AGRI-ENVIRONMENTAL INDICATOR PROJECT

Agriculture and Agri-Food Canada

REPORT NO. 17

INDICATOR OF RISK OF WATER CONTAMINATION:

NITROGEN COMPONENT

PROGRESS REPORT (Ontario)

by

K. B. MacDonald and D. Bruce Gleig
Research Branch, Agriculture & Agri-Food Canada
Guelph, Ontario

December 1996

PREFACE

The Agri-Environmental Indicator (AEI) Project of Agriculture and Agri-Food Canada (AAFC) was initiated in 1993 in response to recommendations made by several agencies, organizations and special studies. The overall objective of the project is to develop and provide information to help integrate environmental considerations into decision-making processes of the agri-food sector.

The project aims to develop a core set of regionally-sensitive national indicators that build on and enhance the information base currently available on environmental conditions and trends related to primary agriculture in Canada. The Indicator of Risk of Water Contamination (IROWC) is an important part of the agri-environmental indicator set. Indicators are also being developed for issues of farm resource management, agroecosystem biodiversity, soil quality, agricultural greenhouse gases and agricultural production efficiency. Research results in the form of discussion papers, scientific articles and progress reports are released as they become available. A comprehensive report is planned for fiscal-year 1998-1999.

This progress report has been prepared on behalf of the IROWC technical team: P. Milburn-Fredericton Research Centre, Fredericton, NB; R. Simard- Soils and Crops Research Centre, Ste-Foy, PQ.; B. Bowman-Pest Management Research Centre, London, ON.; C. Chang-Lethbridge Research Centre, Lethbridge, AB; and B. Zebarth-Pacific Agri-Food Research Centre, Summerland, B.C. The report describes the methods used and results obtained for the Indicator of Risk of Water Contamination for the province of Ontario. Work is in progress to extend the scope of the indicator nationally and to assess the risk of water contamination from phosphorus.

Comments and questions on this paper should be addressed to:

Dr. K. Bruce MacDonald
Ontario Land Resource Unit,
Greenhouse and Processing Crops Research Centre
Agriculture & Agri-Food Canada
70 Fountain Street East, Guelph, Ontario, N1H 3N6

Telephone: 519-826-2086
Facsimile: 519-826-2090
E-mail: Macdonaldb@em.agr.ca

ACKNOWLEDGMENT

The authors thank Andrew Couturier for his assistance in summarizing the results of the Soil & Water Environmental Enhancement Program (SWEEP) Pilot Watershed Studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

1 Introduction:

The **I**ndicator of **R**isk **o**f **W**ater **C**ontamination (IROWC) is one component of Agriculture and Agri-Food Canada's (AAFC) Agri-Environmental Indicators (AEI) project. IROWC measures the risk of water contamination from agricultural activity; encompassing nitrates, phosphates, and pesticides. The risk of water contamination is affected by different types and intensities of agricultural activity, as well as soil and climatic conditions. The agricultural activities that affect water quality include: the type of crops and their rotation sequence, inputs of nutrients and pesticides, and general land management practices (such as subsurface drainage, buffer strips, tillage practices, etc). Soil and climatic conditions are outside of the control of the land managers, and cannot be altered to improve water quality. Unlike the soil and climate conditions, cropping and land management practices are controlled by the manager. Changing the extent, timing, and/or intensity of these activities may affect water quality, soil quality, and/or greenhous gas emissions (issues that are addressed by other AAFC indicators).

In addition to the direct requirements of the AEI Project, IROWC is also related to a variety of other work dealing with water quality. Several INRA laboratories in France have research projects dealing with various aspects of agricultural impacts on water quality. AAFC and INRA are sharing information on water quality. AAFC is also cooperating with other OECD countries to assess the impact of agriculture on water quality. Within AAFC, the Policy Branch is interested in developing a predictive capacity (including water quality impacts) to evaluate various policy alternatives. This work will help support policy decisions regarding water quality and agriculture.

2 Background and Context:

2.1 Concepts and Principles

The basic concepts and principles of IROWC were outlined in the working paper Indicator of Risk of Water Contamination: Concepts and Principles (MacDonald and Spaling, 1995a) IROWC is designed to address several policy needs:

- clarify agriculture's potential impact on this public resource
- target remedial policies and programs to areas at higher relative risk of contamination from agriculture
- develop predictive models and systems, that can assess the potential impacts of agricultural policies and programs on water contamination risk.

IROWC utilizes a series of nested heirachical levels, ranging from a broad national view, to detailed field level studies. Different temporal scales-ranging from single seasons, to decades-are appropriate for use at varying spatial resolutions (Table 2.1). The current work on IROWC

Table 2.1: IROWC Hierarchical Levels

Hierarchial Level	Spatial Extent	Spatial Analysis Units	Temporal Extent	IROWC Sensitivity/Resolution
Level 7	Canada	Canada	decades to centuries	Comprehensive analysis
Level 6	Canada	Province	decades to centuries	population, livestock numbers, kinds of crops, extents and quantities of inputs
Level 5	Ecozone	Ecodistrict	5 years to decades	relative risks from nutrients and pesticides
Level 4	Ecoregion	SLC polygon	5to 10 years	relative risks by specific nutrient and class of pesticide associated with specific crops and soil textures
Level 3	Ecodistricts or Subsub Watersheds	SLC soil polygon or detailed soil map	1 to 5 years	relative risks by specific nutrient and class of pesticide associated with specific crops, soil types and pathways (surface or groundwater)
Level 2	SLC Polygon or farm	detailed soil map polygon or field	season to 5 years	estimated actual risks associated with specific crop, soil and land management conditions with estimates for surface and subsurface pathways.
Level 1	Field or detailed soil map polygon	plot area or pedon	season to 5 years	measured/modeled/actual risks associated with specific crop, soil and land management conditions patitioned to surface and subsurface pathways.

has focused on Level 5, working with a spatial resolution of Ecodistricts[1] (or Soil Landscapes of Canada (SLC) polygons in B.C. and Atlantic Canada). This level of resolution is detailed enough to show regional differences within a Province, and is an appropriate scale at which to show changes occuring over 5-10 year periods. The Census of Agriculture (CoA) data is available in 5 year intervals and is available for all the agricultural regions of Canada. Given the time frame and spatial resolution of the analysis, the CoA data is the most appropriate source of crop and management practice data available for Canadian agriculture.

IROWC is expressed as an indicator of risk to water quality from agricultural activities. Risk is characterized by two general attributes: the possibility of an undesirable outcome (hazard), and the probability of its occurrence (exposure) (i.e. the uncertainty in the duration or magnitude of exposure). The <u>possibility</u> of an undesirable outcome (i.e. the transport of substances into the surface or groundwater) is determined by locating areas to which nutrients or pesticides are applied. The <u>probability</u> of exposure is determined relative to a fixed threshold value. For IROWC-Nitrogen (IROWC-N) the drinking water standard of 10 mg NO_3-N per litre is used as the threshold value. The probability of exposure is expressed as the potential magnitude of contaminant concentration.

2.2 Proposed Methodology

As described in MacDonald and Spaling (1995b) IROWC uses a partial budgeting approach to estimate the water balance and the concentration of potential contaminants. IROWC does not rely on process models at the regional level (level 5). While some studies have achieved good results with these models, they are generally applicable only at the field or small watershed scale. Many of these models have extremely detailed data requirements that are not available on a province-wide basis. The models also require calibration (in some cases annually) before they can be used in a specific region. This entails additional field work and verification of the results. While the model-based approach may be viable in the long term, it is not feasible at the present time.

Data availability is one of the key factors affecting the development of the IROWC methodology. Existing data must be used, since it is not within the budget or the scope of this project to collect new field data. Data are derived from three sources: the SLC database provides soil information at a 1:1,000,000 scale, the CoA database details cropping and land management practices, and the Land Potential Database contains long term climate normals. Research is in progress to improve the climate data by using more recent (1961-90) normals data, summarized for each Ecodistrict. Data from these three sources are used to calculate the partial budget and the IROWC indicator values.

---

[1] Appendix 1 provides a map showing the location of Ecodistricts across the agricultural region of southern Ontario.

The partial budget approach calculates (for each contaminant) the known inputs, the known outputs, and then assumes that the remainder is potentially available for transport into surface or ground water. The following inputs and outputs are included in the balance for IROWC-N:

INPUTS
Fertilizer N
Manure N

OUTPUTS
Harvested Crop
Leaching or Run off

The quantity of N remaining in the soil after harvest is calculated by subtracting harvested outputs from inputs. The entire quantity of this excess N is potentially available for transport; soil N is assumed to be constant (therefore no immobilization of excess N). Although soil N shows great degrees of variation over the short term (e.g. seasonal fluctuations) it tends to be constant over long time periods in soils with a long history of cultivation (Fried et al, 1976). Most agricultural soils in Canada have been cultivated for several decades (or longer), therefore it is assumed that soil N concentrations are relatively constant over a 5 to 10 year time frame.

Pratt et al (1972) determined that three calculations are required to make estimates of NO_3^- concentrations in the unsaturated zone below the zone of root influence.

the volume of drainage water
the annual excess of NO_3^- available for leaching (fertilizer rates - removal in harvested crops)
rate of denitrification

The volume of the drainage water is calculated using precipitation and evapotranspiration data from the Land Potential Database. This moisture balance is based on monthly normals for Precipitation - Potential Evapotranspiration (P-PE). The annual excess of NO_3^- N is available from the recommended rate of nutrient inputs during the growing season, and the proportion of the N in the crop removed during harvesting. Measured values for denitrification are not available, and therefore must be estimated. (Pratt et al. 1972). Estimating denitrification is difficult since the process is extremely variable, and is affected by a variety of environmental factors and soil management practices. In the current estimates of IROWC-N, the quantity of nitrogen remaining after harvest has not been reduced by denitrification. Including estimates for denitrification could improve the accuracy of the IROWC calculation.

2.3 Revisions to Proposed Methodology

As summarized above, previous work on IROWC has resulted in a conceptual framework (MacDonald and Spaling, 1995a) for the research and a proposed methodology (MacDonald and

Spaling, 1995b). The proposed methodology was illustrated for Ontario with draft examples for nitrogen, triazines, and a combination of both. These examples were sufficient to allow the technical team and external reviewers to determine that an integrated indicator is not feasible but rather a separate indicator is required for each class of potential contaminant (e.g. nitrogen, phosphorus, pesticides, sediment, biological entities, heavy metals, other).

This report details the revised methodology, which was tested for IROWC-N at hierarchical level 5 (Ecodistrict) or SLC polygon for areas where agricultural areas are more limited. Initial validation of the results was done by comparison to localized studies (at hierarchial levels 2 and 3).

3 General Considerations

3.1 The Regional IROWC Approach (approximately at Hierarchial Level 5)

3.1.1 Components of IROWC

The various indicators of water quality (nitrogen, phosphorus, pesticide, etc) are based on components of the hydrological cycle related to water balance and partitioning and on a partial budget of the nutrient, pesticide or other material as determined by the level and kind of agricultural activity. The following table outlines the components and indicates which are used in the various water quality indicators.

