the actual existing climatic resources and (ii) the existing soil resources;

3) Matching the requirements of (1) with the existing resources of (2) and calculating the agroclimatic anticipated yield potential for each individual crop;

4) Assess the agroclimatic suitability of individual soil units for the production of each crop irrespective of the soil resource;

Fig. 1

F.A.O. CROP POTENTIAL LAND
Suitability Assessment Procedure



5) Assess the soil suitability of individual soil units for the production of each crop;

6) Compare the agroclimatic suitability with the soil suitability assessment in evaluating the overall land suitability for the production of each crop.

As mentioned, this project involves assessment of the rainfed production potential for each crop separately. F.A.O. also considers each crop at two levels of input: low and high. For Canadian purposes, however, only the high level of input level is assumed which involves mechanical cultivation under capital intensive management practices.

The first phase of the project involves inventorying the individual crop requirement for climate and soil followed by the inventorying of existing land resources.

Data Inventory

Crop-climatic and soil requirements. Definition of the crop climatic and soil requirements is one of the most important facets of the F.A.O. agro-ecological zones project. Accordingly, F.A.O. has prepared a comprehensive inventory based on the crop climatic requirements for both photosynthesis and phenology for the world's 20 most important crops by acreage. The inventory has been simplified somewhat by separating the photosynthetic and phenological requirements of all crops into five major groups. The groups of crops under investigation in Canada and some of the major characteristics associated with each are outlined in Table 1. Similarly, individual crop soil requirements for agricultural production have also been inventoried as shown in Table 2.

Inventory of existing land resources. With the crop-climatic and soil requirements identified, the next step involves inventorying the existing land resources with respect to the available climatic and soil resources.

Climatic Resources. In the case of climate, water availability and temperature are the key factors in determining the crop suitability for rainfall production. For the purposes of this project climatic is inventoried on a growing season basis or period in days when available temperature and water regimes permit crop growth. The major climatic variables included in the inventory are listed in Figure 1.

F.A.O. defines the growing season (GS) from a moisture point of view. By their definition the GS begins (GSS) on the date average precipitation (P) is first exceeded by one half the potential evapotranspiration (PET) value. The GS ends on the date, after including the average P receipt, the soil reservoir has decreased by 100 mm equivalent water storage. The period between these dates represents the potential growing season since moisture is not limiting to the crop. By this definition temperature and the length of the growing season are the limiting factors to crop production.

This definition is quite adequate for Africa where the F.A.O. methodology was developed and where freezing conditions for the most part present little problem for plant growth at any time of the year. In Canada, however, the climatic situation is quite different. Temperatures are at or below freezing from 4 to 8 months of the year and as a result the date when P = .5 PET often occurs several weeks before the mean air temperature reaches $0^{o}C$. For this reason the F.A.O. growing season definition was not considered applicable to the Canadian situation.

For Canada the growing season has been defined using a thermal or temperature basis and is considered to be the period in days during the year when the mean minimum air temperature is above $5^{o}C$. To make this definition equivalent to the F.A.O. potential growing season, moisture is assumed to be not limiting for crop production during this period. Actual moisture effects on plant production are brought into the assessment procedure in a later phase (anticipated yield determination) when the quantification of agroclimatic constraints and subsequent calculation of the agronomically attainable yields are undertaken.

Once the growing season length for each soil unit is determined average values of the major climatic elements representing this period are then to be computed. As mentioned previously, these are listed in Figure 1.

Soil resources. The soil resources inventory is based on the format of the F.A.O.-UNESCO Soil Map of the World. For all soil units, information on texture, slope and various phases are to be inventoried.

On completion of the land resources inventory the climatic information is to be superimposed onto the Soils Map of Canada to derive values of major climatic requirements for each individual soil unit. This data will then provide the physical basis for the overall land suitability assessment.

Matching of crop requirements to the land resources inventories.

Comparison of the crop climatic and soil requirements with the actual available climatic and soil conditions within the individual soil units of Canada forms the basis of the suitability assessment. The initial phase in the matching process involves comparing individual crop temperature requirements with existing temperature conditions for all soil units. This procedure identifies those soil units to be considered for production estimates from a temperature point of view only. When this is completed the next step in the matching process is to evaluate the constraint-free yield over the existing available growing season in the absence of any yield reducing factors.

Constraint-Free Yield Estimation. Evaluation of the constraint-free yields for each crop is to be undertaken using the deWit (1965) photosynthesis model. First, the net biomass production (total drymatter) is calculated taking into account a) the gross biomass production capacity of the crops as influenced by the crops response through photosynthesis to temperature and radiation, and b) the respiration losses as influenced by temperature.

Following this, by incorporating the use of appropriate harvest index values (the fraction of net biomass that is economically useful), constraint-free or potential yield data can be derived from the net biomass figures. In this stage factors that affect yield such as moisture stress, losses due to disease pests and weeds, etc. are ignored and the climatic potential yield from a thermal viewpoint is calculated.

Anticipated Yield Determination. The above section provides the anticipated constraint-free or potential yields. These data, however, do not take into account yield reducing factors such as: moisture stress, excess moisture losses due to diseases, pest and weeds, etc. Such constraints have to be considered in order to derive anticipated yields that are agronomically attainable. In view of this, F.A.O. divided the major yield reducing factors into 4 main groups including losses due to: 1) moisture stress, 2) pests, diseases and weeds, 3) losses arising from (1) and (2) on yield formation components and quality, and 4) workability. For the developing countries, the F.A.O. procedure involves assigning arbitrary values 0%, 25% or 50% for each constraint depending on the severity of the constraint for the particular region under consideration.

The Canadian procedure deviates from the F.A.O.'s at this point with the actual quantification of the moisture stress and workability constraints being undertaken. Moisture stress is being evaluated using a soil moisture budgeting procedure which ultimately enables determination of the ratio of actual to potential evapotranspiration. This ratio in turn can be related to the individual crops yield response to water deficits in terms to be individual crops yield response to water deficits in terms of the ratio of actual to potential yields.

Quantification of the workability parameter involves use of a fall workday probability analysis developed by the Agrometeorological Section of L.R.R.I. Yield reducing factors (2) and (3) as yet have no direct means of quantification and are assumed to be negligible for the Canadian situation.

Suitability assessment for the production of crops

One estimation of the agroclimatically attainable yields has been achieved the final phase of the agro-ecological zones project begins with the actual assessment of the soil units for the suitability of individual crop production. The suitability assessment essentially involves three assessments: 1) the agro-climatic suitability, 2) the soil suitability, and 3) the overall potentail land suitability.

Agroclimatic Suitability Assessment. The agroclimatic suitability assessment is achieved by considering the whole range of agronomically possible yields involving all soil units in Canada. The agronomically attainable yield of each soil unit is rated in terms of a percentage against the maximum attainable yield in Canada without constraints.

Each soil unit is then placed in one of four suitability categories depending on its percentage rating. For example, soil units with growing periods capable of yielding 80 percent or more of the potential are classified as "very suitable; areas yielding 40 to 79 percent are classed as "suitable"; areas yielding 20 to 39 percent, "marginally suitable"; and those yielding less than 20 percent as "not suitable".

The agroclimatic suitability assesses the soil unit from a climatic capability only and is independent of the soil factors affecting crop production.

Soil Suitability Assessment. For the soil suitability assessment a qualitative approach is taken for matching the individual crop-soil requirements with actual soil conditions. This involves comparing the crop-soil requirements with conditions in each soil unit gauged according to three main attributes which include texture, slope and phase. If the soil unit soil conditions largely meet the crop requirements, it is assigned a rating of "suitable" since that particular attribute would not affect the constraint-free yield to any extent. On the other hand, if the soil conditions only meet part of the crops requirements, the soil unit is assigned a "marginally suitable" rating as the soil conditions would not allow the full crop climatic yield to be attained. Failure to meet the minimum crop-soil requirements results in the soil unit being rated as "not suitable" meaning the soil could not support the production of that particular crop. On completion of the agroclimatic and soil suitability assessment the data base then exists to assess the overall potential land suitability.

Potential land suitability. The final step in the project is the potential land suitability assessment which is achieved by merging the soil suitability assessment with the agroclimatic suitability assessment. In this instance soil units which have been assessed as "suitable" for the production of a particular crop in the soil suitability assessment have no change made in their agroclimatic suitability. Soil units for which the soils have been adjusted as "marginally suitable", however, have their agroclimatic suitability ratings downgraded by one suitability class. Finally, any soil unit with a soil suitability rated as "not suitable" are assigned a final suitability rating for that particular crop as "not suitable". In all cases, severe soil limitations override the climatic attributes in the potential land suitability assessment.

The derived potential land suitability assessment for the production of each crop in final form comes down to 4 categories: 1) very suitable, 2) suitable, 3) marginally suitable, and 4) not suitable. Each of the 4 classes is directly related to the anticipated yield as a percentage of the maximum attainable under optimum agroclimatic and soil conditions, and so provides the data required to estimate the rainfed production potential for any given area.

TABLE 1

CROP ADAPTABILITY INVENTORY

A) PHOTOSYNTHESIS CHARACTERISTICS

	Characteristic		Group I Potato Phaseolus Bean Wheat Soybean	Group IV Maize
1)	Photosynthesis Pathway		C_3	C_4
2a)	Temperature Response to Photosynthesis for all crops except soybean	Optimum	15 - 20°C	20 - 30°C
		Operative Range	5 - 30°C	10 - 35°C
2b)	Temperature Response to Photosynthesis for soybean	Optimum	20 - 25°C	
		Operative	15 - 30°C	
3)	Radiation Intensity at Max Photosynthesis		0.2 - 0.6 cal cm^{-2} min^{-1}	1.0 - 1.4 cal cm^{-2} min^{-1}
4)	Max net rate of CO_2 exchange at light saturation		20 - 30 mg dm^{-2} h^{-1}	70 - 100 mg dm^{-2} h^{-1}
5)	Max crop growth rate		20 - 30 gm^{-2} day^{-1}	40 - 60 gm^{-2} day
6)	Water Use efficiency		.4 - .8 kg/m^3	.8 - 1.6 kg/m^3

TABLE 2

SOIL AND LAND SUITABILITY REQUIREMENTS OF CROPS

CROP	SLOPE (%)		SOIL DEPTH (cm)		(1) SOIL DRAINAGE CLASS		(2) SOIL TEXTURE CLASS		INHERENT FERTILITY LEVEL	SALINITY (mmho/cm)		pH (1:2.5)		$CaCO_3$ (%)		GYPSUM (%)	
	Optimum	Marginal	Opt.	Marg.	Opt.	Range	Opt.	Range	Marginal	Opt.	Marg.	Opt.	Range	Opt.	Marg.	Opt.	Marg.
Wheat	0-8	9-30	50	10-50	MW-W	I-SE	SiL-CL	SL-MC	Moderate	0-5	6-10	5.5-8.2	5.2-8.5	0-25	26-50	0-2	3-20
Maize	0-8	9-15	50	10-50	MW-W	I-SE	SiL-CL	SL-MC	Moderate	0-4	5-6	5.5-8.2	5.2-8.5	0-15	16-25	0-0.2	0.3-2.0
Potato	0-8	9-15	75	50-75	W-SE	MW-E	L-SiCL	FS-KC	Moderate	0-3	4-6	5.5-7.0	5.2-8.5	0-15	16-25	0-0.2	0.3-2.0
Soybean	0-8	9-20	75	50-75	MW-W	I-SE	SiL-CL	LS-KC	Moderate	0-4	5-6	5.5-7.5	5.2-8.2	0-15	16-25	0-0.2	0.2-2.0
Phaseolus Bean	0-8	8.20	75	50-75	MW-W	I-SE	L-CL	LS-KC	Moderate	0-1	1-2	5.5-7.5	5.2-8.2	0-15	16-25	0-0.1	0.1-0.5

(1) VP = very poor
P = poorly drained
I = imperfectly drained
MW = moderately well drained
W = well drained
SE = somewhat excessively drained
E = excessively drained

(2) MC = Montmorillonitic clays
KC = Kaolintic clays
SC = sandy clay
SiC = silty clay
CL = clay loam
SCL = sandy clay loam
SiCL = silty clay loam
L = loam
SL = sandy loam
SiL = silt loam
Si = Silt
LS = loamy sand
FS = fine sand

From Table 4.1 (Kassam, 1978 - Report on the Agro-Ecological Zones Project Vol. 1 Methodology and Results for Africa World Resources Report #48.

Agricultural Land Use Sytems Mapping

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Land Resource Research Institute

Traditionally land use maps have been simple portrayals of the various types of ground cover of a particular area - an indication of which parts of the land are covered by trees, which by farms, which by buildings and so on. Included are inferred differences in activities between categories; agricultural production vs. residential vs. extraction of minerals for example, but rarely is there any indication of economic or social differences within each category. This is true particularly in the case of agricultural land use, which is generally designated by terms such as "cleared land", "farmland", "cropland", or even "mixed farming". These terms give no indication of the variation in type of farms, intensity of production, or kind of product and they provide no means of comparing the agricultural activities of one map unit with those of another. And yet, with respect to agriculture as an industry, there is a great deal of variation within an area that in total would be classified as "farmland". And it is precisely this variation in agricultural activities that is important to land evaluation research.

We have attempted to overcome these problems and make agricultural land use mapping a more valuable and feasible tool for use in the assessment of spatial variation in agriculture. The basis of this work is the idea that the combination of physical resources, economic conditions, and social organization of any specific location determines the agricultural focus at that location; and further, that this focus is reflected by the manner in which the farm operator uses his available space. By identifying different patterns of land use - or more specifically land use systems - it should be possible to identify basically different combinations of resources and hence different production patterns.

The Land Resource Research Institute in 1975 was involved in preparing a detailed analysis of the physical resources of the Ottawa urban fringe, primarily as a pilot project for land evaluation research. Part of that detailed analysis involved the preparation of a current land use map of Nepean and Gloucester Townships as a complement to the soil survey of that same area. The scale of mapping of this project was 1:25,000 so a long and very specific legend was developed that made a distinction between a field of hay and one of improved pasture, between improved and natural grass pasture, and between a residential lot and one used for commercial purposes and so on. Even idle agricultural land was subdivided into 3 categories depending on the apparent length of time it had lain idle.

At this level of detail, data collection was time-consuming because the field survey required frequent traverses on foot wherever visibility was restricted by trees or terrain. As a result it took one crew of two mappers the better part of a summer to cover about 28,000 ha. An average of about 730 ha per team perday were mapped over the entire field season.

The final map was a complex and specific effort that is particularly appropriate for a rural-urban fringe area where competing uses and site selection are of significant concern to planners. However the agricultural component of that map, is less than 100% effective because it is dated; there is no assurance that a field used for corn this year will be used for corn next year. If it is part of a monocultural farm enterprise, then it will be planted to the same crop every year, but if the farm operator is using a rotational cropping system, the designation of the mapping unit will likely change from year to year. Furthermore the Nepean-Gloucester map gave no indication of any relationship between different crops, and it is this type of relation that is important to land evaluation.

A third concern with the Nepean-Gloucester survey was that the scale and detail involved, and hence the extensive field time required, made it economically impractical for application to land use studies of large agricultural areas. Obviously, in a land use mapping project, air photo interpretation should be used to a greater extent in data collection, both to increase speed and to enable one to see cropping patterns of two different years.

