Environmental Accounting for Agricultural Producers

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ENVIRONMENTAL ACCOUNTING FOR AGRICULTURAL PRODUCERS

BY

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A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

Abstract

Environmental accounting is a method of accounting for changes on the natural capital base. Based on principles of traditional accounting systems, it incorporates environmental effects and their effects on productivity to produce indicators that reflect a sustainable picture of the value of the natural capital.

The objective of this study is to develop a set of environmental accounts to monitor changes in soil quality and productivity. The accounts will be developed for an individual producers and therefore farm specific. The accounts will be able to provide producers with a means of evaluating the effects of changes in management decisions (crop selection, chemical applications, tillage systems, etc.) on the soil base and its inherent productivity.

The construction of the accounts will be in physical units and based on the cycling of nutrients in the soil. A set of accounts and statements will be presented for nitrogen and phosphorous. A step-by-step guide will be presented on how to use the accounts and general quantitative estimation will be provided to indicate the relative levels of the process at work.

Analysis of the accounts and their net results will done in qualitative terms by use of a framework guide for evaluation that links economic-management decisions-crop productivity and environmental concerns.

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Chapter One - Introduction

1.0 Need for Environmental Accounting

Traditional accounting systems monitor productive assets through recording of their original purchase price or current price, depending on the method of accounting used, and a yearly depreciation measure to allow for productivity changes in the asset over time. Land, which is also a productive asset with the ability to generate future income streams, is treated differently by these traditional accounting systems. The original purchase price is recorded, but no other entry is made for depletion or degradation of the resource incurred during the production process year after year, to reflect changes in its productivity over time. This lack of recording of the changes in the value of the asset results in valuation that do not accurately reflect the sustainable position of the asset. This can lead to mis-management of the natural capital, which in turn can influence decisions that affect the sustainability of the enterprise.

Environmental accounting is a method of accounting for changes on the natural capital base. Based upon principles of traditional accounting systems, it attempts to incorporate environmental effects and their affect on productivity to produce indicators that reflect a sustainable picture of the value of the natural capital. In agriculture, environmental accounting can be used to account for effects of on-farm resource management practices and related off-farm consequences, producing indicators and information that aids producers in their future practices and productivity decisions. Agricultural environmental accounts can be structured to include broad issues such as genetic diversity in crop species and global climate change, or narrowed down to local issues such as soil and water quality.

1.2 Research Goal and Objectives

1.2.1 Research Goal

The goal of this research is to develop a framework of resource accounts for agriculture at the farm level for use by producers. The resulting framework will be applicable to cash crop farms as well as mixed crop and livestock operations. The accounts will monitor on-site damages and potentially act as due diligence of off-site costs associated with degradation and depletion on the farm.

1.2.2 Research Objectives

In order to achieve the above goal, the research will use the following detailed objectives:

1. create a separate section of the financial statements based on physical unit data that deals with the natural resource accounts;
2. develop the accounts for the producer level by concentrating on data a producer either has on hand or is readily available to them;
3. develop the asset accounts for land based on the use of soil quality measures—concentrating on the macro-nutrients of nitrogen and phosphorous;

4. construct a flow statement, based on a combination of a nutrient budgeting technique and financial accounting methods, showing the inputs and outputs of each nutrient, to obtain an indication their short-term and long-term availability;
5. construct a stock statement, based on financial accounting methods, to show annual changes in the total amount of each nutrient;
6. reconcile the flow and stock statements to each other to ensure their internal validity and the overall ability of the accounts to act as a monitoring device;
7. demonstrate the use of the framework with a generalized case example.

1.3 Organization

The overall objective of this study is to develop a framework of agricultural environmental accounts at the level of the producer to reflect environmental degradation and depletion effects on productivity to produce a sustainable picture of the land asset. This study attempts to develop a framework where a standardized model for this task does not readily exist, as environmental accounting is a new process in the initial stages of its development.

This study is broken down into six chapters, each chapter being one component in a step by step progression beginning with need for environmental accounting (chapter one) and cumulating in a set of actual accounts and case study demonstration (chapter six). Chapter two discusses background to the environmental accounting issue and the current research to date. Chapter three presents the accounting and soil science theory used for construction of the accounts, in terms of the soil asset. Chapter four details the specific environmental accounts for nitrogen and phosphorous. Chapter five will present the developed environmental accounts. A brief case study is then presented in chapter six to demonstrate how the accounts can be used with producer data. The last section, chapter seven, discusses the summary, conclusions and presents extensions for further research.

Chapter Two - Background to Environmental Accounting

2.0 Sustainability

In North America, there is a growing awareness of environmental impacts. For business this means a new reality to face in the twentieth century— that of sustainable development and environmental stewardship. In the past, sustainable resource use was not a major concern as environmental impacts were small and isolated, such that when resources became depleted, business would abandon the site and move on to another location (Selley 1991, Hawkshaw 1991). Today, with the growing population and its subsequent demands, moving on is much more difficult, if not impossible. The regulatory and liability trend is to make business responsible for their actions forcing them to now take into account social responsibilities and ethical considerations (Selley 1991, Hawkshaw 1991). Speaking in economic terms, it is the demand curve for the environment shifting out.

In order to maintain the current standard of living, industrial growth and production is necessary. In general, many environmentalists would argue that we are over consuming and overproducing, or at the very least producing inefficiently at the expense of damaging the natural capital base. They would contend that tighter controls on production practices are necessary. Business would argue that if they were to produce in accordance with all the environmentalist constraints they would no longer be able to make a profit and would eventually become insolvent (Gray 1990).

These two positions leave a large middle area between them and a need to find a way to make environmental and social responsibility financially attractive for the firm (Gray 1990). To achieve this, sensitivity to markets and the neo-classical economic idea that prices convey information must be utilized. This need not go so far as to insist that markets are perfect and the invisible hand of Adam Smith doctrine will miraculously produce the proper incentives that are necessary in order to protect the environment. Markets sometimes do need regulation to produce the necessary incentives to encourage business to benefit the social good (Thornton 1993).