Table 3.1: Components of IROWC

Components	IROWC-Nitrogen	IROWC - Phosphorus	IROWC - Pesticides
Water Balance	X	X	X
Water Partitioning		X	X
Nutrient Balance - Nitrogen	X		
Nutrient Balance - Phosphorus		X	
Active Ingredient(s) - Quantity, Persistence, Mobility. Toxicity			X
Sediment Transport		X	depends on compound
Soil type - influence on moisture balance and partitioning	X	X	X
Soil type - influence on reaction (organic carbon content etc)			depends on compound
Intermediated sources or sinks e.g. wetlands	possible		X
Modeling periods	annual	annual	may be portions of a year

3.1.2 Water Balance

Currently IROWC uses a very approximate water balance. Precipitation is the only input to the water balance (contributions from irrigation, the watertable or capillary rise are neglected), while evapotranspiration is the only output. Ideally the output would be calculated by crop type to account for the potential moisture uptake requirements of different crops. This figure would be modified by crop yield, weather or seasonal climate, and soil type (as it affects soil moisture storage).

In an associated research project, Dr R. de Jong (Eastern Cereals & Oilseeds Research Centre - ECORC) is using modeling approaches to calculate water balances for representative crop rotations on various soil textures in the Mixed Woods Plain area, and is modeling estimates of probabilities for the Great Plains region. The results of this research project will be jused to refine the current approach.

At this broad level of generalization, the water balance is calculated from thirty year climatic normals[2] data. Monthly values of precipitation and potential evapotranspiration from these data were used to estimate the water balance. An average water holding capacity (AWHC) was calculated for each Ecodistrict based on soil texture group (cf. de Jong et al. 1992). The soil moisture content at the start of the growing season (arbitrarily taken to be April 1) was estimated from climate data. From this starting point, P-PE was used to budget additions, removals and water losses from the soil storage.

Different approaches to calculating water balances are necessary for different regions of Canada. In the more humid regions of the country (e.g. the Mixedwood Plains Ecozone) extended periods of moisture excess are normal; these conditions can be characterized by the duration and quantity of excess moisture. For the semi-arid regions (e.g. the Great Plains Ecozone) conditions of moisture excess are less predictable and are characterized by a probability of excess (e.g. the number of days when there will be sufficient excess water above a threshold such as 5 mm to cause movement and pollutant transport to surface or groundwater reservoirs).

3.1.3 Water Partitioning

Water partitioning deals with the portion of water available from precipitation and irrigation, which is not lost through evapotranspiration. It is the amount of water leaving the agricultural system by surface runoff, tile flow or groundwater recharge. The factors which control water partitioning include: precipitation intensity, soil infiltration rate, soil moisture budget, topography, artificial drainage, proximity (travel time to surface water streams, ponds or surface drains). There are no factors in the CoA which directly relate to water partitioning. At the

---

[2]Dr A. Bootsma (ECORC) is advising the technical team on the use of climate normals data. He has provided 1961-90 Climate Normals and is assisting in further calculations to convert the values for climate stations to estimates for Ecodistricts or SLC polygon areas.

regional level, water partitioning is not included in the IROWC-N calculations. This exclusion is reasonable in areas where the predominant pathways for excess water are through the rooting zone to subsurface drains or to groundwater. In areas where surface runoff is important, the excess water may contain ammonium-a potential contaminant that has not been dealt with in the IROWC calculations. Other IROWC calculations will require an estimate of partitioning which must be modeled from soil type and topography, subsurface drainage, and the surface drain and stream network.

3.1.4 Nitrogen Balance

A complete nitrogen balance includes inputs from organic and inorganic sources, contributions from the previous crop, exports in the crop, sequestering of nitrogen in crop residues, atmospheric deposition, and nitrogen fixation by non-symbiotic bacteria. The census attributes related to nitrogen balance include: area fertilized, livestock, area receiving manure, crop type. These factors have been used at the regional level to estimate the nitrogen inputs (from fertilizer and manures) and, the quantity of nitrogen remaining in the soil at harvest (using a nitrogen harvest index which gives the proportion of total nitrogen harvested and the proportion remaining in crop residue).

Nitrogen balance requires both temporal and spatial assessment. For each crop rotation it is possible to calculate nitrogen levels based on the requirements of each crop in the rotation. It is then possible to determine the nitrogen level present in spring and also one present after harvest (based on the nitrogen added minus the quantity removed in the harvested portion). From a temporal standpoint, the total nitrogen is available during the spring quarter before crop uptake. The quantity in the residue is present from October to March. For the summer quarter, the nitrogen is largely tied up in the growing crop. From a spatial standpoint, any crop will occupy only a portion of the spatial unit under consideration (Ecodistrict or SLC polygon).

4 Estimation of Farming Systems Based on Census of Agriculture Information:

4.1 General Principles

For a national level indicator it was essential to choose sources of information which are consistent across the country and available over time to show trends. On this basis, data from the Census of Agriculture (CoA) were selected as the most consistent coverage which would be routinely available every 5 years. These data were used as a basis for characterizing agricultural activities into farming systems/crop rotations for 1981 and 1991. It was recognized that provincial summaries are compiled annually and that remotely sensed imagery could provide greater resolution and detail; however, the cost and inconsistent coverage in space and time made these unsuitable.

As a general guideline, the following criteria are used to characterize agricultural regions: 1) include Ecodistrict or SLC polygons, which contain the greatest proportion of agricultural activity, 2) include at least 85% of the agriculture in each region, 3) for each polygon characterize the farming systems/crop rotations to account for greater than 95% of the agricultural activity occurring in the polygon. Representative crop rotations are then identified to account for the land use. These rotations are intended to illustrate realistic sequences and intensities of cropping, but are not an exhaustive catalogue of all the variants in farming systems. Inputs of fertilizer, manure, pesticides and conservation management practices are then assigned to these representative rotations based on recommended practices. The amounts and areas receiving inputs are then compared to those reported in the CoA and from other provincial sources. Adjustments are made to account for the amounts of manure, fertilizer and pesticides sold. The following sections provide specific details of the activities, using Ontario as an example.

4.2 Characterizing Crop Rotations in Ontario

4.2.1 Purpose:

The census data only records the areal extent of a given crop, it does not consider the sequence in which crops are typically grown. The sequence of crops is important; rotations change the nutrient requirements and erodibility of the soil. Calculating rotations will assist in the further development of indicators of water quality, soil quality, and the identification of sources or sinks of greenhouse gases. Representative crop rotations permit a more detailed estimation of nutrient and pesticide inputs than can be achieved by simply using Census of Agriculture (CoA) data.

4.2.2 Method:

The ideal method for calculating crop rotations and a nutrient balance would be from the field level up to the Ecodistrict level, using actual rotations and nutrient inputs. Since these data are not available it is necessary to characterize each Ecodistrict with representative rotations and estimates of nutrient inputs. Three steps are involved in calculating the crop rotations and associated nutrient inputs:

1) Characterize rotations and land-use.
2) Calculate nutrient requirements.
3) Determine rotations receiving conservation tillage and no-till.

_1._ Characterizing Rotations and Land-Use

I) Identify areas of farmland.
ii) Remove perennial horticultural crops from the data used to calculate rotations.
iii) Characterize the land use with the crop rotations. Examples of the worksheets for several Ecodistricts are included in Appendix 2. Rotations are applied to the data in a specific order of

priority. This ensures that crops that compose a relatively small portion of the Ecodistrict are accounted for before the more common crops are placed in rotation. The rotations, and the order in which they are applied are as follows:

a) Tobacco/Winter Wheat or Fall Rye (WWFR)
b) Corn/Beans/WWFR
c) Ann.Hort./Ann.Hort./Cereals or WWFR or Beans
d) Corn/Beans (adjust length of rotation according to relative proportions)
e) Beans/Beans/Cereal/Hay/Hay
f) Corn/Corn/Cereal/Cereal/Hay (3 to 5 years)
g) Cereal/Cereal/Hay (3 to 5 years)
h) additional hay rotations, or continuous corn or beans as required.
I) continuous improved pasture

iv) Adjust the length of the forage rotations to achieve a "best fit" of the data.
v) Calculate the % of farmland in the rotations, and the % of farmland unaccounted for.

2. Nutrient Amendments

I) OMAFRA Publication 296, Field Crop Recommendations details the estimated nutrient requirements of Field Crops in Ontario. Nutrient requirements can be quite variable, depending on soil conditions, and desired yields. For field crops, assume that the N requirement is the median value of the recommended application rates, while the requirement for annual horticultural crops is the average of N recommendations listed in OMAFRA Publication 360, Fruit Production Recommendations. Using these figures (Table 4.1), calculate the recommended N additions for the crops in rotation.

Table 4.1: Recommended Nitrogen Inputs by Crop Type

Crop	Nitrogen Required (kg/ha)
Annual Horticulture	130
Beans	0
Corn	155
Hay	60
Improved Pasture	90
Spring Cereal	70
Tobacco	25
Unimproved Pasture	50
WWFR	90
WWFR in rotation with Tobacco	70

**deduct 55 kg N/ha for crops following hay in a rotation

ii) Calculate N availability from livestock manure and distribute it over the farm area on the following basis:

a) N is 50% available in the year of application
b) N from manure is applied at a maximum of 75% of the crop requirement
c) Improved pasture receives cattle manure at up to 50% of the manure production level (i.e. 6 months of cattle on pasture) or up to the full N requirement for the grass pasture.
d) Unimproved pasture receives cattle manure at up to 33% of the manure production level or up to 50% of grass requirement for N (compensation for lower production and carrying capacity).
e) Remaining manure N is applied predominantly to corn, starting with silage corn then grain corn (reserve 25% of the remaining manure N to be distributed to hay and spring cereals because of timing for field application).
f) Calculate area receiving manure (exclusive of pasture) and compare to the CoA figure.
g) Calculate associated levels of P + K applied

iii) Calculate the N required from fertilizer to make up the difference (if any) between N available from manure, and the crop requirements.

a) Calculate adjustments from previous crop and manure applied
b) Calculate fertilizer required to meet crop requirements
c) Compare area fertilized to CoA figure
d) Compare provincial sales figures to the calculated additions
e) Calculate nutrient requirement and area by Ecodistrict and distribute any excess or deficit on this basis

3. Conservation Tillage and No-Till

a) Assume a homogeneous mix of crops
b) Distribute conservation tillage and no-till in proportion to Corn-Soy or Corn-Soy-Winter Wheat/Fall Rye starting with sandy soils and working towards soils with an increasing clay content.

5 Calculating IROWC-N:

5.1 Ontario Example- Water Balance

The water balance is based on long-term (1951-80) climatic normals for Ontario. P-PE gives an indication of the quantity of surplus water available in each Ecodistrict. The P-PE values are calculated on a monthly, quarterly, and annual basis. As the methodological development progresses the water balance will be revised to reflect the 1961-90 climate normals. These data are available for climate stations across Ontario, but have not yet been associated with the Ecodistricts. The monthly values for P-PE are shown in Appendix 3 for all agricultural Ecodistricts in Ontario. These data show that the non-crop months are periods of moisture excess whereas, on a long term normal basis, the crop period is one of moisture deficit.

The soil is an important factor in the water balance. The available water holding capacity (AWHC) of the soil provides a reservoir to store moisture during periods of excess input and release it for plant growth during periods of deficit. It represents a mixing volume for soluble contaminants. The AWHC was calculated for each Ecodistrict using the SLC layer and component files (cf de Jong et al, 1992). The following estimates of AWHC were applied to layer 3 (the parent material layer) of component 1 (the dominant component) for each SLC polygon:

Table 5.1: Soil Texture and AWHC

TEXTURE	AWHC (mm) (based on 100 cm rooting depth)
Sand or Sandy Loam	100
Loam	150
Clay Loam	200
Clay	250

The AWHC values for each SLC polygon were area weighted as a proportion of ecodistrict, and then summed for a final value for the Ecodistrict. If the available moisture (P-PE) is less than the AWHC, then the soil profile will not be saturated, and movement of contaminants to the ground water or tiles is not likely. If P-PE is greater than the AWHC, then the soil profile may become saturated, and transport of available N to the ground water or through subsurface drains is likely.