In 1977 we took these ideas to the field in a project designed to map land use in the rest of the Ottawa-Carleton Municipality, with the intention of producing a map that would have reasonable validity over a number of years, as well as indicate differences in farm operations.

Some preliminary efforts at generalizing the Nepean-Gloucester map had indicated broad categories of agricultural land use systems such as "specialized commercial", and "abandoned land and permanent pasture", so we began by trying to develop a methodology of identifying these types of systems directly in the field. The first problem encountered was to decide where one system ends and another starts. In the Nepean-Gloucester survey that was simplified as each field was treated as a separate map unit. However in cropping systems, several or numerous fields are included in each unit. The areal extent of one individual farm is not apparent from air photos nor from the ground, but property boundaries are usually quite distinct. In the original land survey, separate units of 100 acres each were defined in a regular pattern over the landscape, and this pattern is visible on the air photos. Consequently the 100 acre parcel was established as the basic mapping unit for identifying land use systems.

It should be pointed out that a land use system is different from a farming system. A farming system may be composed of more than one land use system considering that a farm operator may manage different parcels of land quite differently, depending on whether he owns or rents the land, on the distance it is from his home location, or on the quality of the land.

Establishing the legend for identification and differentiation of different land use systems involved 2 weeks of field work in which the types of crops, the mix of different crops, and the proportion of land area devoted to each crop within separate 100 acre parcels were assessed and identified. By looking at two years of cropping patterns - one from the air photos, and one from the ground, six different recurrent systems were identified.

1) Monoculture, a system of continuous corn or cereal grain cultivation with no crop rotation,

2) Corn system, corn, cereal grain, hay and pasture in rotation and in which corn covers between 25 and 75% of the total area,

3) Mixed system, corn, cereal grain, hay and pasture in rotation but in which corn covers less than 25% of the total area,

4) Hay system, cereal grain, hay and pasture in rotation, with hay being dominant in terms of area,

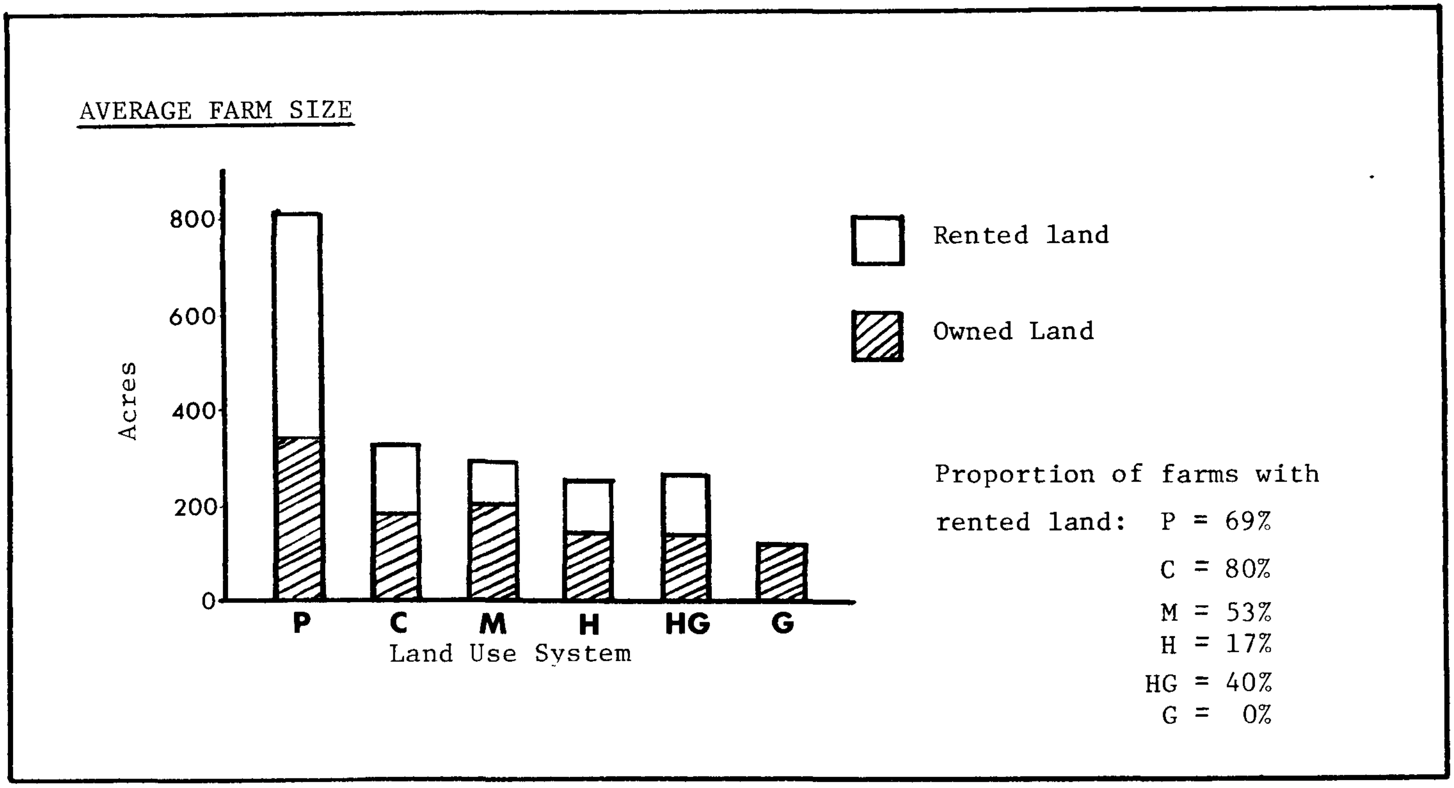
5) Pasture system, hay and pasture with little or no rotation,

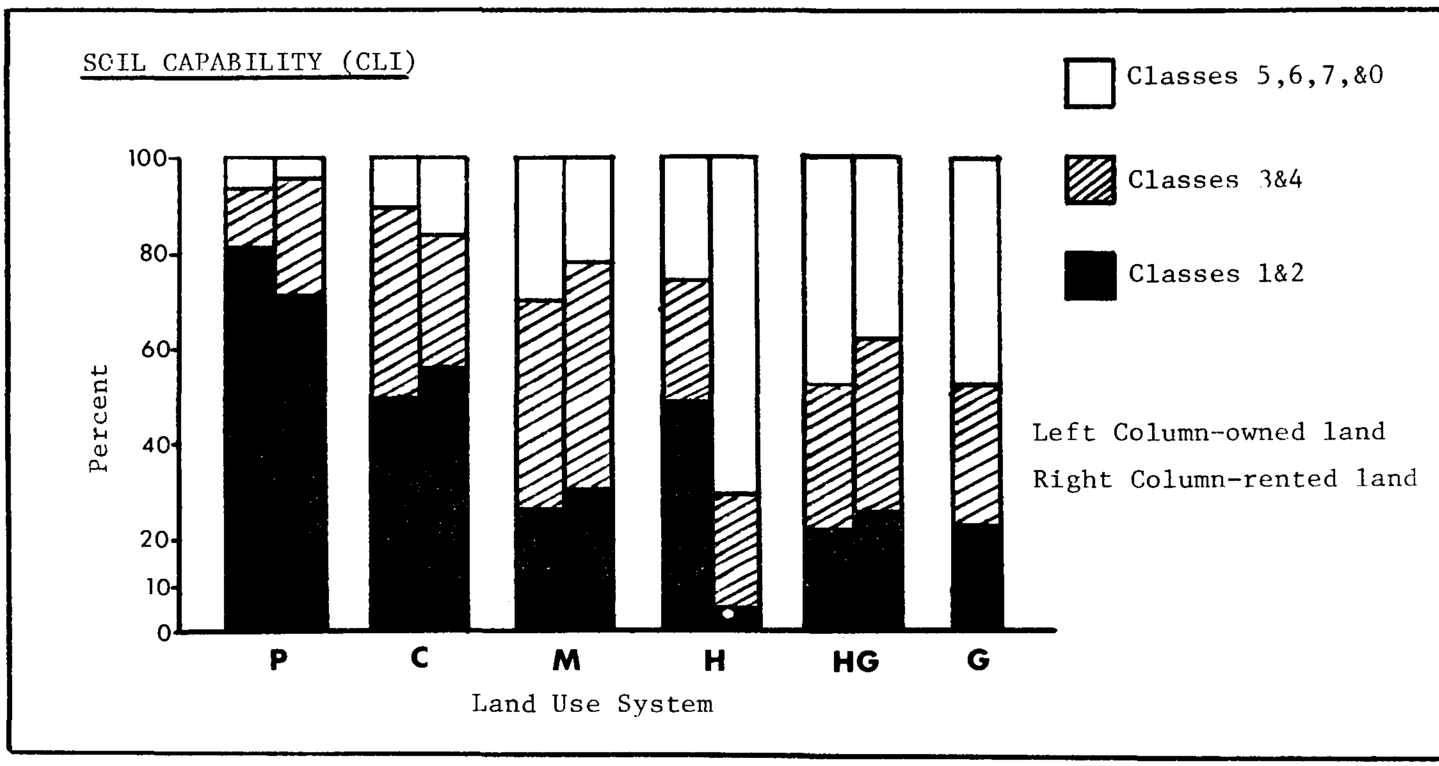
6) Grazing system, simply the running of livestock on improved or native grass pasture.

In addition to these systems, the legend included a number of specific land use types such as abandoned farmland, forest, built-up, recreation, and specialty agriculture. Also a modifier was added to identify areas of small, irregular shaped fields, and a separate legend to identify the size and condition of farm buildings.

Once the identification criteria for each of these categories was established the study area was mapped using a standard technique of pre-typing on air photos followed by ground traverses. The pre-typing involved the delimitation of recognizable land cover, such as forest and built-up areas, and the establishment of map unit boundaries along property lines, watercourses, roads and railway lines. In the field boundaries were adjusted where necessary, and anomalies to the legend, obvious land use changes, and farm building descriptions were recorded. In practice one hour of pre-typing accomodated 7 hours of field work, giving an overall average mapping rate of 3000 ha/team/day, a fourfold increase over the Nepean-Gloucester survey. At this rate, with 2 crews working, 212,000 ha were mapped in 35 days. The final map was compiled and will be printed at a scale of 1:50,000.

A second phase of the study was approached through a series of farm interviews designed to differentiate and define various parameters of each system. Land ownership maps were compiled from information contained in townships tax rolls, and combined with the land use map to indicate the land use system (or systems) of each individual farm in the study area. All farms were selected in which were at least 80% pure in one land use

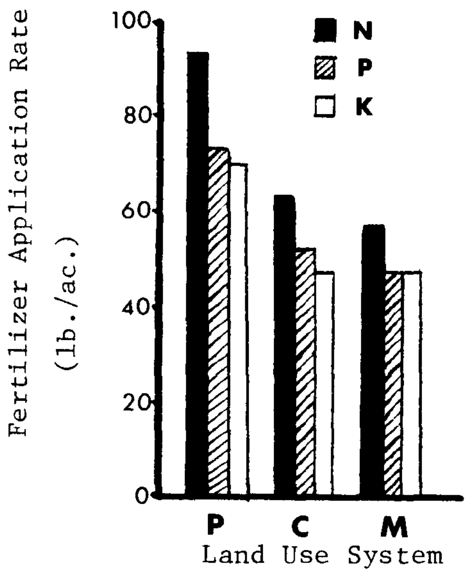


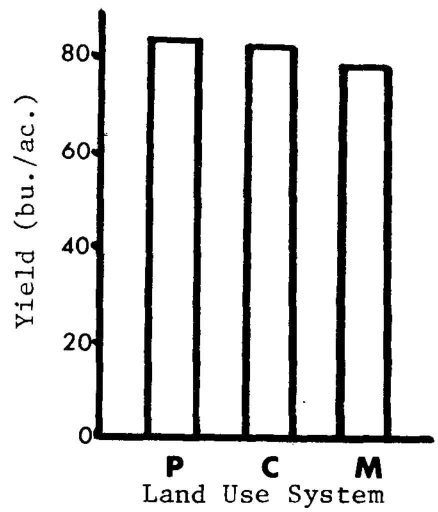


NOTE: Ottawa-Carleton Land Use Systems -

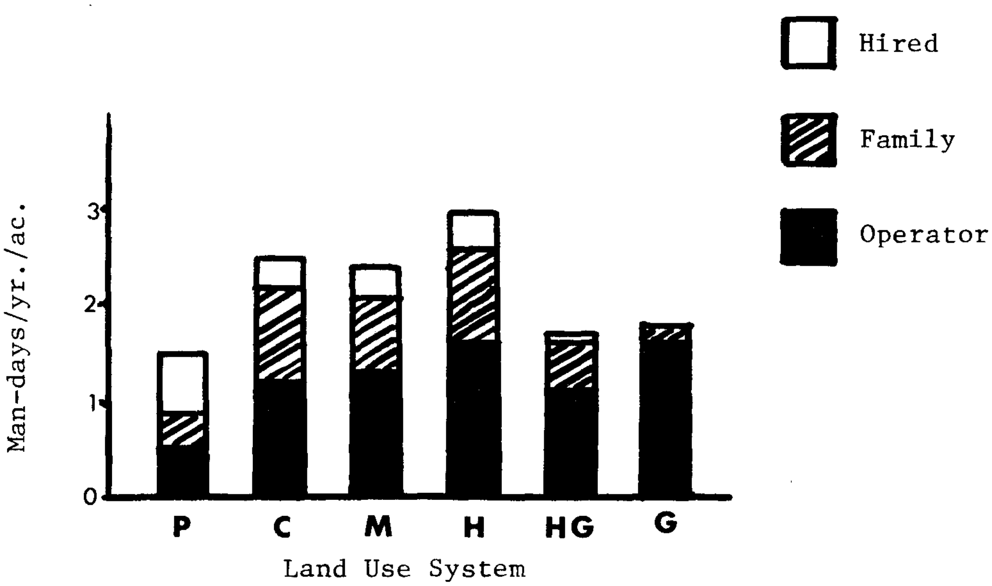
P = Monoculture System
C = Corn System
M = Mixed System
H = Hay System
HG = Pasture System
G = Grazing System