In the case of the environment, this type of thinking will be utilized in putting the situation in perspective. Prices convey information as the bottom line of the firm is profit and the better that the capital stock is maintained, natural or man-made, the more productive an asset it becomes and the longer it is able to produce, enabling it to retain more value.

Total asset value is a largely a function of short-term depletion (use) and long-term depreciation and/or appreciation. The market price of the asset conveys both elements in its determination. Thus, one incentive for balancing profit and environmental concerns is maintenance of long-term net financial position (Thornton 1993). The other is future regulatory considerations aimed at forcing producers to take responsibility for their environmental effects through government legislation and lender liability issues. Disclosure of environmental costs and risks are likely to become standard practice in the future (Hawkshaw 1991).

At this stage, in agricultural policy, it is an issue of comparative advantage as producers that begin now will be in a better position for future compliance, but in the future it will be an issue of adherence.

2.1 Sustainable Agriculture

With the incentives recognized, measures and methods of Sustainability can now be addressed. There is no standard definition of "sustainable agriculture". Most definitions hinge on maintaining productivity and profitability while minimizing environmental impacts (Faeth 1993). None of the definitions are quantitative in nature and there is no standard method of incorporating the productivity of the resource base, which is fundamental to Sustainability, into agricultural production decisions (Faeth 1993). The current definitions of agricultural Sustainability are of limited use as the effects of the various technologies on the resource base are still being determined.

The starting point for quantifying agricultural Sustainability is to examine the present system of how agricultural assets are valued. As mentioned in chapter one, the current accounting system treats land differently than other assets. All productive assets under a traditional accounting system include a yearly depreciation measure, known as the capital consumption allowance (CCA), to account for productivity changes over time. This allowance is subtracted from net revenues in calculating annual income (Faeth 1993).

Land, which is also a productive asset with the ability to generate future income streams (Harrison 1989), undergoes an asymmetrical treatment as it does not have a depreciation measure. Its productivity changes, due to depletion or degradation, are not recorded and accounted for (Faeth 1993), leaving its value unchanged beyond the initial recording of its purchase price on accounting statements. A standard accounting textbook defines the issue as "With the exception of land, (tangible) assets gradually wear out or otherwise lose their usefulness with the passage of time" (Niswonger and Hess 1977).

This asymmetrical treatment means that as land productivity is diminished and no allowance is made in the land account for these asset losses, myopic management decisions that encourage short-term results at the expense of jeopardizing future income may result (Repetto 1986, Repetto 1993). In this way the depletion of a valuable asset is being confused with the generation of income in that any gain in income may be illusionary because it may be at the expense of a permanent loss of wealth (Repetto 1993). As a result, the loss of future productivity is not reflected in agricultures' public or private value (Faeth 1993).

Combining basic accounting principles and the standard definitions of agricultural Sustainability, it can be further stated that production systems that damage soil structure or deplete the soil of nutrients, organic matter or biota, are unsustainable. Such that, if soil were treated like other assets, with land value being a proxy for its value, agronomic Sustainability could then be quantitatively determined. Production practices that degraded soil productivity, would be depreciated. Conversely, practices that increased soil productivity, would be appreciated (Faeth 1993).

2.2 Environmental Accounting—Macro Focus

Most of the research done thus far in the environmental accounting area has been on a macro level in relation to modifying the United Nations System of National Accounts (SNA) for environmental effects. The SNA accounts were developed in the 1950s for the purpose of providing an empirical framework to analyze the performance of an economy with the main indicator being Gross Domestic Product (GDP) (Gilbert and Haftkampt 1986). GDP measures the economic growth and progress of a country through recording the market value of all final goods and services produced in a given period of time within the boundaries of that country or, more specifically, the value of all income payments including labor, farm, non-farm, investment and any depreciation on the capital stock (Wilton and Prescott 1987). Since their inception, the SNA have had a tremendous influence on the policies of nations and of international lending institutions. For instance, if GDP were to drop in continuous quarters, a recession would be declared and policy makers would begin to stir (World Resources Institute 1991).

Most literature, up to the current time, concerns itself with justification of the need for environmental accounting and devising alternate methods of technique and procedure to achieve the appropriate sustainable indicators of growth and/or utility (El Serafy and Lutz 1989, Peskin 1989, Hershfindahl and Kneese, Repetto 1993, Bartelmus 1989). These all involve direct monetary modifications of the aggregates of GDP using different techniques.

Very little work has been done on bringing environmental accounting down to the micro level of the producer. The starting point is to look at what was done at the national accounts level as many parallels can be drawn from the macro to a micro analysis, especially in regards to specific accounts and procedures in which items are recorded. The issues that affect the macro accounts are, presumably, the same issues that a micro level producer would face and insights gained from examination at the national level can be used by a producer for use in their accounts.

2.3 Environmental Accounting—Micro Focus

Research at the micro level, or firm or industry level, is just beginning. Recently there has been a flurry of work done in the corporate arena, with respect to auditing and disclosure procedures for environmental liabilities. But, this is still in the initial stage of framework and development. No formal implementation process has yet been agreed upon and put into place.

In Canada, work is being done in the corporate field by the Chartered Accountants Association, Statistics Canada and the Universities (Canadian Institute of Chartered Accountants 1993, Statistics Canada—National Accounts and Environment Division 1994, University of Alberta 1992). In reference to specific industries, most work has been concentrated in the non-renewable sector—mainly in the oil and gas industry and recently the Government of Alberta and the University of Alberta have been developing accounts for the forestry sector (Alberta Resource Accounting Working Group, 1992).

2.4 Environmental Accounting—General

With no standard model or procedures (micro or macro) for environmental accounting in practice that is easily adaptable to any industry, new accounts being developed at the micro level for various industries should reflect upon previous work done (in both levels) to guide their development. Macro level analysis provides valuable insights and micro evaluation techniques are applicable to all industries.

With no one model to adapt from, to promote continuity between the new accounts being developed, all new systems should be based on similar fundamental underlying principles. With basic principles in place, new accounts will develop in the same manner which promotes their acceptability between various industries and may help to encourage their use. The following basic guidelines, based on traditional accounting procedures, can be used by any industry or level of government and be applied to small producers, large corporations or an entire industry, in their account development (Green, 1989):

1. Prepare a balance sheet giving a profile of what stocks of the resource are available at a given point in time.
2. Prepare an account of what uses are made of these stocks, what sources they are derived from and how they are added to and transformed over time.