5.2 Nitrogen Balance

The N balance was calculated using inputs of N in fertilizer and manure (see section 4.2 for a detailed description of crop rotations and N application), the proportion of nitrogen remaining in residue after harvest, atmospheric deposition, and fixation by non-symbiotic bacteria. Nitrogen leaves the system during harvest, while the remaining N is available for leaching if sufficient water is present (No adjustments have been made for atmospheric deposition, non-symbiotic N fixation, or denitrification).

5.2.1 Calculating Residual N from Crops

After harvest a proportion of the above-ground biomass remains in the field. A harvest index (HI) is typically used to determine the proportion of biomass harvested, and the proportion remaining. However the HI does not account for N, the bulk of which is typically stored in the grain. Therefore the HI is often different than the Nitrogen Harvest Index (NHI). The amount of N remaining in the crop residue after harvest was calculated by multiplying the N applied to the crop by one minus NHI (or the Nitrogen Residual Index). The amount of N in the crop residue varies by crop type.

Table 5.2: Calculating Residual N from Crops

CROP	N-HI	N-RES I	N-APPLIED	N RES(per ha)
Spring Cereals	0.66	0.34	70	21
WWFR	0.48	0.22	90	20
Corn	0.63	0.37	155	57
Hay	0.80	0.20	60	12
Tobacco	0.90	0.10	25	2.5
Soybeans	0.70**	0.30	0	64
Pasture	0.70	0.30	90	27
Perennial Hort.	0.70	0.30	—	—
Annual Hort.	0.7	0.30	130	65

(based on Western Canada Fertilizer Association Uptake Figures, obtained from the Canadian Fertilizer Institute)

**Calculated from plant food utilization figures.

Since N additions from fertilizer and manure are assumed to equal the recommended application rate, the crop residuals become the primary source of excess N.

5.3 Calculating IROWC-N

The IROWC-N value is the ratio of the amount of potential contaminant present (in this case nitrate-nitrogen) to the amount of excess water available. It represents an average concentration of nitrogen in the water leaving the rooting zone. In this assessment of IROWC-N it was apparent that the water contained in the rooting zone serves as a buffer and mixing zone. The potential contaminant is distributed throughout the water in the rooting zone and the excess water which has passed through. In this calculation, the budgeting starts on April 1 with the AWHC at full capacity. Through April to September there is a moisture deficit condition as the crop grows and the AWHC is depleted, after harvest the moisture excess first replenishes the AWHC and any additional contaminant moves through to the groundwater or the tile lines. (Appendix 3 provides details of P-PE.) The calculations reflect this process and assume complete mixing between water in the rooting zone and excess water.

Characterizing crop rotations in each Ecodistrict produces the following figures for use in the IROWC-N calculation: i) crops by rotation and by Ecodistrict; ii) manure N amendments by crop, rotation, and by Ecodistrict; and iii) fertilizer N additions by crop, rotation, and by Ecodistrict. Appendix 2 shows an example of the rotations in an Ecodistrict, the average level of nitrogen input, the residual nitrogen at harvest (October 1) and the carryover of nitrogen from manure applied the previous year (based on a 10% carryover).

The first step is to calculate the kg of N lost per ha:

Equation 1:

$$\text{N Lost (kg/ha)} = \frac{\text{(Residual N (kg) x P-PE (mm)) / (AWHC (mm) + P-PE (mm))}}{\text{Area used as a source of excess water (cropland, farmland, Ecodistrict)}}$$

Assuming that there is sufficient moisture to move the excess N, then the next step is to calculate the concentration of N in the water and compare it to the drinking water standard of 10 mg NO_3-N per litre. This is the value of IROWC-N.

IROWC-N is calculated with the following formula:

Equation 2:

$$\text{IROWC-N(mg/l)} = \frac{\text{(N lost in kg per ha) x 100}}{\text{P-Pe (mm)}}$$

5.4 IROWC-N Considerations for the Spatial Base

Agricultural activities occupy only a portion of the overall Canadian landscape. The actual proportion of farmland or cropland in the landscape varies by region, consequently, the area of agricultural activity impacting the ecosystem for aspects such as water quality is not uniform across Canada.

A variety of spatial bases can be used in the calculation of any indicator, ranging from the specific location where the impact occurs (e.g. cropland) to the area where the enterprise is situated (in this case farmland) to the total area available (the Ecodistrict). IROWC-N has been calculated on all of these spatial bases and the results are summarized in Appendix 4.

It is difficult to decide on the best form of representation for IROWC-N. The impact of agricultural activity on water quality can be expressed on the basis of the specific area of agricultural activity (cropland) or on the total area of agricultural activity (farmland). This highlights the effects of the activity but does not indicate the overall impact on the ecosystem. Maps 1 and 2 show the spatial distribution of IROWC-N calculated on the basis of cropland and farmland.

Map 3 shows the impact of agricultural activity on water quality for the entire Ecodistrict. This map is more effective at showing the impact in terms of the entire area. Agricultural activity does not cover the total area of any Ecodistrict so this value shows the dilution effect of the non-agricultural land mass (assuming that the non-agricultural land does not contribute any contaminant to the water supply). Since this project only deals with agricultural sources it is more realistic to represent IROWC-N on the basis of total farmland (Map 2).

Map 4 shows another representation of the information. It displays the amount of residual nitrogen remaining after harvest, calculated on the basis of the farmland. This map removes the influence of dilution from areas with a higher moisture excess.

The intent of an indicator is to provide an indication of intensity, which is a combination of extent, duration and amount. For IROWC-N this has been estimated by choosing a threshold level for concentration (10 mg/l of NO_3-N) and mapping the proportion of the polygon where the threshold value is likely to be exceeded (Map 4).

5.5 IROWC-N Temporal Changes

In the previous section, IROWC-N is used to show the varying effects of agricultural activities on water quality across the agricultural region of Ontario using data for 1991 (Map 2). While these spatial patterns are important, it is equally important to determine the changes over time. For this calculation, the time step is limited to the five year periods (years ending in 1 and 6) when Statistics Canada carries out the Census of Agriculture to collect information on land use and management. Data on agricultural land use and management were available for 1981 and IROWC-N has been calculated and displayed on the basis of farmland (Map 6). Examining changes over time can provide valuable insight into the relative impact of changing cropping and management practices on water quality. Since the same climate normals and soil data are used for both time periods, comparisons between 1981 and 1991 are directly related to changing agricultural practices.

Appendix 5 details the changes between 1981 and 1991 for IROWC-N on the basis of farmland. On a provincial basis the mean IROWC-N value increased 8%, from 4.32 ppm of nitrate-N in 1981 to 4.67 ppm of nitrate-N in 1991. At the Ecodistrict level, changes in IROWC-N values between 1981 and 1991 ranged from an increase of 45% (Ecodistrict 559) to a reduction of 19% (Ecodistrict 556). There was also considerable range in the IROWC-N values: in both 1981 and 1991 Ecodistrict 550 recorded the lowest values (0.63 ppm nitrate-N and 0.64 ppm nitrate-N respectively) and Ecodistrict 572 recorded the highest values (11.85 ppm nitrate-N and 12.61

ppm nitrate-N, respectively).

Generally, unless the changes are quite large, it is difficult to observe them from comparison of two separate maps. It is, however, a simple matter to calculate changes between the two census years and express the changes as a percentage change in concentration using 1981 as the base year (Map 7). This calculation may not, however, provide the best assessment of the relative change in risk over the time period because it is change expressed as a percent of the 1981 value which is not directly related to the threshold of interest (10 ppm of nitrate N, the drinking water standard). Map 8 shows the changes from 1981 to 1991 expressed as a percent of the drinking water standard. Ecodistricts 568 and 571 show up in the high category on both change maps. This is an area of sandy soils where the area of tobacco has decreased and been replaced by crops such as corn which have a higher overall nitrogen balance. Ecodistrict 559 (which is dominated by organic soils used for vegetable production) showed the greatest absolute change. As would be expected, the areas showing the greatest increase are associated with Southwestern and Eastern Ontario where agricultural activity has intensified.

When the 1996 Census of agriculture data become available the IROWC-N calculations will be repeated to determine whether these trends are continuing.

6 IROWC-N Sensitivity Assessment and Validation:

It is not feasible to validate the IROWC-N results at the Ecodistrict level. However, it is possible to compare the broad level estimates to the results measured in detailed research studies.

6.1 Detailed Research Studies

Established research plots at the Eugene F. Whelan Experimental Station (Agriculture and Agri-Food Canada, Woodslee, Ontario) have been instrumented to provide detailed measurements of the movement of water and dissolved and suspended materials moving off the plot throughout the year. Recently the plots have been planted to corn with various tillage systems and bluegrass to measure the amounts of nitrogen in surface runoff and drainage water. The results (Drury et al. 1993) showed that the concentrations of nitrate in the tile water from corn plots exceeded the safe limit for drinking water (10 mg/l) in 79% of the leaching events. Flow-weighted mean concentrations ranged from 12 to 18 mg/l over 1989 and 1990. Comparable losses from the bluegrass plots were 1 to 2.6 mg/l. In the discussion of the results, the authors cite studies which suggest that the volume of water flowing through the soil was the predominant factor responsible for N loss. They further suggest that, consistent with their results, the increased yield and N uptake in grain resulting from conservation tillage systems would reduce the amount of N available for leaching.

In a companion study (Drury et al. 1996), the results from studies of normal and controlled drainage were summarized to show that 88 to 95 % of the nitrate losses from all treatments occurred in the non-crop period (1 November to 31 April). The use of controlled drainage resulted in a 49% reduction in the nitrate losses in drainage and a very slight increase in the loss through surface runoff.

The calculated IROWC-N for corn in this climate-soil combination was 16 mg/l, a value which falls within the range of flow-weighted mean concentrations observed in the drainage water.

6.2 Pilot Watershed Studies of Moisture Balance and Nitrogen Concentrations

The Pilot Watershed Study (PWS) was undertaken from 1987 to 1992 as part of the Soil and Water Environmental Enhancement Program (SWEEP). It was designed to evaluate the effects of established conservation farming practices on a variety of agri-environmental attributes (e.g. soil properties and water quality) at the field, farm and small watershed scales. The PWS took place in three southwestern Ontario, Lake Erie sub-watersheds (Essex, Kettle Creek and Pittock) using paired test (conservation oriented) and control (conventional practices) basins within each to assess the influence of conservation practices.

Over the course of the PWS study, information was collected on stream flow volumes and concentrations of nitrate such that an IROWC-N could be calculated for the areas based on actual measured values. These results were calculated quarterly and on a crop year basis and have been summarized in Appendix 4, Tables 1 - 3 for the three years of the study. These measured values generally support the assumption, based on times of moisture excess and deficit, that most of the flow occurs during the non-crop time from October to March. The Essex watersheds during the 1989-90 crop year and the Pittock Control watershed during the 1991-92 crop year are exceptions. When the flow volumes were corrected for watershed area, the average on the Essex test (conservation) watershed was 8% less than on the control, for Kettle Creek the flow was 10% greater on the test watershed and for Pittock the flow on the test watershed was 45% higher. In all cases the IROWC-N calculated from the measured values was larger for the test (conservation) watersheds than for the control.

The average observed/measured IROWC-N values ranged from 6.4 on the Essex control watershed to 10.8 mg/l on the Pittock test. The values for the Essex watersheds were about one third of the flow-weighted mean concentrations observed by Drury et al (1993); however, they represent a mix of crops and some non-farm land whereas the study by Drury dealt with a corn crop.

