Agriculture and the Environment: An Economic-Ecologic Input-Output model of the Canadian economy

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An Economic-Ecologic Model of the Canadian Economy

RÉSUMÉ

L'ampleur du mouvement environnemental exige une réévaluation des relations économiques et écologiques. La présente recherche a pour objet d'identifier la part prise par chacun des secteurs industriels et des demandes finales à la production de résidus et à l'utilisation de ressources naturelles. Un modèle économique-écologique de l'économie canadienne fut développé à partir du modèle des entrées-sorties de Statistiques Canada tel que modifié par Thomassin et collègues (pour Agriculture Canada) afin de mieux analiser différentes politiques agricoles. Le modèle estime l'érosion, la quantité de pesticides et de fertilisants utilisée, ainsi que les polluants atmosphériques, aquatiques, et terrestres générés par chacun des secteurs économiques d'intérêt.

Deux scénarios furent analisés. Le premier simule l'effet sur l'économie et l'environnement de changements dans la demande finale des biens agricoles et agro-alimentaires. La demande finale de chacun des biens fut augmentée de 1$ million et l'impact de chacune des simulations comparée. Les dix biens étudiés eurent des effets comparables sur l'économie, par contre les effets environnementaux différèrent considérablement. L'augmentation de la demande finale pour le blé et les graines oléagineuses eut l'impact le plus important. Le deuxième scénario compare l'impact d'une augmentation de 1$ million pour différentes catégories de demandes finales. L'impact de cette augmentation sur le produit industriel fut le plus important pour

la construction, l'exportation et les dépenses personelles. La stimulation des exportations généra une grande quantité de résidues et utilisa plus de ressources naturelles. Les exportations générèrent deux fois plus d'érosion soit vingt fois plus que la prochaine classe la plus élevée (construction).

ABSTRACT

The current environmental movement calls for a re-evaluation of many economic-ecologic relationships. The objective of this study is to identify industrial sectors and final demands most responsible for particular types of residual discharge and resource use. An economic-ecologic model was constructed for the Canadian economy from the Statistics Canada I-O as modified by Thomassin et al. (1992). This modified version with its 12 agricultural sectors and 16 food processing sectors is best suited for agricultural policy analysis. The model estimates national erosion, pesticide and fertilizer use as well as air and water pollutants, solid waste, and water use associated with specified economic activities.

Two different scenarios were analyzed. In the first, the impact on both the economy and the environment from changes in the final demand for agricultural and food commodities was simulated. Each commodity's final demand was increased by $1 million and its impact compared to the other simulated results. The ten commodities studied yielded similar economic impacts, while their environmental impacts differed considerably. Changes in the demand for wheat and oilseeds had the largest environmental impacts.

In the second scenario, the effects of a $1 million increase in each final demand category were compared. This scenario focussed on markets rather than products. The construction, exports and personal expenditures categories were the greatest generator of wastes and the largest user of free resources. The exports category yielded twice as much erosion than personal expenditures and twenty times more than the next highest value (construction).

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CHAPTER ONE

PROBLEM STATEMENT

1.1 Agriculture and the environment

Throughout history economic processes have generated waste. Initially, the repercussions of economic development on the ecosystem's capacity to support life were usually both local and reversible. With growing industrialization, however, the effects began to exceed national and temporal borders as problems were passed on to subsequent generations on a worldwide scale. The inherent interdependence between human development and the environment is just now being realized, and with it the need to refine the natural and environmental resources management practices.

This recognition has led many industrialized countries, including Canada, to adopt the concept of sustainable development as a focus of its management strategies[1]. Sustainable development was defined by the World Commission on Environment and Development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their needs" (cited in Thomassin et al, 1991, 689). To fulfill this ideal, many economic-ecological relationships must be re-evaluated. Undoubtedly, government initiatives to enhance both economic and environmental standards are likely to conflict with

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[1] Adequate management implies a priori data collection, researches etc. in addition to the economic sacrifices that it might imply. This tradeoff is more harshly felt by less developed countries.

one another. This thesis attempts to assess the impact of different policy initiatives upon economic sectors, and especially upon the agricultural and food sectors. OECD (1991a) identifies erosion along with the use of pesticides, fertilizer, and irrigation water as the agricultural sector's environment policy concerns of the 1990s. This suggests that effective policy tools must contain these environmental commodities. Various policy alternatives to meet sustainable development criteria can then be investigated from macro-economic and environmental perspectives.

1.2 Input-Output models and the environment

In Canada, the most often used macroeconomic model is the national Input-Output (I-O) model developed and maintained by Statistics Canada. It is a commodity-by-industry model based on the System of National Accounts (SNA). The model's rectangular framework, unlike the Leontief I-O models, allows each industrial sector to produce more than one commodity[2], making it an excellent tool for analyzing residuals, or the by-products of production.

The 1986 I-O model was modified by Thomassin et al. (1992b) to serve agricultural policy purposes for Agriculture Canada[3]. The single agricultural sector in the Statistics Canada I-O model was disaggregated into 12 agricultural industries in order to take into account the individual production functions and joint products

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[2] W. Leontief was the originator of modern I-O models. His models were industry by industry models.

[3] A similar technique was used to model the 1981 I-O model by Thomassin and Andison (1987).

of the 12 agricultural industries[4]. This modified model, with its twelve agriculture industries, was altered using the method developed by Victor (1972), in order to stress economic-ecological linkages between the industrial sectors and the environment. There are 74 industrial sectors linked to 7 environmental inputs and 27 environmental output commodities. Emphasis is placed on the linkages between agricultural and food-processing industries and the environment.

Economists disagree on the most appropriate means of integrating the environment into economic analysis. Most, however, would agree that the resource base which supports the economic activities must be part of the analysis. The I-O method is a blend of theoretical, mathematical and statistical analyses based on the notion of interdependence. The development of an extended I-O model, that accounts for the interdependence between industry and the environment, is a step towards more fully integrated policy analyses since this model generates economic and environmental estimates that can be used by public and private agencies to analyze public or industry policies.

1.3 Problem statement

Resource management is being challenged by growing urban populations, industrial expansion and the increased demand for agricultural products. The growing pressure on the resource base underscores the need to understand the trade-

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[4] The 12 agriculture production functions are: dairy, cattle, hogs, poultry, wheat, small grains, field crops, fruits, vegetables, miscellaneous specialty, livestock combinations, and other combination farms.

offs between economic growth and the environment. Prospects for sustainable development depend on our ability to understand these economic-ecological relationships. Incorporating environmental commodities into the Canadian I-O tables will assist in analyzing agricultural policy questions related to the sustainability objective of policy makers. Some questions of interest addressed by this model include: 1) Which sectors of the economy affect the environment the most? 2) How do final demand categories rank in terms of their pollution content and resource use intensity? and 3) Which data are missing, and how reliable are existing data?

1.4 Outline of the thesis

Chapter two discusses the development and evolution of economic-ecologic models while chapter three provides details of such models including their underlying assumptions and implications. The procedure and data used to derive Victor's environmental coefficients are presented in chapter three and the analysis and results are discussed in chapter four. Chapter five contains this study's conclusions and recommendations. The terms "residual" and "waste" are used interchangeably throughout the thesis. The term "pollutant" is avoided because there is no consensus in the literature on the definition of a pollutant; the difference between waste and pollutant depends upon social preferences. In general, if the elimination of a waste, ceteris paribus, increases social welfare it is a pollutant (Victor,1972); if a residual negatively affects the receptor's ability to provide services (disposal, recreation or source of raw material) it is a pollutant (Forsund,1985).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Economic processes transform valuable natural resources into waste, or what Georgescu-Roegen (1971) called low and high entropy respectively. Waste generation is linked to the production process through the first two laws of thermodynamics. These laws ensure that every resource used in the production process must ultimately end up as a waste in the environment[1] and producing more economic goods implies producing more waste. The form in which these wastes are disposed of is a matter of political and economic choice. Given the level of technology, the environment mediums are substitutes for one another. For example, if a given country chooses to incinerate its waste. As a result, less solid materials are disposed of in landfills but more gaseous wastes are generated in the atmosphere. This illustrates the systematic approach required to analyze environmental problems. The pollution problem involves the traditional allocation of scarce resources (environmental mediums) among competing uses (residual receptacles, extractive resource or recreational services).

I-O models are based on interindustry linkages in the economy. They record, in monetary terms, the flow of commodities to industries (intermediate demand) and to final demand, thereby describing the consumption and production processes. Economic-ecologic models are an extension of I-O models that take into account

[1] Recycling only postpones the discharge of residuals to the environment.

environmental commodities. Many appeal to the material balance approach which is based on the laws of thermodynamics: these laws ensure that the economic process transforms natural resources into industrial output plus waste. Hence, residuals or wastes are the rule rather than the exception in the production process. These models do not alleviate the externality problem; polluters would still use the assimilative capacity of the environment at no cost. However, they do provide estimates of the quantity of waste generated and resources used by different mixes of industrial outputs. This provides decision-makers with a more complete set of empirical criteria with which to make public policy decisions.

2.2 Integrating the environment into I-O models

I-O tables that account for the interrelationships between the economy and the environment are abundant in the literature. Many models were proposed in the late 1960's; recent papers are primarily either surveys that describe and criticize these models in terms of their advantages and disadvantages, or extensions of existing models. A chronological review of the six main models developed along with their improvements in recent papers will follow. Further details on these models can be found in literature reviews by Stokoe (1990), Miller and Blair (1985), Lonergan and Cocklin (1983), James et al.(1978), Emmett (1975), Firestone (1975), and Victor (1972).

The I-O approach to environmental problems can be traced back to Cumberland's work in 1966. Cumberland recognized the environmental counterpart to regional development, and his model included rows of environmental costs and benefits and a column of cost to restore the environment to its initial level. Costs and Benefits were to be recorded in monetary terms, however; Cumberland did not mention how these net benefits could be estimated. Another shortcoming was that the model did not specify any fixed relationship between the level of economic activity and the net environment benefit, and hence did not incorporate material flows between the economy and the environment.

Daly's model (1968) was divided into four quadrants: the usual I-O tables or human sector, the nonhuman sector (comprising a subquadrant for living and one for nonliving organisms), and the flows from the human to the nonhuman sector and vice-versa[2]. Daly tried to estimate the I-O coefficients by summing across the rows, adding economic (dollar values) and ecological (physical unit) commodities. These coefficients could not be interpreted directly since it meant, for example, adding a dollar's worth of steel and tonnes of CO2 released in the atmosphere. A similar problem occurred in the environmental sector when ecological outputs had different units of measurement (e.g. cubic meter of water added to tonnes of manure).

Isard (1972) integrated the environment into the traditional Leontief I-O model in 1969. Major differences with Daly's model were: 1) the use of a commodity-by-industry model and 2) the use of direct production coefficients (rather

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[2] The human sector is the usual I-O matrix of economic activities. The nonhuman sector was to be modelled like the economic sector except that the inputs are lower links in the food chain. For example, spiders eat flies which in turn eat nonliving organisms and their feces and fossils are externalities.

than those derived from accounting data). The model was theoretically consistent, although no data were available to model the ecological system.

Ayres and Kneese (1969) and Kneese et al. (1970) based their model on the Walrasian general equilibrium system. Nonmarket goods (externalities) were included in this model using the materials balance approach. The Walrasian accounting framework prevented empirical applications since commodities were recorded in units of mass,e.g. gallons of water, number of cars, kilowatts of electricity, etc.

This model was criticized by Victor (1972) for two major reasons: 1) failure of the model to account for environmental flows to final-demand categories, and 2) no clear distinction between valuable resources going into and waste leaving the economic system. While Kneese and Bower (1979) refined the model, it still lacked the linkages between the delivery of residuals and environmental quality. Their main contribution was the recognition that waste generation was inherent to the production process.

Leontief (1970) added a pollution commodity and an antipollution industry into his original I-O framework. This general equilibrium model was a simplification of the Walrasian model and allowed for empirical estimation (as opposed to the Ayres-Kneese model). This model predicted price effects of different abatement policies by directly transferring them to consumers as costs, since no input sector existed for the antipollution industry. Leontief's model did not include the flow of ecological commodities to the economy, therefore it is not an economic-ecologic model. Lack of data on pollution eliminating activities led Leontief and Ford (1986) to estimate only the matrix of direct pollution output coefficients.

2.3 Model modifications and estimation

Many researchers have tried to overcome the deficiencies of previous works. For example, Johnson and Bennet (1981) extended Victor's framework by developing a nonlinear submodel of the environmental sector at the regional level, wherein ecological commodities were classified by extraction sources and sinks where they were discharged. Rose (1977) proposed a dynamic I-O system: where different levels of air pollution control were related to the I-O model and several assumptions were made concerning the method of air pollution control, capital intensity, increasing marginal cost and interindustry cost differences. Finally, Hafkamp (1983) proposed a triple layer model that simultaneously analyzed the economic, employment, and environmental policy effects on both the economy and the environment. A multiple objective criteria model was used to model the decision-making process on the premise that GNP alone was not the only welfare measure used by decision makers. Other factors such as environmental quality and culture were also taken into account.

Few studies, however, have provided an empirical application of an economic-ecologic model at the national level. Canada and some European countries, such as the Netherlands, have developed integrated national I-O models. Forsund (1985) estimated the discharge to air, water and land caused by a final demand shock of 100 million Norwegian crowns. The analysis showed the impacts of increasing each category of final demand by 100 million crowns. The export category generated the highest level of pollution for most of the environmental commodities included in the model.

Schafer and Stahmer (1989) used the Leontief framework to extend the analysis of environmental protection activities for the German economies. Three categories of environmental protection activities were developed: internal to the firm, external to the firm, and fixed capital formation. Each of these categories of environmental protection were estimated using different techniques. Internal environmental protection was estimated using values of inputs going into the production of the environmental good. External protection was estimated as the value of goods purchased from a third party, while changes in fixed capital formation for environmental protection were analyzed through final demand categories (Schafer and Stahmer 1989). These categories of environmental protection were added to the model as rows or columns, and their estimates were removed from the existing commodity group estimates. The model provided an estimate of the economic importance of environmental protection activities to the German national product. It did not, however, consider the non-market resource base going into the production process or the non-market commodities produced in the production or consumption processes.

Ridker (1972) developed a national I-O model that projected the discharge of liquids, solids, and gases to air, water, and land under various population and economic growth scenarios. Such predictions were possible by constructing a submodel that estimated all of the alternative combinations of factor inputs required to produce a given output of goods and services (an activity model). This activity model was then related to the structure and function of the ecosystem (natural systems model). This approach was called Residual Environmental Quality Management (REQM) and was developed by Resources for the Future (RFF).

Ayres and Gutmanis (1972) predicted the environmental consequences of different scenarios of economic growth and abatement policy. The authors compared two scenarios of population growth, forecasted possible technological change (by substitution of one purchased input for another), and attached pollution and treatment cost coefficients to the model.

2.4 Victor's model

Victor (1972) limited the scope of Isard's model by deleting the ecosystem matrix and emphasizing the flow of commodities from the environment to the economy and economic externalities to the environment. This model was less comprehensive but allowed for empirical estimation. While the data requirements of models developed by Cumberland, Leontief, and Isard prevented them from being fully operational, Victor used the Ayres and Kneese material balance principle with a rectangular I-O model. These features had two main advantages. First, the material balance approach assumes that if there is no change in the inventory (or capital accumulation) of a firm, then the total material inflows must equal the total material outflows. Second, it is possible to model the environmental sector outside of the model, with nonlinear relationships where appropriate.

The rectangular I-O model provides a better estimate of the monetary and material flows resulting from a change in final demand. This model specification provides greater detail in the accounting framework and allows each industry to produce several commodities. This is important for economies that have a large number of industries producing by-products. Victor used this model to quantify water use and the production and disposal of waste in Canada for 1961. Ecological commodities were measured in units of mass and these were combined with the monetary flows in the I-O model. Victor first related the ecological commodities to industrial output, assuming that ecological commodity inputs and outputs of an industry were proportional to the industry's output. This allowed him to estimate the environmental waste generated from industrial production that resulted from a change in final demand.

An estimate of the social value of the ecological commodities was made using a method of payments. The compensation payments were determined by a vector that provided the weighted social value of the flow of ecological commodities. Victor also attempted to estimate the least cost to the environment of producing the economic commodities required to meet final demand. This was done using linear programming by minimizing the ecological commodities subject to the gross final demand for domestic industrial output.

2.5 Summary

The I-O material balance approach is a recognized method of investigating the interrelationship between the economy and the environment. With this approach the environmental sector can be fully or partially integrated into the economic sector. Partially integrated models contain matrices of flows from the environment to the economic sectors and flows from the economic sectors to the environment. Fully integrated models, as their name implies, complete the cycle by including flows of environmental commodities within the ecosystem. Fully integrated models have never been completely estimated because of the lack of data. Partially integrated models can use an industry-by-industry (square) or commodity-by-industry (rectangular) framework. The latter better fits the material balance approach, since it accounts for by-products in the production process.

The I-O approach is designed to assess the change in industrial output needed to satisfy a change in final demand. It can also be used to evaluate different methods of producing a given good (or meeting final demand). Economic-ecologic models allow the analyst to generate similar information for environmental commodities. This model's greatest advantage is that the economy and the environment are considered simultaneously. Since computer capability is no longer an issue in macro-modelling, the major limitation to estimating economic-ecologic models is data availability and reliability.

CHAPTER THREE

PROCEDURES AND HYPOTHESES

3.1 Introduction

An economic-ecologic model consists of an I-O model adapted to account for ecological commodities. Intermediate and final demands for economic and ecological commodities (in monetary and physical units respectively) are recorded in a general equilibrium framework. Ecological commodities are defined as services provided by the environment. They also include natural resources that are exchanged in the market since the price signal for many of these do not reflect their true values. Water use, for example, is included as an ecological commodity since water license fees in Canada are largely economically irrelevant (Tate, 1989).

Section 3.1.1 presents the partially integrated model. Section 3.2 elaborates on the model's limitations and technicalities associated with the ecological commodities, with emphasis on the agriculture-related ecological commodities. The study's hypotheses are explained in section 3.3.

3.1.1 I-O model specification

This study applies Victor's method to the Thomassin et al. (1992b) I-O model modified for the agriculture sector. The model's industries and commodities correspondence to the System of National Accounts (SNA) industry codes at the medium level of aggregation and are given in Appendix A (Tables A.1 and A.2). The food processing sectors are similar to those found in the link level of the Statistics Canada I-O model, while all other industries are at the Statistics Canada (1990a) medium level of aggregation. The model consists of 178 commodities, these include 170 intermediate goods and services and 8 primary inputs, and 74 industries. The model emphasizes the agriculture and food system by including 12 agricultural and 16 food processing sectors. The two main advantages of this commodity-by-industry framework are that (1) each industry can produce several commodities (economic and ecological) and (2) the agricultural sector is better defined. These properties increase the model's ability to address agricultural production and pollution policy questions. Table 3.1 provides a general description of the partially integrated commodity-by-industry economic-ecologic model developed by Victor.

Table 3.1. The Economic-Ecologic Framework

	Commodities	Industries	Final demand	Total[a]	Ecological output[b]
Commodities		U	F	q	Q
Industries	V			g	A
Primary inputs		YI	YF		
Totals	q'	g'			
Ecological inputs	S	R			

Source: Victor (1972, 56)

[a] Economic matrix entries are in monetary terms.
[b] The ecologic matrix are divided into water, air and land and are in physical units.

The economic accounting framework is defined with the following matrices:

U is a [170,74] matrix of industry intermediate inputs.

V is a [74,170] matrix of commodity sales by industry, the Make matrix.

F is a [170, 28] matrix of commodity flows to final demand categories.

YI is a [8,74] matrix of primary inputs used by industries[1].

YF is a [8,28] matrix of primary inputs used by the final demand categories.

q is a vector of total commodity outputs.

g is a vector of total industrial outputs.

The economic accounting framework equilibrium requires that the intermediate plus final demand commodities equals total commodity output. In addition, the total sales of each industry must equal the value of industrial output. Hence:

(3.1) $Ui + Fi = q$

(3.2) $Vi = g$ where i is a column vector whose elements are unity.

The economic accounting framework is developed using these two relationships and a number of assumptions on industrial technology and the way demand is allocated to industries. The general equilibrium assumption requires that each industry's total cost (g')[2] equals the total value of its output (g). Similarly, total demand (q) must equal total supply (q'). The first production technology assumption

[1] The Use matrix = U + YI

[2] Where ' indicates transposed vector

is that each industry uses a fixed input ratio in the production of its outputs.

(3.3) $U = B\hat{g}$ where B is the Leontief or technical coefficient matrix[3].

The same assumption holds for primary inputs.

(3.4) $YI = H\hat{g}$ where H is a coefficient matrix.

Finally, the industrial output required to fulfill a change in final demand is assumed to be supplied in fixed market shares by each industry:

(3.5) $V = D\hat{q}$ where D is the market share matrix.

The production requirement to satisfy a change in final demand on an industry basis (g) is obtained by substituting these identities and rearranging terms.