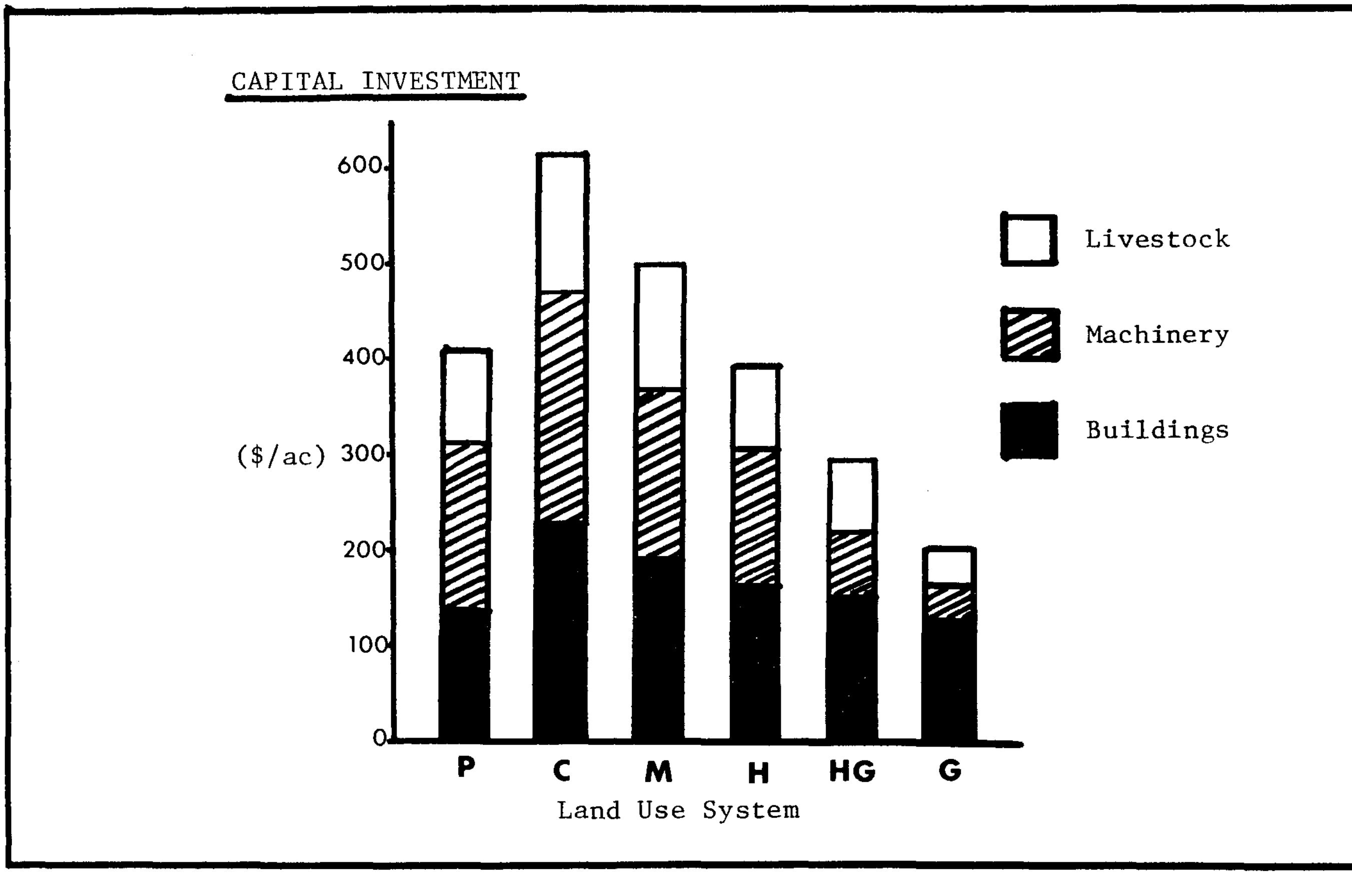
FERTILIZER USE AND CROP YIELD - Grain Corn

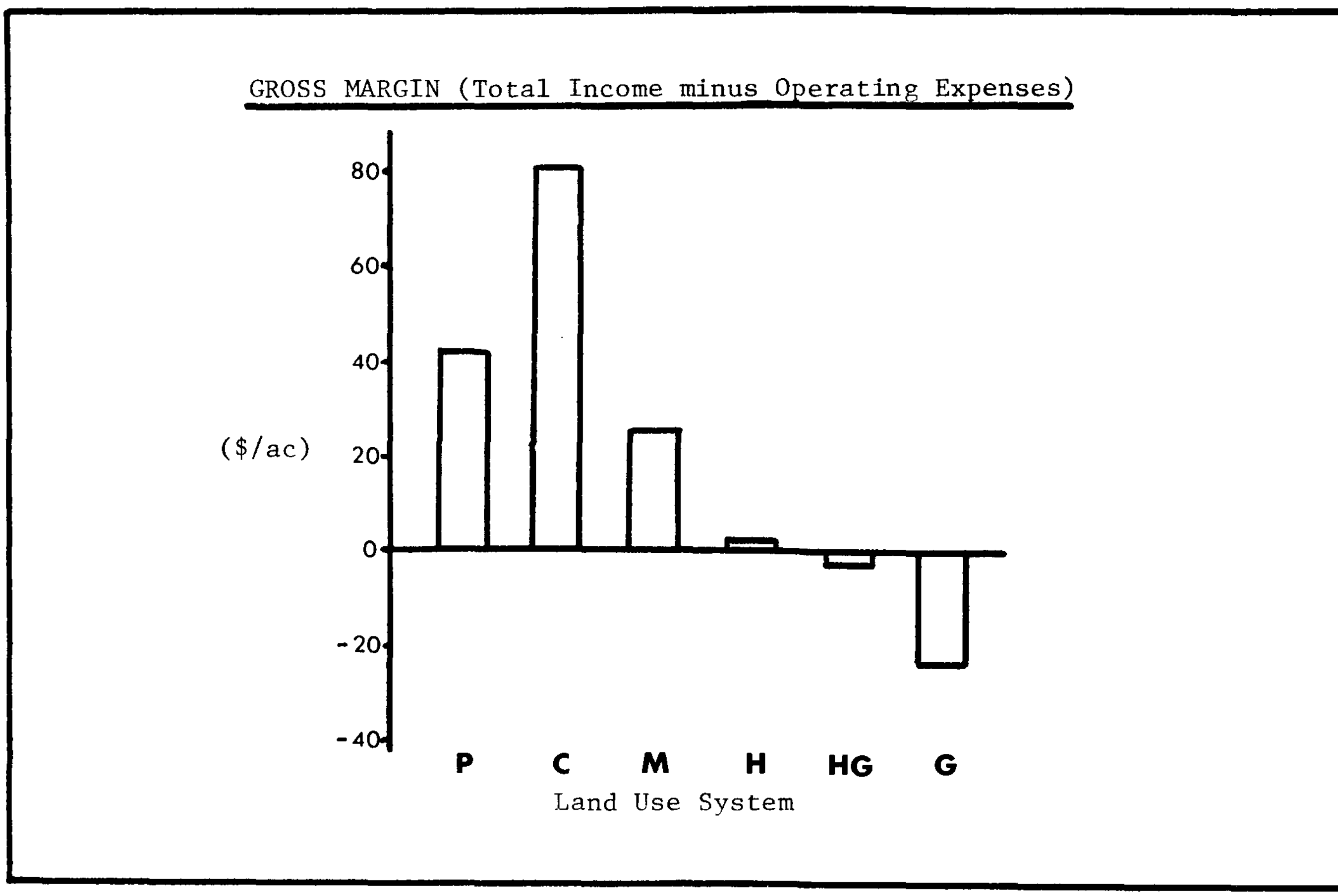




LABOUR INPUT




CAPITAL INVESTMENT
600
500
400
($/ac) 300
200
100
0
P
C
M
H
HG
G
Land Use System
Livestock
Machinery
Buildings


GROSS MARGIN (Total Income minus Operating Expenses)
80
60
40
($/ac) 20
0
-20
-40
P
C
M
H
HG
G
Land Use System

system, and from these 40 farms were randomly chosen as representing each system. Questionnaires dealing with such diverse aspects as farm location and size, age and education of the operator, etc. were administered in the form of personal interviews.

About 6 out of every 10 farms visited resulted in a completed questionnaire and of these, about 50% of the respondents had used their previous years tax returns or other records to supply financial information. The data from all questionnaires were tabulated on coding forms in preparation for computer analysis. Preliminary results in the form of averages, by system, for several basic variables show the results of these calculations.

In 1978, the entire project was repeated in a selected area of south-eastern Saskatchewan, specifically the south half of the Melville map sheet. The objective in this instance was to test the method of mapping land use systems as outlined for Ottawa-Carleton in a completely different agricultural setting, as well as to incorporate some improvements which had come to light during previous work.

The method of legend development followed the same routine of familiarization with farming operations, determination of differences in land use systems, comparison of air photo and ground characteristics, and establishment of identification criteria. For this survey the square mile 'section' was designated as the map unit. Four different land use systems were identified:

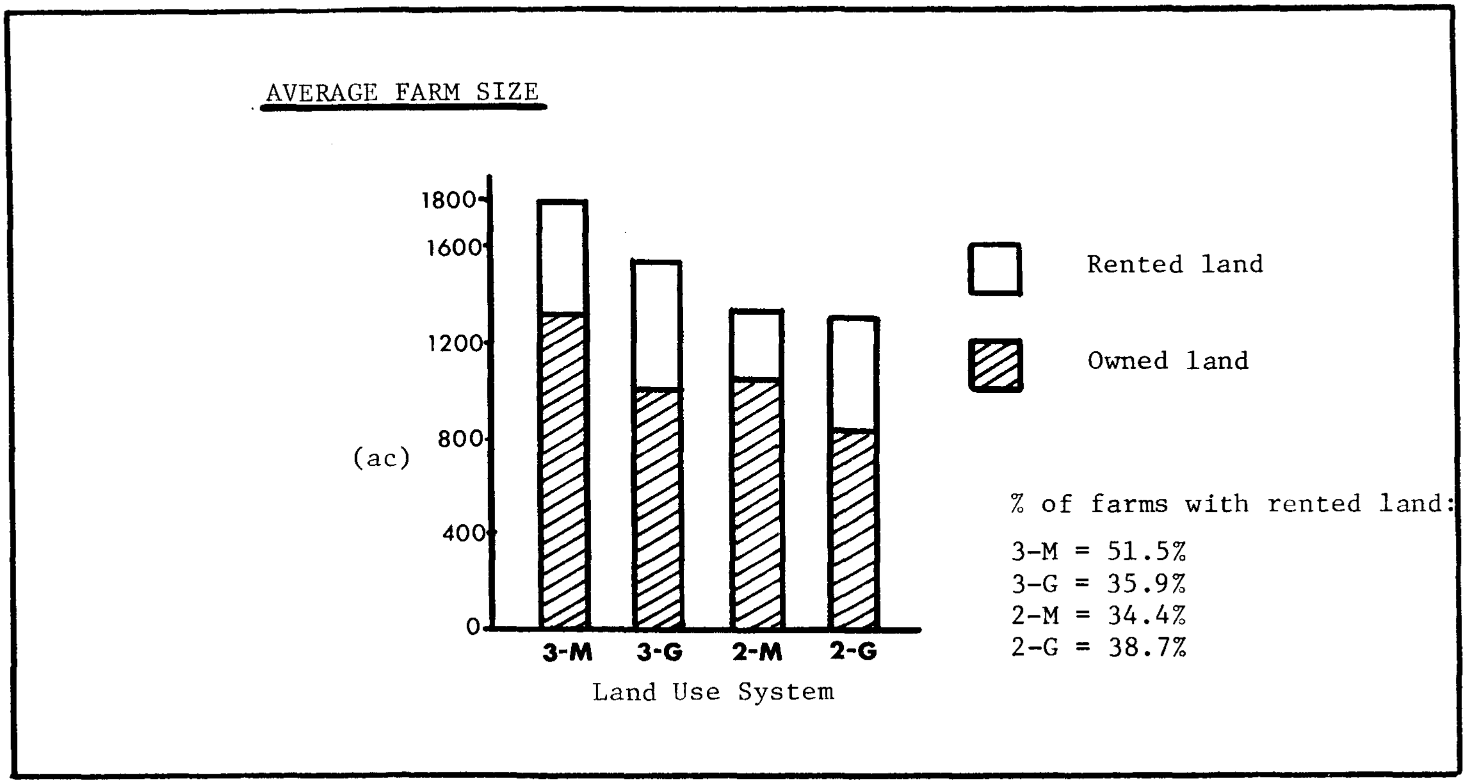
1) straight grain in a 2 year rotation (summerfallowing each field every 2nd year),

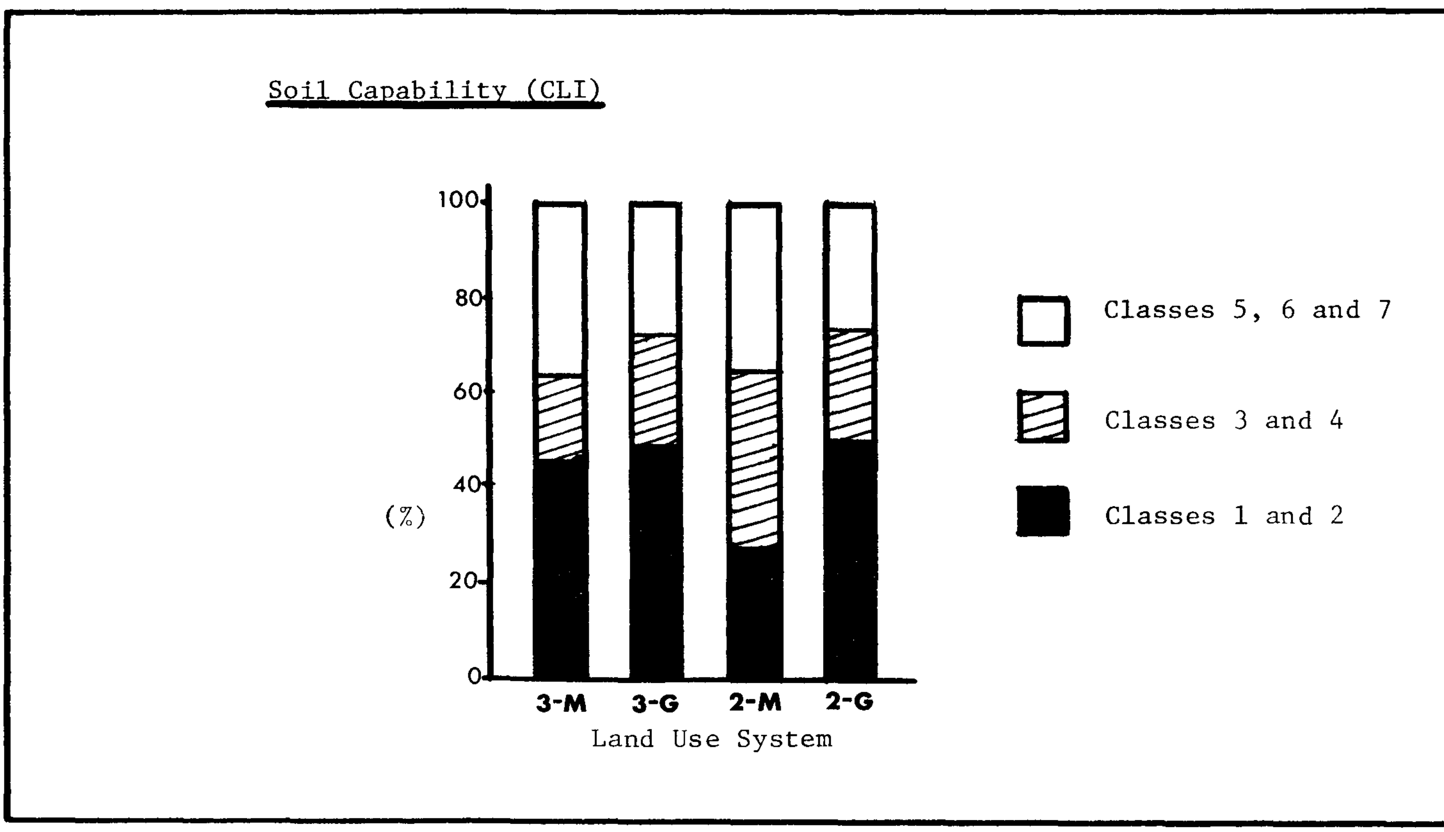
2) 2 year grain rotation in association with tame hay or pasture,

3) straight grain in a 3 year rotation (summerfallowing each field less often than every 2nd year), and

4) 3 year grain rotation in association with tame hay or pasture.