In addition to an IROWC-N calculated from measurements at the pilot watersheds, it was possible to calculate IROWC-N using the methodology developed in this report. This was done based on the distribution and proportion of crops present, the soil AWHC and climate normals data. These results are summarized in Appendix 5, table 4. Based on this approach, the IROWC-N values ranged from 13.3 for the Essex test (conservation) watershed to 7.4 for the Pittock test. These values suggest that the Essex area should be highest and Pittock lowest, in contrast to the measured values. However, it should be noted that the climate normals data suggest a greater volume of excess water would be present in Pittock (hence greater dilution). This was not shown by measured flow volumes. In addition to providing an estimate of IROWC-N for comparison, this approach provides a method for comparing different areas with different combinations of crops by calculating an expected IROWC-N value.

It is interesting to compare these values to those calculated for the entire Ecodistricts. Table 6.1 summarizes these results. While there are discrepancies at the detailed level between these numbers, the general level of correspondence appears to be acceptable. On this basis, the current approach to determining IROWC- N appears to be appropriate for the Ecodistrict level of analysis.

Table 6.1: Summary of results from the pilot watersheds

Watershed	IROWC-N from measured flow and N concentration	IROWC-N from crop distribution in PWS	IROWC-N for Ecodistrict based on crop area	IROWC-N for Ecodistrict based on Ecodistrict
Essex Control	6.4	12.8	13.8	9.5
Essex Test	6.5	13.4	13.8	9.5
Kettle Creek Control	6.9	9.4	9.8	5.7
Kettle Creek Test	9.7	9.8	9.8	5.7
Pittock Control	9.4	8.5	6.5	4.3
Pittock Test	10.8	8.0	6.5	4.3

7 Conclusions:

A method has been demonstrated for calculating IROWC-N at the Ecodistrict level and its sensitivity evaluated by comparison with data from small watersheds and research plots. This method needs to be applied in other areas of the country but the results presented in this report are encouraging.

IROWC-N is sensitive to the mix of crops and levels of nutrient inputs from fertilizer and manure. Additional work is required at the more detailed level to determine the effects of other management practices such as conservation tillage etc.

A main feature of IROWC-N would appear to be the dynamics of nitrogen during the traditional non-crop period. Research on controlled drainage and with catch crops (crops grown late in the season to take up nitrogen and retain it in biomass over winter) offer some potential to mitigate the effects of intensive cropping on IROWC-N

A variety of anthropogenic influences affect the overall nitrogen balance in the environment. This project has considered only the impacts of agricultural activities. Nitrogen inputs from atmospheric deposition or non-symbiotic nitrogen fixation are not included nor are losses from denitrification. Other factors which affect the rural land and water (such as nitrogen from rural septic systems) should be considered in placing this agricultural IROWC-N in perspective of the overall ecosystem health/integrity assessment for sustainable development.

8 Bibliography

Drury, C.F., McKenney, D.J., Findlay, W.I. and J.D.Gaynor. 1993. Influence of Tillage on Nitrate Loss in Surface Runoff and Tile Drainage. Soil Science of America Journal. 57(3): 797-802.

Drury, C.F., Tan, C.S., Gaynor, J.D., Oloya, T.O. and T.W.Welacky. 1996. Influence of Controlled Drainage-Subirrigation on Surface and Tile Drainage Nitrate Loss. Journal of Environmental Quality. 25(2): 317-324.

Fried, M., Tanji, K.K., Van de Pol, R.M. 1976. Simplified long term concept for evaluating leaching of nitrogen from agricultural land. Journal of Environmental Quality. 5(2): 197-200.

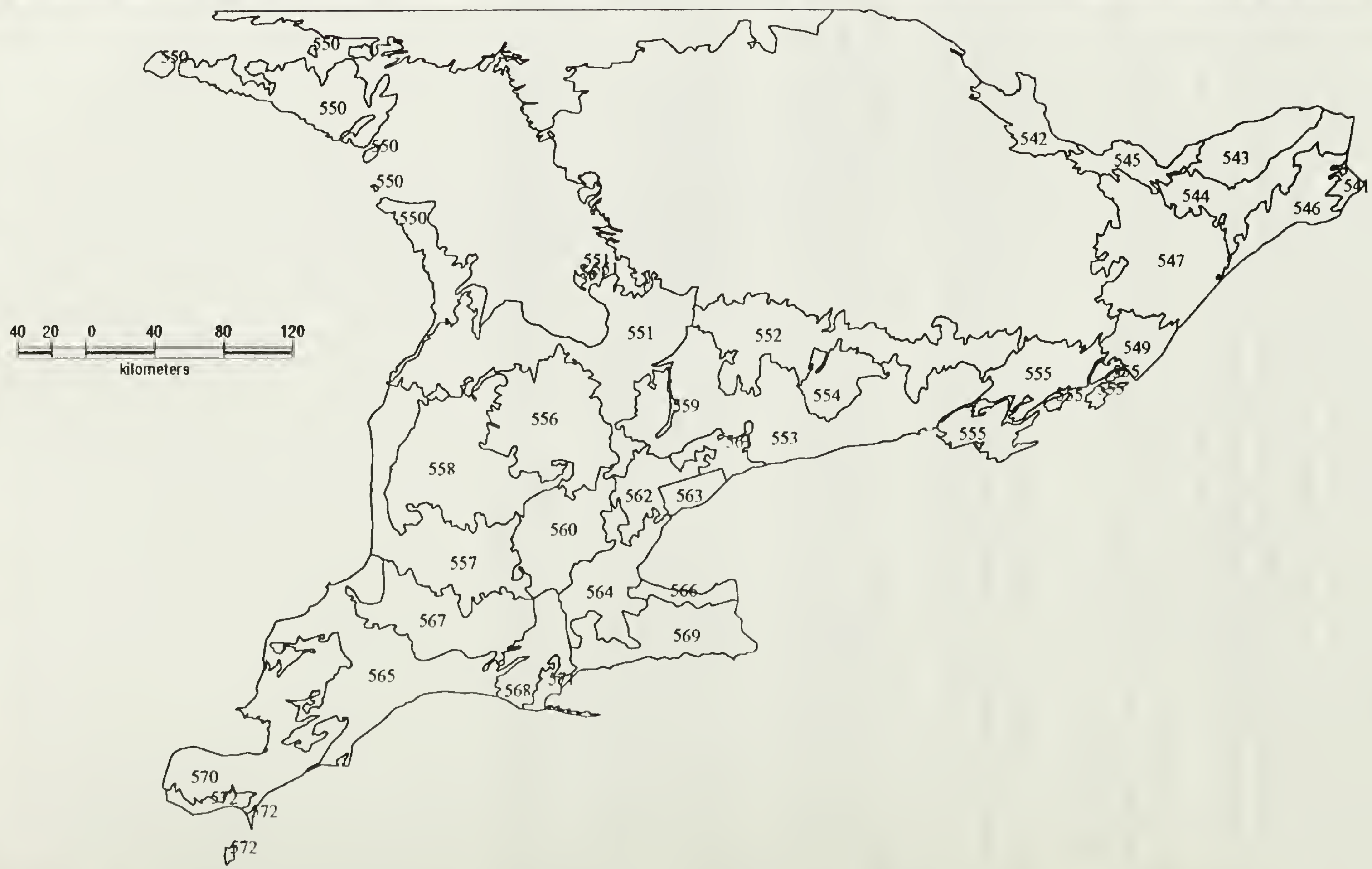
R. de Jong, A. Bootsma, J. Dumanski and K. Samuel. 1992. Characterizing the soil water regime of the Canadian prairies. Technical Bulletin 1992-2E, CLBRR contribution No 91-130. Centre for Land and Biological Resources Research, Ottawa, Ontario.

MacDonald, K.B. and H. Spaling. 1995. Indicator of Risk of Water Contamination: Concepts and Principles. Working Paper prepared for the Water contamination Risk Team of the Agri-environmental Indicator Project. Agriculture and Agri-Food Canada. Ontario Land Resource Unit, Guelph, Ontario.

MacDonald, K.B. and H. Spaling. 1995. Indicator of Risk of Water Contamination: Methodological Development. Working draft prepared for the Water contamination Risk Team of the Agri-environmental Indicator Project. Agriculture and Agri-Food Canada. Ontario Land Resource Unit, Guelph, Ontario.

Pratt, E.F., Jones, W.W. and V.E. Hunsaker. 1972. Nitrate in deep soil profiles in relation to fertilizer rates and leaching volume. J.Environ.Qual. 1(3): 97-102.

APPENDIX 1: ECODISTRICTS OF SOUTHERN ONTARIO



Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by
Ontario Land Resource Unit
Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

APPENDIX 2: Sample Rotation Worksheets for Ontario Ecodistricts

ECODISTRICT 572		Total	Tobacco	Corn	Beans	Annual Hort.	Hay	WWFR	Spring Cereal	Improved Pasture	Unimp. Pasture
Crop Area:		26467	26	6937	12880	3741	746	1670	389	78	320
Rotation 1: Tobacco, WW/FR	**Area in Rotation**	**52**	**26**	**0**	**0**	0	**0**	**26**	**0**	**0**	
	Remainder		0	6937	12880	3741	746	1644	389	78	
Rotation 2: Corn, Beans, WW/FR	**Area in Rotation**	**4932**	0	**1644**	**1644**	0	**0**	**1644**	**0**	0	
	Remainder		0	5293	11236	3741	746	0	389	78	
Rotation 3: AnnHort, AnnHort, Beans	**Area in Rotation**	**5612**	0	**0**	**1871**	**3741**	**0**	**0**	**0**	**0**	
	Remainder		0	5293	9366	0	746	0	389	78	
Rotation 4: Corn, Beans	**Area in Rotation**	**10586**	0	**5293**	**5293**	**0**	**0**	0	**0**	**0**	
	Remainder		0	0	4073	0	746	0	389	78	
Rotation 5: Beans, Beans, Cereal, Hay, Hay	**Area in Rotation**	**1865**	0	**0**	**746**	0	**746**	**0**	**373**	**0**	
	Remainder		0	0	3327	0	0	0	16	78	
Rotation 6: Continuous Beans	**Area in Rotation**	**3327**	0	**0**	**3327**	**0**	**0**	**0**	0	**0**	
	Remainder		0	0	0	0	0	0	16	78	
Rotation 7: Continuous Pasture	**Area in Rotation**	**78**	0	**0**	**0**	**0**	**0**	**0**	**0**	**78**	
	Remainder		0	0	0	0	0	0	16	0	
Total Farmland	31360										
Total Managed Farmland	28158										
Annual Horticultural Crops	3741										
Perennial Horitcultural Crops	1190										
Managed Farmland - Perennial Hort.	26968										
Crop Area	26467										
Land In Rotation	26451										
Land Unaccounted For in Rotation	16										
% of Managed Farmland In Rotation	**94**										
% of Crops in Rotation	**100**										