(3.6) $g = (I-DB)^{-1}DF_{t}$ where I is an identity matrix.

To improve the model's accuracy, leakages in the economy must be removed. Leakage coefficients estimate the share of demand satisfied by imports, withdrawals from inventories and government production. Leakages are obtained by

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[3] Where ^ indicates diagonalization.

disaggregating the final demand into its components and assuming that imports, withdrawals from inventories and government production are a fixed proportion of commodity demand. The result is the following equation (Thomassin et al. (1992b)):

(3.7) $g = [I-D(I-P-J-T)B]^{-1}D$ where P,J and T are the matrices of the ratio of imports, inventory withdrawal and government production to commodity use.

Equation 3.7 estimates the direct plus indirect effects on industrial output of a change in final demand[4]. It cannot estimate the impact of this change in industrial production on the environment. In order to account for this, the environmental sectors must be integrated into this framework.

3.1.2 Ecologic model specification

The following matrices represent the environmental sectors of the model (Table 3.1):

R is a [7,74] matrix of ecological inputs used by industries (in units of tonnes or in million m^3 of water/year) in the production process.

A is a [74,27] matrix of residuals produced by industry (in units of tonnes/year).

S is a [1,170] matrix of direct ecological commodity inputs used in the consumption of economic goods.

Q is a [170,7] matrix of direct ecological commodity outputs resulting from the consumption of economic goods.

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[4] Constant returns to scale is implicitly assumed.

Victor linked residual generation to industrial output by using fixed discharge coefficients. For the production side of the economy the following equations are derived (Victor, 1972):

(3.8) $R = Z\hat{g}$

(3.9) $A' = ¥'\hat{g}$

where:

Z is a matrix of ecological input coefficients (in units of tonnes or in million m^3/$ for water), and

¥' is a matrix of residual coefficients (in units of tonnes/$).

Incorporated into the traditional I-O table, which yields:

(3.10) $E = Z([I-D(I-P-J-T)B]^{-1} DF_o)$

(3.11) $W' = ¥'([I-D(I-P-J-T)B]^{-1} DF_o)$

where:

E is a matrix of direct plus indirect requirements of ecological commodity inputs for the production of economic goods,

W' is a matrix of direct plus indirect discharges of ecological commodity outputs resulting from the production of economic goods, and

F_o is a matrix of final demand, net of imports for each commodity.

The following equations take into account the consumption side of the economy[5,6]:

[5] Victor's (1972) notation is changed for simplification.

(3.12) $S = d\,F_o$

(3.13) $Q' = b'F_o$

where:

d is a matrix of ecological commodity input coefficients, and

b' is a matrix of ecological commodity output coefficients.

The total national ecological commodity flow associated with the final demand for economic goods can be expressed as:

(3.14) $E + S = Z\,([I\text{-}D(I\text{-}P\text{-}J\text{-}T)B]^{-1}\,DF_o) + d\,F_o$

(3.15) $W' + Q' = ¥'([I\text{-}D(I\text{-}P\text{-}J\text{-}T)B]^{-1}\,DF_o) + b'F_o$

for ecological inputs and outputs respectively.

Imported goods and services are not included in the R matrix and exported goods are not included in the Q matrix. Exports must be subtracted from the total final demand to yield domestic consumption (F_0).

3.1.3 Assumptions

Two assumptions were used to relate ecological commodities to economic commodities. The first involves the technology used in the production process and the second relates to the assimilative capacity of the environment. I-O models are based on either a commodity technology or an industry technology. Commodity

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[6] The consumption side ecological input and output matrices have not been estimated in this study.

technology assumes that the amount of waste produced for each commodity is the same irrespective of which industry produces that commodity. Industry technology assumes that all commodities produced by one sector generate the same level of pollution per unit of output irrespective of which commodity is produced. The commodity assumption is more appropriate for residual production. However, both Victor (1972) and Forsund (1985) used the industry technology assumption due to the lack of appropriate commodity technology data. Similar to the previous authors, this study uses the industry technology assumption because of the availability of this data. The second assumption involves the relationship between the level of residual discharge and the assimilative capacity of the environment. Since the ecologic system is not modelled, a linear relationship is assumed. This may be an appropriate assumption until the assimilative capacity of the environment is reached. Once it is exceeded, residuals affect the receptor's ability to provide its services therefore increasing social costs at a faster rate. These possible increases in social costs are omitted. Modelling the ecologic system would approximate the relationships between the environment as a receptacle and as a resource extraction basin, albeit at larger information costs. Whether these costs are justified or not is an empirical question still to be resolved.

In addition, it is implicitly assumed that technological change will occur at the same rate in the pollution abatement industry as in other industries. As regulations intensify, two outcomes, with different consequences, are possible. End-of-the-pipe technologies might be employed, leaving the base technology untouched, rendering this assumption's effect negligible[7]. In other cases, where regulations have built-in incentive, it might induce faster development in the pollution abatement sector than in the rest of the economy.

3.2 Definitions and limitations

This study's limitations can be divided into two areas (1) limitations due to the I-O method itself and (2) those due to the inclusion of the environmental sector. One limitation common to both areas is that cyclical and seasonal variations in the economic and the ecological processes are ignored.

3.2.1 I-O models limitations

The most discussed shortcomings of I-O models are their linear production functions and fixed market shares. These assumptions respectively imply that the inputs used by an industry are proportional to the level of industrial output, and that industrial sectors' relative importance does not vary with increased demand. These assumptions can bias results when economies of scale follow increased demand. Static I-O models also assume that both supply and demand are perfectly elastic. An increase in the demand for inputs and outputs does not affect price, therefore no substitution can take place[8]

[7] According to Hafkamp (1983) pollution is often treated by end-of-the-pipe equipment installed by the polluting firm itself. In 1980, 80 to 85 percent of the pollution treatments were end-of-the-pipe equipment (Ketkar, 1983).

[8] Some authors have addressed these problems by introducing substitution and other dynamic factor into I-O models (see Rose (1983) and Forsund (1985)).

Despite these limitations, Post-Keynesian theory uses the Leontief production function and fixed coefficients as an alternative to the Neoclassical production function. This choice tends to be supported by empirical observations (Eichner, 1983, 212).

3.2.2 Ecological commodities definitions

Each ecological commodity input, soil and water use, and output -- solid wastes, airborne wastes, waterborne wastes and pesticide and fertilizer use -- is reviewed next. Environmental commodity matrices are presented in Appendix B (Table B.1 to B.7). Procedures used to allocate ecological commodities to industrial sectors differed greatly depending upon data availability. Industrial water use and airborne wastes compiled by Environment Canada were the most complete data sets. These data sets were aggregated to conform to the industry level in the model.

Information on the other ecological commodities were harder to locate. In many cases more than one data source was used. When more than one source was found, they were compared. If large discrepancies between data sources were found, other information was used to choose the source deemed most accurate. Information on the agricultural sector was generally available at the provincial level. In this case, estimations were performed for each province and summed to the national level. The largest problem was with the allocation of residuals generated and resources used by the 12 farm types. Proxies were used to allocate residuals to crops (or *on a per crop basis*) and animals and then, to farm types. These proxies and distribution factors are presented in Appendix C (Table C.1 and C.2). The ecological commodities are briefly reviewed below, technical details for each commodity can be found in Appendix D.

Erosion

Soil erosion is a naturally occurring process; it becomes a problem when improper farming practices accelerate the process. Modern agriculture places strains upon the land resource base through water and wind erosion, compaction, acidification, and salinization. Of these, water erosion is " the most widespread and recognized form of agricultural land degradation in Canada" (Agriculture Canada, 1986,50). The environmental impact of water erosion is the transportation of sediments, nutrients, herbicides and insecticides to surface and groundwater. The Universal Soil Loss Equation (USLE) was used to estimate the potential erosion. It is defined as:

(3.16) $A = RKLSCP$[9]

where:

A is the potential soil erosion (tonnes/ha/yr),
R erosivity of rainfall, snowmelt, and winter runoff,
K is the soil erodibility factor,
LS are slope length and steepness (dimensionless),
C is the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow[10,11], and
P is the conservation practice ratio. It is the ratio of soil loss with a practice like contouring, stripcropping, or terracing to soil loss with straight-row

[9] Wischmeier and Smith (1978).

[10] C=1 for bare, unprotected soil.

[11] From Wischmeier and Smith (1978).

farming up and down the slope.

Data needed to estimate the equation were extracted from the Land Resource Research Center's Generalized Soil Landscape Map (LRRC's GSLM)(LRRC, 1990). Erosion estimates depend on the reliability of each of the equation's component, R, K, LS, and C. The least reliable component was slope length and steepness (LS) which could vary greatly, especially in large polygons.

A sediment delivery ratio (DR) was applied to equations 3.16 to derive an estimate of the amount of soil delivered from the field to the environment[12]. DR varies with watersheds, however, for this study a provincial delivery ratio was used. The DR was estimated to be 2% in the Prairie Provinces, 8% in Québec and Ontario, and 10% in the Maritimes (Coote, 1991, Personal Communication). Using an average DR for a region grossly estimates soil delivery. A DR should be estimated for each watershed (or site) but this process would be time consuming and expensive[13]. To account for this, potential erosion was estimated along with the amount delivered to the environment (Table 3.2). The relative ranking of each crop, in terms of soil delivery, should still be valid.

Wind erosion has not been modelled separately; it is accounted for in the air pollution coefficients (particulate matter). Wind erosion is usually associated with arid and semi-arid regions. Its environmental impacts are loss of fertility, loading of

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[12] Other activities also deliver sediments but were not estimated. The DR agricultural delivery estimates.

[13] The DR is usually an exponential function of the distance to the nearest stream and of an intervening land cover coefficient.

Table 3.2 Potential Erosion in Eastern and Western Canada

EASTERN CANADA

Crops	New Brunswick	Nova Scotia	Prince Edward Island (Tonnes)	Quebec	Ontario	Total Per Crop	Total Delivered to Stream
Nursery	297	1,234	0	12,905	26,567	41,003	3,311
Tree Fruit	562	5,681	0	5,554	26 400	38,197	3,181
Potatoes	225,518	16,710	274	83,002	131 297	456,801	41,394
Sugar Beets	0	0	0	15,953	5	15,958	1,277
Small Fruit	3,879	14,485	2	7,082	5,416	30,864	2,836
Vegetables	45,925	66,121	37	362,914	833,286	1,308,283	106 904
Grain Corn	3,017	18,952	2	712,245	7,877,906	8,612,122	689 409
Beans	5,149	2,611	5	13,140	2,911,848	2,932,753	234,776
Silage Corn	19,932	45,683	27	691,028	3,178,371	3,935,041	316,116
Alfalfa	2,474	4,043	4	56,345	296,557	359,423	28 884
Other Hay	0	0	0	0	0	0	0
Summerfallow	155,765	173,822	90	1,114,584	1,412,331	2,856,592	235,121
Grapes	0	14	0	17	11,546	11,577	926
Fall Grains	1,771	33,754	11	10,913	1,502,177	1,548,626	124,601
Spring Grains	182,693	121,392	609	1,936,886	4,940,340	7,181,920	580,648
Sod	89	254	0	2,710	3,434	6,487	526
Root Crops	81	495	0	2,496	548	3,620	301
Tobacco	2,990	7,300	30	12 483	314 265	337,068	27,172
TOTAL	650,142	512,551	1,090	5,040,257	23,472,294	29,676,334	2,397,382

WESTERN CANADA

Crops	Alberta	Saskatchewan	Manitoba (Tonnes)	Total per Crop	Total Delivered to Stream
Summerfallow	12,787,700	43,682,300	4,065,690	60,535,690	1210713 8
Spring Grains	17,554,200	33,381,600	9,597,680	60,533,480	1210669 6
Corn & Sunflw	39,586	28,707	1,146,760	1,215,053	24301 06
Flax & Canola	1,206,380	2,181,950	2,222,150	5,610,480	112209 6
Peas & Beans	17,978	78,766	250,561	347,305	6946 1
Winter Grains	302,742	287,399	147,162	737,303	14746 06
Sugar Beets	32,947	0	41,914	74 861	1497 22
Corn for Silage	37,776	14,700	117,101	169,577	3391 54
Potatoes	11,144	3,884	92,200	107,228	2144 56
Tame Hay	0	0	0	0	0
Pasture	0	0	0	0	0
TOTAL	31,990 453	79 659 306	17,681,218	129,330 977	2 586 620

streams with sediments, removal of herbicides from agricultural land and airborne wastes.

Water

Water use was categorized by user class: industrial, agricultural and municipal (where municipal water includes both domestic and commercial/institutional). All water used in 1986 was included in the model[14]. In 1986, water charges for industrial water use were only applied in British Columbia (B.C.) and Nova Scotia. A charge for agricultural water use was only found in B.C. Saskatchewan and Alberta received most of their irrigation water from district irrigation and/or local/provincial associations. Water charges in these cases were not for the water but to cover the operating, administration and maintenance costs of services (Environment Canada, 1987).

Industrial water use. Ecological commodities associated with industrial water use were: total intake, recycled, gross water use, total discharge, and total treated discharge. Water is used in manufacturing industries mainly for processing, cooling, condensing and steam generation. Industrial water use data were obtained from a survey undertaken by the Inland Water Directory of Environment Canada (1990a). Water use for manufacturing, mineral extraction, thermal power, and hydro power were extracted from this survey. These data were classified by Standard Industrial Classification (SIC) number, hence total industrial water use was aggregated to the medium level (ind. 13 to 52 in Table B.1).

[14] Water paid for also appears in the economic part of the model (in monetary terms).

Municipal water use (Final demand and ind. 54 to 71). Municipal rates vary among municipalities across Canada. The two most common types of rate schedule were a flat rate or the declining block rate[15]. These schedules offer no incentive to reduce water consumption. Total municipal water intake and discharge in 1986 was 4,716 Million Cubic Meter (MCM) and 4,022 MCM (Statistics Canada 1991, 208).

Agricultural water use (ind. 1 to 12). Water user classes for the agricultural sectors were: domestic, livestock watering and irrigation. The last two categories are presented in Table 3.3. The estimated water use for livestock production is 317 MCM. Irrigated water use was estimated on a per crop basis. Provincial irrigation data differed between region. Ontario was the only province to have an irrigated crop survey. Provincial studies and personal communications were used to gather other provincial information. The only national source of data was

Table 3.3 Water use in Agriculture by Farm Type

	Livestock Watering	Irrigation
	(Million m³)	
Dairy	47.43	197.43
Cattle	171.12	425.23
Pigs	22.54	66.32
Poultry	10.37	12.82
Wheat	10.56	637.44
Small Grains	27.33	817.45
Oth. Field Crops	0.80	324.85
Fruit	0.25	8.68
Vegetable	0.21	325.29
Livestock Comb.	12.65	381.53
Misc. Spec.	8.57	68.66
Other	4.92	79.71
Total	316.75	3345.41

15 **Flat rate:** fixed levy in each billing period which gives unlimited access to water and sewage system. **Declining block rate:** volume charges vary among user groups; use in each ascending block is charged at a lower price than the previous block.

Environment Canada (1987) which estimated irrigated areas per province in 1986.

Solid wastes

A breakdown of solid waste -- industrial and municipal solid waste, animal solid and liquid waste, reused and remaining waste -- can be found in Appendix B.2[16]. Little information was available on reusing and recycling solid waste. A general source for solid waste estimates was the International Solid Wastes and Public Cleansing Association (ISWA)(1988, Chapter 3). Provincial solid waste studies did not include additional information, and no study relating solid waste generation to their source was found for Canada American sources were used as proxies. In Canada, 73 million tonnes of waste were generated, out of which 10 million tonnes were reused and 0.25 % of municipal waste was recycled (ISWA,1988)[17]. These figures were supported by OECD (1991b,45).

The chemical product industries, primary steel industries and other utilities (Electricity power generation and waste treatment) generated the largest percentage of solid waste (Table B.2). The use of U. S. percentages of waste generation per dollar of industry output implies similar production processes in the two countries.

Agricultural wastes. Agricultural residuals originate from crop and animal production. Crop residuals are not waste. They offer protection against wind and

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[16] Sludge is included in solid waste. When no estimate are provided, reused waste is not included. Remaining waste is total waste minus reused.

[17] 95.75% of the solid waste is landfilled in Canada. Incineration is still in an infancy stage (4%).

water erosion, when left on the ground, and can be reincorporated in the soil at plowing time. Animal manure is a waste if disposed of and an input into production if used as a fertilizer material. However, in a limited area, a high concentration of animals does not result in a wise use of manure as fertilizer. Animal manure is thus assumed to be a waste[18].

Municipal and mine wastes. Municipal waste was estimated to be 12,677 tonnes by the ISWA (1988). These were allocated to the household categories in the final demand matrix. Mine tailing waste, 600 million tonnes, was allocated to the mine industry.

Airborne residuals

Air emission estimates were available from Environment Canada's Residual Discharge Inventory System (RDIS). Major source categories included industrial processes, stationary fuel combustion, waste incineration, transportation and open sources[19]. The data were compiled on a provincial and national basis and classified by SIC numbers. Airborne wastes included in the model are: nitrogen oxides (NOx), volatile organic compounds (VOC), hydrocarbons (HC), sulphur dioxide (SO_2), carbon monoxide (CO) and particulate matters (part)(Table B.3).

Waterborne wastes

There was limited information on wastewater generation by source for

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[18] Nutrient enrichment from livestock operations is a major source of ground and surface water pollution in many states in the U. S. and in Canadian regions.

[19] See Johnson et al. (1991) for detail on emission coefficients.

Canada. The World Health Organization (WHO, 1982) handbook for rapid assessment of sources of land, air and water pollution was used in this study. The residual loads for 5-days biological oxygen demand (BOD5), chemical oxygen demand (COD), total dissolved solids (TDS), total solid (TS), suspended solids (SS), nitrogen (N) and oil were generated with the handbook's load factors. These estimates should suffice temporarily, as Statistics Canada's Environment and Wealth Accounts Division is now in the process of compiling more accurate coefficients.

Pesticides and fertilizers

Pesticide and fertilizer use are ecological outputs because their discharge on land alters the quality of the water and land resources. Pesticides threaten the environment through surface runoff to streams and from leaching to the ground water. Many factors, such as: the environment, the type of agricultural practice, and the pesticide properties, affect whether or not a pesticide will leach.

There is limited information on pesticides that is not confidential. For instance, each year Environment Canada and Agriculture Canada conduct the "Pesticide Registrant Survey". This survey contains sales (in physical and monetary units) of major pesticide products, but this information is kept confidential due to the high level of concentration in this sector. Shoakat et al. (1985) identified data sources related to pesticide use in Canadian agriculture; not only are most of these no longer available but new sources are rare[20]. Given this data constraint, the

[20] Crowe and Mutch (1991) surveyed a number of models that were utilized to assess the pesticide threat to the environment. These models required large amounts of data not available for the entire country. The available data bases

pesticide commodities included in the model were: triazine, phenoxy (2,4-D and MCPA), dicamba/bromoxynil, other herbicides, captan, other fungicides, insecticides and others (nematocides, growth regulators and others nonspecified). In 1986 most of the herbicides used in western Canada were phenoxy, dicamba/bromoxynil and wild oats herbicides. This pattern has changed over time with new products entering the market. Pesticide use in 1986 may not be representative because of uncontrolled wild oat growth and a grasshopper infestation. In addition, market conditions induced farmers to switch to older, cheaper pesticides such as 2,4-D. These two factors affect the 1986 values. The total sales of pesticides in 1986 was $762 million, herbicides accounting for 70% of this amount. The Pesticide Registrant Survey included all pesticides sales in Canada. Thus, pesticides used by other sectors and households were included in the agricultural sectors. Given the lack of public information on pesticide use, model coefficients can only be used as approximations.

The environmental problems most often associated with fertilizers are nitrate and phosphorus leaching (i.e. excess nutrients). Environment Canada (1991f) includes fertilizer volume and composition as environmental indicators. Total fertilizer consumption was allocated using the area fertilized per farm type in 1986.

3.2.2.1 Limitations of the ecological commodity estimates

Interpreting the model's results, one must keep in mind that there is no direct

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that contain information necessary to estimate pesticide harm were at best incomplete despite many years of research in this area. These models cannot be used with confidence at the national level.

relationship between material masses and prices, and that limitations in the environmental sector are substantial. For example, industry classification is based on the source of income amounting to 51% or more of total income coming from a particular activity (Statistics Canada (1981)). Since there is no direct relationship between a dollar's worth of output and the level of pollution generated, the industry technology assumption may introduce some bias in the determination of the ecological commodity coefficients. Victor (1990) argues that both the monetary and physical values should be included in the SNA. This is because not all factors can be valued with the same level of certainty and such valuation leads to many conceptual and technical problems. It should also be noted that no values were attributed to the ecological commodities and that only ecological commodity flows to and from the economic system are included in the model. Accordingly, the flows within the ecosystem, and the ecological commodities generated by the consumption side are excluded.