3. Ensure that the stock accounts and the flow accounts are consistent, so that the balance sheet in any one year can be derived from the balance sheet of the previous year plus the flow accounts of that year.

Beyond defining basic guidelines of procedure, there exists a large debate between environmental accounting advocates as to the best method of representing the information on the statements. There are currently two main schools of thought, the physical and the monetary approach.

Most economists favor the monetary approach as they feel comfortable with market and non-market valuation methods (Green 1989). They believe they can accurately attach monetary values and directly link them to corporate financial statements or National Accounts to produce the necessary revised estimates.

Sceptics of this approach, concerned with the practical limits of nonmarket valuation, favor the physical approach and advocate that multiple accounts should be developed to show the linkages between economic accounting and physical accounting (Norgaard 1989). Neither method strictly dominates the other. To determine which is better for different circumstances, and in particular which is most applicable for agricultural environmental accounts, a more complete description of the methods is needed.

1. The physical unit approach—is a system of accounting and budgeting where all stocks and flows are accounted for in physical units such as units of energy or of mass. The accounts usually consist of two parts. Firstly, an emissions account which deals with degradation by the use of the resource base as a waste sink by

taking account of the emissions of waste products in water and land. Secondly, a state account which describes the state of the environment at different points in time and the changes, additions and depletions, of the environment in the periods between them (Green 1989). The main drawback of this approach is the lack of a common numeraire, or common base unit, in which all types of natural capital can be consistently evaluated upon (Bartelmus 1989). These accounts would have no direct link to financial accounts as they are not in monetary units, but can be used as an additional decision tool for policy makers to consider (Green 1989).

2. The monetary valuation approach—directly links the resource accounts to financial accounts, via attached satellite accounts, as all valuation of all direct market and non-market items is done in monetary terms. They concern themselves with long-run welfare measures and would include measurements of effects such as proper recording of defensive expenditures, depreciation of environmental capital, degradation effects on Sustainability and placing a monetary value for the effects of pollution on the future productivity of the resource base. This approach has many drawbacks associated with it due to the inherent difficulties in determining accurate nonmarket values along with concerns over proper accounting procedure for degradation effects (Green 1989).

Within these two very different approaches, a third approach is emerging that incorporates elements of both the physical and monetary aspects.

3. The combination approach— can be characterized by three stages. Firstly, modification of financial accounts such that monetary amounts are associated

with maintaining resource stocks and environmental quality, where applicable. Secondly, constructing physical accounts describing environmental processes where monetary measures are not accurate reflections. Thirdly, linking of the two accounting frameworks via quantification of the flows in an economic-environment interface (Gilbert and Haftkampt 1986). The main drawback of this approach is the lack of a modeling approach or technique for the construction of the interface. The linking of the two data sets is most readily accomplished through qualitative assumptions, which are project or sector specific, to provide the basis for their interaction. Such assumptions, by their situation specific nature, are not easily adaptable to other situations.

2.5 Environmental Accounting—Agriculture

Environmental accounting for agriculture is in the infancy of development. Most research, up to this point, has been based on developing national or regional agricultural level accounts (Statistics Canada 1994, Faeth 1994, Repetto 1993, Lerohl 1992, Adger and Whitby 1992). The monetary method has been predominately used and work has concentrated on two areas; soil erosion and externalities. The majority of attention has focused on erosion and its associated productivity changes, due to the numerous and well established techniques and computer simulation models (e.g., Erosion Productivity Income Calculator from the United States Department of Agriculture). The goal of erosion calculations is to determine the changes in productivity due to soil loss and then directly link these effects to future income generation streams. Research into externalities has centered on agricultural pollution and the placement of monetary values on the associated impacts with the goal of a revised measure of overall welfare when all positive and negative externalities are included in the calculations. This has mainly involved nitrogen pollution and groundwater contamination.

Between erosion and external effects, there is a large gap to be filled. Erosion easily fits into an agricultural environmental accounting framework as its effects can be linked to productivity to produce monetary figures revising the income streams. But, erosion is a gross measure based on the relationship between the quantity of topsoil and plant productivity response to topsoil limitations. An erosion calculation does not reflect overall soil quality as it does not isolate the elements contained within the eroded soil that are carried off the farm, or for the quality of the sub-soil state which can affect erodability potential. Factors beyond topsoil erosion play an important role in the soil-productivity relationship and should also be included in analysis. Externalities are also important to consider, but they account for only the movement of soil components and do not reflect any changes in soil productivity.

For an agricultural environmental accounting system to model changes in the productive capability of the soil, these additional factors must be looked at, specifically the state of the surface and sub-surface nutrients and their interactions. The nutrients play a critical role in the ability of the soil to nurture plant growth as they reflect the effects of management practice and weather, both of which are unpredictable and not easily modeled, and yet play an extremely important role in productivity. Nutrient monitoring is also able to indirectly highlight any associated externalities through avenues such as leaching. Erosion is still an important element of soil productivity, but the additional step of nutrient analysis allows for a clearer picture of overall soil quality and productivity to emerge.

Monitoring of nutrients can easily fit into environmental accounting using budgeting techniques under the physical unit theory approach. The drawback of the nutrient approach is the inherent difficulty in establishing a direct link between the effects of the nutrients on productivity in isolation of other factors, as soil must be looked at from a systems approach and many factors can affect the system simultaneously. There are also no established direct monetary links between soil nutrients, productivity and future income, there are only generalized guidelines of possible impacts and outcomes. This means that direct monetary figures can not be obtained linking nutrient state to soil productivity. But, indirect figures can be highlighted as nutrient deficiencies require compensatory actions to keep the soil productive (i.e., forage rotations, fertilizers) and these have monetary values attached to them. Monitoring of nutrients will alert a producer to potential problems long before they become serious and costly, which aids in the sustainability goal of the soil and the farm enterprise.