ECODISTRICT 572		Total	Tobacco	Corn	Beans	Annual Hort.	Hay	WWFR	Spring Cereal	Improved Pasture	Unimp. Pasture
Total kg of N Required		1805885	650	1075235	0	486330	44760	149780	26110	7020	16000
Rotation 1: Tobacco, WW/FR	Required	2470	650	0	0	0	0	1820	0	0	0
	Manure	0	0	0	0	0	0	0	0	0	0
	Unsatisfied	2470	650	0	0	0	0	1820	0	0	0
Rotation 2: Corn, Beans, WW/FR	Required	402780	0	254820	0	0	0	147960	0	0	0
	Manure	16028	0	16028	0	0	0	0	0	0	0
	Unsatisfied	386752	0	238792	0	0	0	147960	0	0	0
Rotation 3: AnnHort, AnnHort, Beans	Required	486330	0	0	0	486330	0	0	0	0	0
	Manure	0	0	0	0	0	0	0	0	0	0
	Unsatisfied	486330	0	0	0	486330	0	0	0	0	0
Rotation 4: Corn, Beans	Required	820415	0	820415	0	0	0	0	0	0	0
	Manure	51603	0	51603	0	0	0	0	0	0	0
	Unsatisfied	768812	0	768812	0	0	0	0	0	0	0
Rotation 5: Beans, Beans, Cereal, Hay, Hay	Required	70870	0	0	0	0	44760	0	26110	0	0
	Manure	22544	0	0	0	0	15029	0	7515	0	0
	Unsatisfied	48327	0	0	0	0	29731	0	18596	0	0
Rotation 6: Continuous Beans	Required	0	0	0	0	0	0	0	0	0	0
	Manure	0	0	0	0	0	0	0	0	0	0
	Unsatisfied	0	0	0	0	0	0	0	0	0	0
Rotation 7: Continuous Pasture	Required	23020	0	0	0	0	0	0	0	7020	16000
	Manure	17580	0	0	0	0	0	0	0	7020	10560
	Unsatisfied	5440	0	0	0	0	0	0	0	0	5440
kg of N in Manure	215508		Area Receiving Manure		833						
kg of N Available 1st year	107754		CoA Figure		1042						
Remaining kg of N in Manure	0		Unimp. Pasture * 0.66		10560						
Unsatisfied N Requirement*	1692691							* does not include unimproved pasture.			

ECODISTRICT 572		Total	Tobacco	Corn	Beans	Annual Hort.	Hay	WWFR	Spring Cereal	Improved Pasture	Unimp. Pasture
Total Fertilizer N Required		1692691	650	1007605	0	486330	29731	149780	18596	0	0
Rotation 1: Tobacco, WW/FR	**Fertilizer N**	2470	650	0	0	0	0	1820	0	0	0
Rotation 2: Corn, Beans, WW/FR	**Fertilizer N**	386752	0	238792	0	0	0	147960	0	0	0
Rotation 3: AnnHort, AnnHort, Beans	**Fertilizer N**	486330	0	0	0	486330	0	0	0	0	0
Rotation 4: Corn, Beans	**Fertilizer N**	768812	0	768812	0	0	0	0	0	0	0
Rotation 5: Beans, Beans, Cereal, Hay, Hay	**Fertilizer N**	48327	0	0	0	0	29731	0	18596	0	0
Rotation 6: Continuous Beans	**Fertilizer N**	0	0	0	0	0	0	0	0	0	0
Rotation 7: Continuous Pasture	**Fertilizer N**	0	0	0	0	0	0	0	0	0	0
Area Fertilized		**12693**	**26**	**6501**	**0**	**3741**	**496**	**1664**	**266**	**0**	**0**
Area Fertilized	12693										
Area Fertilized (CoA Figure)	21085										
Total N Applied as Fertilizer	1692691										

Summary of Rotations (1991)

Rotations	Area in Rotation	Manure N Applied	Fertilizer N Applied	Mean N Applied	Mean Manure N Residual	Mean Residual N From Crops	Mean Residual N From Crops and Manure
Tobacco/WWFR	40712	0	2235160	54.90	0.00	11.25	11.25
Corn/Beans/WWFR	461511	5655715	31780125	81.12	1.23	46.99	48.22
Annual Horticultural Crops	115550	0	11056899	95.69	0.00	61.66	61.66
Corn/Beans	835261	13134347	53823909	80.16	1.57	60.35	61.92
Beans/Cereal/Hay	24918	316023	630842	38.00	1.27	34.60	35.87
Corn/Cereal/Hay	984428	15259553	61051592	77.52	1.55	24.99	26.54
Cereal/Hay	378149	3182985	14646384	47.15	0.84	15.39	16.23
Continuous Corn	55054	1838172	6695185	155.00	3.34	56.85	60.19
Continuous Beans	33619	0	0	0.00	0.00	64.00	64.00
Continuous Pasture	493440	35510637	15875196	104.14	7.20	22.10	29.29
Total	3422642	74897434	197795293	79.67	2.19	37.15	39.34

APPENDIX 3: Monthly P-PE and AWHC

P-PE and AWHC for Ontario Ecodistricts (mm)

ECO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AWHC
541	79.45	73.81	67.54	6.29	-33.21	-40.44	-33.69	-2.89	43.30	53.54	81.72	96.63	200
542	66.30	60.95	50.35	-5.20	-38.35	-41.05	-57.20	-23.05	32.00	52.35	74.45	90.45	223
543	87.35	75.60	69.83	7.83	-27.17	-28.23	-26.31	0.50	40.77	58.91	91.06	111.08	170
544	77.54	73.00	64.54	-1.15	-38.68	-49.23	-43.50	-15.45	30.00	48.77	79.12	97.37	180
545	76.05	67.50	61.62	-0.21	-36.03	-38.06	-42.19	-18.01	33.23	52.90	82.23	100.27	212
546	79.45	73.81	67.54	6.29	-33.21	-40.44	-33.69	-2.89	43.30	53.54	81.72	96.63	159
547	73.90	72.59	61.29	1.74	-33.65	-49.85	-47.53	-14.40	30.90	51.78	78.37	97.45	127
549	76.18	61.75	58.76	1.04	-23.89	-32.45	-33.62	3.69	50.82	64.10	96.71	86.61	146
550	85.05	57.93	56.50	4.71	-26.59	-35.79	-55.80	-16.93	31.65	53.35	82.74	105.19	131
551	94.50	74.70	66.83	4.37	-24.40	-46.50	-51.12	-15.68	28.94	59.66	91.67	109.29	141
552	94.50	74.70	66.83	4.37	-24.40	-46.50	-51.12	-15.68	28.94	59.66	91.67	109.29	138
553	94.50	74.70	66.83	4.37	-24.40	-46.50	-51.12	-15.68	28.94	59.66	91.67	109.29	118
554	94.50	74.70	66.83	4.37	-24.40	-46.50	-51.12	-15.68	28.94	59.66	91.67	109.29	100
555	85.55	79.82	75.12	6.62	-23.53	-48.55	-58.98	-22.30	33.62	57.85	95.52	109.92	207
556	109.45	81.04	74.45	14.09	-17.58	-37.73	-39.08	0.85	37.41	67.88	103.35	124.09	149
557	105.11	77.71	71.06	18.83	-23.50	-40.81	-49.39	-14.74	26.37	55.51	93.46	119.88	200
558	109.45	81.04	74.45	14.09	-17.58	-37.73	-39.08	0.85	37.41	67.88	103.35	124.09	169
559	94.50	74.70	66.83	4.37	-24.40	-46.50	-51.12	-15.68	28.94	59.66	91.67	109.29	500
560	79.52	65.95	77.67	18.77	-17.23	-35.55	-43.25	-8.18	22.40	57.54	86.77	97.87	133
561	94.50	74.70	66.83	4.37	-24.40	-46.50	-51.12	-15.68	28.94	59.66	91.67	109.29	159
562	79.17	64.07	63.74	6.97	-28.17	-53.08	-56.22	-22.15	12.23	47.20	78.00	93.60	219
564	80.62	64.26	74.06	15.18	-31.61	-52.38	-63.27	-21.26	14.26	42.37	77.50	95.11	211
565	80.62	64.26	74.06	15.18	-31.61	-52.38	-63.27	-21.26	14.26	42.37	77.50	95.11	204
566	80.62	64.26	74.06	15.18	-31.61	-52.38	-63.27	-21.26	14.26	42.37	77.50	95.11	181
567	80.62	64.26	74.06	15.18	-31.61	-52.38	-63.27	-21.26	14.26	42.37	77.50	95.11	188
568	80.62	64.26	74.06	15.18	-31.61	-52.38	-63.27	-21.26	14.26	42.37	77.50	95.11	106
569	82.32	68.37	76.28	20.48	-30.28	-47.83	-69.61	-19.67	21.23	53.90	73.93	97.60	238
570	68.54	58.11	30.83	9.49	-40.06	-47.35	-61.46	-29.63	-3.59	28.86	65.66	88.12	247
571	80.62	64.26	74.06	15.18	-31.61	-52.38	-63.27	-21.26	14.26	42.37	77.50	95.11	125
572	68.54	58.11	30.83	9.49	-40.06	-47.35	-61.46	-29.63	-3.59	28.86	65.66	88.12	215

APPENDIX 4: IROWC-N by Ecodistrict (1991)

ECODISTRIC	IROWC-N ECODISTRICT mg N per l	IROWC-N FARMLAND mg N per l	IROWC-N CROPLAND mg N per l
541	2.78	4.53	6.34
542	0.75	1.34	2.94
543	1.20	2.57	4.09
544	2.82	4.28	6.29
545	0.69	1.73	3.94
546	1.38	3.06	5.54
547	0.98	2.32	5.56
549	0.64	1.51	3.64
550	0.16	0.64	2.69
551	0.91	1.99	3.83
552	0.67	1.47	3.82
553	2.01	3.83	6.47
554	1.20	2.02	4.42
555	0.99	1.94	4.06
556	0.63	1.21	2.16
557	4.09	5.13	6.72
558	2.52	3.18	4.93
559	2.13	4.24	5.80
560	3.15	5.10	7.06
561	1.99	4.74	6.82
562	1.70	4.50	6.07
564	2.51	5.22	7.41
565	6.43	8.49	10.45
566	0.73	1.83	7.29
567	5.58	7.85	9.66
568	4.60	6.36	8.99
569	2.00	3.99	5.91
570	9.41	12.44	13.80
571	2.98	6.35	9.73
572	8.26	12.61	15.00

APPENDIX 5: Temporal Changes in IROWC-N (1981-91)

ECODISTRICT	IROWC-N FARMLAND 1981 mg N per l	IROWC-N FARMLAND 1991 mg N per l	% CHANGE IN IROWC-N VALUE 1981-1991	% CHANGE RELATIVE TO THE DRINKING WATER STANDARD (10 mg per l)
541	4.18	4.53	8.37	3.50
542	1.54	1.34	-12.99	-2.00
543	2.40	2.57	7.08	1.70
544	3.68	4.28	16.30	6.00
545	2.00	1.73	-13.50	-2.70
546	2.59	3.06	18.15	4.70
547	2.37	2.32	-2.11	-0.50
549	1.46	1.51	3.42	0.50
550	0.63	0.64	1.59	0.10
551	2.41	1.99	-17.43	-4.20
552	1.62	1.47	-9.26	-1.50
553	3.64	3.83	5.22	1.90
554	2.15	2.02	-6.05	-1.30
555	2.09	1.94	-7.18	-1.50
556	1.50	1.21	-19.33	-2.90
557	4.51	5.13	13.75	6.20
558	3.07	3.18	3.58	1.10
559	2.92	4.24	45.21	13.20
560	4.58	5.10	11.35	5.20
561	4.56	4.74	3.95	1.80
562	3.77	4.50	19.36	7.30
564	4.73	5.22	10.36	4.90
565	7.66	8.49	10.84	8.30
566	1.48	1.83	23.65	3.50
567	7.15	7.85	9.79	7.00
568	4.91	6.36	29.53	14.50
569	4.00	3.99	-0.25	-0.10
570	11.01	12.44	12.99	14.30
571	5.07	6.35	25.25	12.80
572	11.85	12.61	6.41	7.60