Field determination of the rotation system was based on whether fields which were cropped last year, which were identified from air photos, were also cropped this year. A minimum of 40 ha of cropped stubble per section designated a 3 year rotation, and a minimum of 40 ha of tame hay and/or pasture per section designated a hay system. Also included was a rating for field irregularity, which was designed to indicate the amount of turning around sloughs and bush that is required during field operations. An '0' rating signified no or minor irregularity, '1' moderate, and '2' severe irregularity. Using a standardized symbolization format for land use system, irregularity, and farm building size and condition, approximately 15,000 ha per crew per day were mapped. The 727,000 ha of the study area were completed in 50 days. The data were compiled at a scale of 1:100,000.

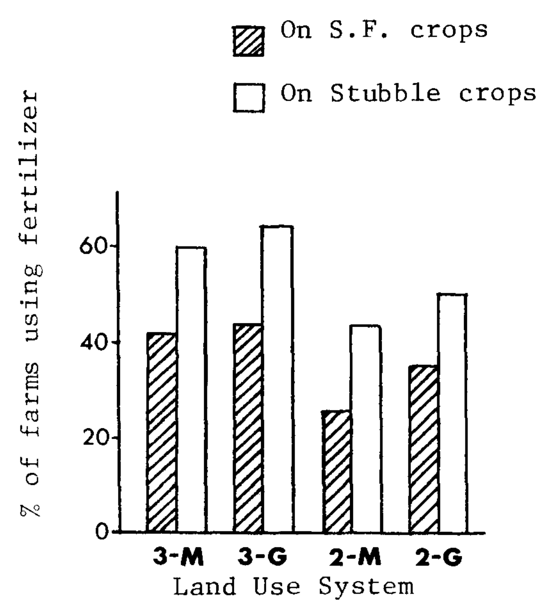


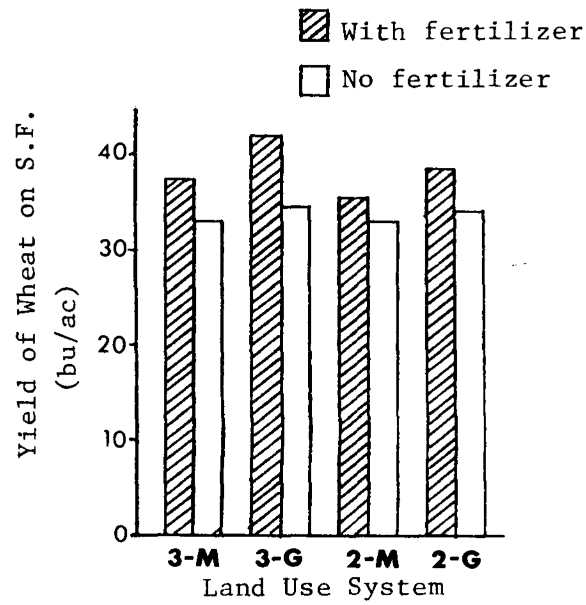


NOTE: Saskatchewan Land Use Systems -

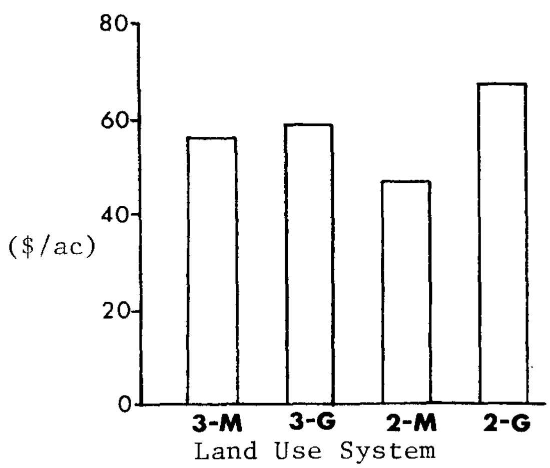
3-M = 3 year rotation, mixed.
3-G = 3 year rotation, straight grain.
2-M = 2 year rotation, mixed
2-G = 2 year rotation, straight grain

FERTILIZER USE AND CROP YIELDS

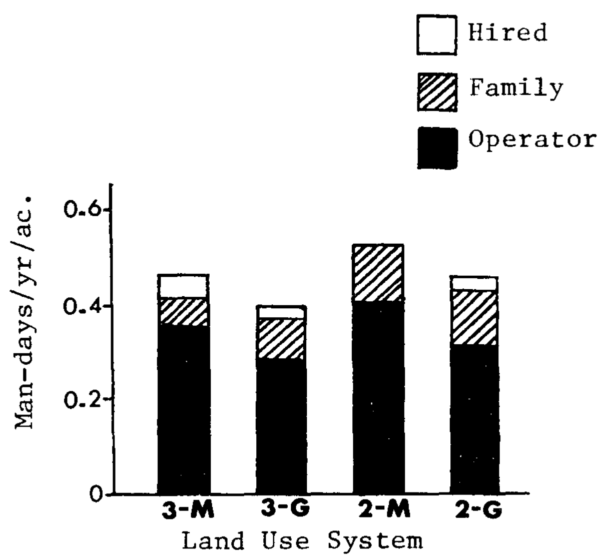




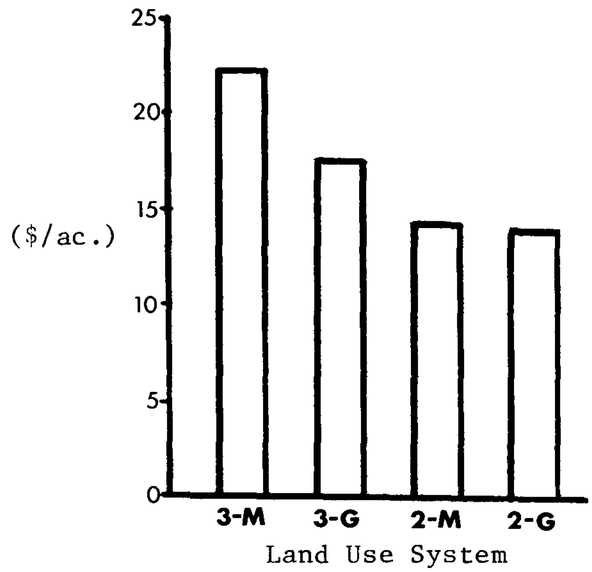
MACHINERY VALUE



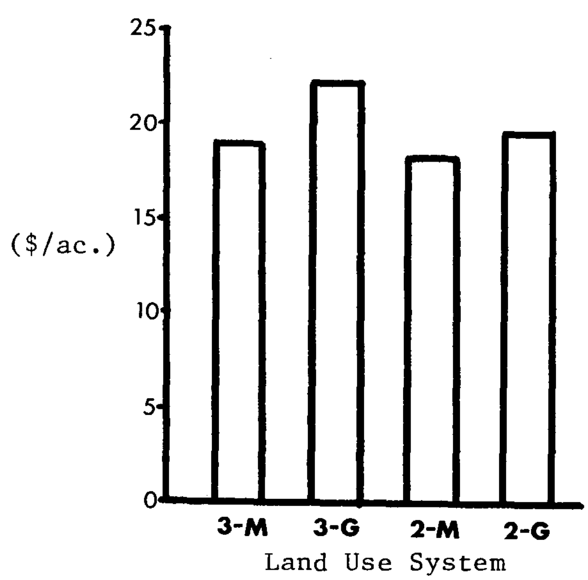
LABOUR INPUT



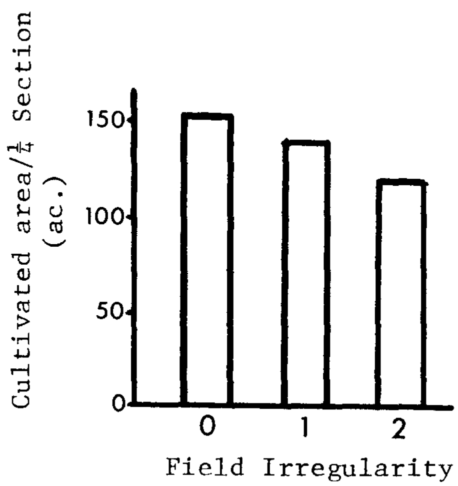
ANNUAL OPERATING EXPENSES

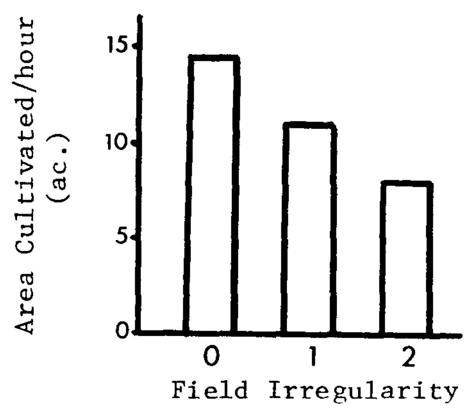


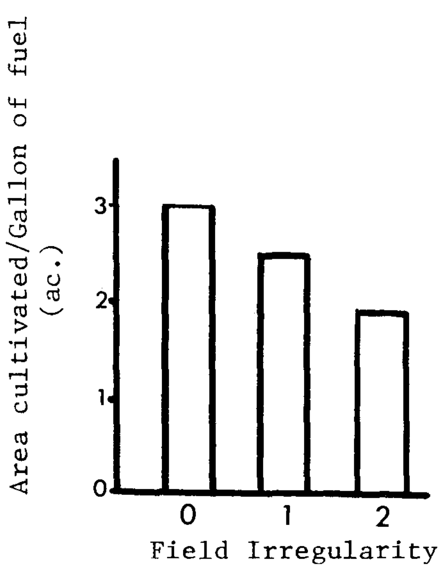
GROSS MARGIN
(Income minus Operating Expenses)



FIELD IRREGULARITY







NOTE - Field irregularity codes: 0 = minor irregularity
1 = moderate irregularity
2 = severe irregularity

The questionnaire used in the Saskatchewan interviews had basically the same format as that for Ottawa-Carleton, but some modifications were made to the content in order to accommodate the different nature of farming, and to concentrate more specifically on economic rather than social aspects of the systems. More emphasis was placed on getting the actual physical quantity of inputs such as fuel, fertilizer, and pesticides and of products such as pounds of beef or milk, rather than rely on only gross dollar values as a measure of input-output characteristics. This approach worked well, as farmers were generally more willing to discuss in detail such things as the number of hours they spend cultivating summerfallow, and how much fuel their machines use, than they were to discuss what their annual fuel costs are. Accuracy in the Saskatchewan study was also improved by somewhat better farmer co-operation. On the average, 8 interviews were completed for every 10 farms visited, with about 70% using their books as reference. In 6 weeks, 156 interviews were conducted, resulting in 140 useable questionnaires and preliminary analysis of these questionnaires has been completed.

The figures are only a preliminary overview of the types of analyses that are possible with the questionnaire data. When all of the data has been arranged for computer manipulation tests will be run for similarities and differences in a number of other variables in an attempt to characterize each system more completely. Also the opportunity of examining variation between and within systems is possible, of determining which variables have the least and which the most variation, and of comparing systems on the basis of other factors such as energy conversion or biomass production. There is a great deal more work to be done, and a great deal more to learn, but experience has indicated that mapping land use systems, using farm interviews as detailed site descriptions, can be a worthwhile and workable tool for use in land evaluation studies.

Soil Potential*

Donald E. McCormack
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Interpretations Division U.S.D.A.

Washington, D.C.

Soil potentials are ratings of soil quality with the application of modern technology to overcome soil limitations. Their purpose is to help achieve sound decisions about the use and management of land. They are considerably more versatile and more useful than ratings of soil limitations, and avoid some of the problems that users have with soil limitations, e.g., if a soil has severe limitations for a given land use, then it shouldn't be used for that purpose. This is not true of course, and was never intended, but is a misinterpretation that is much too common.

The rating of soil potential is achieved using the following expression:

$SPI = P - CM - CL$, where

SPI - soil potential index
P - performance standard
CM - corrective measures
CL - continuing limitation

Each term is defined in the National Soils Handbook, Section 404. We would like to see more efforts like the Canfield (Ohio) Subdivision Regulations where corrective measures were discussed intensively locally, and adopted in ordinances. To have one set of specifications for design of homes and streets that applies to all areas (all soils) of a municipality (or county) is ridiculous, and especially where detailed soil surveys are available.

Developing ratings of soil potential requires that soils be placed into an array based on SPI, and that class limits be set locally. They are intended to cover only the local universe of soils. Local data on measures and their costs and on the severity of continuing limitations are used. To make this work the way it should, the soil scientists must recognize that they have a big limitation. That limitation is the grand delusion that they are the only ones who know about soils. That simply isn't true! The people who know by far the most about soils are those who use them -- farmer, the engineer, the contractor, etc. Our job is to organize what they know so that it may be properly applied to new problems and new areas.

*We appreciate comments by Wil Westerveld indicating use of soil potentials in the Netherlands. We hope that the concept can be tested in other nations and by our cooperating agencies in the U.S. We would like to be kept informed of your use of soil potentials and send us copies of the assumptions, definitions, criteria, and rating clases that you develop.

Pilot exercies have been conducted in Leon County, Florida and Medford, Oregon, the former for septic tanks and the latter for pear production. In Florida, two sanitarians of the county department of health and two from the State participated for three days and completed the basic system.

The purpose of these projects was to test the procedure outlined in NSH Section 404, and to provide traning in this procedure. We believe that additional pilot exercises should be conducted to assure that State staffs are properly trained in the procedures, we suggest that the technical Service Centers assist with one project in each State.

Whether or not to publish soil potentials in soil surveys has been left up to the States. If the State feels that publication would help achieve full use of the soil survey, then we will publish them. There are no plans to require coordination of the ratings at any level above the survey area. To do so would negate one of the major merits of the system.

APPENDIX 3

WORK SHOP SESSIONS

Summary of Proceedings of the Workshop on Soil Mapping Ssytems

K.W.G. Valentine
Land Resource Research Institute

The Mapping Systems Working Group presented the second draft of "A Proposed Soil Mapping System for Canada". This was discussed over two days, portions of it were revised and it was issued for further evaluation in the 1979 field season.

Section 1 dealt with the rationale of the System and defined soil mapping procedures.

Section 2 covered the size of map delineations, map legibility, inspection density and the rates of land coverage. Recommendations for these and various survey planning procedures were made.

Section 3 on "The Establishment of Map Units" defined the relationship of soil taxonomic units to map units, and recommended the recognition of one simple and five compound kinds of map units, and specified their composition. Inclusions were defined as similar or dissimilar, limiting or non-limiting for interpretive purposes, and different methods of representing inclusions both on a map and in its legend were discussed. Different kinds of soil map phases were defined, and recommendations for better usage were made. A set sequence of procedures to establish map units was summarized, including the ways of subdividing the units and naming them.

Section 4 explored the differences between closed and open legends, and presented reasoning why we should aim for more closed legends on soil maps. Recommendations included preferred ways of describing map units, the need for a CanSIS map unit file and a map unit description form and procedures for map symbolization. Preferred methods for laying out a legend were presented.

In Section 5, various aspects of the soil map were discussed with recommendations for defining map delineations, for characterizing map texture intensity, for symbolization, for the use of colours to improve map readibility and other aspects of cartographic presentation.