The value of an environmental accounting system for agriculture at the level of the producer lies in its ability to monitor and record physical changes in the asset (erosion or nutrients) and in highlighting the implications these changes yield. These types of accounts can help the producer promote sustainable stewardship of their asset which will aid in promoting good status with financial institutions and show due diligence to proposed future government regulations. They will also provide valuable information about the state of the resource that will aid producers in making future decisions about their productivity mix which ultimately affects the overall net profit position of their operation.

Soil erosion and nutrient monitoring can easily be incorporated together in an environmental accounting system using the budgeting technique, as will be demonstrated in the theory chapter (chapter three).

2.6 Summary

Environmental accounting is a recent technique and at the current time there is no standard procedure or techniques for its implementation. Most research has been focused on the macro level of the National Accounts, but recently the micro level of industry has been receiving attention. Some work has been done on developing agricultural accounts, focusing attention on the effects of soil erosion on productivity. In developing accounts for the agricultural producer, this study will use the general guidelines presented for developing environmental accounts in any industry. The agricultural accounts are constructed in terms of generalized soil quality and productivity, expanding on previous works of soil erosion to now include the state of soil nutrients, to yield a more robust picture of soil productivity. The next chapter builds and describes the model for the agricultural accounts.

Chapter Three - Theory and Model for Agriculture

3.0 Accounting, Economics, and Ecological Systems

Relating accounting and the environment can best be achieved using models based on systems theory. Systems theory is a way of looking at the world that recognises all things are interconnected and understanding of one thing requires understanding of the others. Based on first law of thermodynamics, which states: "matter can neither be created nor destroyed, it only changes form" (Obert and Gaggioli 1963), the theory implies all flows coming into the system must go somewhere and all flows leaving the system must come from somewhere for a complete balance.

In practical use, the theory also recognises that such complete understanding is impossible. Issues must be made more manageable by bounding the overall system into sub-systems and looking at the influence and interactions between these. Systems thinking has had a major influence on environmental matters, but only a slight one on accounting and economics (Gray 1989).

Interaction between the environment and other technical sub-systems is complex, but can be modelled by isolating the sub-systems accounting and economics operate upon and then determining the relationship between these and the environmental sub-system. Environmental accounting is based on this type of modelling. First the accountants' perspective will be considered, then that of the economist and finally the link of these to the environment (Gray 1989).

The accountants' sub-system centres around the entity (individual or firm) they are financially reporting upon. Flows of the system are represented by physical goods and services, physical monetary funds and information regarding monetary amounts owed to and by the firm. This system is bounded by being able to include only those economic elements which can be expressed in financial terms, meaning that the system is limited to those elements which have prices attached to them. Social issues (e.g., infrastructure, waste) and items for which no prices exist (e.g., air) are largely ignored. This implies the information from accounting systems, which is used in all management decisions, may be deficient from including elements that may otherwise affect decisions. These limitations of accounting are derived directly from a more fundamental matter, the economic view of the world (Gray 1993).

The current economic view is dominated by neo-classical frameworks where everything is based on prices, as generated through the exchange of property rights between parties. The exchange interaction determines which of the elements involved are positively priced, which constitute costs and if there exists any stewardship value (reflecting use and scarcity) of the item. The economic system can value only those items which can be exchanged through property rights, and can price only those elements of the exchange process the involved parties recognize a principle of ownership being attached to. Items like common property resources (e.g., air) and social aspects (e.g., clean air) that have no ownership attachment can not be priced by the economic system as there is no transaction process to base prices upon. This weakness of the economic system is inherited by the accounting system and explains why many environmental items do not have attached prices and therefore are not part of the accountants' system (Gray 1993).

Linking accounting and economics is straightforward, linking this world back to environmental matters is more complicated. A simple interpretation of the problem is that prices generated through property right exchange are incorrect as they fail to reflect the full costs of the item being exchanged. Starting from this interpretation, a link can be developed.

Economic reasoning strives towards a "utilitarianism" view of the world whereby all actions are judged according to the net benefits derived from them. Actions and exchanges that reflect a net positive overall effect to involved parties are termed as increases in the utility of those parties. Exchanges that reflect a negative benefit are termed as dis-utility activities. The goal of all transactions in society, according to positivist economic thought, is to increase utility.

The utilitarian view can be applied to accounting as the goal of financial reporting is to isolate all actions/elements that reflect the greatest financial gains and therefore increase financial utility or wealth.

The utilitarian view can also be extended to environmental matters using the methodology that those activities that negatively affect the environment reflect social dis-utility to the involved parties. Relating this back to economics, these effects are decreases in utility, and in terms of accounting theory, these are decreases in wealth. Applying this to agricultural environmental accounting, it can be stated that those practices which degrade the environment are depreciated and those which improve are appreciated.

Utility is a subjective concept that is not easily quantified, but its implications are clearly distinguishable and can be included in management decisions in terms of positive or negative measures. At this stage in environmental accounting recognising the factors that can cause dis-utility, even if they are non-quantified, is an important step in eventually being able to price environmental effects and quantitatively model utility (Gray 1993).

3.1 Ecological and Physical Theory

The agricultural accounts developed to reflect land productivity and environmental sustainability will be constructed in terms of the soil asset and based on the cycling of nutrients within the soil. Soil quality is seen as one of the keys to sustainable agriculture as it encompasses the relationship between physical, chemical and biological factors as well as the effects of management practice and nature (Karlen et al., 1992). These relationships are summarized in Figure 1 (located at the back of the chapter).

At present there is no single, universal, scientifically accepted method for quantifying and measuring overall soil quality (Parr et al., 1992). In lieu of one index bringing everything together, a variety of methods can be used as tools of potential indicators (Granatstein and Bezdicek 1992). Environmental accounting is one such method.

The environmental accounts for agriculture will concentrate on physical unit monitoring (through the soil science technique of nutrient budgeting) of two soil macro-nutrients: nitrogen and phosphorous. The nutrients will be modelled independently and each have separate accounts. These nutrients were chosen because of their essential roles in the plant growth process. This particular nutrient combination will serve as a good, although simplistic, overall indication of soil quality due to their importance in Manitoba soils in terms of controlled addition in fertilizers and effects as externalities.