APPENDIX 6: Observed Values from SWEEP Watersheds

Table 1: Observed Values for 1989-90 Crop Year

1989-90		Quarter 2	Quarter 3	Quarter 4	Quarter 1	Year
Flow	ET	549191.52	90932.40	17190.00	694678.32	1351992.24
(000 l)	EC	368182.80	68810.40	13834.08	575858.16	1026685.44
	KT	190810.80	2880.36	39409.20	1002650.40	1235750.76
	KC	118245.60	8060.40	25995.96	793278.00	945579.96
	PT	217188.00	723.60	23285.52	609242.40	850439.52
	PC	118166.40	5119.20	3348.00	449790.48	583688.88
Total Nitrogen	ET	15.19	0.98	0.32	5.01	21.50
(kg/ha)	EC	16.32	3.13	0.79	8.40	28.64
	KT	4.84	0.05	1.03	26.29	32.20
	KC	1.98	0.09	0.54	13.67	16.28
	PT	6.37	0.04	0.83	10.94	18.18
	PC	3.24	0.05	0.13	11.67	15.09
Nitrogen	ET	12.03	4.67	8.20	3.14	6.92
Concentration	EC	12.45	12.78	16.07	4.10	7.84
(mg/l)	KT	10.39	7.39	10.70	10.75	10.68
	KC	5.92	3.95	7.34	6.10	6.09
	PT	10.53	17.46	12.75	6.45	7.67
	PC	10.54	3.54	14.83	9.97	9.93

Note: ET = Essex Test, EC = Essex Control, KT = Kettle Creek Test, KC = Kettle Creek Control, PT = Pittock Test, PC = Pittock Control

Table 2: Observed Values for 1990-91 Crop Year

1990-91		Quarter 2	Quarter 3	Quarter 4	Quarter 1	Year
Flow	ET	260280.00	412182.00	1224428.40	324630.00	2221520.40
(000 l)	EC	195649.20	352882.80	877276.80	242866.80	1668675.60
	KT	306241.20	372847.68	888536.52	397007.28	1964632.68
	KC	228859.20	255805.20	676526.40	431298.00	1592488.80
	PT	134872.92	76672.80	647820.00	523325.52	1382691.24
	PC	132033.60	41032.08	335239.20	587041.20	1095346.08
Total Nitrogen	ET	5.98	2.08	6.04	1.86	15.95
(kg/ha)	EC	3.84	1.30	11.52	2.38	19.03
	KT	9.09	4.22	18.18	4.66	36.15
	KC	5.92	2.03	7.58	3.73	19.26
	PT	5.74	3.51	17.71	12.02	38.99
	PC	5.88	2.03	8.56	13.95	30.42
Nitrogen	ET	9.99	2.19	2.15	2.49	3.12
Concentration	EC	5.51	1.03	3.69	2.76	3.21
(mg/l)	KT	12.17	4.64	8.39	4.81	7.54
	KC	9.15	2.82	3.96	3.06	4.28
	PT	15.29	16.45	9.81	8.25	10.12
	PC	17.09	19.02	9.81	9.13	10.67

Note: ET = Essex Test, EC = Essex Control, KT = Kettle Creek Test, KC = Kettle Creek Control, PT = Pittock Test, PC = Pittock Control

Table 3: Observed Values for 1991-92 Crop Year

1991-92		**Quarter 2**	**Quarter 3**	**Quarter 4**	**Quarter 1**	**Year**
Flow	ET	315902.88	0.00	152556.48	747518.40	1215977.76
(000 l)	EC	176739.84	0.00	58484.16	417090.24	652314.24
	KT	118765.44	0.00	132157.44	771170.40	1022093.28
	KC	112164.48	0.00	26040.96	650775.60	788981.04
	PT	187220.16	950.40	20831.04	440880.48	649882.08
	PC	242412.48	19103.04	3481.92	179442.72	444440.16
Total Nitrogen	ET	7.12	#	4.98	14.12	26.21
(kg/ha)	EC	4.82	#	3.16	10.71	18.68
	KT	1.91	#	5.26	20.01	27.18
	KC	1.19	#	1.36	20.64	23.19
	PT	5.16	0.01	0.76	13.11	19.05
	PC	7.04	0.06	0.03	6.46	13.59
Nitrogen	ET	9.80	#	14.19	8.22	9.38
Concentration	EC	7.66	#	15.18	7.21	8.05
(mg/l)	KT	6.61	#	16.32	10.64	10.90
	KC	3.76	#	18.52	11.22	10.40
	PT	9.89	3.86	13.16	10.68	10.52
	PC	11.15	1.24	3.63	13.82	11.74

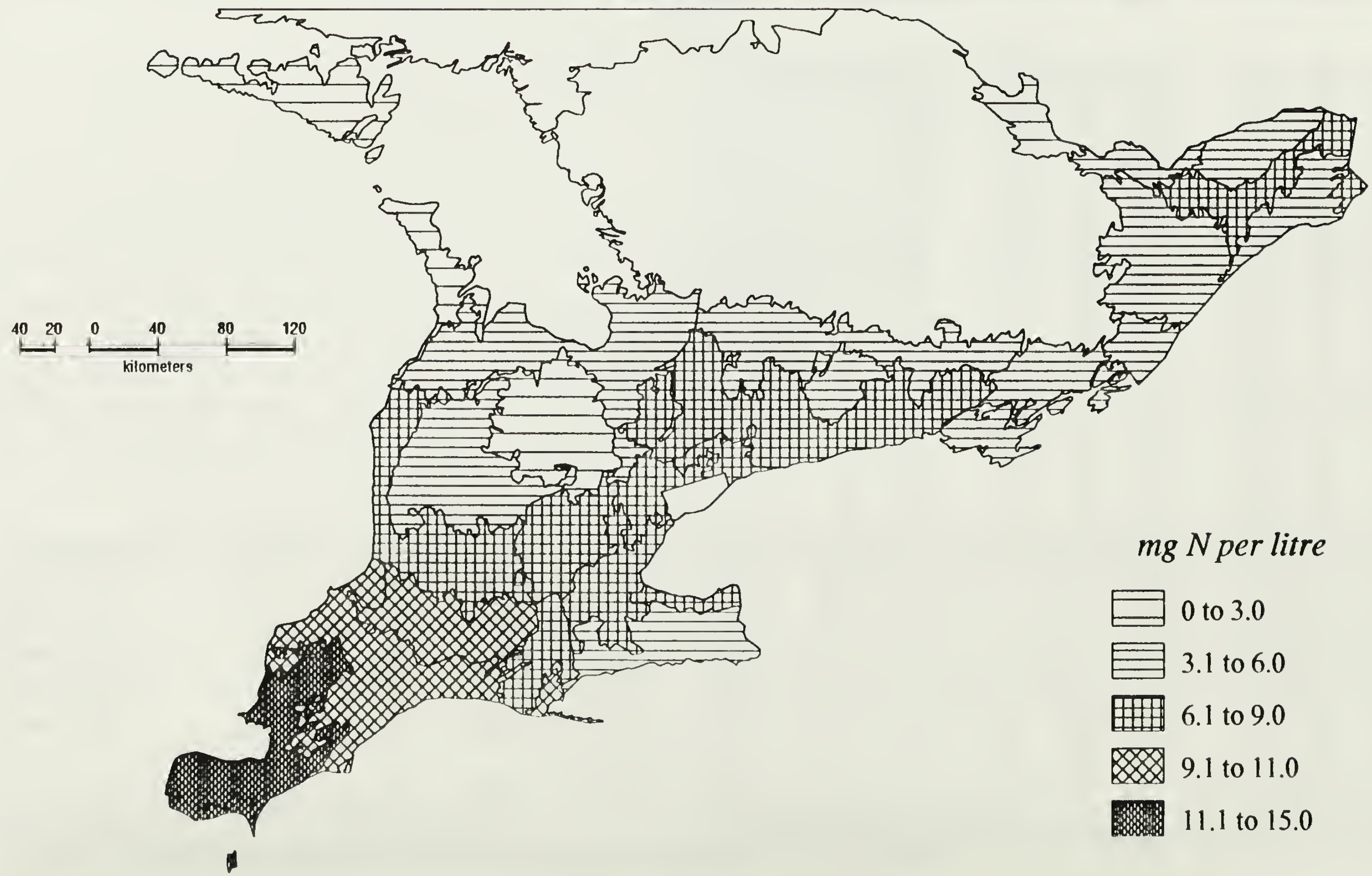
Note: ET = Essex Test, EC = Essex Control, KT = Kettle Creek Test, KC = Kettle Creek Control, PT = Pittock Test, PC = Pittock Control

Table 4: IROWC-N calculated from Crop Distribution and Climate Normals data

WATERSHED	IROWC-N (mg/l)				AVG. N LOSS (kg/ha)				TOTAL N LOSS FROM CROPLAND (kg)			
	1989	1990	1991	Avg. 89-91	1989	1990	1991	Avg. 89-91	1989	1990	1991	Avg. 89-91
Essex Test	12.3	13.32	14.45	13.36	20.68	22.38	24.28	22.45	7487.61	8639.45	9274.96	8467.34
Essex Control	12.32	12.31	14	12.88	20.7	20.68	23.52	21.63	5443.6	5438.8	6185.76	5689.39
Kettle Test	9.8	9.9	9.6	9.77	28.9	29.08	28.32	28.77	9759.4	9655.56	9457.88	9624.28
Kettle Control	8.53	9.34	10.26	9.38	25.15	27.54	30.26	27.65	8953.8	9804	10530.83	9762.88
Pittock Test	7.41	8.07	8.65	8.04	29.82	32.48	34.8	32.37	10317.72	10037.4	10226.35	10193.82
Pittock Control	8.46	8.17	8.72	8.45	34.03	32.85	35.06	33.98	10210.32	10281.77	11290.13	10594.07