The lack of accurate data limits this research. The Canadian Green Plan involves the collection and publication of a set of environmental indicators and the development of environmental monitoring systems and programs (Environment Canada, 1991f). Given this new commitment, data collection and publication are expected to improve in the near future. Environmental problems are often local and are better dealt with at a local or regional level. National level studies may suffer in prediction accuracy, but they are necessary for national policy purposes. Some authors have criticized these types of models on different grounds. Hafkamp (1983,

21) denounced the scant attention paid to means of reducing pollution. This could be partially overcome if an activity model was constructed to forecast impacts of alternative ways of producing given goods and services (e.g. in Ridker, 1972). Another interesting question is whether pollution abatement activities have expansionary or contractionary economic impacts (Ketkar (1983), Rose (1983)).

3.2.2.2 Ecological commodities specific to agriculture

The risk of water erosion, estimated with the USLE, is linked to the number of hectares under given agricultural conditions. Production increases to meet a change in final demand for a given commodity must come from a greater area under cultivation. An increase in production through more intensive practices would require different USLE coefficients, hence different production functions for intensive and less intensive agriculture. The USLE predicts the long term average water erosion risk[21], which limits the model's usefulness for short term analyses. The USLE can be used to compare the erosion of one crop relative to another crop selection and the amount of erosion could be an important agricultural policy variables. As stricter regulations are imposed, changes in quantity of soil erosion can be estimated by varying the conservation practices (P) and cover (C) coefficients.

Soil erosion is underestimated because the provinces of B.C., Newfoundland and the Gaspé péninsula of Québec were excluded. The latter two have negligible impacts because they only have small agricultural areas. In B.C., however, large areas

[21] Gross erosion is based on a 10 year weather average.

of land are in agriculture and the potential erosion may be considerable[22]. Some errors are also introduced when proxies are used to distribute the environmental effects to farm type.

All pesticides and fertilizer use in 1986 were allocated to agriculture, thereby overestimating figures for pesticide and fertilizer use by agriculture[23]. It has not been possible to model, at the national level, the proportion of pesticides and fertilizers reaching ground and surface waters. Therefore, pesticides and fertilizer utilization are viewed as indicators of potential environmental effects. These indicators are included in many recent government publications (Environment Canada (1991f), Statistics Canada (1991), and OECD (1991b)). The quality of water used in agriculture for irrigation and watering is affected by the delivery of sediments from eroded soil and pesticide and fertilizer use. Land and water conservation issues that are important in a policy context are: soil acidification by nitrogen fertilizers, ground water deterioration due to chemicals, loss of soil by water and wind erosion, and sedimentation of surface water. A systematic approach to soil and water conservation requires the inclusion of all these issues to arrive at an economically viable policy package.

The goal of this model is to provide decision-makers with macroeconomic and environmental estimates to facilitate sustainable development. Nonmarket goods

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[22] B.C. data is now available thus can be included in future studies.

[23] Pesticides and fertilizers are used for other than agricultural purposes (small gardens, lawns, rail and power line clearing, forestry, etc.).

cannot be expressed in monetary terms at the same level of precision as traded goods. Their inclusion in physical units is a step toward dealing with pollution policy problems and the use of environmental services as free goods.

3.3 Hypotheses to be tested

It is proposed that an I-O model augmented with ecological commodities will aid in the appraisal of the environmental effects of a given increase in demand, describing the environmental performance of different industries. This environmental performance can be compared with other industrial sectors of the economy. The procedure assesses the trade-off between economic growth and environmental quality.

Results of two policy scenarios are presented in chapter 4. The first scenario looks at the trade-off between the economic and environmental impacts of an increase in final demand of selected agriculture and food commodities. These results permit a comparison of the agricultural and food industries in terms of both their economic and environmental performances. The second scenario studies the pollution content of Canada's final demand categories. Decision-makers are interested in knowing which expenditures will result in the greatest returns and at what environmental cost (physical terms). By looking at the pollution content of government, personal expenditure, construction, machinery and equipment categories of final demand this trade-off becomes more obvious. Forsund (1985) analyzed the pollution content of Norway's categories of final demand to find that exports dominated for most pollutants. Since many subsidy programs are oriented toward enhancing agricultural and industrial exports, these government expenditure, and their corresponding environmental impacts should be scrutinized carefully. Affirmations such as "the wheat industry is exporting our soil" can be verified and quantified with the economic-ecologic model[24].

[24] Goods (wheat) are exported but their related externalities (erosion in this case) remain in the exporting country.

CHAPTER FOUR

RESULTS

4.1 Introduction

The economic-ecologic model derived above extends I-O analysis to estimate the environmental impacts of exogenous changes in final demand. This model provides a framework for obtaining quantitative estimates of 3 economic indicators, 27 ecological outputs, and 7 ecological inputs. The model emphasizes the agricultural and food sectors with its 12 agriculture and 16 agri-food industries. It also contains 16 ecological commodities "exclusive" to agriculture. Waterborne, airborne and solid waste estimates are supplemented with pesticide, fertilizer and soil use. Livestock and poultry solid and liquid wastes are also included. This model describes the structure of the economy in terms of inter-industry and environment-industry production relationships.

The environmental effects of conventional pollutants is well known and hence not discussed here. Concerns over agricultural pollutants arise because 1) overuse and subsequent "discharge" of pesticides and fertilizers within a watershed affect other water uses such as irrigation, livestock watering, and human consumption 2) erosion (soil use) reduces the fertility of the land resource base, and 3) soil deposited into streams affect water quality, hence potential services from this resource.

Two policy scenarios were analyzed in this study. The first compares the economic and environmental impacts of an increase in the demand for agricultural and processed food commodities. This analysis compares the direct and indirect economic and environmental impacts of these changes on the agricultural and food sectors and the other sectors in the economy. In an attempt to achieve sustainable growth, the residual and resource content of contemplated consumption and production stimuli is necessary (i.e., increase domestic versus foreign demand and/or construction versus government spending). The second scenario analyzes the pollution content of five categories of final demands.

4.2 Direct plus indirect effects of a change in final demand of selected agricultural and food processed commodities.

Equation 3.7 is used to estimate the change in industrial output requirements to satisfy a change in final demand. The impact matrix, $[I-D(I-P-J-T)B]^{-1}D$, was estimated using GAUSS 386[1,2]. Multiplying the impact matrix by the change in final demand provides an estimate of the direct plus indirect industrial output (g) required to satisfy the change in final demand. The Gross Domestic Product at factor cost (GDP), employment and ecological commodity coefficients[3] were then post-multiplied by g to yield the macro economic and environmental effects.

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[1] GAUSS 386. Version 2.1. Aptech System Inc. Washington: 1984-1991.

[2] The author is grateful to Martin Cloutier who shared his GAUSS programs. These programs were modified to fit this model's needs.

[3] Environmental commodity coefficients are presented in Appendix B.

Final demand vectors were used to shock the model. Each vector was a $1 million (M) change in the demand for an agriculture or food processed commodity. The changes in agricultural commodities were: Cattle (1), Wheat (6), Grains (7-Barley, oats, corn, grains), Vegetables (13), and Oilseed (17). Changes in food processed commodities were: Beef (33-Beef, veal, mutton, and pork), Wheat flour (71), Bread (75), Vegetables (59-Vegetables and preparations canned), and Processed Oilseed (84-Oilseed, meal and cakes)[4]. The direct plus indirect effect of each change in the final demand for an agricultural commodity was compared to the other agricultural commodities. These simulations are presented in Tables 4.1 through 4.5. The estimates are aggregated into three broad industrial sectors: 12 agricultural sectors (Agr.), 16 food processing sectors (Agri-food) and the entire economy (Total). The ecological commodities specific to agriculture are displayed in Tables 4.6 through 4.8.

4.2.1 Economic effects

The estimated impact on industrial output, GDP and employment were similar for each change in the final demand for the agricultural commodities (Table 4.1). The largest estimated impact on industry output was $2.3 million for the cattle simulation. Sixty-three percent of this change in industrial output was from the

[4] The number in parentheses corresponds to the commodity number in the model (see Table A.2).

Table 4.1 Impact on Industrial Output, Income and Employment, by Industry Aggregate, of a $1 M Change in Final Demand for each of the Listed Commodities

	Aggregate	Industrial Output $	GDP	Total Employ-ment	Industrial Output % of total	GDP % of total	Total Employment % of total
Agriculture Commodities							
Wheat	Agr.	974,940	470,417	22	0.48	0.52	0.71
	Agri-food	53,612	12,078	0	0.03	0.01	0.01
	Total	2,040,227	910,118	31			
Cattle	Agr	1,470,220	549,558	31	0.63	0.62	0.83
	Agri-food	146,857	29,244	1	0.06	0.03	0.01
	Total	2,327,229	885,060	37			
Vegetable	Agr.	848,953	404,099	22	0.48	0.47	0.63
	Agri-food	45,150	11,137	0	0.03	0.01	0.01
	Total	1,784,956	859,950	34			
Grains	Agr.	1,151,386	481,978	24	0.54	0.54	0.75
	Agri-food	66,399	14,258	0	0.03	0.02	0.01
	Total	2,129,490	885,449	33			
Oilseed	Agr.	1,107,556	467,060	23	0.53	0.53	0.73
	Agri-food	59,641	13,220	0	0.03	0.01	0.01
	Total	2,107,549	886,047	32			
Total		10,389,450	4,426,624	167			
Total Agr.		5,553,055	2,373,112	122			
Processed Food Commodities							
Beef	Agr.	702,366	293,228	13	0.28	0.35	0.46
	Agri-food	1,062,252	168,319	4	0.42	0.20	0.14
	Total	2,537,253	836,427	28			
Wheat	Agr.	140,795	65,527	3	0.08	0.09	0.18
flour	Agri-food	952,443	337,107	5	0.51	0.45	0.31
	Total	1,858,544	746,282	17			
Processed	Agr	62,161	30,462	2	0.04	0.04	0.08
vegetable	Agri-food	813,109	293,954	5	0.46	0.39	0.26
	Total	1,773,970	756,297	20			
Bread	Agr.	33,411	15,441	1	0.02	0.02	0.03
	Agri-food	750,110	352,284	8	0.44	0.41	0.31
	Total	1,688,178	851,673	27			
Processed	Agr.	577,224	243,486	12	0.25	0.35	0.59
Oilseed	Agri-food	941,838	125,007	1	0.40	0.18	0.07
	Total	2,343,798	704,710	21			
Total		10,201,744	3,895,389	112			
Total agri-food		4,519,751	1,276,670	24			

agricultural and food sectors. All other commodity impacts, with the exception of vegetables, were greater than $2 M. GDP varied between $859,950 for vegetable and $910,118 for wheat. The largest employment impacts were for cattle and vegetable, being 37 and 34 jobs respectively.

Beef and processed oilseed commodities provide the largest industrial outputs (among the 5 processed commodities), $2.5 million and $2.3 million respectively (Table 4.1). However all GDP results were similar, with bread being the largest at $851,673. The beef and processed oilseed simulations had the largest impacts on the agricultural and food sectors. For example, 70% of the change in industrial output for the beef simulation is accounted for in the agricultural and food processing sectors. This decreases to 46% in the bread simulation.

Both agricultural and processed food products provide similar economic impacts. The total impact for all of the agricultural commodities is $10.4 M in industrial output, $4.4 M in GDP and 167 jobs. For the food commodities these total values are $10.2 M, $3.9 M and 112 jobs respectively.

4.2.2 Airborne emissions

Particulate emissions are the only significant airborne residual from the agriculture and food products industries. Particulates occur as a result of agricultural practices and are therefore allocated to the agricultural sectors (see Table 4.2). These emissions included dust resulting from pesticide crop dusting and spraying,

Table 4.2 Impact on Air Pollution, by Industry Aggregate, of a $1 M Change in Final Demand for each of the Listed Commodities

	Aggregate	NOX	VOC	THC	SO2	CO	PART
				(tonne)			
Agriculture Commodities							
Wheat	Agr.	0	0	0	0	0	546,288
	Food	7	5	5	7	0	19
	Total	5,124	1,976	3,787	4,062	7,453	677,773
Cattle	Agr.	0	0	0	0	0	281,702
	Food	21	12	12	22	1	64
	Total	2,284	1,241	2,824	3,724	4,408	325,109
Vegetable	Agr.	3	2	0	0	5	149,444
	Food	5	4	4	5	0	13
	Total	2,126	2,451	3,734	3,102	3,888	191,310
Grains	Agr.	0	0	0	0	0	407,785
	Food	9	6	6	9	0	26
	Total	4,012	1,699	3,596	4,059	6,324	504,237
Oilseed	Agr.	0	0	0	0	0	441,796
	Food	8	6	6	8	0	22
	Total	3,873	1,758	3,690	4,123	6,179	532,903
Total		17,418	9,125	17,632	19,070	28,252	2,231,333
Processed Food Commodities							
Beef	Agr.	0	0	0	0	0	118,543
	Food	45	10	10	44	3	54
	Total	2,181	2,161	3,122	2,791	3,857	164,214
Wheat	Agr.	0	0	0	0	0	60,399
flour	Food	72	62	59	41	5	53
	Total	2,629	1,687	2,345	2,434	4,607	119,803
Processed	Agr.	0	0	0	0	0	9,765
vegetable	Food	7	3	3	2	1	6
	Total	2,254	2,330	2,982	3,420	4,738	58,704
Bread	Agr.	0	0	0	0	0	10,181
	Food	23	997	997	8	2	10
	Total	1,722	4,455	4,987	1,955	3,496	47,170
Processed	Agr.	0	0	0	0	0	229,855
Oilseed	Food	255	880	880	248	14	228
	Total	4,418	2,347	3,622	3,539	5,665	335,813
Total		13,203	12,979	17,058	14,139	22,364	725,704

wind erosion and tillage, and fertilizer application.

Particulate matter was the most significant airborne emission for the processed commodities with processed oilseed having the highest level. Increased demand for bread had the lowest emissions of all airborne residuals except THC and VOC. The backward linkages in the model resulted in large particulate emissions from the agriculture sectors for the beef, wheat flour, and processed oilseed simulations. With the exception of VOC, smaller airborne residuals were generated with the processed food simulations than with the agricultural commodities.

4.2.3 Waterborne emissions

In Table 4.3, waterborne wastes were non-existent or negligible for the agriculture and food aggregates when agricultural commodities were shocked (with the exception of TDS when the demand for cattle is increased). The agricultural sector did not produce any waterborne waste in the production of either agricultural or processed food commodities. This was an underestimation due to the model specification. Agriculture does produce waterborne waste in particular from pesticide and fertilizer leaching and soil sediments moving into watercourses from erosion. An indication of the potential waterborne waste problems is the estimated amount of pesticide and fertilizer required in the production process (see discussion in chapter 3). The production of agricultural commodities generates significant levels of TDS and SS by other industrial sectors (in the total aggregate). The largest

Table 4.3 Impact on Waterborne Waste, by Industry Aggregate, of a $1M Change in Final Demand for each of the Listed Commodities

	Aggregate	BOD5	COD	SS	TDS	OIL	N
				(tonne)			
Agriculture Commodities							
Wheat	Agr.	0	0	0	0	0	0
	Food	10	19	4	659	14	3
	Total	475	936	6,580	2,074	2,074	1,704
Cattle	Agr.	0	0	0	0	0	0
	Food	15	51	7	2,011	29	5
	Total	603	1,231	6,186	3,687	1,573	1,106
Vegetable	Agr.	0	0	0	0	0	0
	Food	14	15	5	497	11	2
	Total	497	939	4,283	2,092	1,070	760
Grains	Agr.	0	0	0	0	0	0
	Food	10	24	5	850	16	3
	Total	523	1,045	6,583	2,358	1,701	1,175
Oilseed	Agr.	0	0	0	0	0	0
	Food	11	22	5	745	15	3
	Total	514	1,018	6,634	2,253	1,720	1,184
Total		2,612	5,169	30,266	12,464	8,138	5,929
Processed Food Commodities							
Beef	Agr.	0	0	0	0	0	0
	Food	622	79	398	1,576	963	582
	Total	1,215	1,098	3,963	3,997	1,790	1,203
Wheat Flour	Agr.	0	0	0	0	0	0
	Food	676	413	37	15,218	775	5
	Total	1,241	1,121	2,244	18,670	1,253	368
Processed vegetable	Agr.	0	0	0	0	0	0
	Food	863	35	297	333	25	5
	Total	1,493	796	2,324	4,298	428	328
Bread	Agr.	0	0	0	0	0	0
	Food	119	59	29	2,135	110	3
	Total	736	875	2,070	5,703	514	335
Processed Oilseed	Agr.	0	0	0	0	0	0
	Food	31	3,685	33	154,654	1,147	2
	Total	494	4,621	4,280	155,961	2,197	758
Total		5,179	8,509	14,880	188,629	6,181	2,992

emissions were estimated for the increases in the demand for grains, wheat and cattle.

Significant levels of TDS and SS were produced when the demand for processed food commodities was stimulated; 188.6 and 14.9 thousand tonnes respectively. More than 92% of TDS was produced by the food industries. The largest output of TDS can be found in processed oilseed.

Agricultural commodities yield twice as much SS and N as the processed food commodities. Agricultural commodities also generate more oil. However, more BOD5, TDS (14 times more) and COD was generated when the processed food commodities were shocked. TDS originating from the processed oilseed simulation was by far the largest waterborne emission.

4.2.4 Land residuals

The increase in demand for cattle generated 7.6 of the 14.8 M tonnes of liquid and solid animal wastes generated by all of the agricultural commodities (see Table 4.4). Animal waste estimates for the other agricultural commodities were comparable. Beef and processed oilseeds provided the largest animal waste levels when the processed food commodities were shocked. These levels of animal wastes were partly due to backward linkages but also to the model's specification and the

Table 4.4 Impact on Solid Wastes, by Industry Aggregate, of a $1M Change in Final Demand for each of the Listed Commodities

	Aggregate	Solid Liquid Animal	Solid Animal	Solid
			(tonne)	
Agriculture Commodities				
Wheat	Agr.	1,781,614	3,340,462	0
	Food	0	0	296
	Total	1,781,614	3,340,462	1,402,216
Cattle	Agr.	7,607,936	14,464,940	0
	Food	0	0	589
	Total	7,607,936	14,464,940	1,278,982
Vegetable	Agr.	881,899	1,630,858	0
	Food	0	0	362
	Total	881,899	1,630,858	1,069,645
Grains	Agr.	2,548.757	4,818,014	0
	Food	0	0	332
	Total	2,548,757	4,818,014	1,746,883
Oilseed	Agr.	2,028,129	3,789,863	0
	Food	0	0	317
	Total	2,028,129	3,789,863	1,817,631
Total		14,848,334	28,044,137	7,315,357
Processed Food Commodities				
Beef	Agr.	3,108,631	5,520,165	0
	Food	0	0	24,232
	Total	3,108,631	5,520,165	655,470
Wheat flour	Agr.	285,702	531,703	0
	Food	0	0	4,248
	Total	285,702	531,703	302,158
Processed vegetable	Agr.	95,098	174,047	0
	Food	0	0	25,460
	Total	95,098	174,047	352,814
Bread	Agr.	87,861	163,554	0
	Food	0	0	1,835
	Total	87,861	163,554	21,755
Processed Oilseed	Agr.	1,060,082	1,980,592	0
	Food	0	0	22,806
	Total	1,060,082	1,980,592	1,004,589
Total		4,637,373	8,370.061	2,336,786

industry technology assumption[5].

The increases in demand for all agricultural commodities yield similar solid waste levels with the agricultural and food processing sectors accounting for negligible amounts. Solids generated from the processed oilseed commodity, 1 million tonnes, accounted for half the solids generated by the processed food commodities. The main solid waste component was mine tailings from mining operations (with 60 million tonnes generated annually) and was due to the model's specification.

4.2.5 Water use

For both the agricultural and processed food commodity simulations the agricultural sector aggregate was the largest water user (see Table 4.5). Other water impacts (recycled, gross, discharge and treated) varied slightly. The largest water intake was for the vegetable simulation, 383 million m^3. Other water intake impacts from the agricultural commodity simulations ranged from 235 to 261 million m^3. The water intake requirements to satisfy the increased demand for processed food products varied considerably. The largest water user from these simulations was the agricultural sector aggregate. Processed oilseed and beef simulations required 190

[5] An increase in demand for an agricultural commodity, say wheat, stimulates an increase in industrial output of the wheat sector. The wheat sector also produces large quantities of cattle. Since the wheat industry has been shocked, all of the commodities produced by the wheat sector are stimulated - which explains the relatively large increase in manure for all the increase in demand for agricultural commodities.