Section 6, (the Soil Report) and 7 (Interpretations) indicated mostly the general directions for further work to systematize and improve these aspects of soil reporting.

Most of the recommendations of the Working Group were adopted, with the exception of minor parts such as the definition of map subunits, and the proposed newly-coined terminology for kinds of map units. However, the system is still under trial and further modifications are expected. Apart from the continued evaluation in depth of all the recommendations in the individual Soil Survey Units across Canada, there is continued activity in defining user needs from soil surveys and in preparing a Handbook of Soil Survey Procedures, including correlation techniques. The whole field of interpretations of soil surveys may require the establishment of a separate working group.

Editorial Note. The complete report of the soil mapping systems working group has been published in September 1979 and is available at the Ottawa offices of Land Resource Research Institute.

Progress Report - Soil Water Working Group

J.L. Nowland
Land Resource Research Institute

"Act our way into a new mode of thinking rather than trying to think our way into a new mode of action".

(Summary material is in this style)

Membership

The group was set up in September 1978. It consists of R.G. Eilers, D.E. Moon, C. Tarnocai, G.C. Topp, C. Veer and J.L. Nowland. It will be expanded by two more members, with regional affiliations in Central Canada and the Prairie Provinces. One or two foreign correspondents will be enlisted. The members are responsible for cultivating appropriate regional feeder groups on a formal or informal basis as they see fit.

Objectives

a. In the long term to develop a framework for more adequately describing and measuring the water state of soil in relation to capacity and transmissibility.

b. Systematically to distinguish and define the various components of the water regime.

c. To formulate soil water regime research needs.

d. To prepare a Manual of field research methods on the water regime, or to contribute this material to a broader Manual on all field research methods, as a companion volume to the Manual already existing for the laboratory methods.

e. As the priority area within these objectives, to construct a working classification and a standard format for characterization of water regime for testing in soil survey beginning in the 1979 field season.

Definition of soil water regime and preamble

Soil water regime refers, firstly, to the range and sequence of states (conditions) and quantities of water in soil and, secondly, to the soil properties and hydrologic conditions which control the states and quantities of water in the soil.

Thus, the water deficit classes, zone of saturation classes, wetness persistence classes and ground ice classes described below all pertain to the "state and quantity" of water in the soil. The climatic and hydrologic zonations are classifications of controlling "hydrologic conditions". And the water retention and soil transmissibility classes are soil properties.

Thus far we have addressed only objective e (see above) using an initial position paper by Nowland and Veer. Much of the position paper survives here, with modifications.

Our starting point was the Report of the Subcommittee on Soil Water Regimes (Chairman, E.E. Mackintosh) following the CSSC Meeting in Guelph, February 1976 (1). This report was a succinct statement of the state-of-the-art, at least from the soil mapping point of view. It provided a solid base for further progress. Meanwhile, correlation activities in Eastern Canada continued to expose the inadequacy of the soil drainage classification and Nowland and Veer began to formulate a suggestion for trial in Eastern Canada in the 1978 field season. Ideas came forth on the direction to be taken, thanks especially to G.J. Beke's working group on "kinds of saturation" and submissions by Macdougall and Michalica.

Problems with the existing approach and direction to go

Problems with the present scheme that the subcommittee must address have been well aired. To summarize some of them:

a. Poor differentiation between water availability and transmissibility.

b. The same "drainage class" has radically different water regimes in different climatic zones. Imperfect drainage is a limitation in some zones, an advantage in others.

c. Poor sensitivity to many important factors, such as persistence of saturation and existence of nutrient rich seepage.

d. Less than desirable correlation in the assessment of "drainage" between individuals and provinces, and also in the application of gleying criteria.

e. Weaknesses in the last Subcommittee Report were evident, e.g. in the recommended application of the soil moisture subclasses of the Soil Climate Map, and in omission of guidelines on separating profile and site drainage.

f. The problems posed by the adoption of the Leskiw 1973 scheme in the CanSIS Manual when it was never officially adopted by CSSC. Some minor technical considerations:

- i It relies on soil climatic classes that need modifying.
- ii Doubtful practice of grafting water storage capacity criteria on to drainage class definitions.
- iii Lack of definitions to aid use of vegetation criteria for drainage classes outside B.C.

iv No indication of the portion of the soil on which perviousness classes are determined, or how to handle contrasting layers.

v Not clear how mappers are to handle major lateral seepage.

Rummaging through the subcommittee correspondence of the last few years, one is struck by the degree of consensus on the four or five key parameters in a classification of moisture regimes. But when we start imposing firm class intervals on these parameters, in order to make them consistently usable across the country, we will inevitably

i create separations that will appear meaningless in some regions; therefore there has to be regional flexibility to lump or divide classes

ii rely on criteria, e.g. zone of saturation depths, that are much more difficult to estimate in some areas than others; therefore, mappers will have to go out on a limb until field measured data starts to flow, as flow it must.

The hard fact remains that many soil surveyors can do a better local job of characterizing the water regime by inspired empiricism than by slavish application of arbitrary class limits. Many could be happy with placing every site or mapping unit in one of five classes of "moisture status", a modal class plus two degrees up and down, drier and wetter, as perceived in an intuitive synthesis of key plant species and soil colours.

This is no way to get consistency, either between regions or individuals; it involves lengthy indoctrination of recruits in the mystique of the old ways; it omits vital considerations such as soil permeability; and it gives correlators disturbed nights.

The objectivity of a "parametric" approach is presently assumed to outweigh apparent disadvantages such as arbitrariness of class limits, temporary data deficiencies, and the awkwardness of using a cumbersome national scheme for meeting specific detailed local needs.

It is recognized that there are many uses other than soil survey uses for a simple method of characterizing the moisture regime, for example, in standard descriptions of research sites. The soil survey use of the system will remain the prime consideration because its need is judged to be greatest, and many other users will almost certainly demand refinement and subdivision within the classes, which can come later.

At the CSSC Meeting, in 1976, disenchantment with the soil drainage classification was enough to produce a motion to abandon it, which was carried. Subsequently, in the cold light of day, we clung to the scheme like the proverbial drowning man, there being some uncertainty as to how to apply the Committee's five-pronged approach. And there did remain a number of aspects requiring further study.

According to the Subcommittee Report, we are supposed to be using the old drainage classification "in conjunction with those segments of the new scheme that have been developed to a workable stage" (p. 1). We will briefly review these segments and propose some improvements.

Climatic Regionalization

There has been some recent progress in conceptualizing the relationship of climate to soil inventory, in appreciating its importance in land evaluation and in continued development of ecological mapping.

Some provinces have the benefit of useful climatic/vegetation zonation schemes, e.g. Damman's classification of Newfoundland (2) and Krajina's in British Columbia (3), and others have classical pure climatic zonations, e.g. Putnam's scheme for the Maritime Provinces (4). The Prairies have their strongly correlated climate/Soil Great Group zones, and Quebec has its Thermic Regions. But there is still no uniform zonation treatment agreed upon as a basis for relating and explaining variations in water regime across Canada. The nearest approaches were the schemes of Chapman and Brown (5), the Soil Climatic Map of Canada and Sly's Climatic Moisture Index (6).

Climatic zonation is retained as a fundamental part of this proposal (see Table 1) because it is the highest most generalized level in a possible hierarchical approach to classifying water regimes. (It is also basic to the proper building of soil mapping units). However climatic zonation will continue to be treated at a local or provincial level, without much interprovincial coordination, unless we can demonstrate the need for a national network in soil mapping and correlation.

The geographic grid-square data bank system of Solomon et al. (7) may offer the best possibility of a consistent national system of zonation for use on soil mapping, and ipso facto, water regime characterization. But the system is weak in hilly areas.

Furthermore, soil surveyors ought to be able to retrieve standard climatic data packages, station by station or generalized by these zones, or both, for insertion in legends and reports for each survey area. They should not have to spend time pondering how far to process basic data, whether to include sunshine hours or not, and how to create better graphs and tables ("wind roses are fine for sailors but..."), unless of course they have a special avocation for these things.

Landscape Criteria

a. The landscape criteria were to be developed to delineate hydrological zones of recharge, discharge, etc. and possibly to identify surface drainage patterns, such as trellised, radial etc. These two elements have a certain appeal in a hierarchical approach. They might serve to set soil water regimes in their landscape perspective, just as landform units frame soil mapping units. Unfortunately, the relationship between soil water state and deep-seated hydrology may be rather weak because of the complexity of interflow patterns. The surface of broad elevated recharge areas of basal till in humid climates commonly has a complex pattern of local "recharge" areas and seepages with widely variable runoff and infiltration rates, all reflected in soil morphology.

The relations between soil hydrology (interflow) and deeper subsurface hydrology appear to be tenuous enough to require more study before concepts of recharge and discharge can add much to our classification of soil water regime in the field at least in humid climates. The extremes of recharge and discharge may be readily recognized in the field, but unless he has the benefit of instrumented sites, ie. strings of piezometer nests, the mapper could often be left with much larger areas labelled "indeterminate" or "complex".

To be useful, the hydrological zone segment of the classification must do more than simply label well drained parts of the catena "recharge", the gleysols "discharge", and areas of gleyed soils a mixture of both, with recharge dominant in Newfoundland and discharge in southern Ontario. As an elegant link in the hierarchy of classification, hydrological zonation is retained in this proposal, but with a value that will be conceptual rather than practical for the time being.

b. Stream pattern is a pretty geographical classification with advantages in soil survey that require some demonstration. A classification scheme has recently surfaced from the Lands Directorate (8).

c. The need to classify surface (external) drainage quite separately from soil drainage has been pleaded on frequent occasions. Since it is not dealt with in the subsequent innovative parts of this proposal, the subject should probably be considered with landscape criteria in this section. Part of Leskiw's (1973) scheme re-defines the traditional drainage classes as mainly for site classification, with some reference to internal soil drainage. The CanSIS Manual interprets it as a site classification and therefore a classification of external drainage. The two are difficult to separate, and the semantic confusion is compounded by a further classification of external (site) drainage also referred to as "Surface Runoff" in the CanSIS and U.S. Manuals. Others have classified external drainage in terms such as shedding, receiving and normal, thus coming right back to considerations of hydrological zonation.

This can be settled by accepting that the classification of Surface Runoff is the only current scheme of site drainage classification, even though it was apparently lifted from the US Manual and never officially adopted in Canada. The Leskiw/ CanSIS Manual classification of "Soil Drainage Classes" (p. 38) is just that, and not really a classification of "Soil Site Drainage Classes" (p. 36 of the CanSIS Manual).

Some of the terminological difficulty can be ascribed to the fact that the soil and its drainage cannot be separated from the site and its drainage.

Water Deficit (D) Classes ("soil moisture subclasses")

These are the classes developed for the Soil Climates of Canada map and presently used in the Family level of the System of Soil Class ification. *There has been some uncertainty as to whether classes developed for spatial representation of average or zonal conditions at small scales could be used for characterizing a pedon. More debate may be necessary, but it seems a somewhat academic issue since there is no doubt that the parameters can be estimated or measured at point locations, as well as being spatially generalized.*

The Mackintosh Subcommittee sanctioned this segment of water regime classification, but realistically noted a need for regional modifications in British Columbia, and also in The North, where the soil is commonly frozen at the diagnostic 50 cm depth. Inclusion of soil porosity and depth terms was also suggested.

There has also been a suggestion (Bob Eilers) that separate class limits be set up for natural and cultivated systems.

In this proposal, we retained the Soil Moisture Subclass component as the third level in the hierarchy, after climatic and hydrological zones. While currently more useful than the two other components, its immediate value is limited by class overlaps and imprecise definitions.

Under the present definitions, many soils in Eastern Canada and British Columbia fit into both subaquic and perhumid or humid (or even subhumid) classes. They are saturated for short periods in the growing season and experience marked deficits in the root zone at other times. There are difficulties interpreting terms such as "short periods", "long periods" and "saturation" (in any part of the profile?).

The classification rests on the calculation of water deficits, assuming 100 mm water storage with precipitation and evapotranspiration data of the nearest weather stations taken as representative. Local mesoclimatic influences and soil variability alone are probably sufficient to bounce soils from one class to another, even without the effects of groundwater redistribution.

Many of these problems might eventually be resolved with refined definitions, and data from field instrumentation leading to local climatic modelling. For the present, the ultimate value of the moisture subclasses in water regime classification is unclear.

The remaining segments of the classification are probably of greater significance in the field characterization of soil water regime, and could be operated (operationalized as the jargon goes) immediately in the mapping program, at least on a trial basis.

Soil Water Regime Classes (transmissibility, zone of saturation, depth and persistence)

The proposed water regime classes cover the two remaining subject areas outlined in the 1976 Subcommittee Report, a zone of saturation (water table) component and a soil transmissibility component. But they are treated differently, and have an optional saturation persistence component added, plus some other recent accretions.

Under the proposed scheme, instead of two soils being compared as imperfectly and poorly drained, they might be designated E3 and D5 (see Table 1).

In the classification E3, the E says that the soil has low overall saturated vertical transmissibility (hydraulic conductivity), less than 0.5 cm/hr, mainly controlled by an impeding layer or layers below 50 cm (see Table 1). The arabic 3 characterizes the zone of saturation (water table) as reaching a mean highest annual level within 0 to 50 cm from the surface and the mean lowest at a level below 150 cm. This characterization of the water table borrows from Dutch practice, with modifications (10).

Immediately it will be pointed out that we lack the network of water table observations enjoyed by the Dutch. This may not be a serious deterrent since early indications are that the proposed classification can be estimated at least as readily as the old "drainage status". And greater accuracy will come as we lay out more dip wells, and perhaps learn to "read" mottles better. Of greater concern should be the relevance of the "zone of saturation" parameters to our needs in soil survey.

In the second example given above, the D5 soil has moderate and fairly uniform transmissibility within the control section, and a zone of saturation fluctuating between a high within 50 cm of the surface and a low that rarely falls below 150 cm (such a situation might be found in a Gleyed Dystric Brunisol on a loamy basal till in a humid climate).

In either example, E3 or D5, the period when a zone of saturation remains near to the surface might vary significantly, requiring the splitting of the class. Thus if it were possible to estimate persistence of saturation at or above 50 cm depth, the observer could add to the designation, e.g. E3-4 or D5-5, but this elaboration might only be thought necessary in certain climates or soils. Some Gleyed Brunisols and Podzols have subsoils so dense and impermeable that a perched zone of saturation may be evident many weeks after the rainy period in which it appeared. In such soils, classification of the water regime would be improved by incorporation of the persistence term. The E3 class may be subdivided into E3-2 and E3-4 (see Table 1), on the basis of the number of days in the 200 day period between mid April and the end of October that the water table is estimated to remain at 50 cm or higher.