3.1.1 Nutrient Budgets

Nutrient budgeting is a systems approach of analysing the state of the soil based on the monitoring the cycles of nutrients within the soil. Specifically, direct sources of addition (inputs) and pathways of loss (outputs), as well as capturing indirect effects such as erosion and externalities (Chapman 1976). When constructing a nutrient budget, it is important to distinguish between a new input to the system and the recycling process of previous inputs (i.e., net mineralization - a scientific process to be further discussed in chapter four) in order to avoid double counting (Chapman 1976).

Nutrient budgets are commonly used in soil science applications (Chapman 1976, Frissel 1978, Foth 1990, Miller and Donahue 1995). The technique is easily adaptable and budgets can be constructed on a farm level (Frissel 1978) or on a global scale (Foth 1990).

The underlying premise of the environmental accounts is their construction as a tool to be used by producers, and therefore must be producer friendly. This means the data necessary for their construction be information the producer has on hand or has access to, and the computations be straightforward and interpretation transparent, yet meaningful. Nutrient budgets are ideally suited to this task as their budgetary format is one most people are familiar with, due to its fit with the standard format of financial statements , and the majority of the necessary data is either producer derived or reliable estimates can be obtained.

Having the budgets based on ecosystem cycles within the soil provides the necessary underlying scientific accuracy to provide a simple and general picture of the soil state. Other, more complex methods (i.e., soil tilth indexes, micro and macro nutrient analysis, etc.) can provide a more in depth analysis, but their information requirements are generally beyond that of the producer and their interpretation may involve prior scientific training in order to clearly differentiate results. Nutrient budgeting is therefore the tool of choice.

The budgets would be constructed for crop and mixed farm operations. Not all account entries will necessarily apply to all operations. If an entry did not apply, can be simply left out.

3.2 Accounting Theory

3.2.1 Financial Theory

There are four basic steps in financial analysis: definition of financial statements, interpretation of the statements, analysis of the results and comparison over a specified time period (Myer 1956). The environmental accounts for soil, based on nutrient cycles and the nutrient budgeting technique, will be constructed in the format of standard accounting statements and in terms of adapting to the basic financial analysis methods.

Constructing the accounts along this basis conforms with the general guidelines for the development of any environmental account (discussed in chapter two). It also enables a familiarity between the traditional financial statements a producer currently keeps and these new environmental accounting statements, as they can be attached in the appendix of a standard financial report.

The first and second steps in financial analysis are the construction of the basic statements: income statement and balance sheet. These are the basis of financial reporting for any organization. The income statement records all revenues (inflows) and expenses (outflows) to yield a net profit or loss figure. The balance sheet details all assets (positive amounts), liabilities (negative amounts) and owners investment in the organization. It yields a figure of net worth.

The third step involves the reconciliation of these two statements. Profits from the income statement are added to the balance sheet and losses are subtracted from it. Together, these two statements give the total financial position of any organization (Tracy 1994) and their reconciliation provides the validity of context for further analysis of the results in terms of operating at a net profit or loss and net worth (Myer 1956, Larson et al., 1987).

The last step, comparison, takes the analysis from a one period static, short-term procedure to a dynamic, long-term procedure based on a number of periods. A particular set of statements, known as comparative statements, can be compiled for the flows, balances and reconciliations in order to provide this long-term information. Comparison is important because a statement for a single year may be unduly influenced by unusual conditions during that year and may not be representative. A comparison of several years yields greater value in its information (Myer 1956). The comparative statements can also highlight any trends, by use of ratio analysis, of the net figures over a number of periods (Myer 1956). With the conclusion of this step, complete analysis of the statements has been performed.

3.2.2 Ecosystem Adaptation

The construction of nutrient budgets is the key to the construction of the agricultural environmental accounts. Nutrient budgets provide the link between the physical units of soil science and financial units of accounting. By capturing the inflows and outflows of the system, nutrient budgets present a net position of the nutrient state in the soil, similar to a net position on a financial statement. This similarity enables a link between the two theories to be easily established. This is the starting point for the physical construction of the agricultural environmental accounts.

3.3 The Agricultural Accounting Statements

3.3.1 Flow Statements

The flow statement will be based on a nutrient budget of inputs and outputs, representing the major avenues of loss and addition to the system. This will show the systems net change. The general procedure is as follows. First, all of the inputs will be sub-totalled together (positive amounts) and the outputs will be sub-totalled together (negative amounts). Second, the outputs will be subtracted from the inputs to arrive at a net change figure. If the net change figure is positive, then the inputs are greater than the outputs and the nutrient system is appreciating. If the net change figure is negative, then the outputs are greater than the inputs and the system is depreciating. This is analogous to financial gains and losses and economic utility increases or decreases.

Two types of flow statements will be constructed, differentiated by time frame: periodic and comparative. The periodic flow statement is constructed at the end of each growing season to show the net change in the nutrient state during a particular period and highlights short-term information. The comparative flow statement is a side-by-side yearly tabulation of information from a number of periodic statements onto one synopsis statement.

A comparative flow statement distinguishes itself from a periodic statement in its ability to analyse for long-term implications. This is achieved through two steps. First, to highlight any directions in trends by looking at the increases/decreases between years. Second, to calculate the percentage change of these differences. This will aid in a clear portrayal of the magnitude of these changes.

The comparative flow statement is based on accounting theory (Myer 1956), but the importance of the implications can readily be seen in a soil science context as it can clearly show the direction of changes in the nutrient situation over time. These changes will most likely be of small magnitudes each year, such that if one year is looked at in isolation the effects may not be clearly noticed. But, by looking at small changes over a number of periods, their presence becomes more prominent and their effects more distinguishable. This is particularly important in nutrient cycles where only a small portion of a large stock amount is being affected each year.

The gain and loss statements yield important information, but can not be looked at in isolation. The next step is to look at the stock statement and determine where in the system, to which particular asset, the gains and losses are accruing. For instance, if we show a negative flow balance (loss) the system is considered to be depreciating. But, if the loss is balanced by an increase in the available asset pool and decrease in leaching externalities, then the loss is not as negative as it first appeared.