MAP 1 1991 IROWC-N: CROPLAND

Concentration of N in Water from Agriculture



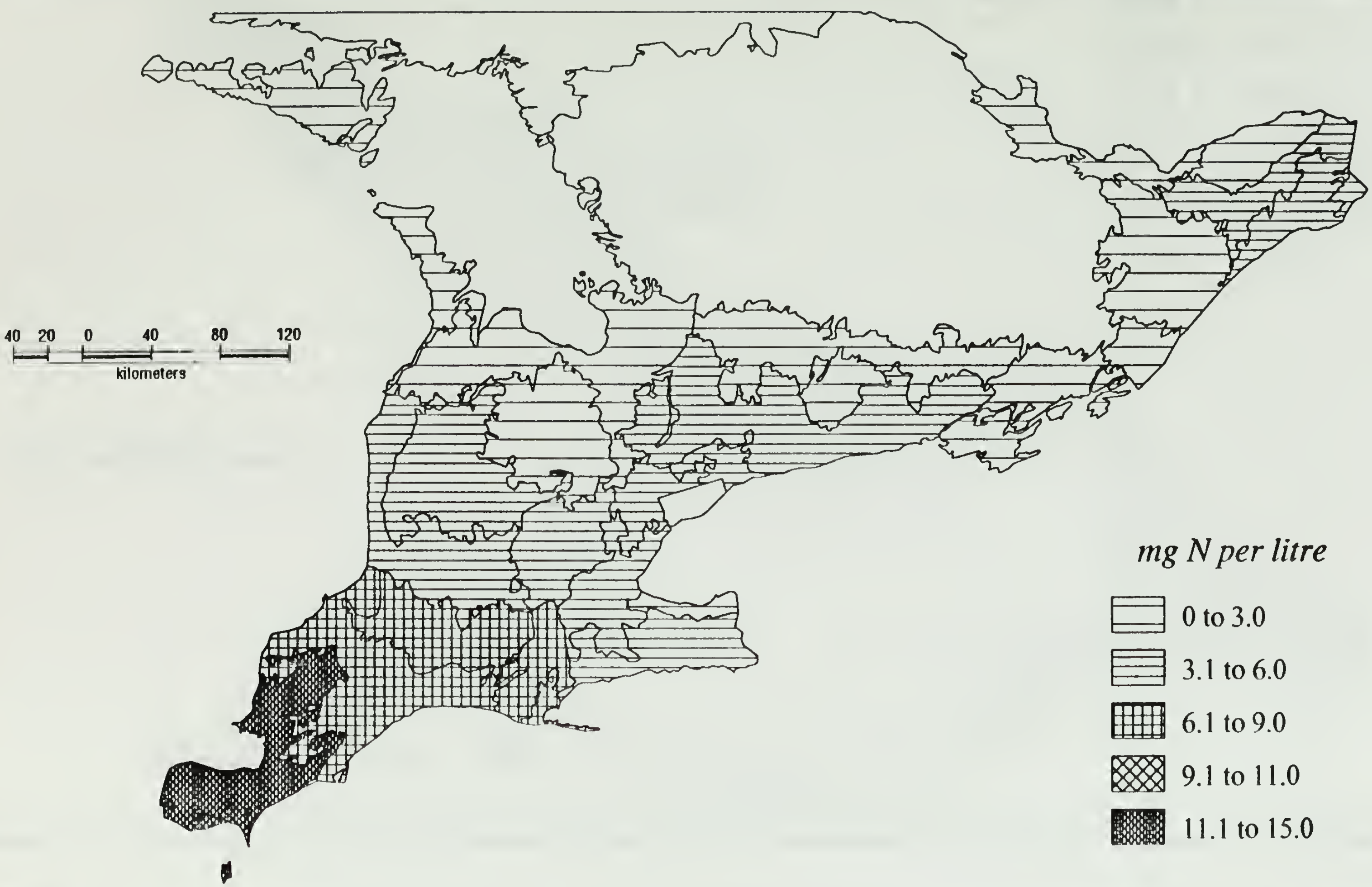
Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by
Ontario Land Resource Unit
Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

MAP 2 1991 IROWC-N: FARMLAND

Concentration of N in Water from Agriculture



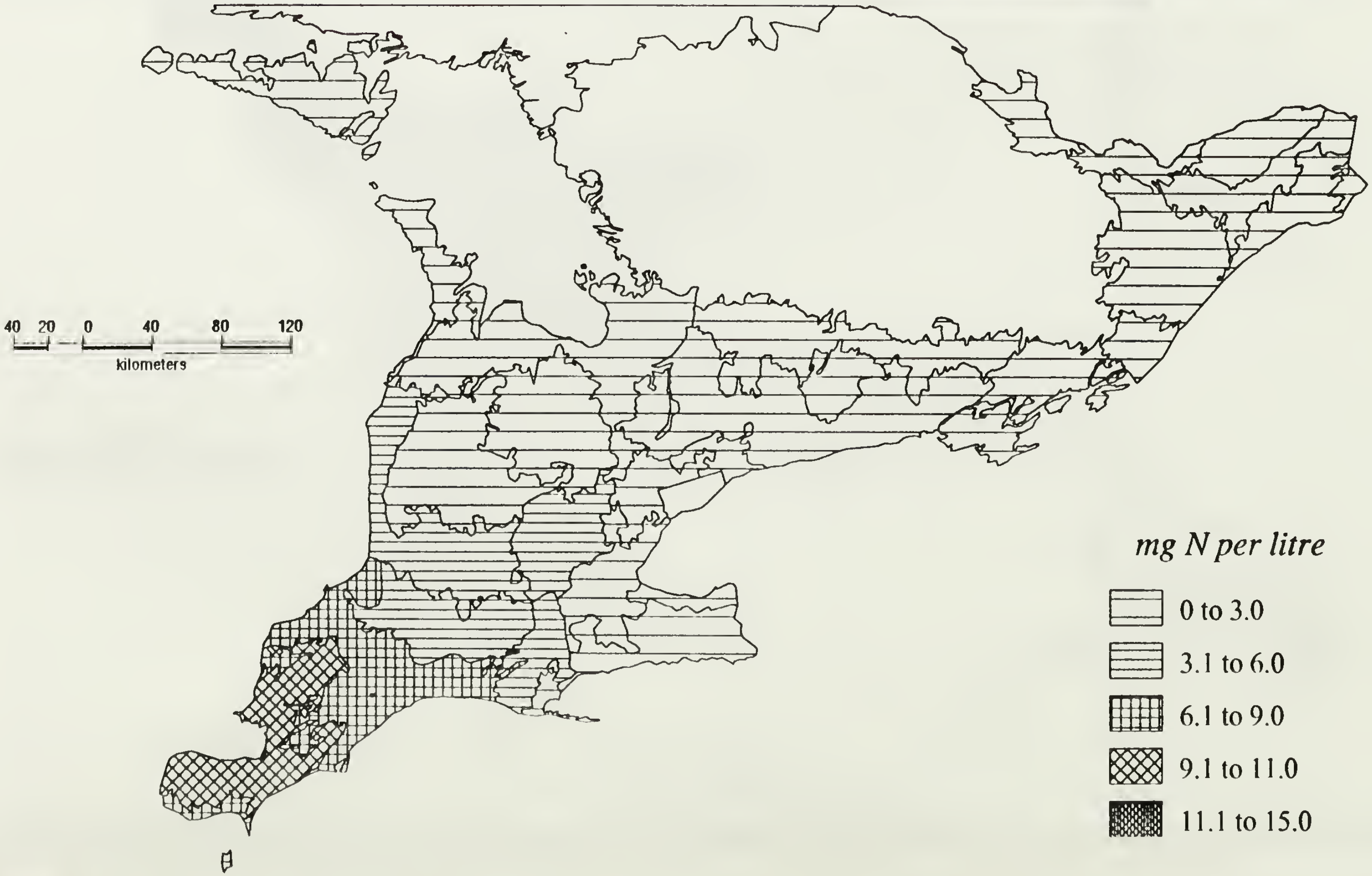
Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by
Ontario Land Resource Unit
Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

MAP 3 1991 IROWC-N: ECODISTRICT

Concentration of N in Water from Agriculture



Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

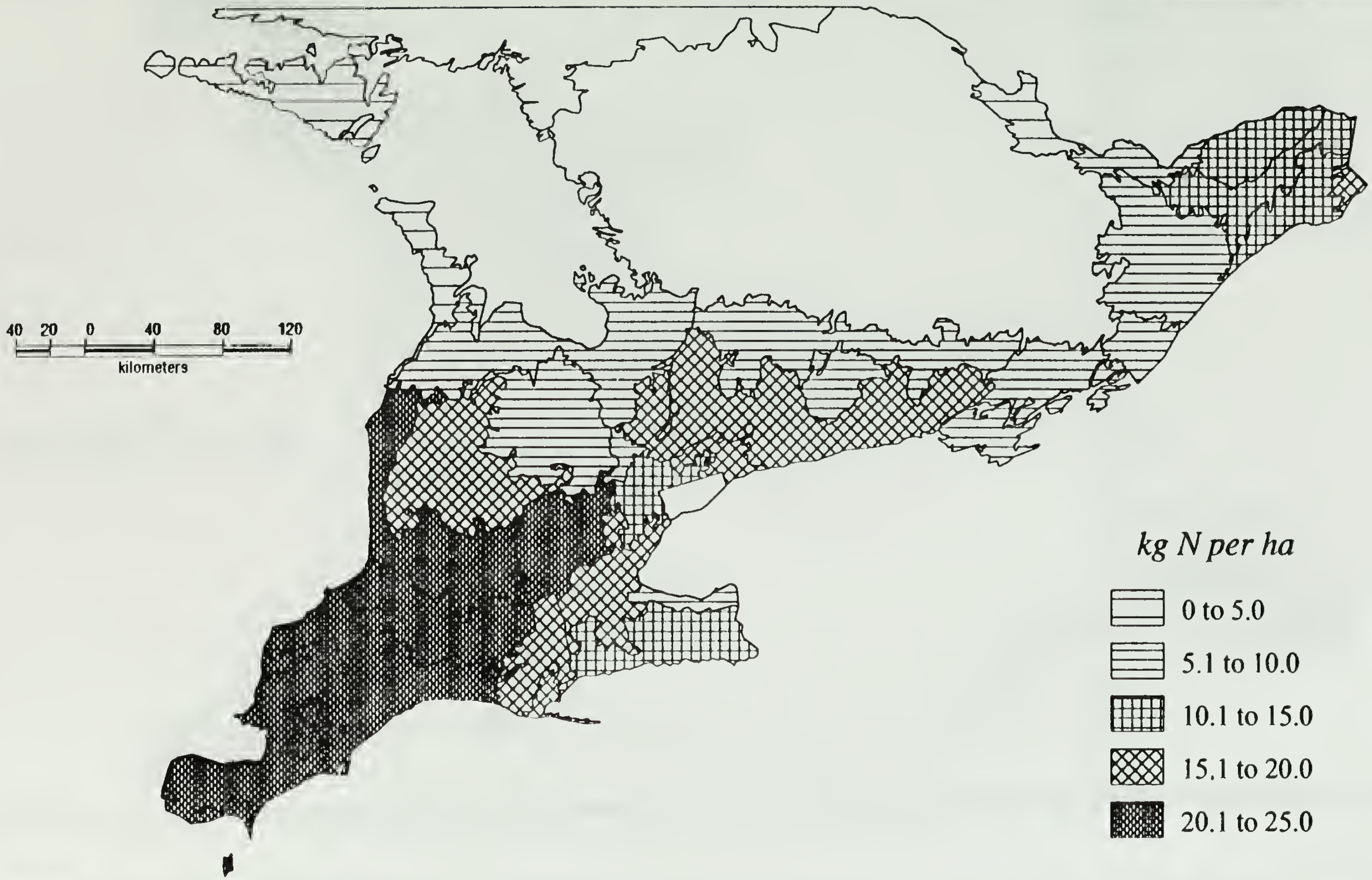
Map prepared by
Ontario Land Resource Unit
Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