Table 4.5 Impact on Water Use, by Industry Aggregate, of a $1M Change in Final Demand for each of the Listed Commodities

		Water				
	Aggregate	Intake	Recycled	Gross	Discharge	Treated
				(Million m3)		
Agriculture Commodities						
Wheat	Agr.	191	0	0	0	0
	Food	0	0	1	0	0
	Total	235	22	61	43	26
Cattle	Agr.	209	0	0	0	0
	Food	1	0	1	1	0
	Total	261	22	68	52	31
Vegetable	Agr.	342	0	0	0	0
	Food	0	0	1	0	0
	Total	383	18	54	41	24
Grains	Agr.	208	0	0	0	0
	Food	0	0	1	0	0
	Total	257	24	67	48	28
Oilseed	Agr.	205	0	0	0	0
	Food	0	0	1	0	0
	Total	254	24	67	48	28
Total		1,390	109	317	232	137
Processed Food Commodities						
Beef	Agr.	83	0	0	0	0
	Food	5	2	7	4	2
	Total	130	18	60	47	29
Wheat flour	Agr.	26	0	0	0	0
	Food	10	9	19	9	2
	Total	69	24	63	42	22
Processed vegetable	Agr.	18	0	0	0	0
	Food	11	7	17	9	6
	Total	65	22	65	45	29
Bread	Agr.	5	0	0	0	0
	Food	3	1	5	2	0
	Total	43	14	48	37	23
Processed Oilseed	Agr.	107	0	0	0	0
	Food	43	24	66	42	1
	Total	190	40	118	82	26
Total		497	117	354	252	128

and 130 million m^3 of which 107 and 83 million m^3, were used in the agriculture sectors. Other simulations yielded low water intake requirements; 43, 65, and 69 million m^3.

4.2.6 Ecological commodities used by agriculture

The largest amount of soil was delivered to the environment with increases in the final demand for wheat, oilseed and grains; 1.0, 0.9, and 0.8 M tonnes respectively (Table 4.6). The wheat simulation accounts for more than one-third of the total amount of soil erosion (3.9 M). Changes in the demand for processed oilseed generated the largest amount of delivered soil among the processed food commodities. Soil delivered in the processed vegetable and bread simulations were significantly lower than the other commodities. As expected, processed food commodities have smaller soil erosion estimates than the agricultural commodities. This is because a larger percentage of their value is from value added transformations in the processing of the raw agricultural commodities.

With the exception of vegetable and cattle, agricultural commodities used similar amounts of fertilizer material and nutrients to produce their increased production. The largest amount of fertilizer was required for the increase in oilseed production. Fertilizer requirements for the processed food simulations varied greatly from 7,457 to 191,181 tonnes (Table 4.7). It should be noted that the fertilizer requirement for the beef simulation is approximately 2.6 times larger than that

Table 4.6 Impact on Potential Erosion and Soil Delivery, by Industry Aggregate, of a $1 M Change in Final Demand for each of the Listed Commodities

	Potential Erosion (tonne)	Delivered to the Environment
Agriculture Commodities		
Wheat	15,155,899	1,019,043
Cattle	7,329,384	591,585
Vegetable	5,695,548	598,984
Grains	10,778,561	820,674
Oilseed	11,671,486	868,303
Total	50,630,877	3,898,589
Processed Food Commodities		
Beef	3,139,339	258,809
Wheat flour	1,665,325	118,219
Vegetable	342,441	34,680
Bread	282,473	21,437
Oilseed	6,072,887	451,873
Total	11,502,465	885,017

Table 4.7 Impact on Fertilizer Material and Nutrient Content Use, by Industry Aggregate, of a $1M Change in Final Demand for each of the Listed Commodities

	Fertilizer Material	Nitrogen (tonne)	Phosphorus	Potash
Agriculture Commodities				
Wheat	325,828	91,097	52,503	29,817
Cattle	248,789	69,558	40,089	22,767
Vegetable	136,693	38,217	22,026	12,509
Grains	346,781	96,955	55,879	31,734
Oilseed	367,493	102,746	59,217	33,630
Total	1,425,584	398,572	229,715	130,456
Processed Food Commodities				
Beef	105,187	29,409	16,950	9,626
Wheat flour	40,785	11,403	6,572	3,732
Vegetable	8,934	2,498	1,440	818
Bread	7,457	2,085	1,202	682
Oilseed	191,181	53,451	30,806	17,495
Total	353,544	98,846	56,969	32,353

required for the wheat flour simulation. This occurred because feed is a major input into cattle production and because of the importance of cattle as an input into the process beef commodity.

The most intensive use of pesticides was found in the increased production of wheat, oilseeds and grains; 2,449, 2,335 and 2.191 tonnes of active ingredients (AI) respectively (Table 4.8). Triazine use was low for the vegetable and wheat commodities but high for grains and oilseed. This can be explained by the presence of corn in the grains category, the most intensive user of atrazine. Captan and other fungicides use was low, with the largest estimates being from the vegetable simulation. As was expected, the impact of pesticide use was significantly lower for the processed food commodities. Total AI used for the production of agriculture and processed food commodities was 10.1 and 2.4 million Kg, respectively.

Discussion

Similar changes in the total industrial output were found for a $1 M increase in the demand for either agriculture or processed food commodities. Total GDP and employment were slightly higher for the agricultural commodities, however. The largest changes in industrial output were found for the following commodities: beef, processed oilseed, cattle, grains and oilseed. Impacts to the agriculture and agri-food sectors accounted for half of the total direct plus indirect effects.

The environmental impact of these increases in final demand varied greatly.

Table 4.8 Impact on Pesticide Use, by Industry Aggregate, of a $1 M Change in Final Demand for each of the Listed Commodities

	Pesticides								
	Phenoxy	Dicamba Bromoxynil	Triazine	Other Herbicide (Kg AI)	Fungicide	Captan	Insecticide	Other AI	Total
Agriculture Commodities									
Wheat	532,890	267,655	87,273	1,074,014	26,383	1,113	251,636	208,720	2,449,683
Cattle	254,454	132,011	100,414	701,012	44,953	2,127	111,388	101,877	1,448,236
Vegetable	135,590	72,869	79,873	765,612	395,464	7,220	142,176	85,008	1,683,812
Grains	372,722	196,542	165,908	1,067,773	56,525	2,138	172,487	156,633	2,190,728
Oilseed	406,625	213,924	174,563	1,139,116	44,586	1,569	185,651	169,407	2,335,442
Total	1,702,280	883,002	608,030	4,747,528	567,911	14,168	863,338	721,645	10,107,902
Processed Food Commodities									
Beef	108,103	58,209	60,348	336,781	21,601	1,028	50,079	44,290	680,439
Wheat flour	57,766	29,478	14,628	133,298	7,222	264	27,642	23,234	293,532
Vegetable	8,878	4,794	5,219	43,845	54,811	2,835	11,708	5,378	137,466
Bread	9,600	4,957	3,087	24,054	2,825	145	4,752	3,911	53,332
Oilseed	211,558	111,300	90,816	592,654	23,307	822	96,610	88,138	1,215,205
Total	395,904	208,738	174,098	1,130,632	109,767	5,093	190,791	164,951	2,379,974

From the agricultural commodities simulated, wheat and oilseed had the largest environmental impacts. The increase in the final demand vegetable for had the greatest impact on fungicides and captan use and VOC produced, although the smallest in most other ecological commodities. The largest values for animal waste, BOD5, COD and water intake occurred with the cattle simulation. Important ecological commodities (largest stimulated values) were particulate, SS, animal and solid waste and ecological commodities specific to agriculture.

Of the processed food commodities, processed oilseed had the highest residuals discharged and resource use for all of the important ecological commodities (TDS in addition to the above-mentioned). Beef comes second for most of these. The bread simulation had the largest VOC and THC emissions. Fungicide and captan use were greatest for the wheat flour simulation and BOD5 emission was largest for the processed vegetable simulation. Solid and animal wastes were largest for the beef simulation, as could be expected[6].

The previous analysis illustrates how the model can provide policy makers with the trade-offs between economic and environmental factors of various policies. The economic and environmental implications of a policy aimed at increasing beef and

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[6] Some results are due to the model aggregation. For example the commodity oilseed is produced by most agricultural sectors while wheat is mainly produced by the wheat sector. An increase in final demand for oilseeds increased all inputs used by oilseed producers in all sectors. This happened although the model was disaggregated to account for 12 agricultural sectors.

processed oilseed demand versus cattle and grains demand would result in almost half the solid, pesticide, fertilizer, water and delivered soil requirements. This policy would increase all waterborne wastes except N and TDS (TDS would be 10 times greater). Animal waste would be reduced by two-thirds. Similar waterborne wastes would be generated but less particulate would be emitted. The demand for beef and processed oilseed would generate similar macroeconomic impacts as cattle and grains demand. As a result, policies that promoted the demand for beef and processed oilseed would be favoured because even though they have similar macroeconomic impacts as cattle and grains they have less adverse environmental impact.

4.3 The pollution content and resource intensity of final demand

One area of interest to economists is the resource intensity and residual discharge of different categories of final demand. The final demand vector in the input-output model was disaggregated into a number of categories to estimate this. The categories used were: personal expenditures, machinery and equipment, construction, inventories, gross government expenditures, exports, re-exports, and imports. Shocking any one of these categories had a different effect on both the economy and the environment.

The analysis consists of shocking the final demand of each of the 5 categories by $1 million[7]. The $1 million was pro-rated to the various commodities that make

[7] Re-exports, Imports and Inventories are not included in the analysis.

up the final demand categories. The impacts were then compared. Commodities 49 and 57 were negative entries in the machinery and equipment category. Shocking this demand had two opposite effects. Negative impacts must be subtracted from the positive impacts. The two negative entries were set to zero and this new total pro-rated across the rows according to the commodities purchased. The vector sum of 1.18 indicated that 18% of the purchase belongs to the negative values. Hence 180,000 and 820,000 were allocated to the respective vectors. The machinery and equipment results in Table 4.9 are the net effects (positive minus negative effects) of these two simulations.

The direct plus indirect effects of a change in final demand for each category of final demand is given in Table 4.9. The highest industrial output was generated in the construction, exports, and personal expenditure categories. The shock to the personal expenditure category produced the highest employment (19) and GDP (0.8 million) estimates. Overall, the residual discharge and resource utilization intensity were greatest in the exports and personal expenditures categories of final demand. A notable exception was found in the airborne residuals. The airborne waste content of construction was highest for VOC, SO2, and particulate and was second for THC and CO. The construction category yielded the lowest pesticide and fertilizer usage, and animal and solid waste estimates. The government category had the lowest economic impact, air pollution (except THC), solid yield, and soil and water use. The estimates for the other final demand categories simulated fell within the same

Table 4.9 Impact on the Economy and the Environment of a $1 M increase in each of the Final Demand Categories

	Personal Expenditure	Export	Construction	Government	Machinery & Equipment
Economic					
Total Output ($)	1,561,567	1,698,392	1,739,673	571,609	1,384,295
GDP ($)	828,874	663,895	746,749	283,016	587,561
Total Employment (#)	19	14	17	7	13
Airborne waste (tonne)					
NOX	2,675	4,226	1,609	1,115	1,525
VOC	2,005	3,004	3,551	615	1,272
SO2	4,150	5,461	31,317	1,622	1,922
THC	3,181	211,923	24,624	21,753	6,173
CO	5,105	21,772	10,977	1,828	4,738
PART	61,088	96,467	308,220	29,081	29,491
Pesticides (Kg AI)					
Phenoxy	9,450	20,815	598	886	702
Dicamca	5,091	10,691	318	467	372
Triazine	5,251	6,005	295	395	333
Other Herbicide	32,424	50,258	1,859	2,595	2,081
Fungicide	20,984	6,271	529	634	314
Captan	1,218	336	29	35	16
Insecticide	6,985	10,355	340	479	359
Other Ative Ingredient	4,381	8,483	260	375	296
Erosion (tonne)					
Erosion	302,373	601,381	26,535	18,276	21,165
Delivery	27,244	43,600	2,172	1,565	1,757
Land waste (tonne)					
Liquid animal waste	183,123	152,752	11,697	15,697	11,807
Solid animal waste	330,947	280,766	21,333	28,731	21,541
Solid waste	796,971	3,320,647	531,728	209,018	707,508

Table 4.9 Continued

Fertilizers (tonne)

Quantity	9,228	15,472	576	801	646
Nitrogen	2,580	4,326	161	224	181
Phosphorous	1,487	2,493	93	129	104
Potash	844	1,416	53	73	59

Waterborne waste (tonne)

BOD5	1,164	1,494	381	299	377
COD	2,228	1,307	752	481	505
SS	4,710	4,568	1,709	1,980	1,166
TDS	4,519	11,971	1,160	1,501	2,260
OIL	1,068	916	374	471	242
N	843	696	303	344	188

Water Use (million m3)

Water intake	92	87	30	25	29
Water recycled	23	46	12	8	15
Gross water	94	116	34	34	40
Water discharged	81	75	24	29	28
Treated discharged	50	47	14	18	16

range and were relatively small compared to Exports and Personal Expenditures.

Since the export and personal expenditures categories estimates were of similar magnitude they are compared below. Shocks to these categories of final demand provided similar macroeconomic impacts. Exports contained more air pollution, in particular CO and SO2 (22 and 212 tonnes as opposed to 5 and 3 tonnes). Similar amounts of pesticides were found for both categories, except for fungicide and captan which were highest for the personal expenditures category. Fungicide and captan are used mainly in fruit and vegetable production. These products usually remain in the domestic market. This partly explains why the fungicide and captan values were higher in the personal expenditures category. Potential erosion and delivered soil were twice the personal expenditures estimates. This can be explained by Canada's wheat exports. This product generates the most erosion of all the agriculture commodities stimulated. Exports contain four times more solid waste (3.3 million t) than personal expenditures. This is due to the high level of exported commodities produced in the mining sector. Mining was the largest generator of solid waste, mainly through tailings (Table B.2). Exports also contained twice as much fertilizer material and nutrients. The water pollution and water use contents were similar except for TDS which was larger in Personal Expenditures (12 and 5 tonnes respectively) and COD.

Discussion

Schocking the various final demand categories resulted in differences both in terms of economic and environmental impacts. Economic impacts were similar among categories except for the government category, which was smaller. In most cases, the export category followed by personal expenditures had the largest impact on ecological commodities. These results corroborate Forsund's finding in Norway (Forsund, 1985). The construction category, although having the smallest estimates for most of the ecological commodities, was the highest generator of airborne residuals. Other ecological commodity estimates were low and of a similar magnitude for the construction, government, and machinery and equipment categories.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Overview of the model and data

An economic-ecologic model has been constructed for the Canadian economy based on Victor's approach. Thirty-four ecological commodities, forming the environmental matrices, were integrated into the Statistics Canada I-O model modified by Thomassin and al. (1992b). This modified version, with its 12 agriculture sectors and 16 food processing sectors, is best suited for agricultural policy analysis. The economic matrices contain 178 commodities and 74 industries. The model estimates national erosion, pesticide and fertilizer use associated with specified economic activities. Other ecological commodities linked to the Canadian economy are: air, water, solid waste, and water use.

Pesticide and fertilizer use were indicators of potential environmental damage caused by these products to the land and water resources. These are the best national proxies given the very expensive alternative of estimating leaching potential regionally, and then aggregating them to the national level. Until a method is developed that can make these estimates at the national level, (similar to the USLE for erosion) with the necessary data sets made available[1], national economic analysis will have to rely on this type of proxy.

[1] This implies getting access to very disaggregated pesticide information now kept confidential.

Erosion was calculated on a polygon basis for the entire country and then aggregated to give national estimates of soil erosion by the agriculture sectors. Water use and air pollution data were estimated by Environment Canada and were fairly accurate. The solid and waterborne waste data sources are scattered and, at best, approximations of the Canadian situation. Estimates of these ecological commodities require improvement if an accurate environmental assessment is to be made[2]. Irrigation, pesticide, and fertilizer use are badly documented and would required major efforts to correct the situation. Perhaps the case of Manitoba's Crop Insurance body, which collects data on pesticide and fertilizer applications, is an example to be followed by other provinces.

5.2 Results

Two different scenarios were analyzed to show the usefulness of this model. In the first, the impact on both the economy and the environment of changes in the final demand for agricultural and food commodities was simulated. Each commodity's final demand was increased by $1 million and its impact compared to the other simulated results. The ten commodities studied yielded similar economic impacts, while their environmental impacts differed considerably. Beef, processed

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[2] As mentioned in chapter 3, Statistics Canada is building a data set on wastewater. No mention of similar efforts in the solid waste area has been found. Solid waste information is scarce because only 0.25% of Canadian waste is incinerated (the easiest way to collect information regarding proportion and extent of waste generation).

oilseed, cattle, and grains simulations had, in that order, the largest economic effects. Increases in the demand for wheat and oilseeds generated the largest amounts of particulate matter, COD, BOD5, and pesticide use. From this analysis, the trade-offs between agricultural policies aiming at specific products and the environment are highlighted.

The second scenario attempted to answer a different set of questions. The effects of a $1 million increase in each final demand category was compared. This scenario focussed on markets rather than products. The construction, exports and personal expenditure categories generated the largest industrial output. The exports category was the greatest generator of wastes and the largest user of free resources. This finding corroborates Forsund's results for Norway. The argument that Canada is exporting its soil cannot be denied by this analysis. Twice as much potential soil was delivered to the environment with the exports category as compared to the personal expenditures and twenty times more than the next highest estimate (construction). The impact of the personal expenditures category followed for most other ecological commodities. The construction category, with the highest simulated industrial output, generated lower or similar ecological waste and input use as other categories (with the exception of air pollution).

These two scenarios showed how this model can be used as a tool toward sustainable development and explicitly illustrates the economic and environmental trade-offs implied by different policies. This model can be used for other purposes in its original form or slightly modified. The economic and environmental effects of a pesticide ban, of meeting an emissions standard, of imposing different agricultural conservation practices of environmental effects of the NAFTA[3] can all be simulated with the model. In the first case, economic information (such as yield changes) and expected substitutions (cost of substitute pesticide) need to be determined and these changes incorporated into the model. Similar transformations would be required for the second scenario (emissions standard). The effects of various agricultural conservation practices can be introduced into the model by adding another industry (13th agriculture sector) with a different production function. Assume for example that Manitoba imposes a conservation practice. The Manitoba estimate can be removed from the national aggregate and put into a new industry. The erosion estimates have to be recalculated with a value for P (P was assumed equal to 1 in chapter 4). A similar process may be used to introduce intensive and extensive agriculture in the model. NAFTA environmental effects can be estimated through expected commodity demand changes. In the latter case, projected changes in production, where these changes will take place, can be used to estimate both macroeconomic and environmental effects. An activity model can also be constructed with different production practices and used to compare the direct plus indirect effects on both economic and environmental indicators.

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[3] NAFTA: North American Free Trade Agreement.

5.3 Limitations

The main assumptions underlying this model are: 1) industry technology and 2) fixed market shares. These assumptions have been widely discussed in the literature (for the economic component) and are reviewed in chapter 3. The main limitation relates to the poor environmental data that prevents the application of commodity technology in the model and weakens the reliability of most environmental estimates. The reliability and timeliness of data raises the issue of cost of information. The I-O model year (1986) and erosion estimates (1981) were both used because of economic considerations. More recent data were not available due to government departments' budget constraints. The next logical step, before any further data are collected, would be to study the potential gains in policy effectiveness and efficiency from further information. These benefits should be compared to the costs of collecting, manipulating and updating new or more accurate data. More specifically, the benefits from better coordination between government agencies collecting different pieces of information should be carefully examined[4].

5.4 Recommendations and conclusion

Residual dispersion in the ecosystem was not modelled. Thus the interdependency between the different services provided by the environment (ambient

[4] If in the first place different agencies could get together and establish their specific needs, the "right" information could be collected and processed to satisfy every agency's needs at less costs.

or medium), receptor of waste, supplier of resources and recreational services was not modelled. Future study should look at how the ecologic system could be modelled in a cost effective manner to fully integrate the model; by closing the economic-ecologic cycle. It would then be possible to model potential cost savings from varying targeted firms' compliance throughout the year to take advantage of changes in the environment assimilative capacity and economic seasonality.

The 1991 Statistics Canada's Census is expected to be digitized and introduced in the Land Resource Research Center's (LRRC) Generalized Soil Landscape Map (GSLM) system; the erosion coefficients could be replaced in the model[5]. The trend in erosion along with changes in crop mixes could provide insight to this field. This suggests that Agriculture Canada's dissagregated I-O model for 1981[6] could be updated to 1991. In the pesticide and fertilizer case, national estimates of the proportions reaching bodies of water must await scientific development (formulation of a model similar to the USLE for erosion estimates).

Further research on the impact on land values of increased soil erosion is needed. Other land deteriorations (salination, wind erosion and compaction) should also be incorporated into the system of national accounts (SNA). A review of the Journal of Soil and Water Conservation reveals that reduction in productivity due to

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5 The GSLM system requires a physical overlapping of Statistics Canada enumeration areas and LRRC polygon numbers. This process is costly and time consuming.

6 See Thomassin and Andisson (1987) and Thomassin et al. (1992b).

erosion is trivial; however, the less documented off-site costs of erosion have been found to be major, and should therefore be accounted for in the SNA. Some economic studies at the national, regional or provincial levels have been conducted in this area, such as those for Agriculture Canada by Thomassin and Andison (1987) and Thomassin et al. (1992a), and others.

This model can identify industrial sectors and/or final demands most responsible for particular types of residual discharge and resource use. With little modification it can project residuals, economic and environmental effects under various policy scenarios. The impacts on the economic and environmental system of different technological changes can also be predicted. The major advantage of the model is the extended agriculture sector and a rectangular accounting framework.