To put this in a finance perspective, the equivalent would be to show a loss on the income statement, because a large investment was made (increasing the capital asset accounts) that is diminishing current profits, but will pay off in future earnings. Looking at the stock statement puts the results of the flow statement in a context for analysis.

3.3.2 Stock Statement

The agricultural environmental accounts' stock statement will be an assessment of the capital account assets. In this case, the state of nutrient accumulations in various forms within the soil asset. All balances will be held in positive amounts.

The statement will be comprised of various sub-accounts each representing a form, or holding cell, of the nutrient in the soil. A typical statement will have four main sub-accounts: plant, animal, manure and the nutrient pools. Each sub-account will be independent and have separate opening and closing balance entries. The difference between the opening and closing balances represent the net change in each sub-accounts.

The sub-accounts will capture, indirectly, the transformations of the nutrient cycle. In particular, the movement between the banks through the differences in their individual initial and closing balances through a three step procedure. First, the initial recording of the asset values will be done at the start of each year, or cycle. Second, at the end of the year/cycle, another entry will be made to reflect the closing balance. No flow or immediate entries will be made to the capital accounts during the year as the intermediate process will be reflected in the flow account (nutrient cycle budget). Third, the difference, if any, between opening and closing balances for each sub-account is determined.

These differences, or net changes per account, are added together to arrive at a total net capital asset change for the year. It is this net change figure that is compared to the net imbalance figure from the flow account for the following step of the reconciliation adjustment.

All of the sub-accounts, together, represent the total amount of the nutrient in the soil. The total of their net changes will represent the total net change of the nutrient position in the soil, over a specified period. Two types of stock statements will be constructed, differentiated by time frame: periodic and comparative.

The periodic stock statement allows a producer to isolate short-term quality and quantity characteristics of their nutrient resource. The key distinction being between whether the asset is held in an available or unavailable form, with respect to future plant uptake. The greater the available pool, the higher the quality of that nutrient in the soil, and the less fertilizer the producer has to use as a supplement.

The comparative stock statement measures the individual asset value changes over time through comparison of a series of periodic statements. This allows for monitoring of the individual sub-account net changes over time as well as the overall nutrient position of net change.

Quantity changes are valuable long-term insights, but as it is a system that is being modelled it is equally important to analyze how the different forms in which the nutrient asset is held interact. Ratio analysis of these changes, individual sub-accounts and overall net change, can be calculated to highlight any trends in direction or pathways of the changes that may be emerging.

For instance, if a pattern emerges of decreases in the available nutrient pool while groundwater leaching is increasing, a problem with soil structure may be being highlighted and this is an indication of poor soil quality. These types of insights will give the producer not only a long-term picture of how his asset values are changing, but also one of where potential problems may lie.

Once the flow and stock statements have been tabulated, the next step in accounting procedure is to check and balance the system. This necessary step, known as the reconciliation adjustment, ensures the timeliness and validity of the statements (Larson et al., 1987).

3.3.3 Reconciliation Adjustment

The reconciliation component relates the stock and flow statements to each other with the goal of checking for differences in the net changes between the two statements. In finance this procedure simply involves checking the mathematics (additions and subtractions) of the statements to look for a mis-entry as accounting theory dictates both statements balance and their net changes equal, after all errors have been corrected for.

Complete balance works for a financial entity as the accounting system is based on a closed and static sub-system where all items affecting financial position are easily recognised and included through their monetary amounts.

But, a nutrient cycle is dynamic and part of an open ecosystem, which is subject to many uncontrollable effects, and complete modelling is not always possible. In environmental accounting, the statements will likely not balance. With respect to the nutrient cycles, this difference is attributable to eco-system processes not modelled in the accounting system along with small errors in estimation.

For environmental accounting purposes, the two statements can be balanced using nutrient cycle principles and basic accounting theory. This procedure has two steps.

First, the net change figure from the stock account is subtracted from the net change figure of the flow account, yielding an amount to be termed the net difference. Avenues of flows (additions, depletions and movements within) of the nutrient cycles may relate to more than one element in the capital stock accounts. For this reason, the accounts on the flow statement will not be separated and directly linked to the stock accounts. Instead, flow inputs and outputs will be tabulated within their respective budget sheets and their net figures will be compared.

Second, this net difference is then added/subtracted as a separate entry on the flow statement, the account balances on the stock statement remain unchanged.The adjustment entry is structured to affect only the flow statement because the net difference entry is reflective of a non-modelled process or inaccuracies in the estimation procedure. The flow statement is where the dynamics of the nutrient cycle are captured. The reconciliation entry changes the statement to an adjusted version where the flow balance now also reflects the reconciliation effect

The underlying basis of the adjustment is the assumption that it is within the nutrient cycle that an un-modelled process would appear. With the inclusion of the reconciliation entry on the flow statement all elements in the system are assumed accounted for.

3.3.3.2 Reconciliation Implications

The reconciliation procedure is valuable because it highlights the magnitude and direction of differences and can monitor these over time. The ability of the accounts to capture the system is crucial in ability of the relevance of the information tabulated to base future productivity decisions upon.

The short-term significance is emphasised in the reconciliation between the immediate periods' stocks and flows. This will show the magnitude of the processes and estimation mis-calculations not modelled by the accounting system. If the number is large, the data should be re-calculated for error or a revision of the flow processes may be necessary in order to capture the effect. If the number is small, the accounting adaptation can be deemed to be fairly accurate and modelling complete.

The long-term significance is highlighted in the relative magnitudes of the reconciliation entry, when monitored over a number of cycles. If the adjustments continually increase in size or move in an erratic manner, this may indicate an important aspect of the system is not being accurately captured. On the other hand, if the adjustments are decreasing, this may be an indication that the reliability of the estimates is increasing and a greater share of any un-modelled processes is being captured.