Discussion of assumptions

The 200 day period, a sort of stretched growing season, has been used as the diagnostic period on the assumption that struggling with uncertain winter conditions does not yield much more useful information than can be read into water regime conditions in April. Extreme variability of water table from one winter to the next was observed in wells in imperfectly and poorly drained soils in Nova Scotia, as a function of the date of soil

TABLE 1 CLASSIFICATION OF SOIL WATER REGIME

(OUTLINE)

Level of Abstraction	Classification Components
A. Climatic zonation	1. Climatic regions, zones
B. Regional hydrology	2. Hydrological zone
C. Soil climate	3. Water deficit (D) classes (6)
D. Soil Material and Soil Hydrology (interflow zone)	4. Water retention (R) classes (4)
	5. Soil transmissibility (K) classes (7)
	6. Zone of saturation (S) classes (14)
	7. Wetness persistence (P_{50}, P_{20}) classes (12)
E. Ground ice	8. Ground ice classes
F. Artificial modification	9. Artificial drainage modifiers (10)

(DETAIL)

1. CLIMATIC REGION
   Subregions, zones

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2. HYDROLOGICAL ZONE
   a. surface pattern, radial, trellised etc. (15 classes approx.)
   b. subsurface flow, recharge, discharge (3-5 classes)

---

3. WATER DEFICIT (D) CLASSES
   (6 classes drawn from the "soil moisture regime subclasses" used for Soil Climate Map of Canada and Soil Family Classification)

a.	Aquic and Perhumid	Soil Moist or saturated all year, seldom dry. No significant water deficits in the growing season: deficits <2.5 cm. CMI >84.
b.	Humid	Soil not dry in any part as long as 90 consecutive days in most years. Very slight deficits in the growing season: deficits 2.5-<6.4 cm. CMI 74-84.
c.	Subhumid	Soil dry in some parts when soil temperature is $\geq 5^{\circ}C$ in some years. Significant deficits within growing season: deficits 6.4-<12.7 cm. CMI 59-73.
d.	Semiarid	Soil dry in some parts when soil temperature is $\geq 5^{\circ}C$ in most years. Moderately severe deficits in growing season: 12.7-<19.9 cm. CMI 46-58.
e.	Subarid	Soil dry in some parts or all parts most of the time when the soil temperature is $\geq 5^{\circ}C$. Some

Table 1 (continued).

	periods as long as 90 consecutive days when the soil is moist. Severe growing season deficits: deficits 19.1-38.1 cm in BOREAL and CRYOBOREAL temperature classes, 19.1-<50.8 cm in MESIC or warmer classes. CMI 25-45.
f. Arid	Soil dry in some or all parts most of the time when soils is ≥5°C. No period as long as 90 consecutive days when soil is moist. Very severe growing season deficits: deficits ≥38.1 cm in BOREAL and ≥50.8 cm in MESIC or warmer classes. CMI <25.

---

4. WATER RETENTION (R) CLASSES
(4 classes to be developed based on some combination of texture, pore space distribution, bulk density, organic matter content and depth criteria)

a. High c. Low
b. Moderate d. Very low

---

5. SOIL TRANSMISSIBILITY (K) CLASSES
(7 classes of saturated vertical transmissibility within the control section, with 3 modifiers for quality of lateral seepage)

A	high throughout control section	>10 cm/hr
B	medium, due to impeding layer(s) below 50 cm	0.5-10
C	medium, due to impeding layer(s) within 50 cm	0.5-10
D	medium, and uniform	0.5-10
E	low, due to impeding layer(s) below 50 cm	<0.5
G	low, and uniform	<0.5

seepage modifiers:
d, dystrophic; m, mesotrophic; e, eutrophic
(see notes 2, 3, 4, 5)

---

6. ZONE OF SATURATION (S) CLASSES[6]
(7 classes of Mean Highest (MH) and Mean Lowest (ML) zone of saturation (water table))

Soil without a perennially frozen horizon within the control section
(Mean annual soil temperature greater than 0°C)

Classes	1	2	3	4	5	6	7
MH (cm depth)	>100	50-100	0-50	50-100	0-50	0-50	0*
ML (cm depth)	>150	>150	>150	100-150	50-150	<50	<50

Table 1 (continued)

Soils with a perennially frozen horizon(s) within the control section
(Mean annual soil temperature 0°C or less)

Classes[7]	1Z	2Z	3Z	4Z	5Z	6Z	7Z
MH (cm depth)	>100	20-50	0-20	20-50	0- 20	0-20	0*
ML (cm depth)	>150	>100	>100	50-100	20-100	<20	<50

*MH water table above the surface, ie. inundation implicit in Class 7.

7. WETNESS PERSISTENCE CLASSES (P_{50}, P_{20})

Soils without a perennially frozen horizon within the control section
(Mean annual soil temperature greater than 0°C)

(6 classes of persistence of zone of saturation within 50 cm of the surface between April 15 and October 1st (max. 200 days)).

Class (P_{50})	Days	%
1	0- 1	0 - 0.5
2	2- 30	0.6- 15
3	31- 60	16 - 30
4	61-120	31 - 60
5	121-180	61 - 90
6	181-200	91 -100

Soils with a perennially frozen horizon(s) within the control section
(Mean annual soil temperature 0°C or less)

(6 classes of persistence of zone or saturation within 20 cm of the surface between April 15 and October 1st (max. 200 days))

Class (P_{20})	Days	%
1Z	0- 1	0 - 0.5
2Z	2- 30	0.6- 15
3Z	31- 60	16 - 30
4Z	61-120	31 - 60
5Z	121-180	61 - 90
6Z	181-200	91 -100

8. GROUND ICE CLASSES

In this part the perennially frozen water will be classified according to the classification developed by engineers. (C. Tarnocai is in the process of obtaining this classification from NRC).

9. ARTIFICIAL DRAINAGE MODIFIERS

2 grades of impact by artificial means on S (zone of saturation) and P (wetness persistence) ratings only.

Table 1 (continued)

D, DD:	open ditched
T, TT:	tube drained (tile, plastic pipe, wooden box)
M, MM:	moled
S, SS:	subsoiled
R, RR:	"rigg and furrow", ridged, listed, rond-plat

Table 1 notes

1. *CMI - Climatic moisture index is an expression of the percentage contribution of growing season precipitation to the total amount of water required by a crop if lack of water is not to limit its production.*
2. *"Impeding layer" is a layer that reduces transmissibility.*
3. *Soil transmissibility component - Expanded classes (the conductivity values are taken from Mackintosh (1) chosen to coincide with U.S.D.A. practice)*

	cm/hr		*cm/hr*
1A	*>20*	*1D*	*5-15*
2A	*15-20*	*2D*	*1.5-5.0*
		3D	*0.5-1.5*
1B	*5-15*	*1E*	*0.15-0.5*
2B	*1.5-5.0*	*2E*	*<0.15*
3B	*0.5-1.5*		
1C	*5-15*	*1F*	*0.15-0.5*
2C	*1.5-5.0*	*2F*	*<0.15*
3C	*0.5-1.5*	*1G*	*0.15-0.5*
		2G	*<0.15*

4. *For a regime to be classified B, C, E, or F, the impeding layer(s) have to exert a substantial influence, ie. without it, the B and C soils would be classed as A, and the E and F soils as A or D. A less pronounced impeding layer, or layers, would place the soil in classes D or G.*
5. *The transmissibility rating is for the entire control section and therefore represents the least permeable layer. A description of the class groupings high, medium and low is attached (Appendix 1). These are taken from the descriptions of "permeability classes" in the revised USDA-SCS manual, and may require modifying.*
6. *Zone of saturation - a zone of zero moisture tension thicker than 15 cm, persisting longer than 5 days within 150 cm of the surface.*
7. *The Z modified classes are for soils which have a perennially frozen horizon(s) within the control section. They have a mean annual soil temperature 0*

freezing. This did not have a great effect on subsequent well levels after snowmelt. However, a strong case can be made for adjusting the scheme to encompass the whole year, since winter soil water conditions are important to a variety of non-agricultural interests. So the scheme will probably be put on a 365 day basis.

Michalica (pers. comm.) some time ago suggested a classification of moisture regime based mainly on the percentage time persistence of wet and dry states, along with intensity of mottling. This is where the emphasis is being placed in the USDA, according to the 1979 Work Planning Meetings.

The treatment of transmissibility raises some immediate questions:

a. Only vertical transmissibility is considered in terms that can be quantified. The three modifiers for lateral seepage (see Table 1) only offer some expression of quality, though they could be expanded and refined. It is doubtful if sufficient data exist for surveyors to assess <u>rate</u> of lateral seepage.

b. It has been decided to ignore unsaturated conductivity for survey classifications, because of the difficulty of measuring it, and uncertainties of interpretation in relation to other survey data.

c. On which part of the control section is transmissibility to be assessed or averaged: the least permeable layer; the average of the whole or part control section, or deeper layers; or should contrasting layers of certain minimum thickness be recognized by a composite classification? The first approach, maintaining the significance of the least permeable layer, has been adopted. However it might be preferable to recognize contrasting layers by rating two of them (but no more) individually. Thus a regime E5 in sand over clay could be designated A/E 5, if the definitions were changed slightly. A minimum overlay thickness of 50 cm could be specified before it is separately identified. Recognizing contrasting layers in this way would facilitate classification of the active layer over permafrost. Another way of doing it is shown in Appendix 3.

Defence of proposed water regime classes

The water regime classes E3-2, E3-4, B5-5 etc. are probably just as arbitrary and a matter of guesswork as the present drainage classification. But this approach has certain advantages:

a. It incorporates transmissibility, so that poorly drained clays and sands are no longer in the same box.

b. It caters to the more essential distinctions between "groundwater" and "perched water" saturation by denoting the existence of impeding layers and, as necessary, recording the persistence of temporary zones of saturation in the upper solum. It is hoped in some way to remove the separate recognition of pseudogleys and surface water gleying as a soil taxonomic concern, and handle it in soil water regime classification. This is to avoid cluttering the System of Soil Classification with half defensible subgroups of pseudogleyed soils.

By grafting "persistence" on to the transmissibility and zone of saturation depth components, it is hoped to provide enough information on the "kind of saturation", the subject that exercised Beke's working group in 1977. This group proposed definitions of groundwater, surface water and undifferentiated saturation, with subclasses for moving or stagnant water. The definitions were difficult to formulate, and the need for them would disappear if the proposed water regime classes were used.

c. While the estimates of zone of saturation are no less subjective than present assessment of speed of drainage, they do lend themselves to verification by timely spot measurement or continuous monitoring. During the 1977 correlation tours in the Atlantic Provinces, there was some (hesitant) admission that one could estimate seasonal water table extremes from soil morphology. At least human error seemed no greater than when assessing drainage class. Judgement is based largely on mottling distribution, bulk density, root distribution, horizon development in relation to established regional norms, and direct observation of water table, especially in spring and late summer.

Extrapolation from a single observation of the water table depth, as made during a mapping traverse, is greatly aided by reference to benchmark measurement sites that are monitored periodically and related to seasonal precipitation. Soil Surveys in Canada are strongly urged as standard survey practice where feasible, to lay out shallow dip well or piezometer sites for the duration of survey projects. Some units have demonstrated them to be practical, inexpensive and worthwhile projects at survey intensity level 1 to 3. One could not expect too much for exploratory surveys. There are attractive possibilities for research into inexpensive methods of remote and automatic monitoring of water table level and soil moisture content.

d. The proposals do not attempt to be comprehensive, but try to focus on essentials, hopefully in order to meet one absolutely essential criterion - simplicity. Any scheme must be uncomplicated if it is to meet the needs of the least experienced groups of mappers, those who actually do most of the mapping, and do it by growing amounts of guidelines, and who would prefer to specialize in something other than water regime classification.

The objective is to classify the types of water supply in any given soil mapping unit in a way that anyone can understand. Agriculturalists and engineers alike, not to mention planners, have constant trouble with the meaning of the existing drainage classes, and explaining them is downright embarassing. Zones of saturation and soil transmissibility, even if they have to be called water table and permeability, should have more meaning for users of interpreted soil information.

Alternative paths

Possible alternatives will not be discussed in detail, since they are to some degree self-evident.

a. Retain the present drainage classes, with perhaps some added refinement of definitions, or even going to the lengths of assigning values of persistence of saturation to each class.

b. The Leskiw (1973) scheme which resembles a. with the addition of perviousness classes and the soil moisture subclasses of the Soil Climatic Map. This is a superior scheme, and was unofficially adopted for the CanSIS Manual, though not by CSSC. It has not been widely used in its entirety, but is seen as a definite candidate for official adoption if a consensus prefers that. We think it can be improved upon.

c. Since many aspects of moisture regimes are covered by soil subgroup classification, one might envisage the characterization and classification of a few regimes specific to each subgroup. These would be an open ended list, with sub-types set up as needed over the years. Thus a regime could be classified as GL.HFP #6, with a certain porespace distribution, precipitation range, run-off, transmissibility and water table depth and fluctuation.

Such a classification would be installed at the family level of soil taxonomy, so that the moisture and temperature classes as now used would be elaborated and subdivided.

Research and development areas in support of the proposed approach

1 Climate (zonation). The rapid establishment of a national network of atmospheric (as opposed to soil) climatic zones and subzones for use in soil surveys, by the adoption or adaptation of existing regional zonation schemes, and the development of new ones in deficient regions.

The preparation of a standard climatic package for each climatic subzone for incorporation "off the shelf" in soil survey publications, using existing data. (Agrometeorology Group, LRRI, with selected provincial cooperators; Inventory Group, LRRI; and contractors).

2 Climate (soil climate). Improvement of soil moisture subclass definitions (Soil Climatic Map of Canada, and pp. 122-123 in The Canadian System of Soil Classification) to remove overlap of classes, and accomodate regional modifications for B.C. and the North.

Development of regional (provincial) guidelines for the classification of local moisture subclasses in mesoclimatic areas not represented by weather stations, e.g. enclosed basins, river valleys, peat bogs, lake and marine margins. (Agrometeorology and Inventory Group, LRRI; provincial Survey offices; university cooperators).

3 Regional hydrology and water. Feasibility study on developing hydrological criteria for characterizing (descriptively) or classifying (definitively) the soil water regime in its environmental setting. These criteria need not necessarily be for universal application in all situations, but may be derived only for special cases such as salinized soils, groundwater gleysols, and certain organic soils.

Develop guidelines for minimum and desirable hydrological information content in soil survey reports. (Inventory Group, LRRI; cooperators in Inland Waters; and provincial hydro-geology offices).

Feasibility study on the utility of a classification of surface drainage patterns (dendritic, trellised, karst interrupted) in soil survey. There is a link here to proposals of the Wetland Committee for classifying water bodies in the landscape.

4 Water regime field monitoring and modelling

Modelling of seasonal water table pattern and variations in relation to weather data and mapped soil units (LRRI).

Establish the specs for two recommended grades of field monitoring of water regime (see below); coordinate a national program through the correlation staff; develop a method of generalizing the resultant data relating levels and persistence of zones of saturation to precipitation (or adapt the method of Nelson et al. (9)); develop better rapid measurement techniques and automated data recovery over periods of months; investigate improved ways of handling lateral seepage in mapping. Some suggested specs for monitoring sites follow.

<u>Basic economy site</u>

Measurements:	*Depth of zone of saturation only. Daily precipitation from nearest weather station.*
Frequency:	*Weekly to monthly, plus storm event responses, summer months only.*
Hardware:	*On uniform soils: a single well of 3 to 5 cm diameter ABS or similar tube, perforated in the lower 25 cm, sunk to 1.5 m, tightly in a Dutch auger hole.*

Hardware (cont'd.)

In soils with an impeding layer: the 1.5 m well is sealed with bentonite or grouting compound at the impeding layer to prevent penetration of perched water, and a second perforated tube is sunk to the depth of the impeding layer, to monitor perched water separately.