The next step in the valuation of ecological commodities is the modelling of these effects on ambient environmental quality. According to the definition of pollutants used, the utility obtained from a reduction of residual or the extent to which other uses are economically affected by the receptor services can be estimated. This next step will have to take into account the cost of acquiring and maintaining the data base for the model.

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APPENDIX A

LIST OF COMMODITIES AND INDUSTRIES

TABLE A.1

LIST OF INDUSTRIES

No.	INDUSTRY TITLE DISAGGREGATED FORM	MEDIUM LEVEL M
1	DAIRY FARMS	1
2	CATTLE FARMS	1
3	HOG FARMS	1
4	POULTRY FARMS	1
5	WHEAT FARMS	1
6	SMALL GRAIN FARMS	1
7	FIELD CROPS FARMS	1
8	FRUIT FARMS	1
9	VEGETABLE FARMS	1
10	MISCELLANEOUS SPECIALITIE FARMS	1
11	LIVESTOCK COMBINATION FARMS	1
12	OTHER COMBINATION FARMS	1
13	FISH & TRAPPING INDUSTRIES	2
14	LOGGING & FORESTRY INDUSTRIES	3
15	MINING	4
16	CRUDE PETROLEUM & NATURAL GAS	5
17	QUARRY & SAND PIT INDUSTRIES	6
18	SERVICE RELATED TO MINERAL EXTRACTION	7
19	MEAT & MEAT PRODUCTS (EXC. POULTRY)	8
20	POULTRY PRODUCTS	8
21	FISH PRODUCTS INDUSTRY	8
22	FRUIT AND VEGETABLE INDUSTRIES	8
23	DAIRY PRODUCTS INDUSTRIES	8
24	FEED INDUSTRY	8
25	VEGETABLE OIL MILLS (EXC. CORN OIL)	8
26	BISCUIT INDUSTRY	8
27	BREAD & OTHER BAKERY PRODUCTS IND.	8
28	CANE & BEET SUGAR INDUSTRY	8
29	MISC. FOOD PRODUCTS INDUSTRIES NEC.	8
30	SOFT DRINK INDUSTRY	9
31	DISTILLERY PRODUCTS INDUSTRY	9
32	BREWERY PRODUCTS INDUSTRY	9
33	WINE INDUSTRY	9
34	TOBACCO PRODUCTS INDUSTRIES	10
35	RUBBER PRODUCTS INDUSTRIES	11
36	PLASTIC INDUSTRIES	12
37	LEATHER INDUSTRIES	13
38	TEXTILE INDUSTRIES	14
39	CLOTHING INDUSTRIES	15
40	WOOD INDUSTRIES	16
41	FURNITURE INDUSTRIES	17
42	PAPER INDUSTRIES	18
43	PUBLISHING & PRINTING IND	19
44	PRIMARY STFEL INDUSTRIES	20
45	METAL FABRICATING INDUSTRIES	21
46	MACHINERY INDUSTRIES	22
47	TRANSPORTATION EQUIPMENT IND	23
48	ELECTRICAL PRODUCTS INDUSTRIES	24
49	NON-METALLIC MINERAL PROD IND	25
50	REFINED PETROLEUM & COAL PROD IND	26
51	CHEMICAL PRODUCTS INDUSTRIES	27
52	OTHER MANUFACTURED PROD IND	28
53	CONSTRUCTION INDUSTRIES	29
54	TRANSPORTATION INDUSTRIES	30
55	PIPELINES TRANSPORTATION INDUSTRIES	31
56	STORAGE & WAREHOUSING INDUSTRIES	32
57	COMMUNICATION INDUSTRIES	33
58	OTHER UTILITY INDUSTRIES	34
59	WHOLESALE TRADE INDUSTRIES	35
60	RETAIL TRADE INDUSTRIES	36
61	FINANCE & REAL ESTATE INDUSTRIES	37
62	INSURANCE INDUSTRIES	38
63	GOVERNT ROYALTIES ON NATL RESOURCES	39
64	OWNER OCCUPIED DWELLINGS	40
65	BUSINESS SERVICES	41
66	EDUCATIONAL SERVICE INDUSTRIES	42
67	HEALTH & SOCIAL SERVICES	43
68	ACCOMMODATION SERVICE INDUSTRIES	44
69	AMUSEMENT & RECREATION INDUSTRIES	45
70	PERSONAL SERVICES	46
71	OTHER SERVICES	47
72	SUPPLIES INDUSTRIES	48
73	TRAVEL & PROMOTION INDUSTRIES	49
74	TRANSPORTATION MARGINS	50

TABLE A.2

LIST OF COMMODITIES

No.	COMMODITY TITLE DISAGGREGATED FORM	MEDIUM LEVEL
1	CATTLE AND CALVES	2
2	SHEEP AND LAMBS	2
3	HOGS	2
4	POULTRY	2
5	OTHER LIVE ANIMALS	2
6	WHEAT,UNMILLED	1
7	BARLEY,OATS,CORN,GRAIN	1
8	MILK,WHOLE,FLUID,UNPROC	3
9	EGGS IN THC SHELL	3
10	HONEY AND BEFSWAX	3
11	NUTS,EDIBLE,NOT SHELLED	3
12	FRUITS,FRESH,EX.TROP.	3
13	VEGETABLES,FRESH	3
14	HAY,FORAGE,AND STRAW	3
15	SEEDS EX.OIL AND SEED	3
16	NURSERY STOCK&REL.MAT.	3
17	OIL SEEDS,NUTS & KERN.	3
18	HOPS INC. LUPULIN	3
19	TOBACCO.RAW	3
20	MINK SKINS,RANCH UND.	3
21	WOOL IN GREASE	3
22	SERV. INC. TO AGR.&FOR.	3
23	FORESTRY PRODUCTS	4
24	FISH LANDINGS	5
25	HUNTING & TRAPP. PROD.	6
26	IRON ORES & CONC.	7
27	OTHER METAL.ORES & CONC	8
28	COAL	9
29	CRUDE MINERAL OIL	10
30	NATURAL GAS	11
31	NON-METALLIC MINERALS	12
32	SERV. INC. TO MINING	13
33	BEEF,VEAL,MUTT&PORK,F&F	14
34	HORSE MEAT FRESH,FROZ	14
35	MEAT, CURED	14
36	MEAT PREP. NOT CANNED	14
37	MEAT PREP. CANNED	14
38	ANIM.OILS & FATS&LARD	14
39	MARGARINE, SHORT. & LIKE PROD	14
40	SAUSAGE CASINGS, NATURAL & SYNTH.	14
41	PRIMARY TANKAGE	14
42	FEEDS OF ANIMAL ORIGIN NES	14
43	HIDES AND SKINS, RAW, NES	14
44	ANIMAL MAT. FOR DRUGS & PERFUME	14
45	CUSTOM WORK MEAT & FOOD	14
46	POULTRY, FRESH, CHILLED, FROZEN	14
47	POULTRY, CANNED	14
48	MILK, WHOLE, FLUID, PROCESSED	15
49	CREAM, FRESH	15
50	BUTTER	15
51	CHEESE, CHEDDAR & PROCESSED	15
52	MILK EVAPORATED	15
53	ICE CREAM	15
54	OTHER DAIRY PRODUCTS	15
55	MUSTARD MAYONNAISE	15
56	FISH PRODUCTS	16
57	FRUIT, BERRIES, DRIED, CRYSTALLIZE	17
58	FRUITS & PREPARATIONS CANNED	17
59	VEGET.FROZEN, DRIED & PRESERVED	17
60	VEGETABLES & PREPARATIONS CANNED	17
61	SOUPS CANNED	17
62	INFANT & JUNIOR FOODS, CANNED	17
63	PICKLES, RELISHES, OTHER SAUCES	17
64	VINEGAR	17
65	OTHER FOOD PREPARATIONS	17
66	PRIMARY OR CONCENTRATED FEEDS	18
67	FEED FOR COMMERCIAL LIVESTOCK	18
68	FEEDS, GRAIN ORIGIN, N.E.S.	18
69	FEEDS OF VEGETABLE ORIGIN NES	18
70	PET FEEDS	18
71	WHEAT FLOUR	19
72	CEREAL & FLOUR OF OTHER CEREALS & VE	19
73	BREAKFAST CEREAL PRODUCTS	20
74	BISCUITS	20
75	BREAD & ROLLS	20
76	OTHER BAKERY PRODUCTS	20
77	COCOA & CHOCOLATE	22
78	NUTS,KERNELS & SEEDS PREPARED	22
79	CHOCOLATE CONFECTIONERY	22
80	OTHER CONFECTIONERY	22
81	BEET PULP	18
82	SUGAR	21
83	MOLASSES, SUGAR REFINERY PROD.	22
84	OILSEED, MEAL & CAKE	18
85	VEG. OILS & FATS, CRUDE	22
86	NITROGEN FUNCTION COMPOUNDS NES	67
87	MALT,MALT FLOUR&WHEAT STARCH	22
88	MAPLE SUGAR & SYRUP	22
89	PREPARED CAKE & SIMILAR MIXES	22
90	SOUPS,DRIED & SOUP MIXES & BASES	22
91	COFFEE, ROASTED, GROUND, PREPARED	22
92	TEA	22
93	POTATO CHIPS & SIMILAR PRODUCTS	22
94	MISC. FOOD NES	22
95	SOFTDRINK CONCENTRATES & SYRUPS	23
96	CARBONATED BEV.,SOFT DRINKS	23
97	ALCOHOLIC BEVERAGES DISTILLED	24
98	ALCOHOL, NATURAL, ETHYL	64
99	BREWERS'& DISTILLERS'GRAINS	18
100	ALE BEER, STOUT & PORTER	24
101	WINES	24
102	TOBACCO PROCESSED, UNMANUFACT.	24
103	CIGARETTES	26
104	TOBACCO MFG EX.CIGARETTES	26
105	TIRES & TUBES	27
106	OTHER RUBBER PRODUCTS	28
107	PLASTIC FABRICATED PRODUCTS	29
108	LEATHER & LEATHER PRODUCTS	30
109	YARNS & MAN MADE FIBRES	31
110	FABRICS	32
111	OTHER TEXTILE PRODUCTS	33

112	HOSIERY & KNITTED WEAR	34
113	CLOTHING & ACCESSORIES	35
114	LUMBER & TIMBER	36
115	VENEER AND PLYWOOD	37
116	OTHER WOOD FABRICATED MATERIALS	38
117	FURNITURE& FIXTURES	39
118	PULP	40
119	NEWSPRINT & OTHER PAPER STOCK	41
120	PAPER PRODUCTS	42
121	PRINTING & PUBLISHING	43
122	ADVERTISING, PRINT MEDIA	44
123	IRON & STEEL PRODUCTS	45
124	ALUMINUM PRODUCTS	46
125	COPPER & COPPER ALLOY PRODUCTS	47
126	NICKEL PRODUCTS	48
127	OTHER NON FERROUS METAL PRODUCTS	49
128	BOILERS, TANKS & PLATES	50
129	FABRICATED STRUCTURAL METAL PROD	51
130	OTHER METAL FABRICATED PRODUCTS	52
131	AGRICULTURAL MACHINERY	53
132	OTHER INDUSTRIAL MACHINERY	54
133	MOTOR VEHICLES	55
134	MOTOR VEHICLE PARTS	56
135	OTHER TRANSPORT EQUIPMENT	57
136	APPLIANCES & RECEIVERS, HOUSEHOLD	58
137	OTHER ELECTRICAL PRODUCTS	59
138	CEMENT & CONCRETE PRODUCTS	60
139	OTHER NON-METALLIC MINERAL PRODUCTS	61
140	GASOLINE & FUEL OIL	62
141	OTHER PETROLEUM & COAL PROD	63
142	INDUSTRIAL CHEMICALS	64
143	FERTILIZERS	65
144	PHARMACEUTICAL	66
145	OTHER CHEMICAL PRODUCTS	67
146	SCIENTIFIC EQUIPMENT	68
147	OTHER MANUFACTURED PRODUCTS	69
148	RESIDENTIAL CONSTRUCTION	70
149	NON-RESIDENTIAL CONSTRUCTION	71
150	REPAIR CONSTRUCTION	72
151	PIPELINE TRANSPORTATION	73
152	TRANSPORTATION & STORAGE	74
153	RADIO & TELEVISION BROADCASTING	75
154	TELEPHONE & TELEGRAPH	76
155	POSTAL SERVICES	77
156	ELECTRIC POWER	78
157	OTHER UTILITIES	79
158	WHOLESALE MARGINS	80
159	RETAIL MARGINS	81
160	IMPUTED RENT OWNER OCPD. DWEL	82
161	OTHER FINANCE, INS., REAL ESTATE	83
162	BUSINESS SERVICES	84
163	EDUCATION SERVICES	85
164	HEALTH SERVICES	86
165	AMUSEMENT & RECREATION SERVICES	87
166	ACCOMMODATION & FOOD SERVICES	88
167	OTHER PERSONAL & MISC. SERVICES	89
168	TRANSPORTATION MARGINS	90
169	OPERATING, OFFICE, LAB. & FOOD	91
170	TRAVEL, ADVERTISING & PROMOTION	92
171	NON-COMPETING IMPORTS	93
172	UNALLOCATED IMPORTS & EXPORTS	94
173	INDIRECT TAXES	95
174	SUBSIDIES	96
175	WAGES & SALARIES	97
176	SUPPLEMENTARY LABOUR INCOME	98
177	NET INCOME,UNINC. BUSINESS	99
178	OTHER OPERATING SURPLUS	100

APPENDIX B

ENVIRONMENT MATRICES

Table B.1 Water Use In Canada, by Industry, 1986

	Industry	Total Intake	Total Recycled Water	Gross Water Use (Million m3)	Total Discharge	Total Treated Discharge
1	DAIRY FARMS *	244.86	0.00	0.00	0.00	0.00
2	CATTLE FARMS	596.35	0.00	0.00	0.00	0.00
3	HOG FARMS	88.86	0.00	0.00	0.00	0.00
4	POULTRY FARMS	23 20	0.00	0.00	0.00	0 00
5	WHEAT FARMS	647.99	0.00	0.00	0.00	0.00
6	SM. GRAIN FARMS	844.78	0.00	0.00	0.00	0 00
7	FIELD CROPS FARMS	325.65	0.00	0.00	0.00	0.00
8	FRUIT FARMS	8.93	0 00	0 00	0.00	0.00
9	LIVESTOCK COMB.	325.50	0.00	0.00	0.00	0 00
10	MISC.SPECIALITY	394.18	0 00	0.00	0 00	0.00
11	VEGETABLE FARMS	77.23	0.00	0.00	0.00	0.00
12	OTHER COMB	84.63	0 00	0 00	0.00	0.00
13	FISH & TRAPPING	0 00	0.00	0.00	0.00	0.00
14	LOGGIN & FORESTRY	0.00	0.00	0 00	0.00	0.00
15	MINING	507 35	1163.77	1671 12	690.95	390.27
16	PETROL & NAT GAS	86.02	873 45	959.47	43.1	24.2
17	QUARRY & SAND	0 00	0.00	0.00	0 00	0.00
18	SERVICE, MINERAL EXT	0.00	0 00	0.00	0.00	0 00
19	MEAT & MEAT PROD	30.28	16.27	46 55	26.96	19.76
20	POULTRY PROD	251 04	2.67	253.71	248.96	10.99
21	FISH PRODUCTS	90.04	0.7	90.74	88 58	8 51
22	FRUIT & VEGETABLE	34.80	21.64	56 43	29.21	21.18
23	DAIRY PRODUCTS	29.63	10	39 63	27.73	5 74
24	FEED	0 00	0.00	0.00	0.00	0.00
25	VEGETABLE OIL	36 43	20.58	57.01	36.13	1.18
26	BISCUIT	0.00	0.00	0.00	0.00	0.00
27	BREAD & OTHER	3 43	0.18	3.61	2.16	0.15
28	CANE &BEET SUGAR	26.11	7 03	33.15	25.25	0.49
29	MISC FOOD PROD.	62.17	69.25	131.41	55.48	14.12

Table B.1 Continued

	Industry	Total Intake	Total Recycled Water	Gross Water Use (Million m3)	Total Discharge	Total Treated Discharge
30	SOFT DRINK	8.51	2.32	10.84	5 39	2 46
31	DISTILLERY PROD.	20.33	19.5	39.73	16 87	1.88
32	BREWERY PRODUCT	32.35	7.78	40.13	27 11	1.48
33	WINE	1.53	77.22	78.75	1.15	0 98
34	TOBACCO PRODUCT	0.00	0 00	0.00	0.00	0 00
35	RUBBER PRODUCT	23.31	66.69	90	20.96	0.65
36	PLASTIC	29.93	66.37	96 3	27 31	3 34
37	LEATHER	0.00	0.00	0 00	0 00	0.00
38	TEXTILE	107.61	41 64	149 25	104 17	17.63
39	CLOTHING	0.00	0 00	0.00	0.00	0.00
40	WOOD	56.02	7.97	63.99	54 05	6.18
41	FURNITURE	0.00	0 00	0.00	0 00	0 00
42	PAPER	3035.12	2987.74	6022 85	2834 24	2186.65
43	PUBLISHING&PRINTING	0 00	0.00	0.00	0 00	0 00
44	PRIMARY STEEL	1718 18	1349 86	3068 03	1675 26	603 87
45	METAL FABRICATING	25 18	113 56	138 73	24 23	11 77
46	MACHINERY	0.00	0 00	0 00	0 00	0 00
47	TRANSPORTATION E	117 30	236 94	354 24	113.58	44 33
48	ELECTRICAL PROD.	0 00	0 00	0 00	0 00	0 00
49	NONMETALLIC MINERAL	89 67	69.9	159 57	71.63	20.6
50	REFINED PETROL.	487 15	1068 12	1555 27	453 66	752.38
51	CHEMICAL PROD	1673.87	1557.66	3231 54	1614.63	141 52
52	OTHER MANUFACT	0.00	0.00	0 00	0.00	0 00
53	CONSTRUCTION	0 00	0.00	0 00	0 00	0 00
54	TRANSPORTATION	0.12	0 00	0 12	0.10	0 07
55	PIPELINES TRANSP	0.00	0 00	0.00	0.00	0.00
56	STORAGE	0 00	0 00	0 00	0 00	0.00
57	COMMUNICATION	0.06	0 00	0 06	0 05	0.03
58	OTHER UTILITY	24968.13	3775 69	24973 13	24701 96	15759.85
59	WHOLESALE TRADE	0 14	0 00	0.14	0 12	0 08
60	RETAIL TRADE	0.36	0 00	0.36	0.30	0 19

Table B.1 Continued

Industry	Total Intake	Total Recycled Water	Gross Water Use (Million m3)	Total Discharge	Total Treated Discharge
61 FINANCE&REAL ESTATE	0.09	0.00	0.09	0.08	0.05
62 INSURANCE	0.07	0.00	0.07	0.06	0.04
63 GOVERNMENT ROY.	0.00	0.00	0.00	0.00	0.00
64 DWELLINGS	0.00	0.00	0.00	0.00	0.00
65 BUSINESS SERVICES	0.12	0.00	0.12	0.11	0.07
66 EDUCATIONAL SERV.	0.22	0.00	0.22	0.19	0 12
67 HEALTH & SOCIAL	0.25	0.00	0.25	0.22	0.14
68 ACCOMMODATION	0.16	0.00	0.16	0.14	0.09
69 AMUSEMENT & REC.	0.03	0.00	0.03	0.03	0.02
70 PERSONAL SERVICES	0.03	0.00	0.03	0.03	0.02
71 OTHER SERVICES	0.06	0.00	0.06	0.05	0.03
72 SUPPLIES	0.00	0.00	0.00	0.00	0.00
73 TRAVEL & PROMOTION	0.00	0.00	0.00	0.00	0.00
74 TRANSP. MARGINS	0.00	0.00	0.00	0.00	0.00
TOTAL	37,215	13,635	43,417	33,022	20,053
FINAL DEMAND					
1 PUBLIC ADM.	0.18	0.00	0 18	0.153504	0.10
2 HOUSEHOLD	3394.58	0.00	3394.58	0.00	0 00

Source (Ind 13-74): Environment Canada. 1990a Industrial Water Use Survey Tables Vol 1-2.