3.4 Summary

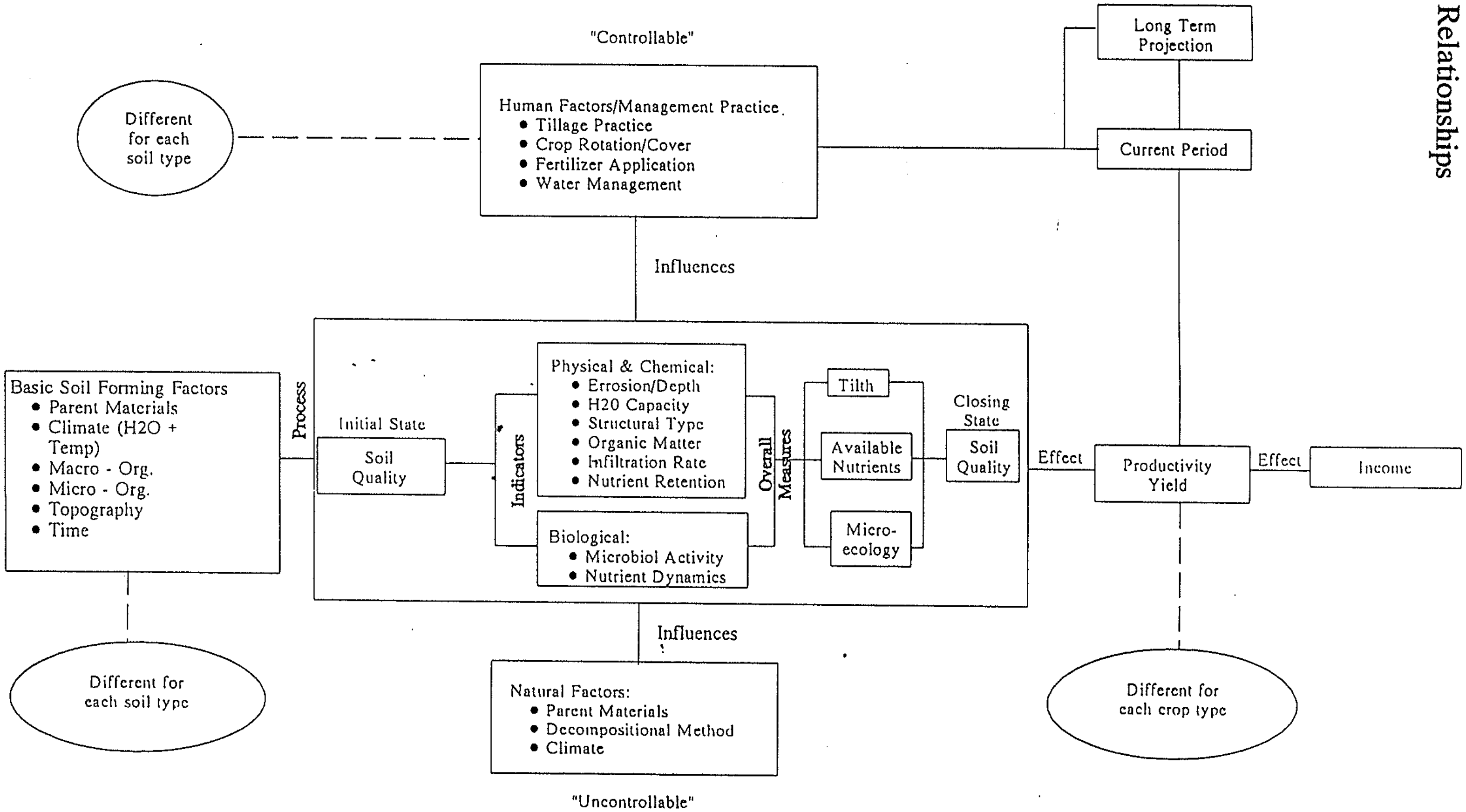
The accountant works within the world of the economist. Environmental effects not priced by the economic system can not be included in traditional accounting statements. One way to model the inclusion of environmental effects involves the economic concept of utility. Those environmental effects which yield negative results that society recognises as affecting individual and social utility but do not have monetary values attached, can now be included in an expanded set of accounting statements (environmental accounts) in terms of positive or negative measures. The relative magnitudes of these can be used in future management decisions.

The agricultural environmental accounts will be constructed in terms of the soil asset and concentrate on modelling the scientific nutrient cycles of nitrogen and phosphorus. The eco-system cycles will be translated into an accounting system by use of the scientifically based nutrient budgeting technique and financially based income and balance sheet statements, in conjunction with standard procedures in financial analysis.

The accounting/environmental adaptation will be judged through the size of the reconciliation entries that serve to check and balance the system. The agricultural accounts will be interpreted in terms of nutrient quantity and quality considerations and show overall increases or decreases in the system. The magnitude of these changes inform the producer of appreciation or depreciation of their soil quality. In terms of economics this reflects utility changes, and in terms of finance these reflect changes in net wealth. The next chapter develops the specific agricultural accounts for nitrogen and phosphorous.

Figure 1

Soil Quality Relationships



Chapter Four - The Agricultural Environmental Accounts

4.0 Introduction to the Agricultural Environmental Accounts

The agricultural environmental accounts will be developed for nitrogen and phosphorous based upon the cycling of these nutrients in the soil. The complete set of accounts will include flows (inputs, outputs and transformations) and stocks (various holding cells within the soil). The recording of the nutrient cycles will be done on a periodic basis, to define the short-term situation. Comparison of a number of periodic statements can be constructed to show longer-term implications.

Quantitative range based estimates of the nutrient cycle components will be provided to demonstrate the relative magnitudes of each effect. The estimates are provided for illustrative purposes only and do not correspond to a particular farm, research station or site. These values will be derived from a combination of Manitoba studies (Racz 1995, Norwest Labs 1995) and various studies undertaken on similar soils in the Great Plains region (Hauck 1971, Frissel 1978, Cowell and Doyle 1993, Miller and Donahue 1995), as a complete Manitoba producer based data profile is not currently available.

The following chapter will detail the specific nutrient cycles for nitrogen and phosphorus. The cycles will be separated into their various components and these components will reflect the accounts developed for the agricultural flow and stock statements. First, a brief introduction to nitrogen and phosphorus in the soil. Then the nitrogen accounts will be detailed, flows and stocks, followed by the phosphorous accounts and its corresponding stocks and flows.