MAP 4 1991 NITROGEN REMAINING AFTER HARVEST: FARMLAND

kg N per ha

Nitrogen contained in the crop residue



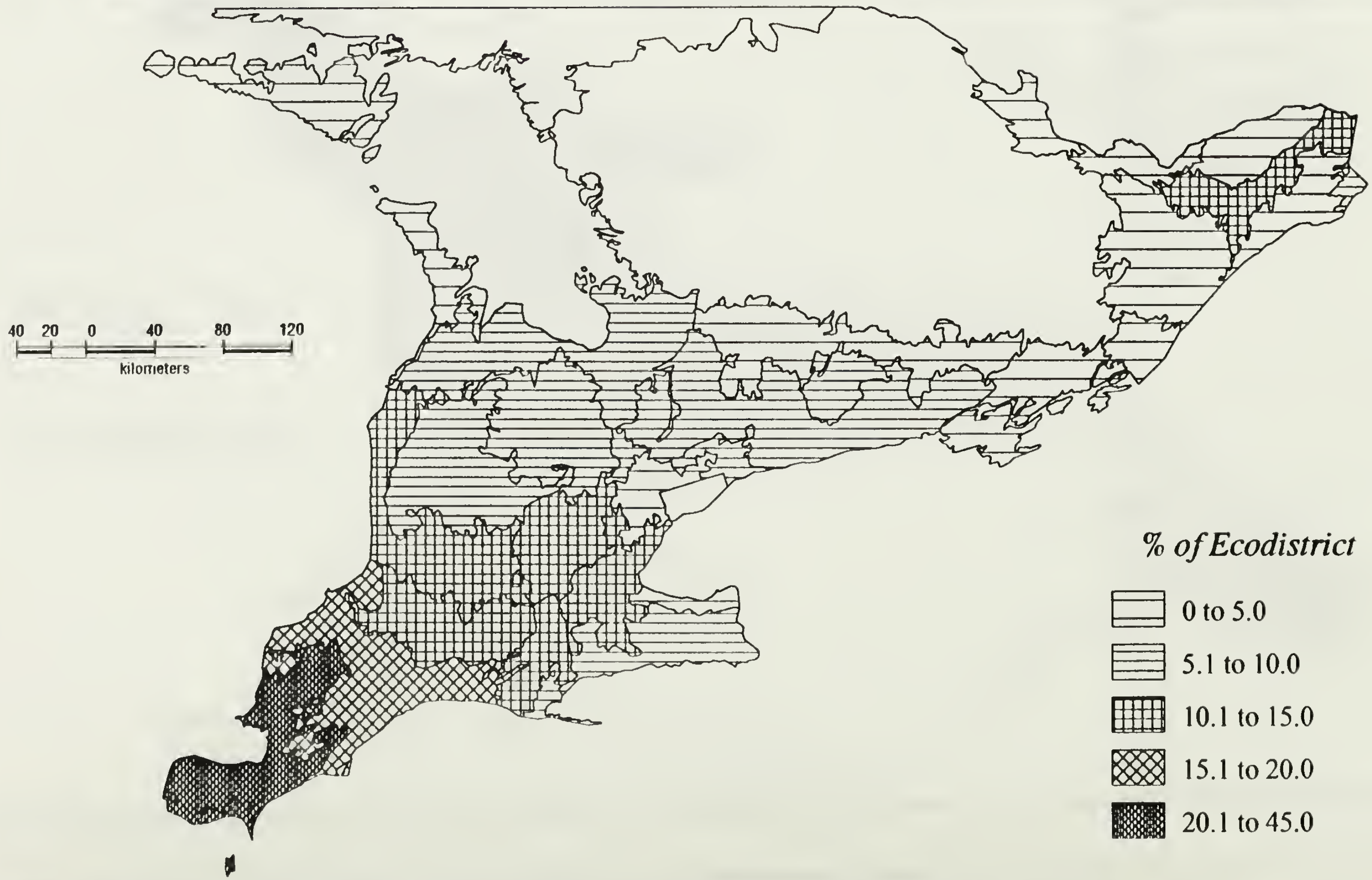
Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by
Ontario Land Resource Unit
Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

MAP 5 1991 PROPORTION OF ECODISTRICT WHERE IROWC-N > 10 mg N per litre

Concentration of N in Water from Agriculture



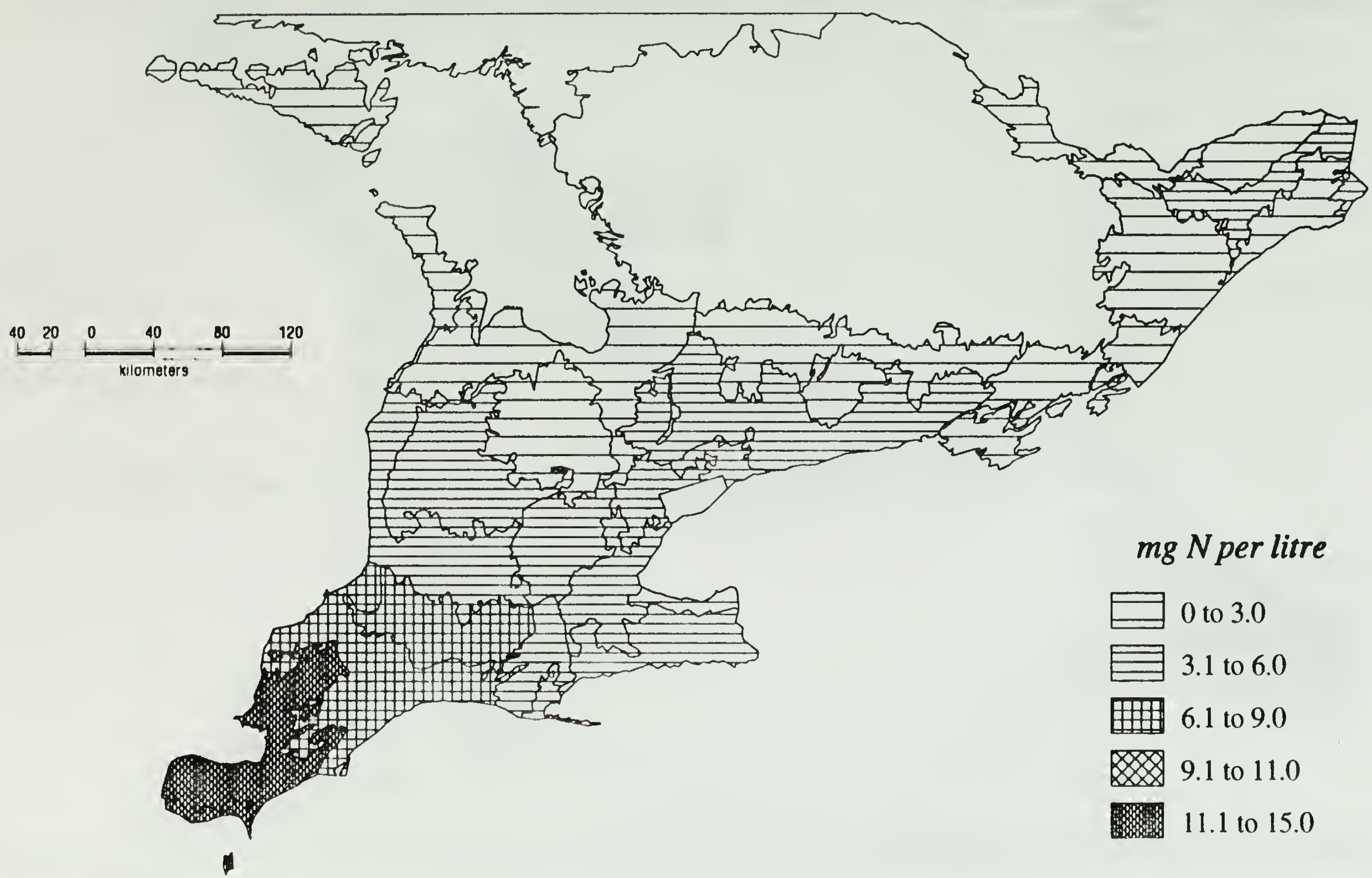
Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by
Ontario Land Resource Unit
Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

MAP 6 1981 IROWC-N: FARMLAND

Concentration of N in Water from Agriculture



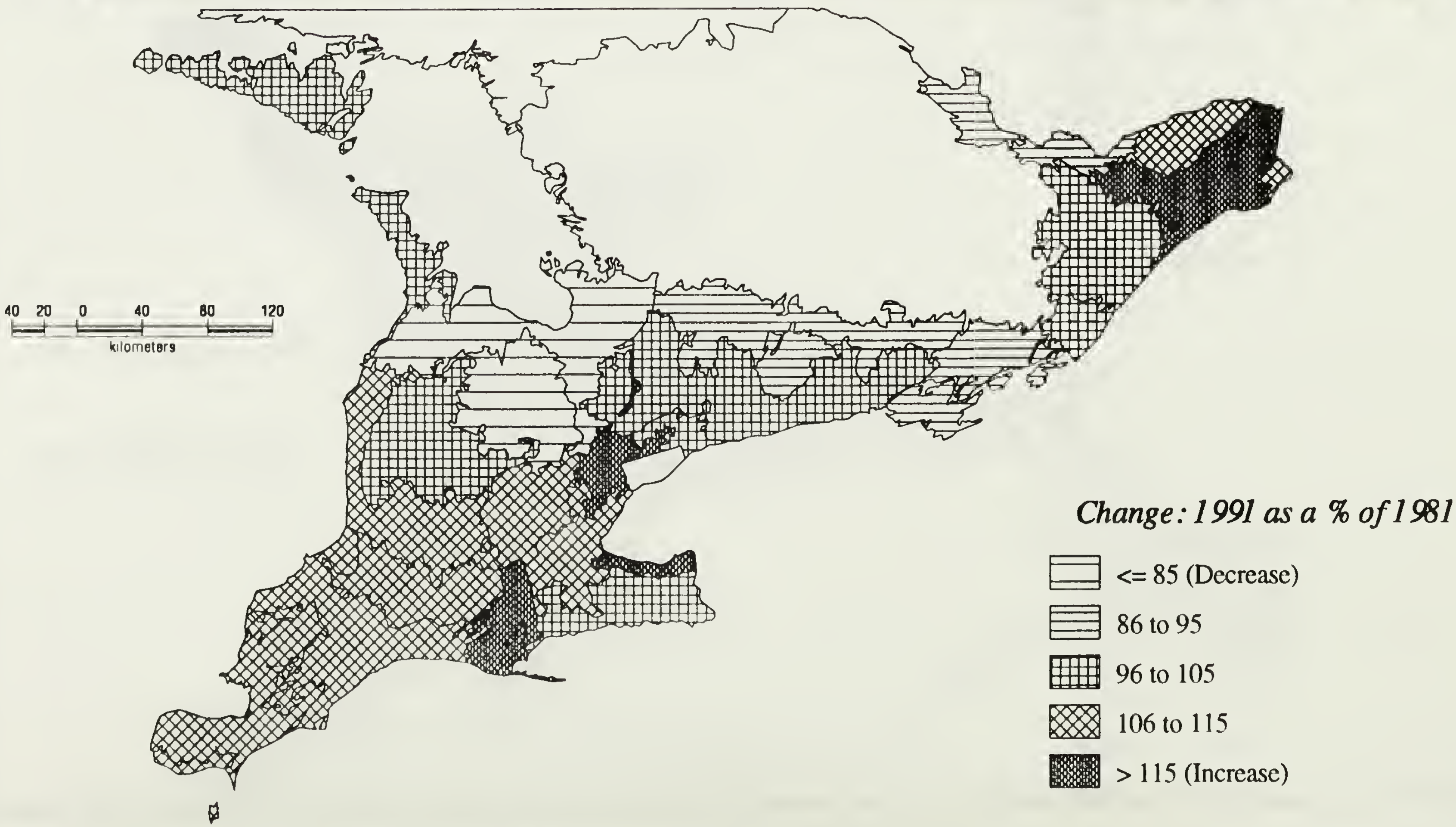
Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by Ontario Land Resource Unit Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

MAP 7 CHANGE IN IROWC-N: FARMLAND 1981-1991

Concentration of N in Water from Agriculture



Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by Ontario Land Resource Unit Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA

MAP 8 CHANGE IN IROWC-N: FARMLAND 1981-1991

Change As a Percent of the Drinking Water Standard

Drinking Water Standard: 10 ml N per l

Greenhouse & Processing Crops Research Centre (Harrow, Ontario)

Map prepared by
Ontario Land Resource Unit
Guelph, Ontario

AGRICULTURE AND AGRI-FOOD CANADA