* Water Use by Agriculture Industries (1-12) = Irrigation plus Watering, See Table 3 3

Table B.2 Solid Wastes Generated by Canadian Industries, 1986

	Industry	Solid Waste	Animal Solid Waste (tonne)	Animal Liquid Waste	Reuse	Remaining Waste
1	DAIRY FARMS	0	17,827,622	9,353,429	0	0
2	CATTLE FARMS	0	65,279,868	34,076,236	0	0
3	HOG FARMS	0	9,301,738	7,189,960	0	0
4	POULTRY FARMS	0	1,744,637	1,305,902	0	0
5	WHEAT FARMS	0	4,132,458	2,163,411	0	0
6	SMALL GRAIN FARMS	0	10,626,590	5,611,413	0	0
7	FEILD CROPS FARMS	0	281,759	152,261	0	0
8	FRUIT FARMS	0	56,464	30,705	0	0
9	LIVESTOCK COMB	0	61,618	34,440	0	0
10	MISC.SPECIALITY	0	368,394	259,253	0	0
11	VWEGETABLE FARMS	0	4,754,128	2,729,423	0	0
12	OTHER COMB	0	1,803,384	961,429	0	0
13	FISH & TRAPPING	0	0	0	0	0
14	LOGGIN & FORESTRY	0	0	0	0	0
15	MINING	600,000,000	0	0	0	600,000,000
16	PETROLEUM & NAT G	0	0	0	0	0
17	QUARRY & SAND PIT	0	0	0	0	0
18	SERVICE, MINERAL EX	0	0	0	0	0
19	MEAT & MEAT PRODU	214,856	0	0	0	214,856
20	POULTRY PRODUCTS	80,535	0	0	0	80,535
21	FISH PRODUCTS	0	0	0	0	0
22	FRUIT & VEGETABLE	82,566	0	0	0	82,566
23	DAIRY PRODUCTS	0	0	0	0	0
24	FEED	0	0	0	0	0
25	VEGETABLE OIL	19,591	0	0	0	19,591
26	BISCUIT	0	0	0	0	0
27	BREAD&OTHER BAKER	0	0	0	0	0
28	CANE &BEET SUGAR	82,404	0	0	0	82,404
29	MISC FOOD PROD	16,048	0	0	0	16,048
30	SOFT DRINK	0	0	0	0	0
31	DISTILLERY PRODUCT	0	0	0	0	0
32	BREWERY PRODUCT	0	0	0	0	0
33	WINE	0	0	0	0	0
34	TOBACCO PRODUCT	0	0	0	0	0
35	RUBBER PRODUCT	31,000	0	0	0	31,000
36	PLASTIC	0	0	0	0	0
37	LEATHER	3,100	0	0	0	3,100
38	TEXTILE	3,100	0	0	0	3,100
39	CLOTHING	0	0	0	0	0

Table B.2 Continued

Industry	Solid Waste	Animal Solid Waste (tonne)	Animal Liquid Waste	Reuse	Remaining Waste
40 WOOD	30,000,000	0	0	30,000,000	0
41 FURNITURE	9,300	0	0	0	9,300
42 PAPER	682,000	0	0	0	682,000
43 PUBLISHING&PRINTING	0	0	0	0	0
44 PRIMARY STEEL	5,332,000	0	0	0	5,332,000
45 METAL FABRICATING	24,800	0	0	0	24,800
46 MACHINERY	15,500	0	0	0	1,500
47 TRANSPORTATION E	40,300	0	0	0	40,300
48 ELECTRICAL PRODUCT	3,100	0	0	0	3,100
49 NONMETALLIC MINERA	1,457,000	0	0	0	1,457,000
50 REFINED PETROLEUM	93,000	0	0	0	93,000
51 CHEMICAL PRODUCT	18,004,800	0	0	0	18,004,800
52 OTHER MANUFACTURE	0	0	0	0	0
53 CONSTRUCTION	0	0	0	0	0
54 TRANSPORTATION	794,450	0	0	0	794,450
55 PIPELINES TRANSP	0	0	0	0	0
56 STORAGE	22,110	0	0	0	22,110
57 COMMUNICATION	405,270	0	0	0	405,270
58 OTHER UTILITY	5,011,110	0	0	200,000	4,811,110
59 WHOLESALE TRADE	912,310	0	0	0	912,310
60 RETAIL TRADE	2,311,370	0	0	0	2,311,370
61 FINANCE&REAL ESTAT	485,240	0	0	0	485,240
62 INSURANCE	485,850	0	0	0	485,850
63 GOVERNMENT ROY	0	0	0	0	0
64 DWELLINGS	0	0	0	0	0
65 BUSINESS SERVICES	809,250	0	0	0	809,250
66 EDUCATIONAL SERVIC	1,439,450	0	0	0	1,439,450
67 HEALTH & SOCIAL	1,641,350	0	0	0	1,641,350
68 ACCOMMODATION	1,071,270	0	0	0	1,071,270
69 AMUSEMENT & REC	213,780	0	0	0	213,780
70 PERSONAL SERVICES	171,390	0	0	0	171,390
71 OTHER SERVICES	415,130	0	0	0	415,130
72 SUPPLIES	0	0	0	0	0
73 TRAVEL & PROMOTION	0	0	0	0	0
74 TRANSPORATION MAR	0	0	0	0	0
TOTAL	72,384,330	116,238,662	63,867,863	30,200,000	42,170,330
Final demand					
HOUSEHOLD	12,702	0	0	32	12,670
GOVERNMENT	1,182,000	0	0	2,955	1,179,045

Table B.3 Airborne Wastes Generated by Canadian Industries, 1986

	Industry	NOx	VOC	THC (tonne)	SO2	CO	Part
1	DAIRY FARMS	0	0	0	0	0	196,674
2	CATTLE FARMS	0	0	0	0	0	570,728
3	HOG FARMS	0	0	0	0	0	187,050
4	POULTRY FARMS	0	0	0	0	0	26,544
5	WHEAT FARMS	0	0	0	0	0	2,518,486
6	SMALL GRAIN FARMS	0	0	0	0	0	1,917,613
7	FIELD CROPS FARMS	0	0	0	0	0	65,758
8	FRUIT FARMS	0	0	0	0	0	2,485
9	LIVESTOCK COMB	0	0	0	0	0	29,861
10	MISC.SPECIALITY	5	3	3	0	9	10,022
11	VEGETABLE FARMS	0	0	0	0	0	175,589
12	OTHER COMB	0	0	0	0	0	86,945
13	FISH & TRAPPING	0	0	0	0	0	0
14	LOGGIN & FORESTRY	59,974	304,606	384,679	323	2,695,726	412,121
15	MINING	3,871	39	261,630	119,740	47,824	274,504
16	PETROLEUM & NAT G	174,541	21,453	79,475	460,055	31,246	5,096
17	QUARRY & SAND	102	0	0	0	68	65,312
18	SERVICE, MINERAL EX	264	10	10	14,108	10	264,714
19	MEAT & MEAT PROD	261	6	6	251	19	56
20	POULTRY PROD	97	2	2	93	7	21
21	FISH PRODUCTS	120	6	6	7	21	37
22	FRUIT & VEGETABLE	14	0	0	0	3	11
23	DAIRY PRODUCTS	668	9	9	58	49	139
24	FEED	387	2	2	419	17	1,411
25	VEGETABLE OIL	217	760	760	211	12	185
26	BISCUIT	0	0	0	0	0	0
27	BREAD & OTHER	33	2,831	2,831	6	2	3
28	CANE &BEET SUGAR	0	0	0	0	0	0
29	MISC FOOD PROD	518	395	378	286	33	362
30	SOFT DRINK	5	0	0	0	1	0
31	DISTILLERY PROD	344	769	769	120	28	139
32	BREWERY PRODUCT	779	46	46	208	52	156
33	WINE	2	0	0	0	0	0
34	TOBACCO PRODUCT	17	1	1	23	1	317
35	RUBBER PRODUCT	923	690	690	13	90	33,619
36	PLASTIC	386	2,698	2,698	185	20	118
37	LEATHER	170	57	57	2	34	0

Table B.3 Continued

		NOx	VOC	THC	SO2	CO	Part
				(tonne)			
38	TEXTILE	1,254	1,619	1,853	7,386	4,482	304
39	CLOTHING	0	0	0	0	0	0
40	WOOD	4,958	37,812	37,901	473	430,032	114,476
41	FURNITURE	0	0	0	0	0	0
42	PAPER	38,793	16,189	16,189	103,032	100,721	152,714
43	PUBLISHING&PRINTIN	66	243	243	27	5	5
44	PRIMARY STEEL	26,721	10,931	11,698	1,825,939	442,720	95,482
45	METAL FABRICATING	622	1,480	1,480	2,560	53	425
46	MACHINERY	200	772	772	105	13	161
47	TRANSPORTATION E	2,004	3,547	3,547	1,816	502	1,799
48	ELECTRICAL PROD	690	136	136	3,388	3,592	355
49	NONMETALLIC MINER	21,589	2,372	2,375	49,161	53,910	55,702
50	REFINED PETROL	36,091	47,970	77,035	120,472	232,566	64,956
51	CHEMICAL PROD	25,170	47,583	52,452	20,941	22,837	17,218
52	OTHER MANUFACT.	66	658	658	8	115	553
53	CONSTRUCTION	0	152,315	2,275,622	0	0	21,768,480
54	TRANSPORTATION	689,173	131,011	141,086	77,388	755,629	21,176,404
55	PIPELINES TRANSP	0	0	0	0	0	0
56	STORAGE	0	0	0	0	0	78,894
57	COMMUNICATION	0	0	0	0	0	0
58	OTHER UTILITY	249,321	8,473	31,967	738,680	68,458	269,631
59	WHOLESALE TRADE	48,468	117,250	126,798	86,677	15,832	25,027
60	RETAIL TRADE	80	295,406	295,406	113	4	17
61	FINANCE&REAL ESTAT	28	1	1	78	1	4
62	INSURANCE	12	0	0	17	0	3
63	GOVERNMENT ROY.	94	2	2	57	7	13
64	DWELLINGS	0	0	0	0	0	0
65	BUSINESS SERVICES	60	21	21	46	132	57
66	EDUCATIONAL SERVIC	595	23	23	1,093	52	98
67	HEALTH & SOCIAL	1,160	49	49	1,500	128	183
68	ACCOMMODATION	51	1	1	92	2	9
69	AMUSEMENT & REC	3	0	0	0	1	1
70	PERSONAL SERVICES	36	14,131	14,131	74	1	5
71	OTHER SERVICES	1,564	4,214	4,216	6,272	756	5,425
72	SUPPLIES	0	0	0	0	0	0
73	TRAVEL & PROMOTIO	0	0	0	0	0	0
74	TRANSPORATION MAR	0	0	0	0	0	0

Table C.3 Continued

	NOx	VOC	THC (tonne)	SO2	CO	Part
FINAL DEMAND						
GOVERNMENT	372	91	91	652	130	390
GAS-OIL-COAL	66	1	1	132	2	5
TRANSPORTATION-GAS	547,063	725,053	809,226	17,365	6,408,786	1,160,521
TOBACCO (SMOKING)	0	0	0	0	1,880	4,699
FUEL COMBUSTION	37,496	2,663	5,270	31,666	16,448	4,562
FUELWOOD COMB.	3,899	107,866	108	3,746	624,212	155,919

Table B.4 Waterborne Wastes Generated by Canadian Industries, 1986

	WASTE VOLUME (10^3 M3)	BOD5 (tonne)	COD (tonne)	SS (tonne)	TDS (tonne)	OIL (tonne)	N (tonne)
1 DAIRY FARMS	0	0	0	0	0	0	0
2 CATTLE FARMS	0	0	0	0	0	0	0
3 HOG FARMS	0	0	0	0	0	0	0
4 POULTRY FARMS	0	0	0	0	0	0	0
5 WHEAT FARMS	0	0	0	0	0	0	0
6 SMALL GRAIN FARMS	0	0	0	0	0	0	0
7 FEILD CROPS FARMS	0	0	0	0	0	0	0
8 FRUIT FARMS	0	0	0	0	0	0	0
9 LIVESTOCK COMB	0	0	0	0	0	0	0
10 MISC SPECIALITY	0	0	0	0	0	0	0
11 VEGETABLE FARMS	0	0	0	0	0	0	0
12 OTHER COMB	0	0	0	0	0	0	0
13 FISH & TRAPPING	0	0	0	0	0	0	0
14 LOGGIN	0	0	0	0	0	0	0
15 MINING	0	0	0	8,284	0	0	0
16 CRUDE PETROL	0	0	0	0	0	0	0
17 QUARRY & SAND PIT I	0	0	0	0	0	0	0
18 SERVICES	0	0	0	0	0	0	0
19 MEAT & MEAT PROD	24,290	5,543	0	3,579	0	8,485	5,274
20 POULTRY PROD	23,385	171	13,969	183	9,354	3,492	0
21 FISH PRODUCT	0	0	0	0	0	0	0
22 FRUIT & VEGETABLE I	7,224	2,898	0	997	0	0	0

Table B.4 Continued

	WASTE VOLUME (10^3 M3)	BOD5 (tonne)	COD (tonne)	SS (tonne)	TDS (tonne)	OIL (tonne)	N (tonne)
23 DAIRY PROD	11,676	3,160	0	1,312	16,055	0	0
24 FEED	0	0	0	0	0	0	0
25 VEGETABLE OIL IND	8,723	20	3,186	25	133,801	986	0
26 BISCUIT	0	0	0	0	0	0	0
27 BREAD & OTHER	752	36	0	52	0	0	0
28 CANE & BEET SUG	18,249	0	0	0	0	0	0
29 MISC FOOD PROD	10,821	5,137	2,709	202	106,061	5,861	0
30 SOFT DRINK	27,004	1,996	0	1,038	0	0	0
31 DISTILLERY PROD	9,126	2,489	0	2,908	55,772	0	0
32 BREWERY PROD	31,846	309	0	529	0	0	0
33 WINE	592	10	0	0	0	0	0
34 TOBACCO PROD.	0	0	0	0	0	0	0
35 RUBBER PROD	0	0	0	0	0	0	0
36 PLASTIC	0	0	0	0	0	0	0
37 LEATHER	2,631	0	13,053	0	17,759	1,012	759
38 TEXTILE	2,873	134	2,329	92	1,212	0	0
39 CLOTHING	0	0	0	0	0	0	0
40 WOOD	1,844	0	3,284	18	2,294	0	108
41 FURNITURE	0	0	0	0	0	0	0
42 PAPER IND	795,792	157,431	0	122,831	1,797,872	0	0
43 PUBLISHING & PR	0	0	0	0	0	0	0
44 PRIMARY STEEL	0	0	74	13	56	12	0
45 METAL FABRICATING	0	0	0	0	0	0	0

Table B.4 Continued

		WASTE VOLUME (10^3 M3)	BOD5 (tonne)	COD (tonne)	SS (tonne)	TDS (tonne)	OIL (tonne)	N (tonne)
46	MACHINERY	0	0	0	0	0	0	0
47	TRANSPORTATION	0	0	0	0	0	0	0
48	ELECTRICAL PROD.	0	0	0	0	0	0	0
49	NON-METAL. MINER.	55,820	0	0	0	3,284	0	0
50	REFINED PETROL.	3,416,776	2,197,000	4,288,099	406,899	0	716,186	298,357
51	CHEMICAL PROD	5,956	235	803	15	61	14,692	175
52	OTHER MANUFACT.	0	0	0	0	0	0	0
53	CONSTRUCTION	0	0	0	0	0	0	0
54	TRANSPORTATION	0	0	0	0	0	0	0
55	PIPELINES TRANSP.	0	0	0	0	0	0	0
56	STORAGE & WARE.	0	0	0	0	0	0	0
57	COMMUNICATION	0	0	0	0	0	0	0
58	OTHER UTILITY	863,685	320,422	715,664	323,164	589,775	0	58,756
59	WHOLESALE TRADE	0	0	0	0	0	0	0
60	RETAIL TRADE	0	0	0	0	0	0	0
61	FINANCE &REAL EST.	0	0	0	0	0	0	0
62	INSURANCE	0	0	0	0	0	0	0
63	GOVERNMENT ROY.	0	0	0	0	0	0	0
64	OWNER OCCUPIED	0	0	0	0	0	0	0
65	BUSINESS SERVICES	0	0	0	0	0	0	0

Table B.4 Continued

	WASTE VOLUME (10^3 M3)	BOD5 (tonne)	COD (tonne)	SS (tonne)	TDS (tonne)	OIL (tonne)	N (tonne)
66 EDUCATIONAL SER	0	0	0	0	0	0	0
67 SOCIAL SERVICES	0	0	0	0	0	0	0
68 ACCOMMODATION	0	0	0	0	0	0	0
69 AMUSEMENT & RE	0	0	0	0	0	0	0
70 PERSONAL SERVIC	0	0	0	0	0	0	0
71 OTHER SERVICES	0	0	0	0	0	0	0
72 SUPPLIES	0	0	0	0	0	0	0
73 TRAVEL & PROMO.	0	0	0	0	0	0	0
74 TRANSP. MARGINS	0	0	0	0	0	0	0
Total	3.97E+10	6.82E+08	5.24E+09	8.81E+10	3.39E+10	4.70E+07	4.13E+05
Final Demand	225,188	1,553,795	3,603,003	3,603,003	0	0	0

Table B.5 Potential Erosion and Delivered Sediments by Farm Type

Farm type	Erosion (tonne)	Delivered
Dairy	7,993,792	1,331,890
Cattle	12,459,949	839,852
Pigs	4,030,668	365,597
Poultry	839,948	79,255
Wheat	80,919,819	4,455,599
SGrain	64,083,278	4,323,288
Other Field	2,023,328	232,687
Fruit	160,283	31,570
Vegetable	1,269,928	328,240
Misc.	341,818	53,180
Livestock	3,578,810	274,686
Other	2 752,700	225,343
Total	180,454,321	12,541,187

Table B.6 Fertilizer Use by Farm Type

	Quantity	Nitrogen (tonne)	Phosphorous	Potash
Dairy	344,452	96,304	55,504	31,521
Cattle	529,628	148,076	85,342	48,467
Pigs	153,463	42,906	24,728	14,044
Poultry	23,965	6,700	3,862	2,193
Wheat	1,177,024	329,078	189,661	107,711
SGrain	1,814,490	507,304	292,380	166,046
Other Field	78,310	21,894	12,619	7,166
Fruit	12,330	3,447	1,987	1,128
Vegetable	24,296	6,793	3,915	2,223
Misc.	18,284	5,112	2,946	1,673
Livestock	130,425	36,465	21,016	11,935
Other	79,299	22,171	12,778	7,257
Total	4,385,967	1,226,251	706,739	401,365

Table B.7 Pesticide Use by Farm Type

Farm Type	Phenoxy	Dicamba/ Bromoxynil	Triazine	Other Herbicides (Kg AI)	Fungicides	Captan	Insecticides	Other AI
Dairy	133,317	96,843	337,715	1,032,126	54,237	2,612	75,610	64,000
Cattle	470,948	233,526	124,319	1,195,618	44,912	2,337	155,762	168,150
Pigs	147,114	99,164	256,271	839,161	39,709	2,061	85,790	65,916
Poultry	20,489	15,037	50,007	152,915	36,857	1,971	17,781	10,240
Wheat	2,526,128	1,240,201	92,521	4,129,916	5,233	136	1,205,499	958,318
SGrain	1,720,948	926,803	975,757	5,448,397	87,374	2,091	742,944	733,416
Other Field	41,219	26,615	28,968	229,503	86,599	1,230	115,221	79,166
Fruit	4,816	4,239	12,163	60,634	1,918,323	131,237	211,577	23,092
Vegetable	17,885	9,761	43,848	691,954	542,630	4,710	88,474	24,783
Misc.	7,785	4,268	6,253	60,501	88,265	4,433	17,810	7,295
Livestock	152,864	80,515	55,733	412,308	20,438	876	73,565	63,289
Other	76,445	41,571	46,206	305,673	184,544	9,039	66,967	41,334
Total	5,319,958	2,778,543	2,029,759	14,558,707	3,109,120	162,784	2,857,000	2,239,000

APPENDIX C

ALLOCATION FACTORS FOR THE TWELVE FARM TYPES

Table C 1 Distribution Factor to Allocate Ecological Commodities to Farm Type

Table C 1 1 **Area Cultivated by Farm Type, 1986**

		Dairy	Cattle	Hogs	Poultry	Wheat	Small Grain	Field Crop	Fruit	Vegetable	Miscellanous Specialties	Livestock Combination	Other Combination
1	Wheats	0 89%	6 81%	1 63%	0 32%	60 16%	25 97%	0 47%	0 01%	0 09%	0 06%	2 32%	1 26%
2	Oats	10 45%	33 26%	1 96%	0 26%	9 55%	34 40%	1 20%	0 10%	0 14%	0 95%	5 22%	2 47%
3	Barley	8 06%	14 62%	6 09%	0 42%	13 34%	51 71%	1 02%	0 03%	0 11%	0 *9%	4 77%	1 64%
4	Corn	18 78%	5 89%	14 19%	2 77%	0 05%	50 66%	1 07%	0 13%	1 20%	0 24%	2 78%	2 24%
5	Vegetables	2 35%	1 49%	1 43%	1 17%	0 10%	8 04%	5 06%	2 53%	66 27%	3 35%	0 99%	7 19%
6	Potatoes	1 21%	0 65%	0 67%	0 15%	0 12%	1 11%	87 11%	0 18%	2 44%	0 35%	1 78%	4 22%
7	Fruit	1 57%	1 43%	1 24%	1 21%	0 06%	1 17%	0 75%	80 81%	2 89%	2 73%	0 53%	5 59%
8	Small fruit	1 84%	1 70%	1 25%	1 24%	0 15%	1 55%	1 28%	74 33%	3 95%	3 24%	0 48%	8 99%
9	Tree fruit	1 33%	1 19%	1 23%	1 18%	0 02%	0 85%	0 30%	86 36%	1 99%	2 29%	0 58%	2 68%