De luxe site

Additional measurements:	*soil water content* *redox potential* *on-site precipitation* *soil temperatures (optional)*
Frequency:	*weekly to bi-weekly, summer months, winter optional*
Hardware:	*Dielectric moisture probes (or neutron probe to fit ABS pipe, or permanent fibreglass blocks and meter)* *Platinum electrodes installed at 3 depths in triplicate* *Recording rain gauge* *Thermistors (optional)* *Security fence (in some areas)*

Special Edition site

Offers fully automated data transmission for long periods, by telemetry or satellite, including automatic chemical analysis of soil water on a weekly basis and continuous read-out of moisture tension at 10 cm depth increments. (Inventory Group, Genesis and Classification Group, LRRI, Provincial cooperators, Fairy Godmother).

5 Transmissibility and Porosity. Determination of critical parameters for characterizing the transmissibility and pore size distribution as part of soil water regime classification for surveys. Develop a modular scheme with expanded scale of classes for special site studies, and identify the significant ranges of class intervals. (Genesis and classification group, LRRI, with Inventory Group).

Future activity (views of J.L.N., without consultation)

a. First priority goes to setting up a working system of water regime classification to serve the needs of the survey program. While being of uniform national application, it will retain the flexibility necessary for emphasizing criteria that are important locally, and for the expansion of general classes for detailed applications.

b. It will be crucial to consider the special needs of the land evaluation program in the selection of key parameters and class limits.

c. Regional concerns and priorities viz-a-vis soil water regimes will be listed and accommodated as much as possible in the classification scheme.

d. Ways of incorporating soil water measurement and monitoring into routine survey activities will be examined. Specifications will be developed for site instrumentation. The benefits of a national soil water monitoring network, beyond that within current survey projects, will be studied.

e. A recommended format for a hydrology/soil water chapter in soil reports will be developed.

f. As the short term matters are taken care of, we shall turn more to the determination of long term research needs, and possibly to the publication of a soil water regime how-to-do-it manual.

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Appendix 1

Soil Transmissibility Classes

(abridged from preliminary write-up of permeability classes for the revised USDA-SCS soil survey manual)

High transmissibility. The capacity to transmit water vertically is so great that the soil would remain wet for no more than a few hours after thorough wetting if there were no obstructions to water movement outside the body classified. The horizons and soils have large and continuous or connecting pores and cracks that do not close with wetting. Many, but not all, fragmental, sandy, skeletal soil bodies provide these conditions, as do some medium and fine textured horizons that have extremely strong, granular structure and large, connecting pores.

Medium transmissibility. The capacity to transmit water vertically is great enough that the soil would remain wet for no more than a few days after thorough saturation if there were no obstructions to water transmission outside the body classified. Most moderately pervious soils hold relatively large amounts of water against the force of gravity, and are considered good, physically, for rooting and supplying water to plants. Soil horizons may be granular, blocky, weakly platy or massive (but porous) if continuous conducting pores or cracks are present which do not close with wetting.

Low transmissibility. The potential to transmit water vertically is so slow that the horizon or the soil would remain wet (saturated) for periods of a week or more after thorough wetting whether or not there were obstructions to water movement outside the body classified. The soil may be massive, blocky or platy, but connecting pores that could conduct water when the soil is wet are few, and cracks or spaces among peds that may be present when the soil is dry close with wetting. Even in positions accessible to plant roots, roots are usually few or absent and if present, they are localized along cracks when the soil is wet.

Appendix 2

Examples of the classification of specific soils

Prov.	Soil Series or Assn.	Subgroup	Parent Material	Climatic region & zone[1]	Soil Moisture Subclass	Hydro-logical Zone	Water Regime Class	Traditic drainage class
N.S.	Woodville	O.HFP	compact basal till	4L/85	e	R	B1-1	Good
	Queens	GLBR.GL	compact basal till	4L/85	c/d	R	F5-5	Imp
	Diligence	GL.GL	compact basal till	4L/85	c/d	R	F5-5	Imp
	Acadia 1	GL.R	marine	4L/85	c/d	D	G5-4	Imp
	Acadia 2	R.G.	marine	4L/85	b	D	G5-5	Poor
	Debert	GLE.DYB	compact basal till	4L/85	c/e	R	F4-4	Imp
	Masstown	O.G	compact basal till	4L/85	b	D	F5-5	Poor
	Kingsville	FE.G	compact basal till	4L/85	b	D	F6-5	Poor
ONT. & QUE.	Bainsville	O.HG	compact basal till	3H/75	b	D	E3-4	Poor
	Carp	GL.GBL	marine clay	3H/75	c	R	B2-2	Imp
	N. Gower	O.HG	marine clay	3H/75	b	D	B5-3	Poor
	Uplands	O.HFP	marine & fluvial sand	3H/75	e	R	D1-1	Good
	St. Samuel	O.HG	marine & fluvial sand	3H/75	b	D	D5-4	Poor
	Ramsayville	GL.SB	marine & fluvial sand	3H/75	c	R	D4-2	Imp
	Ste-Rosalie	O.HG	marine clay	3H/75	c	D	D5-4	Imp
NFLD.	New Bay Assn	O.G	stony basal till	6L/87	b	D	C5-5	Poor
	New Bay Assn.	GLOT.FHP	stony basal till	6L/87	c	R	F5-3	Imp
	Alderburn Assn	GL.HFP	till (stony)	6L/87	c	R	Cm5-4	Imp
	Terra Nova Assn	GLOT.FHP	till	6L/87	c	R	Fm5-4	Imp

[1] Chapman & Brown plus C.M.I.

3 3000 - 3500 d.d.
4 2600 - 3000 d.d.
6 1800 - 2200 d.d.

L water deficit 0
H water deficit 1-3

Appendix 3

Alternative Method of Classifying Transmissibility (Nowland)

H > 15 cm/hr; M 0.5-15 cm/hr; L <0.5 cm/hr

15 classes thus:

H	*throughout control section*
MHH	*M over H within 50 cm from surface*
MMH	*M over H below 50 cm of surface*
LHH	*L over H within 50 cm of surface*
LLH	*L over H below 50 cm of surface*
M	
HMM	
HHM	
etc.	

The designation of expanded classes, as per Note 2, Table 1, would be clumsy e.g. 2MM1H

Porosity classification (Veer)

Classes of transmissibility are not the only way to characterize how water moves and is held in the soil. Veer has proposed classes of porosity based upon depth ranges and upon limiting values of 35% total pore space and 5% macropores (see Table 2). "The 35% total pore space is used as a minimum value for adequate rooting... The 5% macropore space is here assumed to be the lower limit for free water drainage." (Veer, pers. comm.).

Table 2. Classification of porosity (C. Veer)

Class	Depth range of layers with more or less than 35% total pore space		Depth range of layers with less than 5% macro-pore space or a phreatic surface
	cm	%	cm
1a	0-40	<35	<40
1b	0-40	>35	40-80
1c	0-40	>35	80-120
1d	0-40	>35	120-160
1e	0-40	>35	>160
2a	0-80	>35	80-120
2b	0-80	>35	120-160
2c	0-80	>35	>160
3a	0-120	>35	120-160
3b	0-120	>35	>160

In the above classification (which is not being proposed for use at present), the 5% value for micropores may be on the low side; there are also doubts about classes that might include both sand and clay with the same pore space (Topp).

Appendix 5

Table 3. Classification of Soil-Water Relations in the USA

(Proposed for Soil Survey Manual, San Antonio Work Planning Conference, Jan.-Feb. 1979. Summary table compiled by J.L.N.)

			Applicable to			Need for Measurement	
Attribute or parameter	No. of classes	Symbols	Soil Horizon	Profile or pedon	Map Unit	Single	Periodic or time series
1. Soil water-state	3	D,M,W	✓	✓	--	Small	--
2. Water movement							
a) runoff	6	?	--	✓	(✓)	--	none
b) permeability	3→8	?	✓	✓	--	Moderate	--
3. Soil wetness							
a) depth to wet state	6	1-6	--	✓	--	--	moderate
b) duration of wet state	4	a-d	✓	✓	--	--	moderate
c) perched condition (or not)	2	p	--	✓	--	--	--
4. Annual water-state sequence ("Soil Moisture Regime")	4x4x12 matrix. (state x depth x month)	--	--	✓	(✓)	--	moderate
5. Soil wetness class[1] (period of saturation, deficit, adequacy for plant growth)	6	VD→VW	--	✓	--	--	--
6. Available water capacity	Actual value	--	--	✓	--	great	--
7. Drainage	7	1-7	--	✓	--	--	--

[1] Soil wetness class will probably be dropped

Definitions to Accompany the Table 3 (Appendix 5)

Soil-water state is the term used for defined moisture condition. Three soil-water states - dry, moist, and wet - can be estimated in the field.

Runoff is a term referring to the relative amounts and rates of precipitation lost by flow over the surface of the soil. It is "that part of precipitation appearing in the surface streams". Besides surface runoff there is subsurface flow or interflow that results when infiltrated water enters a zone with a higher perviousness than the soil below. Water accummulates in this zone and moves laterally. There is also base flow which comes from material storage such as swamps, aquifers, and from water in temporary storage in adjacent alluvium.

Permeability is the capacity of soil to transmit fluids (water). Permeability classes are assigned to saturated hydraulic conductivity ranges.

Hydraulic conductivity is a proportionality term relating soil-water flux to hydraulic gradient.

Available water capacity. The amount of water a soil can hold in a state that plants can use and at a place in the soil where plant roots have access to it, is appraised by:

a. *estimating the amount of water each horizon can hold*

b. *estimating what horizons or parts of horizons are sufficiently accessible to plant roots to be significant sources of water, and*

c. *summing up the available water capacities of the various horizons to the depth plant roots can reach. The sum is called the available water capacity of the soil. It is the difference between field capacity and the permanent wilting percentage. The concept of available water capacity can apply to an horizon or the whole soil.*

Soil drainage refers to the rapidity of the removal of water from the soil through surface runoff and entry into and through the soil.

APPENDIX 6

BRITISH SYSTEM OF MOISTURE REGIME CLASSIFICATION FOR SOIL SURVEYS (REFERENCE 10)

Soil Moisture Regime

Soil-water state (p.28) is specific to a horizon or part of a horizon examined at a particular time. A succession of soil-water states, and their disposition within the profile constitute the soil moisture regime. It has components of water suction (and hence water content), depth and time.

In the Field Handbook (Soil Survey Staff 1960) soil drainage classes based on soil morphology were used and the terms excessively, freely, imperfectly, poorly, and very poorly drained have been found useful for map users unfamiliar with soil group names and their definitions. The new classification (Avery 1973) requires a careful assessment of, and the present handbook requires detailed description of, all morphological features, including those of colour, particle-size class and structure formerly used to assess the drainage class of a soil. Drainage classes are, therefore, now replaced by soil moisture regime classes (wetness classes and dryness subclasses) which are not assessed by studies of soil morphology but are defined broadly interms of the periodicity of water states in the rooting zone. There is no simple relationship between the soil moisture regime and the morphological expression of gleying, etc., on which the former drainage classes were based. The soil moisture regime of a particular profile can only be assessed properly from information on the soil-water states of all its horizons throughout the seasons over a number of years, and the assessment of soil moisture regime class is therefore not properly a part of profile description. Soil moisture regime is not simply dependent on soil properties but is related to rainfall, evaporation, site, land use and management history. It is described in terms of wetness classes, numbered I-IV (Table 18) to which dryness subclasses (Table 21) lettered a-d are affixed, e.g. Ia, IVd, etc.

Wetness Classes

Soil profiles can be allocated to a particular wetness class on several different bases:

a. Quantitative data recorded over a suitable period using dip-wells, neutron probe or tensiometers at the actual site.

b. Quantitative data from a similar soil and site elsewhere.

c. By interpretation of observation of soil-water states of many similar soils in different seasons.

d. By inference from the morphology and water state of a particular profile at a particular time.

Ideally soil profiles should only be allocated to a particular wetness class using method (a). The basis of any assessment should always be stated. Assessment by method (d) is speculative and very subjective. With experience, however, a soil can be allocated to a particular class with varying degrees of confidence depending on soil morphology, site, vegetation and water condition at the time of examination. For example, an unmottled (not gleyed) profile will usually be placed in Class I in the absence of contrary evidence. Class VI soils are normally wet throughout the year in most seasons and have a peaty surface with hydrophilous vegetation. Class V soils are normally wet within 70 cm when examined, and in the drier parts of lowland Britain are normally confined to basin sites or sites subject to frequent flooding. Profiles should not normally be allocated to Classes II, III and IV using method (d).

TABLE 18

Soil Moisture Regime Classes - Wetness Classes - Duration of wet States

Class	
I	The soil profile is not wet within 70 cm depth for more than 30 days[1] in most years[2].
II	The soil profile is wet within 70 cm for 30-90 days in most years.
III	The soil profile is wet within 70 cm depth for 90-180 days in most years.
IV	The soil profile is wet within 70 cm depth for more than 180 days, but not wet within 40 cm depth for more than 180 days in most years.
V	The soil profile is wet within 40 cm depth for more than 180 days, and is usually wet within 70 cm for more than 335 days in most years.
VI	The soil profile is wet within 40 cm depth for more than 335 days in most years.

[1] The number of days specified is not necessarily a continuous period.

[2] 'In most years' is defined as more than 10 out of 20 years.

Dryness Subclasses

The occurrence of the dry soil state (>15 bar suction) within a profile varies annually and seasonally with the weather, and from site to site depending on land use. It is thus necessary to combine assessments of soil properties and climate to estimate the freqency of dry soil states over a number of years.

The appropriate climatic parameter is 'average potential maximum soil moisture deficit'. This is the theoretical maximum deficit under grass sward growing in a soil with a large water reserve which imposes no restriction on transpiration. It is calculated using local rainfall data for more than ten individual years and not average summer rainfall. Values for 700 stations in England and Wales are given in Table 22.

Given comparable climatic conditions, a soil with a small reserve of available water is more likely to be dried to 15 bar suction in some part of the rooting zone than a soil with a large reserve of available water. Available water capacity (A_V) of a horizon is defined as the volume of water retained between 0.05 and 15 bar suction expressed as a percentage of soil volume in the moist state.

Table 19. Average Available Water Capacity (Av) per cent. of Mineral in relation to Horizon Particle-size Class and Packing Density

Particle-size class		Av% Packing density Low	Medium	High
Sand	A horizons	-	-	-
	Other horizons	-	9*	(4)
Loamy sand	A horizons	13	14	-
	Other horizons	(16)	12*	(8)
	A horizon	20	16*	(19)
	Other horizons	20	15*	11*
Sandy silt loam	A horizons	23	21	-
	Other horizons	20	18*	-
Silt loam	All horizons	-	(25)	-
	Other horizons	-	(22)	-
Silty clay loam	A horizons	27	20	-
	Other horizons	21	17	12
Clay loam	A horizons	25	20	(17)
	Other horizons	19	15	12
Sandy clay loam	A horizons	(25)	17	-
	Other horizons	-	17	16
Silty clay	A horizons	23	17	-
	Other horizons	-	16	12
Clay	A horizons	22	18	(19)
	Other horizons	(19)	15	13
Sandy clay	All horizons	-	-	-
	Other horizons	-	-	14

* These values are derived from soils with mainly medium and coarse sand. For soils dominantly of fine sand increase the figures by 2%. If most of the fine sand is 60-100μm the Av will be 20% except for sandy silt loam (30%).

N.B. Results for 825 horizons were used to construct this table, but some classes are poorly represented, or absent. Certain combinations of particle-size class and packing density may be rare among naturally occurring soils.

( ) Limited data.