Table B 1 2 **Number of Animal by Farm Type, 1986**

		Dairy	Cattle	Hogs	Poultry	Wheat	Small Grain	Field Crop	Fruit	Vegetable	Miscellanous Specialties	Livestock Combination	Other Combination
10	Hogs	2 51%	3 46%	80 19%	1 62%	0 40%	2 70%	0 18%	0 02%	0 06%	0 05%	8 05%	0 76%
11	Poultry	2 24%	2 92%	4 12%	78 38%	1 19%	3 08%	0 05%	0 45%	0 32%	0 49%	3 55%	3 21%
12	Dairy	23 13%	55 86%	1 63%	0 43%	3 90%	9 55%	0 26%	0 06%	0 05%	0 21%	3 41%	1 53%

Table B 1 3 **Imputed Sales by Farm Type, 1986**

		Dairy	Cattle	Hogs	Poultry	Wheat	Small Grain	Field Crop	Fruit	Vegetable	Miscellanous Specialties	Livestock Combination	Other Combination
13	Milk	93 66%	0 70%	1 34%	0 38%	0 07%	0 66%	0 11%	0 00%	0 02%	0 02%	2 71%	0 30%
14	Cattle	14 35%	64 27%	1 83%	0 50%	3 65%	9 47%	0 26%	0 06%	0 05%	0 21%	3 72%	1 59%
15	Pigs	2 52%	3 43%	80 47%	1 63%	0 40%	2 59%	0 19%	0 02%	0 06%	0 05%	7 91%	0 73%
16	Sheep	4 70%	15 56%	2 64%	0 94%	1 53%	5 89%	0 14%	0 40%	0 26%	53 39%	13 45%	1 07%
17	Other Livestock	1 65%	10 09%	0 80%	0 20%	1 42%	3 91%	0 13%	0 26%	0 10%	75 64%	4 96%	0 84%
18	Eggs	1 14%	1 30%	3 37%	84 37%	0 30%	1 43%	0 05%	0 13%	0 12%	0 18%	7 11%	0 51%
19	Chicken	0 41%	0 46%	1 63%	95 09%	0 11%	0 28%	0 00%	0 12%	0 04%	0 08%	1 70%	0 07%
20	Mixed Grain	23 04%	26 37%	1 02%	0 28%	1 50%	36 27%	2 33%	0 20%	0 25%	1 26%	4 73%	2 75%
21	Oilseed	1 19%	3 60%	2 40%	0 47%	11 93%	75 80%	0 76%	0 04%	0 64%	0 09%	1 62%	1 26%
22	Hay etc	23 42%	45 83%	1 50%	0 47%	4 57%	14 41%	4 16%	0 04%	0 08%	1 62%	2 57%	1 31%
23	Forage used	0 71%	2 08%	0 28%	0 07%	2 27%	19 59%	24 74%	0 00%	44 33%	0 21%	0 49%	5 23%
24	Other field crop	1 42%	4 41%	4 18%	0 59%	18 12%	59 84%	4 36%	0 02%	0 50%	0 08%	1 86%	4 58%
25	Tobacco	0 26%	0 20%	0 39%	0 31%	0 00%	2 28%	94 05%	0 06%	0 39%	0 11%	0 17%	1 77%
26	Other spec cro	0 09%	0 06%	0 05%	0 11%	0 02%	0 16%	0 17%	0 10%	0 69%	97 63%	0 09%	0 83%
27	Nursery	0 04%	0 11%	0 11%	0 13%	0 03%	0 19%	0 13%	1 13%	0 30%	96 30%	0 29%	1 25%

Source Statistics Canada (1987b,1990a), Census of Agriculture and Special Tabulation

Table C.2 Distribution Factor for the Environmental Commodities

** The numbers refer to Table C 1 distribution factors

SOLID WASTES	Allocation Factor
Livestock manure	14 and 15
Swine manure	10
Sheep Manure	16
Poultry manure	18 and 19
WATER USE	
Livestock watering	
Poultry	11
Swine	10
Sheep	16
Goats	16
Calves	15
Livestock	17
Horse	12
Dairy and cattle	12
IRRIGATION	
Wheat	1
Oats	2
Barley	3
Oilseed	21
Peas	5
Mixed Grain	20
Hay & Silage	22
Potatoes	6
Sugar Beet	24
Rye	20
Fruit	7
Vegetables	5
Tobacco	25
Nursery and sod	27
Greehouse	26
Forage	23
Corn	4
Other	26
Summerfallow	1
Pasture	23
Beans	5
Greefed	23
Legume & Pulse	5

EROSION **Western Canada**	Allocation Factor
Summerfallow	1
Spring Grains	weighted 1,2,3
Co,n & Sunflw	weighed 4 and 26
Flax & Canola	21
Peas & Beans	5
Winter Grains	1
Sugar Beets	24
Corn for Silage	13
Potatoes	6
Tame Hay	22
EROSION **Eastern Canada**	
Nursery	27
Tree Fruit	9
Potatoes	6
Sugar Beets	21
Small Fruit	8
Vegetables	5
Grain Corn	4
Beans	5
Silage Corn	13
Alfalfa	22
Other Hay	22
Summerfallow	Weighted 1,2,3
Grapes	8
Fall Grains	1
Spring Grains	
Sod	27
Root Crops	10 and 12
Tobacco	25
AIR	
Greenhouse	26
Animal Wastes	10 and 12
Pesticides	1,2,3,4,5,6
Other services	1,2,3,4,5,6
Agricultural wind	
Erosion and tilling	1,2,3,4,5,6
Mushroom production	26

APPENDIX D

DERIVATION OF THE ENVIRONMENTAL MATRICES

D.1 Erosion estimation

The risk of water erosion is estimated with the Universal Soil Loss Equation (USLE)(see Equation 3.16). Recall that A is the potential erosion and R, K, and LS are topographic components. C and P account for crop coverage and conservation practices. These data are available from the Generalized Soil Landscape Map (GSLM) for the year 1981. The GSLM data base comprises 4551 polygons[1] for which the above mentioned variables are reported[2]. These polygons cover the entire country, and some of them are very large. To improve accuracy, two sets of entries were recorded for each polygon, a dominant and subdominant set. The Land Resource Research Center (LRRC) potential soil loss estimated with a weighted average C-factor for all crops grown in a polygon could not be used in this study because the economic-ecologic model requires this information on a per crop basis. The GSLM, which contains soil properties per polygon and the adjusted Census crop data from the Geographic Information System (GIS), was used to estimate the per crop erosion. The model was run, region by region, allocating C-factors to crops in different polygons[3] using the following formula (Coote,Personal Communication,

[1] A polygon is an area on a map characterized by uniform soil landscape attributes. Each one is assigned a unique number on a provincial basis.

[2] The data collection process was not completed for North Ontario, British Columbia, the Québec Péninsula and Newfoundland. Erosion for these regions was omitted.

[3] This was executed by H.Trépanier, a computer programmer for Statistics Canada, Environment and National Accounts Division.

1991)[4]:

(D.1) $A = \{0.675Dom(KLS) + 0.325Subdom(KLS)\} Rproparea C_{reg}$[5]

(D.2) $A = Dom(KLS) RproparaeaC_{reg}$

where:

Dom and Subdom (KLS) are the dominant and subdominant soil characteristics in each polygon.
prop is the proportion of a polygon area under agriculture.
area is the polygon area under a specific crop.
C_{reg} is the C-factor per region within a province[6].

The two constants, 0.675 and 0.325, are the assumed proportions of dominant and subdominant soil in the polygons, respectively[7]. Equation D.2 was used when no subdominant soil was estimated to be in the polygon (100% dominant). Gross erosion was defined as water erosion from agricultural land, thus only the area of the polygon under agriculture (prop) was considered[8]. Equations D.1 and D.2 estimate the potential erosion per crop in a polygon (or gross erosion). Results, summed to provincial levels, appear in column 2 of Table D.1.

Once a delivery ratio is applied to Equation D.1 and D.2 their interpretation changes. They now estimate soil delivered to the environment (stream) instead of

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[4] Dr. Coote is a specialist in soil degradation with the LRRC, Agriculture Canada.

[5] For this analysis the LRRC assumed a P-value = 1

[6] The R*K*LS product depends only on nature and is fixed for each polygon. It represents the soil loss that would occur under continuous fallow. The actual soil loss is reduced by the C and P factors.

[7] More details on the GSLM can be found in Shelton et al. (1991) and in Agriculture Canada (1991).

[8] There are many different sources of erosion but water erosion is the major source.

Table D.1 Comparison of the Model's Results with Statistics Canada Census Data

EASTERN CANADA	Derived with the Model		Statistics Canada Census Year		Statistics Canada Census Year	
	(1)	(2)	(3)	(4)	(5)	(6)
NEW BRUNSWICK	Area (ha)	Erosion (tonne)	1981 (na)	% DIFF col1-col3	1986 (ha)	% DIFF col3-col5
Nursery	48	297	85	-43 5%	169	-49 7%
Tree Fruit	390	562	625	-37 6%	650	-3 8%
Potatoes	20,449	225,518	21,769	-6 1%	19,613	11 0%
Sugar Beets	0	0	0		0	
Small Fruit	1,565	3,879	3,172	-50 7%	4,332	-26 8%
Vegetables	2,273	45,925	3,402	-33.2%	3,269	4 1%
Grain Corn	496	3,017	304	63 2%	332	-8 4%
Beans	347	5,149	484	-28.3%	150	222 7%
Silage Corn	1,887	19,932	1,611	17.1%	1,015	58 7%
Alfalfa	4,310	2,474	5,618	-23.3%		
Other Hay	61,355	0	63,649	-3.6%	70,048	-1 1%
Summerfallow	5,600	155,765	5,183	8 0%	4,289	20 8%
Grapes	0	0	0		0	
Fall Grains	288	1,771	212	35.8%	668	-68 3%
Spring Grains	24,002	182,693	27,970	-14 2%	28,305	-1.2%
Sod1	144	89			169	
Root Crops	9	81			4	
Tobacco	181	2,990	193	-6.2%	140	37 9%
TOTAL	123,344	650,142	134,277	-8 1%	133,153	0 8%

NOVA SCOTIA	Area (ha)	Erosion (tonne)	1981 (ha)	% DIFF col1-col3	1986 (ha)	% DIFF col3-col5
Nursery	234	1,234	95	146 3%	172	-44 8%
Tree Fruit	5,189	5,681	4,824	7 6%	4,555	5 9%
Potatoes	1,715	16,710	1,545	11 0%	1,632	-5 3%
Sugar Beets	0	0	0		0	
Small Fruit	5,476	14,485	6,002	-8.8%	8,746	-31 4%
Vegetables	3,653	66,121	3,161	15 6%	3,608	-12 4%
Grain Corn	2,354	18,952	1,846	27.5%	1,976	-6 6%
Beans	191	2,611	171	11 7%	372	-54 0%
Silage Corn	3,714	45,683	3,126	18 8%	2,467	26 7%
Alfalfa	7,822	4,043	6,425	21 7%		
Other Hay	74,656	0	64,680	15.4%	68,739	3 4%
Summerfallow	6,452	173,822	5,154	25.2%	3,910	31 8%
Grapes	9	14	6		44	
Fall Grains	4,676	33,754	4,294	8.9%	604	610 9%
Spring Grains	16,245	121,392	15,480	4 9%	12,292	25 9%
Sod	403	254			936	
Root Crops	50	495			45	
Tobacco	514	7,300	248	107.3%	243	2 1%
TOTAL	133,353	512,551	117,057	13.9%	110,341	6 1%

Table D 1 Continued

PRINCE EDWD ISLD	Derived with the Model Area (ha)	Erosion (tonne)	Statistics Canada Census Year 1981 (ha)	% DIFF col1-col3	Statistics Canada Census Year 1986 (ha)	% DIFF col3-col5
Nursery	10	47	8	25.0%	5	60.0%
Tree Fruit	60	90	50	20.0%	37	56.8%
Potatoes	27,641	273,957	25,851	6.9%	25,988	-0.3%
Sugar Beets	0	0	0		0	
Small Fruit	659	1,676	407	61.9%	822	-50.5%
Vegetables	1,817	37,408	1,668	8.9%	1,122	84.9%
Grain Corn	172	1,587	117	47.0%	287	-59.2%
Beans	381	4,996	283	34.6%	--	
Silage Corn	2,344	26,777	2,555	-8.3%	1,418	80.2%
Alfalfa	7,111	3,674	6,291	13.0%		
Other Hay	49,328	0	43,790	12.6%	52,069	-3.8%
Summerfallow	3,436	89,674	3,027	13.5%	2,647	14.4%
Grapes	1	1	0		--	
Fall Grains	1,346	10,916	1,257	7.1%	3,112	-59.6%
Spring Grains	81,601	609,256	73,457	11.1%	67,968	8.1%
Sod	0	0			4	
Root Crops	34	247			8	
Tobacco	6,479	0	1,626	298.5%	1,484	9.6%
TOTAL	182,420	1,060,306	160,387	13.7%	156,971	2.2%

QUEBEC	Area (ha)	Erosion (tonne)	1981 (ha)	% DIFF col1-col3	1986 (ha)	% DIFF col3-col5
Nursery	3,036	12,905	1,751	73.4%	6,097	-71.3%
Tree Fruit	8,412	5,554	9,754	-13.8%	9,015	27.6%
Potatoes	18,788	83,002	17,172	9.4%	17,269	55.9%
Sugar Beets	4,152	15,953	3,830	8.4%	0	
Small Fruit	5,710	7,082	4,455	28.2%	6,035	-26.2%
Vegetables	37,445	362,914	32,543	15.1%	32,804	12.8%
Grain Corn	181,698	712,245	165,446	9.8%	234,359	-29.4%
Beans	2,454	13,140	2,147	14.3%	6,100	-64.8%
Silage Corn	99,492	691,028	84,391	17.9%	61,251	37.8%
Alfalfa	179,904	56,345	170,594	5.5%		
Other Hay	935,668	0	794,861	17.7%	1,008,065	-4.2%
Summerfallow	61,820	1,114,584	53,077	16.5%	31,802	66.9%
Grapes	23	17	38	-39.5%	69	-44.9%
Fall Grains	3,054	10,913	3,690	-17.2%	12,962	-71.5%
Spring Grains	453,457	19,366,886	420,840	7.8%	363,703	15.7%
Sod	6,596	2,710			6,097	
Root Crops	333	2,496			61	
Tobacco	1,817	12,483	3,568	-49.1%	3,413	4.5%
TOTAL	2,003,859	22,470,257	1,768,157	13.3%	1,799,102	-1.7%

Table D.1 Continued

ONTARIO	Derived with the Model Area (ha)	Erosion (tonne)	Statistics Canada Census Year 1981 (ha)	% DIFF col1-col3	Statistics Canada Census Year 1986 (ha)	% DIFF col3-col5
Nursery	7,045	26,567	5,610	25 6%	8,178	-31 4%
Tree Fruit	25,214	26,400	20,645	22.1%	21,258	-2 9%
Potatoes	23,578	131,297	15,829	49 0%	14,139	12 0%
Sugar Beets	0	5	0		0	
Small Fruit	2,763	5,416	2,376	16 3%	3,422	-30 6%
Vegetables	68,435	833,286	61,609	11.1%	62,340	-1 2%
Grain Corn	995,531	7,877,906	878,887	13 3%	740,258	18 7%
Beans	373,631	2,911,848	289,281	29 2%	436,963	-33 8%
Silage Corn	293,157	3,178,371	260,303	12.6%	190,090	36 9%
Alfalfa	665,060	296,557	590,211	12.7%		
Other Hay	504,486	0	451,903	11 6%	1,020,092	2.2%
Summerfallow	74,467	1,412,331	63,309	17.6%	80,336	-21 2%
Grapes	11,063	11,546	9,092	21 7%	9,356	-2 8%
Fall Grains	265,753	1,502,177	239,191	11 1%	281,351	-15 0%
Spring Grains	762,886	4,940,340	679,401	12 3%	646,781	5 0%
Sod	11,079	3,434			8,178	
Root Crops	60	548			59	
Tobacco	38,667	314,265	48,733	-20 7%	26,177	86 2%
TOTAL	4,122,875	23,472,294	3,616,380	14 0%	3,548,978	1 9%
TOTAL EASTERN CANADA	6,565,851	48,165,550	5,796,258	9.4%	5,748,545	1 9%

WESTERN CANADA

ALBERTA	Area (ha)	Erosion (tonne)	1981 (ha)	% DIFF col1-col3	1986 (ha)	% DIFF col3-col5
Summerfallow	2,596,220	12,787,700	2,205,468	17 7%	2,127,013	3 7%
Spring Grains	6,916,680	17,554,200	6,159,799	12 3%	6,178,668	-0 3%
Corn & Sunflw	9,190	39,586	4,784	92.1%	4,721	1 3%
Flax & Canola	794,990	1,206,380	630,319	26 1%	1,168,445	-46 1%
Peas & Beans	8,543	17,978	6,694	27 6%	11,202	-40 2%
Winter Grains	220,397	302,742	194,033	13 6%	248,870	-22 0%
Sugar Beets	17,168	32,947	10,092	70 1%	12,006	-15 9%
Corn for Silage	12,829	37,776	14,381	-10 8%	8,809	63 3%
Potatoes	7,273	11,144	6,729	8 1%	9,085	-25 9%
Tame Hay	1,769,030	0	1,408,577	25 6%	1,511,141	-6 8%
Pasture	1,876,420	0	1,376,814	36 3%		
TOTAL	14,228,740	31,990,453	12,017,690	18.4%	11,279,960	6.5%

Table D.1 Continued

SASKATCHEWAN	Derived with the Model Area (ha)	Erosion (tonne)	Statistics Canada Census Year 1981 (ha)	% DIFF col1-col3	Statistics Canada Census Year 1986 (ha)	% DIFF col3-col5
Summerfallow	6,346,920	43,682,300	6,704,464	-5.3%	5,658,250	18 5%
Spring Grains	9,502,460	33,381,600	10,117,441	-6.1%	10,738,331	-5 8%
Corn & Sunflw	7,497	28,707	7,971	-5.9%	3,080	158 8%
Flax & Canola	719,725	2,181,950	691,998	4 0%	1,322,415	-47.7%
Peas & Beans	16,484	78,766	16,987	-3.0%	68,386	-75.2%
Winter Grains	178,103	287,399	195,047	-8 7%	467,306	-58.3%
Sugar Beets	0	0	0	0.0%	0	0.0%
Corn for Silage	2,989	14,700	3,320	-10 0%	3,067	8 2%
Potatoes	1,070	3,884	1,010	5.9%	1,595	-36.7%
Tame Hay	662,791	0	706,568	-6.2%	720,055	-1.9%
Pasture	886,371	0	878,726	0.9%		
TOTAL	18,324,410	79,659,306	19,323,532	-5.2%	18,982,485	1.8%

MANITOBA	Area (ha)	Erosion (tonne)	1981 (ha)	% DIFF col1-col3	1986 (ha)	%DIFF col3-col5
Summerfallow	675,741	4,065,690	598,338	12.9%	509,213	17.5%
Spring Grains	3,136,930	9,597,680	3,000,009	4.6%	2,950,442	1 7%
Corn & Sunflw	233,838	1,146,760	199,393	17.3%	36,383	448.0%
Flax & Canola	704,444	2,222,150	530,479	32 8%	809,969	-34 5%
Peas & Beans	59,619	250,561	51,564	15 6%	68,712	-25.0%
Winter Grains	91,124	41,914	79,558	14.5%	54,420	67.4%
Sugar Beets	12,963	117,101	11,663	11.1%	11,214	4 0%
Corn for Silage	24,963	92,200	19,713	26.6%	12,778	54.3%
Potatoes	18,973	147,162	16,558	14.6%	18,784	-11.9%
Tame Hay	650,978	0	508,912	27.9%	552,278	-7.9%
Pasture	404,878	0	274,944	47.3%		
TOTAL	6,014,451	17,681,218	5,291,131	13.7%	5,024,193	5.3%
TOTAL WESTERN CANADA	38,567,601	129,330,977	36,632,353	9 0%	35,286,638	4.5%
TOTAL CANADA	45,133,452	177,496,527	42,428,611	9.2%	41,035,183	6.4%

Source Stastistics Canada, Census of Agriculture 1981b, 1987b

1. No value appear for sod and root crop because they were not reported in both, the 1981 and 1986 Census

a movement of soil. These calculations were made for the 4551 polygons in Canada for 18 crops in eastern Canada and 9 crop groups in western Canada (see Table D.1 for a list of these crops). The potential soil loss to the environment was then distributed among the 12 farm types using the area of crops grown by each farm type (Table B.5).

Reliability and validation

The reliability and potential application of the erosion estimates had to be evaluated since this was the first attempt to include them in an I-O model. A number of comparisons were made to determine the suitability of the erosion estimates for the economic-ecologic model. First estimates of hectares planted using the GLSM were compared to the 1981 Census Crop Statistics (column 1 and 3 in Table D.1). Over and under-estimates of the number of hectares under various production are given in column four along with an overall difference between the provinces. The largest differences occur in tobacco production with 298% and 107% in PEI and Nova Scotia, and in nursery production with 146.3% and 73.4% in Nova Scotia and Québec. The smallest provincial differences occur for New Brunswick,-8.1%, while in the other provinces, the overall difference is between 13.3 and 14.0%. Comparing the total number of hectares under production for the two regions yield 9.4% and 9.0% differences in Eastern and Western Canada respectively.

A second comparison was made of the Census Crop Statistics reported in 1981 and 1986 (column 3 and 5, Table D.1). Since the economic data base year is 1986, it is important to determine whether the number of hectares planted had varied remarkably or not. The overall farm area change in Eastern Canada since 1981 varies between -1.7 and 6.1% with the gre...st changes found in nursery, fruits, beans, fall grains and tobacco (column 6, Table D.1). The overall difference for Western Canada range from 1.8 to 6.5 in Saskatchewan and Alberta respectively, with the largest departure in Alberta (18%). Among the individual commodities, corn and sunflower accumulated the greatest change in area since 1981[9].

Agriculture Canada's GSLM project requires a physical overlapping of Statistics Canada enumeration areas and LRRC polygon numbers. Some error was introduced in this process since the two working area (polygons and enumerated areas) did not correspond perfectly with one another. Another problem concerns the application of the USLE. This equation was designed to be used at the farm level and not for national estimates. According to Coote (1991), as long as the delivery ratio (DR) was applied to the potential soil loss (A), the use of this equation at a national level is justified.

D.2 Water use

Recycled water refers to water used in the same plant in another production process. Gross water use is the sum of intake and recycled water. Discharge water is water returned to the environment. Treated discharge is the quantity treated prior to discharge. Intake and discharge of municipal water was estimated whereas only

[9] Differences may arise due to map digitalization, to the different units of data collection of Agriculture Canada and Statistics Canada and different definitions of crops.

intake water was estimated for the agriculture sectors. The following subsection covers each of the user classes. Water use was not estimated for industries 53, 72, 73 and 74. Industry 53 was not included in the manufacturing water use survey and 74 is a dummy industry recording transportation margins. Industries 72 and 73 were not classified as services, and hence their reported water use is zero.

D.2.1 Municipal water use (Final demand and ind. 54-71)

Tate and Lacelle (1987, 17) break down municipal water use into domestic and commercial/institutional water user classes. Domestic and commercial/institutional water use was 5.001 MCM and 1.946 MCM per day respectively. This daily ratio of domestic/commercial water use was used to allocate the annual water intake of 4,716 MCM. Thus 3,395 MCM was allocated to domestic users and 1,321 MCM to commercial/institutional users.

Domestic water use was allocated to the household category of final demand. The 1,321 MCM used by commercial/institutional were allocated to service, business, and institution industries. This was done using the number of employees in each of these industries as a proxy. The number of beds in Canadian hospitals, 172,000 (Statistics Canada, 1990c) was added to the work force for health services (67). The number of beds was assumed to be the number of patients in hospitals.

The educational services (66) work force was augmented with the number of students enrolled at all levels in Canada, 5,717,700 (Statistics Canada, 1987c). The number of people served by the accommodation industries (ind. 68) should have been included in this sector's estimate. However, no estimate of this number was found.

found. The work force was doubled arbitrarily as a proxy. As a result, the accommodation estimate is expected to be underestimated; hence others may be inflated.

Water is not recycled in the municipal and household sectors and therefore, gross water use is equal to water intake. The total amount of water discharged by each of these categories was estimated using the same percentage as for annual water intake (Table B.1).

D.2.2 Agricultural water use (1-12)

Domestic water use was mainly from ground water and was accounted for in the previous section.

D.2.2.1 Livestock watering

Water use for livestock watering was estimated in two steps. Total livestock and poultry populations were multiplied by their average annual water consumption (see Table D.2). This was then allocated among farm types using the number of animals per farm type (Table 3.3). Hess (1986) estimated the livestock water requirement in 1981 to be 359 MCM. While this model's estimate for 1986 was 317 MCM. The decrease in the number of animals since 1981 could account for this difference. The Prairie Province Water Board (PPWB,1990) estimated livestock water consumption, for their study area, to be 200 MCM in 1986 while this model's estimate is 152 MCM[10]. Given this comparison, the method used to estimate water consumption in the economic-ecologic model resulted in an underestimation of

[10] The PPWB study area accounted for 90% of the total area in the three provinces.

livestock watering.

D.2.2.2 Irrigation water

Different procedures were used to derive irrigation coefficients. The Atlantic Provinces are more temperate; thus irrigation takes place during the summer in peak drought periods or to prevent frost in the fall. The total irrigated area in the Atlantic Provinces in 1986 was only 2,039 hectares (Environment Canada (1987)). No study was found that could lead to accurate estimates of water use for irrigation in these provinces. Since the amount of irrigated hectare was small, this water use was not estimated. The following sections outline the methods used to estimate irrigation water use in the Prairie Provinces, Ontario, Québec and British Columbia (see Table D.3).

Table D.2 Annual Water Consumption per Animal

Animal Types	Water Consumption per Head (m^3/head/year)
Layer chicken	0.10
Broiler chicken	0.10
Turkey and others	0.18
Bulls	35.41
Dairy	56.21
Beef	23.36
Heifers	23.36
Steers	18.62
Calves	9.31
Swine	2.19
Sheep	1.28
Horse	24.82
Goats	1.28

Source: Appendix C in Hess (1986)

Prairie Provinces. Data from the Prairie Provinces Water Board (PPWB, 1990) were used to estimate water use for private and district irrigation in 1986. District irrigation was estimated from data obtained from the district authorities. The PPWB (1982) formula was used to estimate private irrigation. This formula was based on the consumptive water use of crops, the amount of rainfall, and the type of irrigation system used. Both district and private irrigation was used in Alberta and Saskatchewan, while only private irrigation occurred in Manitoba. Total water use by province was allocated to the percentage of crops irrigated in the province. The crop breakdown was from Shady et al. (1989, 159). The Saskatchewan Irrigation Development Center (fax, 1991) irrigated crop acreage in the South Saskatchewan River Basin in 1987 was used for the province of Alberta[11]. Other basin information in Saskatchewan and Manitoba was obtained from Klassen (fax, 1991). Irrigated areas per crop were converted into percentages, which were then applied to the 1986 basin's total. When a broad category was given (e.g. cereals which include wheat, oats, and barley) the total was distributed evenly amongst the crops.

Ontario and Québec. Myslik (1991) estimated water use for crop production in Ontario for an average year[12]. Water use for spraying was not included here. This was done to be consistent with other provinces that did not have the data.

Irrigation requirements for major crops in southwestern Québec was estimated by Gallichand et al. (1991). Since no other sources were found, Ontario irrigation data were adjusted and used for the province of Québec. This implicitly assumes similar practices in the two provinces. Weather differences between these provinces may bias these estimates.

British Columbia. Van Der Gulik (Fax, 1991) provided irrigated crop area by region

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[11] The basin extends into Alberta.

[12] The level of irrigation in a given year depends on the level of precipitation. An average year means the average precipitation found over some time period, usually 10 years.

and the total water use in the Province. The total water used was allocated to each crop using the area under production as a proxy. This proportional allocation does not consider the different water requirements for each crop.

The allocation of irrigation water use by crop and province is given in Table D.3. A comparison of the estimates from the different data sources is given in Table D.4[13]. The PPWB formula used to estimate private irrigation may exaggerate water use since it presumes that crops receive the optimum amount of water. It also assumes that the cropping patterns were similar from year to year.

D.3 Solid waste

D.3.1 Industrial waste

Total industrial waste in Canada was estimated to be 73.7 M tonnes (OECD,1991a). This amount included 30 M tonnes of wood waste allocated to the wood industries. These residuals were reused mainly by the pulp and paper industries. The remaining 43.7 M tonnes was divided between industrial/ commercial and industrial waste, 12.7 and 31 M tonnes respectively (ISWA, 1988). Waste classified as industrial/commercial residuals was picked up by municipalities. Such residuals could have been accounted for in the "other utilities" industries, however, this would not have related the waste generation to its source. Hence these residuals

[13] Using the following conversion 1,000 L= 1 cubic meter (m^3) and 1000 m^3 = one cubic decameter (dam^3).

Table D.3 Water Use for Irrigation Purpose by Province

	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	British Columbia	Total
			(Million m3)				
Wheat	592.8	123.7	1.3	0.0	0.0	0.0	801.5
Oats	0.0	5.2	1.3	0.0	0.0	0.0	33.1
Barley	381.1	23.4	1.3	0.0	0.0	0.0	402.4
Oilseeed	105.9	62.0	0.6	0.0	0.0	0.0	179.5
Peas	42.3	2.3	0.2	0.0	0.0	0.0	36.8
Mixed Grains	0.0	2.1	0.2	0.0	0.0	0.0	10.4
Hay & Silage	529.3	77.5	4.2	0.0	0.0	0.0	1047.3
Corn	42.3	0.6	1.0	0.0	0.0	1.0	42.5
Potatoes	42.3	3.2	5.2	0.0	0.0	0.0	70.1
Sugar Beet	63.5	0.0	0.2	0.0	0.0	0.0	86.4
Vegetables	0.0	0.4	1.6	20.0	10.5	44.6	108.6
Other	105.9	1.8	0.5	0.0	0.0	14.9	19.6
Pasture	127.0	6.3	0.0	0.0	0.0	0.0	196.9
Beans	42.3	3.5	0.2	0.0	0.0	0.0	45.9
Greenfed	42.3	8.5	0.0	0.0	0.0	0.0	43.4
Fruit	0.0	0.0	0.4	6.4	2.7	114.0	124.0
Nursery &So	0.0	0.0	0.0	191.6	58.6	0.0	250.1
Greenhouse	0.0	0.0	0.0	1.2	0.5	0.0	1.6
Forage	0.0	0.0	0.0	0.0	0.0	410.3	410.3
Tobacco	0.0	0.0	0.0	11.3	1.5	0.0	12.8
Total	2117.2	320.6	18.5	230.5	73.7	584.7	3923.4

Table D.4 Comparison between Irrigation Sources

	Area Irrigated (Ha)				Water Use (million m3)			
Provinces	Census 1986	Environment Canada 1986	Hess 1981	PPWB 1986	Hess 1981	Shady	Others1	PPWB 1986
Newfoundland	29	29	--	--	--	--	--	--
Prince Edward I.	124	124	--	--	--	--	--	--
Nova Scotia	1,169	1,169	--	--	--	--	--	--
New Brunswick	716	716	--	--	--	--	--	--
Quebec	15,284	15,284	14,000	--	14.22	--	--	--
Ontario	52,535	52,535	40,255	--	60.02	--	--	--
Manitoba *	9,732	9,732	6,935	12,141	20.87	--	12.58	18.50
Saskatchewan #	83,931	82,757	70,700	106,439	261.59	106.44	126.97	320.61
Alberta **	466,291	511,429	393,969	506,214	1,867.41	506.22	1,096.33	2,117.20
British Colombia##	117,811	156,680	100,475	--	524.00	118.00	584.00	--
Canada	747,622	830,455	626,334	624,794	2,748.12	730.66	1,819.88	2,456.31

* Source: Manitoba Agriculture, Fax (Soils and Crops Branch, 1988)

Source: Saskatchewan Irrigation District, Fax. 1991.

** Source: Saskatchewan Irrigation Development Centre, Fax. 1991.

Source: Van der Gulik, Report on Water Demand, Fax. 1991.

were allocated to service and institutional industries using the amount of dollars spent by each industry on paper purchases in 1986 (Statistics Canada, 1986).

It is assumed that 99% of the 31 M tonnes of solid waste was generated by 22 industries (see appendix B, Table B.2) and the remaining 1% (31,000 tonnes) was produced by other industries. ISWA (1988, 259) provides a percentage breakdown of solid waste generation by the 22 industrial sectors in the U.S. economy that account for 99% of the total solid waste generation[14]. This breakdown was used in this study because it had been updated and is recognized internationally.

Adjustments were made to the food and kindred products estimates of ISWA (1988). The 1.6% estimate, which represents 496,000 tonnes in Canada, was allocated to the 11 food and kindred product industries. The total output (in tonnes) of each food industry was used as a proxy to allocate this amount.

The other 1% (31,000 tonnes) was allocated to the remaining industries using the dollar value of paper input per industry (Statistics Canada, 1986) as a proxy. This proxy was used because the paper component of solid waste represents 45% of the total composition of municipal waste in Canada (ISWA, 1988, 36).

The use of U.S. percentages of industrial waste generation implies similar production processes in the two countries (hence generate waste in similar proportions). It was also assumed that all the wood waste originated from the wood industry.

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[14] Data on hazardous wastes were unavailable and were not included in this study.

D.3.2 Agricultural waste

Brown (1988) estimated animal manure production per 454 Kg of animal weight. The number of animals from the Census of Agriculture (Statistics Canada, 1986) was transformed into a 454Kg basis and multiplied by the manure generation rate for each type of animal. This estimate was allocated to farm types using the number of animals per farm type.

D.4 Airborne residuals

Airborne waste from the agriculture sectors was allocated to the twelve farm types using different proxies (Appendix B). The primary airborne waste source for this sector was windborne dust from land tilling. Statistics Canada's estimates were used because wind erosion could not be accurately estimated with the GSLM (Coote, personal communication, 1991). Adjustments were also made to RDIS's Meat and Meat product estimates. Their Meat and Meat Products industry included poultry. For the economic-ecologic model, Poultry emissions needed to be separated. Since Poultry represents 27% of the quantity of meat produced in 1986 (Statistics Canada, 1986), 27% of the waste was allocated to the poultry industry.

D.5 Waterborne wastes

The residual loads for BOD5, COD, SS, TDS, Oil and N were estimated using the World Health Organization (WHO, 1982) handbook's load factors. The quantity of goods produced by each industry multiplied by the load provided in the handbook gave a crude approximation of effluent. The quantity of industrial output by sector were from Statistics Canada (1986). When the information was confidential, or when units did not correspond to the handbook's units, the effluent was not estimated. As a result, figures in Table B.4 are underestimated. The following sections discuss the allocation of industrial and domestic effluent. The handbook deals only with urban areas, therefore, the mining sector had to be estimated separately.

D.5.1 Industrial effluent

Residual loads in the handbook were for untreated waste water. The percentage of primary, secondary and tertiary treatments by industry from Environment Canada (1990a) were applied to each of these coefficients to reflect the after treatment residuals. Expected reductions for each of these treatments are:

Primary :30% reduction of BOD5 and SS
Secondary:80% reduction BOD5 and SS
Tertiary:95% reduction of BOD5 and SS
Source: Loehr (1984) and WHO (1982)

The following industrial sectors effluent were not estimated: wood, metal fabricating, transportation equipment, electric product, transportation and other utility industries. Others are only partially estimated. For example, in the primary steel sector, only metallurgic coke and aluminum were included. While in the textile industry, only nylon, wool, and acrylic processing were included. Most of the food processing sectors' loading factors were estimated. This may make them appear relatively worse, in terms of wastewater generation, than other industrial sectors.

D.5.2 Domestic effluent

Domestic effluent was estimated by multiplying the average annual water consumption per person times 0.6 (WHO, 1982). This gives the load coefficient that was then multiplied by the population. Coefficients differ for people served by sewer and those not served. Tate and Lacelle (1987, 17) estimated daily domestic water consumption to be 0.360 M^3 per capita. The annual load coefficient was therefore 78.84[15]. The estimated domestic effluent was allocated to the household category of final demand.

D.5.3 Mining industry effluent

Annual average effluent quality for the metal mining industries by province was found in Environment Canada (1988). The mines production capacity, and in certain cases the rated capacity, was used to weight different mine loading coefficients. This results in a weighted average national loading coefficient. The total treated discharge in 1986 by the mining industry was applied to these load coefficients for metal and Total Suspended Matter (TSM is included in SS and metal in TDS). These values are given in Table B.4.

D.6 Pesticide use

Three factors affect the social cost magnitude of pesticide use: volume used, persistence, and the toxicity in the environment. The Pesticide Registrant Survey identified the 10 most used pesticide products in the herbicide, insecticide, and fungicide groups. The Inland Water Directorate published a series of studies on pesticides of concern (Environment Canada, 1989B, 1990c and 1991a-e). The most

[15] (0.360*0.6*365)

important pesticides in terms of both volume and toxicity/ persistence were: atrazine, glyphosate and metolachlor (in the herbicide category), as well as carbofuran and captan (in the insecticide and fungicide category).

The limited information did not permit the allocation of these pesticides to crops. Given this data constraint, the pesticide commodities included in the model were: triazine, phenoxy (2,4-D and MCPA), dicamba/bromoxynil, other herbicides, captan, other fungicides, insecticides, and others (nematocide, growth regulator and other non specified). Captan and 2,4-D use per crop were from Dunnett (1983) and Stemeroff et al. (1991). Triazine, which includes atrazine and simazine, was only allocated to crops in Ontario, Québec and Manitoba due to data limitations. For the other provinces, triazine was included in other herbicides (Table B.7). In a first attempt to allocate pesticides to crops, provincial recommendations were followed. It was assumed that pesticides were applied to crops that they are registered for. However, most pesticides were registered for many crops and accurate results could not be obtained. The following section discusses the procedure used to derive the herbicide and other pesticide coefficients given the limited information.

Ontario and Québec. The Ontario Ministry of Agriculture and Food (OMAF), has conducted pesticide use surveys every five years since 1973. These surveys identify and quantify pesticides in use by crop area and region in Ontario. The 1988 survey results, published by Moxley (1989), were adjusted to reflect 1986 cropping practices as reported in the Census of Agriculture. The 1988 application rates for each crop were applied to the 1986 crop acreage. Wheat and potatoes were removed from their broader categories - grain and vegetable respectively - and were allocated to the potato and wheat commodities using their respective areas in the grain and vegetable categories as a weighing factor. The last survey results published for Québec were by Reiss and Paré (1984). Since this information was outdated (1982), the Ontario application rates were applied to the 1986 crop acreage in Québec.

Manitoba. The Manitoba Economic Branch publishes the annual total herbicide used (in active ingredient (AI)) for agricultural weed control in Saskatchewan, Manitoba, Alberta and British Columbia. The product data provided was for 2,4-D, MCPA, TCA, bromoxynil/dicamba, wild oat herbicides and a residual category. The Manitoba Crop Insurance Agency data base was used to allocate these totals to crops (Manitoba Agriculture, 1992). It contains the area treated annually by herbicide products. The sample accounts for 60% (5,341,563 acres) of the total acreage treated for weed control in Manitoba, as reported in the 1986 Census (Statistics Canada, 1986). Thus each coefficient was pro-rated to the Census total.

Saskatchewan and Alberta. To allocate the pesticide products mentioned above, a special tabulation provided by Philips (fax, 1991) was used[16]. It gives the wheat, barley and canola areas treated with herbicides. The herbicide products were: bromoxynil, dicamba, phenoxy and other grass and/or broadleaf products. Since the total herbicide application could not be allocated to these three crops alone, their share of the total area under cultivation in each province was used. Wheat, barley and canola represent 84% and 71% respectively of the cropland area in

[16] Al Philips is from Criterion and Research Corp. Winnipeg.

Saskatchewan and Alberta. These percentages were applied to the total active ingredients for each crop weighted with the crop area treated.

Captan. Total captan use in Ontario, from the 1978 and 1986 surveys, was compared and a correction factor (54.4 t in 1986/ 83.7 t in 1978) was used to adjust the total captan used in Canada. The total captan use had decreased by 35% between 1978 and 1986, to 162,794 tonnes AI. Captan is used for three purposes: foliar treatment, seed treatment and home and garden use (Dunnet, 1983). Dunnet (1983) states that 95% (142,618 tonnes AI) of foliar treatment was applied to fruits and 5% (7506 tonnes AI) to vegetables. Seed treatment (12,660 tonnes) serves mainly for potatoes and corn, thus was split evenly between the two. Using the methodology outlined above, 92% of the herbicides, 25% of the fungicides, 17% of insecticides and 62% of others were allocated (Table D.5). The remaining products were allocated to farm types using the allocation factors cited in Appendix C.

D.7 Fertilizer use

As with pesticides, fertilizer materials and nutrient content were needed on a per crop basis. A first attempt to allocate the total consumption of fertilizer was made using listed application rates. This method greatly overestimated the total provincial consumption. Thus an allocation of the total consumption was done using area fertilized per farm type in 1986 (Table B.6).

TABLE D.5 Pesticides Allocation Procedure

Pesticides	Allocated Kg	Total Kg	Remains	Percentage
Herbicides	22,611,095	24,687,000	2,075,905	92%
Fungicides	844,785	3,385.000	2,540,215	25%
Insecticides	496,897	2,857,000	2,360,103	17%
Others	1,378,573	2,239,000	860,427	62%