\- Insufficient data.

To estimate the available water class of a profile:

(a) Assess the particle-size class of the fine earth and packing density class (p. 39) and estimate the Av per cent. of the fine earth of every horizon using Table 19.

(b) Estimate the volume of non-porous stones (>2 mm) in every horizon.

(c) Calculate:

$$Av(\text{horizon}) \doteq Av(\text{fine earth}) \times \frac{100 - \%\ \text{stones}}{100}$$

For porous stones such as Oolitic limestone or ironstone, deduct half the volume of stones before calculating Av (horizon). Very porous stones such as soft chalk and some sandstones can be considered as fine earth and their volume should not be subtracted.

(d) Multiply Av(horizon) per cent. by the thickness of the horizon in cm, and add these values for each horizon to rock or 1 m, whichever is shallower.

(e) Divide the sum by ten which gives the Av of the profile in mm and allocate the profile to the appropriate Av class (Table 20):

Table 20. Available Water Class

Available water class	Available water (mm)
1	<100
2	100-150
3	150-200
4	>200

Using the available water (Av mm) of a profile and average maximum potential soil moisture deficit from Appendix IV the dryness subclass can be allocated using Table 21:

Table 21. Soil Moisture Regime Classes - Dryness Subclasses

Available Water (mm)	Average maximum potential soil moisture deficit (mm) 0-50	50-100	100-150	>150
<100	b	c	d	d
100-150	a	b	c	d
150-200	a	a	b	c
>200	a	a	a	b

Water regimes in Wetness Classes V and VI do not have subclasses, b, c or d. An additional 50 mm should be added to the values of available water for profiles in Classes II, III or IV where groundwater or seepage water affect the profiles. The table does not give values for humose or peaty soils. In many cases groundwater and/or wet climate restricts these soils to subclasses a or b. Where this is not so, as in intensively-drained fenland or horizons of mor humus with Class I water regimes, an Av of 25 per cent. is suggested for humose soil and of 30 per cent. for peaty soils, as an interim estimate until better data are available.

Agriculture
Canada

Land Resource Research Institute
Institut de Recherche sur les Terres
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Your file Votre référence

Our file Notre référence

April 30, 1979

MEMORANDUM TO: Unit Heads
Members, SWIG

SUBJECT: Soil Water Regime Classification

I am encouraged by feedback arising from the SWIG progress report presented at the ECSS Meeting in Ottawa. Willingness to try something new, something virtually impossible to some people, possibly reflects dissatisfaction with the existing drainage classes more than acceptance of the obvious merits of the proposal!

I expect that within the next year or so we will be confronted with a choice between:

1. adopting the framework, at least, of a system resembling the one we are now proposing, one which is "home-grown" in the sense that even though many components are borrowed, their assembly is to fit a specific domestic need.

2. adopting off-the-shelf whatever is finally selected for the U.S. Manual (see attached report for the latest proposals).

3. adopting off-the-shelf some other system - I have an entirely unbiassed liking for the British System (see SWIG Report, Appendix 6).

4. retrenching with the existing drainage classes, and attempting to add some precision.

SWIG is presently committed to the first alternative, and therefore seeks your cooperation in the following matters:

1. Criticize thoroughly the SWIG Progress Report, March 8, and return comments to me by June 1st, please.

2. During the 1979 field season, evaluate the Soil Transmissibility, Zone of Saturation, and Wetness Persistence components of the proposed

classification, and test them in the field (see attached table for revised class limits). How?

* evaluate both the concepts and the class limits, chiefly for relevance to interpretation needs.
* identify sets of local or regional "field clues" that can be used, or with further study offer the possibility of being used, for placing individual pedons or polypedons in the proposed classes of Transmissibility, Zone of Saturation, Depth and Persistence. Samples from the Maritimes and Manitoba are attached.
* identify the most reliable indicators of Transmissibility that you would use in the field, e.g. visible pores, bulk density, structure, horizon thickness, etc.
* assess the feasibility of implanting, monitoring and making useful extrapolations from field monitoring sites such as the "basic economy site" referred to on page 12 of the SWIG Progress Report. This should be done for projects of different Survey Intensity Level in your area.
* Report back to me by mid-October, please.

3. Evaluate the Aridity Index, outline attached, as a method of classifying water-deficient regimes, as opposed to the two-pronged approach in the SWIG Report, and (optional) suggest criteria and class limits for Water Retention Classes (SWIG page 8b). Let's hear it by mid-October, please.

4. Comment on any part of the classification outlined on SWIG Report page 8a to 8e. Any suggestions would be most welcome.

I recognize that the proposed classification framework has only a weak data base and rests on much guesswork at first. This was deliberate - to stimulate a new effort in data collection, and justified as being at least no worse than our current estimates of drainage class. It is my belief that unless we take the step of monitoring water regime more quantitatively, as part of regular survey projects, then the only improvement possible is a monotonous re-shuffling of currently observed properties, with their continuing shortcomings. Let's break out!

Please phone if you have difficulty meeting any of these requests. I do appreciate your taking the time to help make some progress with water regime characterization.

John.

John L. Nowland
Chairman, Soil Water Interest Group
Land Resource Research Institute

JLN/jl

Att.

c.c. J.H. Day
D.E. Moon
G.C. Topp
R.G. Eilers
C. Tarnocai
C. Veer

WATER REGIME CLASSIFICATION 1979
(for soils without a perennially frozen horizon)

WATER DEFICIT (D) CLASSES

(5 classes drawn from the "soil moisture regime subclasses" used for Soil Climate Map of Canada and Soil Family classification)

1.	Aquic and Perhumid	Soil moist or saturated all year, seldom dry. No significant water deficits in the growing season: deficits <2.5 cm. CMI >84.
2.	Humid	Soil not dry in any part as long as 90 consecutive days in most years. Very slight deficits in the growing season: deficits 2.5-6.5 cm. CMI 74-84.
3.	Subhumid	Soil dry in some parts when soil temperature is $\geq 5^{o}C$ in some years. Significant deficits within growing season: deficits 6.5-13 cm. CMI 59-73.
4.	Semiarid	Soil dry in some parts when soil temperature is $\geq 5^{o}C$ in most years. Moderately severe deficits in growing season: deficits 13-19 cm. CMI 46-58.
5.	Subarid	Soil dry in some parts or all parts most of the time when the soil temperature is $\geq 5^{o}C$. Some periods as long as 90 consecutive days when the soil is moist. Severe growing season deficits: deficits 19-38 cm in BOREAL and CRYOBOREAL temperature classes, 19-51 cm in MESIC or warmer classes. CMI 25-45.

WATER RETENTION (R) CLASSES

(4 classes to be developed, based on some combination of texture, pore space distribution, bulk density, organic matter content and depth criteria)

1. High
2. Moderate
3. Low
4. Very low

SOIL TRANSMISSIBILITY (K) CLASSES

A.	high throughout control section	>10 cm/h
B.	medium, due to impeding layer(s) below 50 cm	2.5-10
C.	medium, due to impeding layer(s) within 50 cm	2.5-10
D.	medium, and uniform	2.5-10
E.	low, due to impeding layer(s) below 50 cm	0.5- 2.5
F.	low, due to impeding layer(s) within 50 cm	0.5- 2.5
G.	low, and uniform	0.5- 2.5
H.	very low, due to impeding layer(s) below 50 cm	<0.5
J.	very low, due to impeding layer(s) within 50 cm	<0.5
K.	very low, and uniform	<0.5

(An impeding layer has a K sat value <1/5 of that of the overlying horizon)

Lateral seepage: indicated by symbol attached to transmissibility class symbol to show degree of biological impact of nutrients or oxygen or both in seepage water.

- d dystrophic: soil supports plant growth equivalent to or less than associated non-seepage sites.
- m mesotrophic: plant growth up to 25% greater than on non-seepage sites.
- e eutrophic: plant growth more than 25% greater than on non-seepage sites.

ZONE OF SATURATION (S) CLASSES
(8 classes of Mean Highest (MH) and Mean Lowest (ML) zone of saturation (water table))

Classes	1	2	3	4	5	6	7	8
MH (cm depth)	>100	50-100	0-50	50-100	0-50	0-50	0	0
ML (cm depth)	>150	>150	>150	100-150	50-150	<50	>50	<50

WETNESS PERSISTENCE (P) CLASSES
(6 summer classes of persistence of zone of saturation within 50 cm of the surface between April 15 and October 31 (max. 200 days). 3 winter classes of persistence between October 2 and April 14 (max. 165 days))

Summer Class	Symbol	Days	Winter Class Symbol	Days
ephemeral	e	0-2	e	0-2
very short	v	3-15	s	3-60
short	s	16-30	l	61-165
medium	m	31-60		
long	l	61-120		
prolonged	p	120-200		

WATER REGIME MODIFIERS
(2 grades of impact by artificial means on S (zone of saturation) and P (wetness persistence) ratings only)

D, DD: ditched (open, covered)
T, TT: tube drained (tile, plastic)
M, MM: moled
S, SS: subsoiled
R, RR: "rigg and furrow", ridged, listed, rond-plat
I, II: irrigated (add method used)

Examples

1. Basic classification only (Eastern Canada).

E3: low transmissibility due to an impeding layer below 50 cm (0.5-2.5 cm/h), mean highest zone of saturation within 0-50 cm, mean lowest deeper than 150 cm.

E3sl: ditto, with optional indication of short period of saturation (16-30 days) within 50 cm depth in summer and long period of saturation (61-165 days) in winter.

2. Complete national classification (and longest coding)

21E3sl As above, with added water deficit class (2.5-6.5 cm) and high water retention.

12Ce4mlD - a typical hillside site in Newfoundland
- no significant water deficit (optional)
- moderate water retention, (optional)
- medium transmissibility, due to impeding layer within 50 cm
- eutrophic seepage
- highest zone of saturation 50-100 cm from surface, lowest 100-150 cm
- medium period of saturation (31-60 days) within 50 cm in summer (optional)
- long period of saturation in winter (optional)
- ditching has modified zone and persistence of saturation.

Morphology. I observe depth and intensity of gleying. It might only be a slightly lower chroma, and the persistence in a downslope position might be 2 weeks longer than the top of hill position. Where gleying is indicated by an Apg or Aeg and the impeding layer is at a shallow depth (e.g., 30cm) the water storage capacity is very low and recharge will occur frequently, due to precipitation. The persistence might extend well beyond the normal planting dates. Frequently thse areas are plowed in the fall but left unplanted in the spring.

Classification: J3m (R class 2 undrained, 3 or 4 drained).

The nongleyed members of this group of soils normally have perched water sometime during the winter months and would be in persistence class v or s depending on spring precipitation and soil frost conditions.

Classification: J3v or J3s (R class 1 or 2, P (winter) omitted).

The vegetation on this group might vary from a maple, beech, yellow birch, white birch stand under aerated soil conditions, F3s or F?s, to a stunted black spruce stand on very poorly drained sites. On very poorly drained sites, where light conditions allow even aquatic plants may occur and saturation might persist into late July.

Classification: J5l or J3l (R class 2, P (winter) omitted).

The evaluation of soils with an impeding layer due to cementation might at times be rather difficult. The main division I try to establish first of all is whether it is a continuous horizon or not, its hardness, thickness and such. We known from experience that all have a coarse matrix and that fluctuations in saturation might be rapidly followed by aeration. If the cementation is discontinuous and no evidence of gleying is observed I would judge:

Classification: Dle (R class 3, P (winter) omitted).

For almost all other situations where gleying is present I would judge the site on fluctuating ground water table and seepage.

Maritimes (J.L. Nowland).

Further to the clues of Veer, I would add horizon thickness. In Podzols, Luvisols and Brunisols of Nova Scotia, the thickness of Ae/Aeg horizons commonly increases by 50% from well to imperfectly drained soils, and by 100% from well to poorly drained, with a progressive loss of chroma (on reddish materials (pinkish to white). This trend is correlated with proposed S and P classes, and is usually accompanied by the appearance of a transitional ABg horizon at the base of the Ae/Aeg and decrease in thickness and development of Bf in podzolic soils. In all three Orders structural development and chroma of Bm horizons decrease as water regime becomes wetter. C horizons of reddish soils in S classes 4 to 8 may have little or no mottling, but a loss of chroma difficult to differentiate in the Munsell book is detectable (see diagram).

Manitoba (R. Eilers).

Field clues for the identification and mapping of soil water regimes can perhaps be divided into two categories, namely direct and indirect methods.

The direct methods are primarily those determined on site by examination of soil profiles. The most common water regime indicators in soils are color, mottles, type and degree of development of horizons, structure, homogeneity of parent materials, and of course the water table itself.

Color and Mottles. The depth to the zone where gleyed (or reduced) matrix colors are dominant is taken as an indication of the maximum depth to seasonal water tables for soils predominantly affected by non oxygenated water. The upper limit of mottling in the profile is used as a guide to estimate the most probable minimum dpeth to seasonal water tables. The depth in soils where reddish iron mottling covers a greater area than the matrix colors is used as a guide to estimate the maximum depth to seasonal water tables where oxygenated waters are predominant.

Gleyed or Gleysolic Rego profiles with thick Ah Cca horizons generally indicate permanently high water tables especially when combined with dull and reduced colors.

Structure and stratification of P.M.'s. Affect the rate and direction of water movement and are often used to estimate persistence of saturation conditions in the soil profile.

Poor structural development in some cases is also an indication of persistent wet conditions.

These factors play the dominant role in classifying water regimes of soils, but in the mapping process these factors are used in conjunction with other more indirect or nonsoil features such as time of year, topographic position and natural vegetative indicators.

Transmissibility is not often or routinely measured or estimated for individual sites while in the field. General permeability classes are assigned to soil series as a statment or in table form for characterization at the series level. The criteria generally used are texture, structure and uniformity of materials.

A poll of most people in our unit indicated that assessment of water regimes is as much or more of an <u>art</u> than it is a <u>science</u>, and therein lies the difficulty I suppose. I believe that if we can identify factors or components of the water regime it might be possible to do a more objective analysis of drainage which would supplement the art aspects of water regime assessments.

I don't believe we will ever completely do away with these art aspects of soil water regimes, nor would this be desirable, but I do think we should try to shift more to the scientific side of the scale.

My plan in Manitoba this year is to test some of the criteria as proposed by Nowland and Veer prior to advocating a complete shift to this new system.

APPENDIX 4

RESOLUTION

W.W. Pettapiece
Land Resource Research Institute

Whereas

There is a strong and demonstrated need for a body of pedologists to coordinate and advance all aspects of soil survey; and

Whereas

This body needs to be nationally recognized and constituted; and

Whereas

The new reorganization of the CASCC system gives the official function of the ECSS as a yearly assessment to agricultural soils research and service needs.

Therefore be it resolved

That ECSS establish a Committee for the purposes of coordination of the technical aspects of soil survey. This committee to be known as the Canada Soil Survey Comittee.

The scope of this committee would encompass all aspects of soil survey including taxonomy, mapping, interpretations and data dissemination. It should not be confined specifically to agriculture but respond to all soil concerns.

The membership should be comprised of 3 persons from each province representing federal soil survey, provincial soil survey and university soils departments, the correlation staff of LRRI, representatives from other agencies which use or have an interest in soil surveys (such as Environment, DINA, EMR etc.) and other representatives as the chairman from time to time may appoint.

The chairman of this committee should be the Director of the LRRI.

The committee should meet every two years or at the discretion of the chairman.