Chapter four details the construction of the complete set of accounts. Not the statements which compile the accounts together, but the accounts themselves which make up the statements. Construction of the statements will be shown in chapter five.

4.1 The Nitrogen and Phosphorous Nutrients

There are approximately 16 essential elements plants need for growth. These can be grouped into three categories: primary elements, macronutrients and micronutrients. Hydrogen, oxygen, and carbon are the primary elements; the basic building blocks of life. Plants utilize these nutrients by absorbtion through air and water particles. Nitrogen, phosphorous, potassium, iron, sulphur, calcium, and magnesium are macronutrients; plants use relatively large amounts of these nutrients, over 500 parts per million. Utilization occurs mainly through decomposition of soil organic matter, with additional inputs through fertilizer. The remaining elements, boron, manganese, copper, zinc, molybdenum and chlorine are micronutrients; traces found within the plant. Plants utilize smaller amounts of these mainly through soil organic matter decomposition. (Donahue 1983, Foth 1990).

Of these sixteen essential elements, nitrogen and phosphorous capture the most attention in agriculture as they are the two nutrients most commonly associated with plant deficiency and growth limitation conditions. In the soil cycle, as nutrients are removed from the soil through plant growth, natural biological processes are at work replenishing them. Under the current conditions of intensive agriculture, the rate of nutrient removal has become far greater than the natural rate of nutrient replenishment, causing a deficiency of these nutrients in the soil (Donahue 1983). To achieve maximum economic yields, producers use fertilizers to supplement this renewal rate ensuring the plant receives the nutrients necessary (Donahue 1983) to eliminate nutrient deficiency.

In the Prairie region, nitrogen and phosphorous are the two fertilizer elements predominately added in chemical fertilizer applications. Sulphur and potassium are also added, although to a lesser degree. Fertilizer application rates are based on a pre-determined yield goal (one that balances productivity with input costs to be economically efficient) and soil tests (which give a general recommendation of fertilizer nutrient combinations).

In order to achieve maximum efficiency from the fertilizer recommendations, the next step is to decide on the timing (fall versus spring) and method (broadcast versus seed placement) of application, as plants differ in their fertilizer requirements between species, varieties and growth stage. Some producers apply fertilizer in the fall for reasons of ease and economics (i.e., reduced fertilizer prices), but over the course of winter some fertilizer is lost to natural process (to be discussed in section 4.2.3) and not available to the plant come spring. Knowledge of the extent of these losses, which nutrient monitoring highlights, will allow the producer to factor the deficit into their application rates. This will provide additional information (other necessary information would include the value of the crop, nutrient response curve, cost of fertilizer and magnitude of the loss) to aid in determining answers to questions such as; if the increased fertilizer usage costs outweigh the convince and decreased unit cost per hectare of an early application (Donahue 1990).

Similar reasoning can be used for the application technique decision. The broadcast application is convenient and applies nutrient to the entire crop root system, but requires more fertilizer. Seed placement or bond application techniques concentrate fertilizer directly on, or adjacent to, the plant and therefore result in more efficient fertilizer use, but require additional labour (Cowell and Doyle 1993).

Soil nutrient relationships play an important role in application decisions as they can serve to either enhance or limit the effects of fertilization. An intimate knowledge of nutrient reactions in the soil, specifically their cycles— inputs, outputs, transformations and movements, will heighten the producers ability to make decisions that will increase economic efficiency.

4.2 The Nitrogen Accounts

4.2.1 The Nitrogen Cycle and the Flow Account

The cycling of nitrogen in the soil is a sequence of bio-chemical changes where nitrogen is deposited, utilized by living organisms, transformed upon their death and decomposition then ultimately converted back into a useable form once again (Foth 1990). These relationships are summarized in Figure 2, located at the back of this chapter. This complex, continuous, cycle can be broken down into three sections: inputs, outputs and transformations. Each component is a combination of biological processes and human influence.

Nitrogen is the key element in plant growth, playing a key role in plant biochemistry as an essential constituent of cell walls, proteins, nucleic acids and chlorophyll (Hay and Walker 1989). Adequate nitrogen produces thinner cell walls (allowing the plant to easily absorb nutrients) which results in larger plants with more tillers and grains per ear; hence greater crop yields (Hay and Walker 1989, Donahue 1983).

A deficiency of nitrogen can have a detrimental influence on plant growth and low yields are the result (Hay and Walker 1989). Nitrogen deficiency refers not to a lack of total nitrogen in the soil, but a lack of mineral nitrogen in the (NH_4^+, NO_3^-) form that can be utilized by plants for uptake (Donahue 1983). A balance of nitrogen in the soil, as opposed to oversupply through over-fertilization (undersupply in not usually a concern with the widespread availability of fertilizers), is important to monitor as excessive nitrogen increases the risk of environmental impacts and costs without offsetting increases in yield.

The following section will detail the elements of the nitrogen cycle. First the inputs, second, the outputs and last, processes of transformation. From these cycle actions, all elements necessary to construct the flow statement are present and the state of nutrients in the soil can be monitored. Following the discussion will be a sample flow statement, based on the relative relationships between the accounts. As noted in the introduction to this chapter, the quantitative construction of the accounts into the statements will be shown in chapter five.

4.2.2 Inputs

There are four main direct additions to the nitrogen cycle: fertilizer, fixation of atmospheric nitrogen, precipitation/dry deposition and manure.

4.2.2.1 Fertilizer

The largest direct input in agricultural ecosystems is inorganic fertilizer, accounting for upwards of 50 per cent of the total input into the system or approximately between upwards of 59 to 48 kilograms per hectare (Hauck 1971, Miller and Donahue 1995). Fertilizer is added to supplement the nutrient power of the soils and compensate for soil nutrient losses incurred over the growing season. The most popular nitrogen fertilizers are anhydrous ammonia and urea (Donahue 1983). The approximate amount of fertilizer addition is based on predetermined yield goals and soil tests.

4.2.2.2 Fixation

Nitrogen fixation is the microbial process in which molecular (N_2) nitrogen is taken from the air and converted into a form that can be used by the plant (Donahue 1990). Fixation accounts for approximately 10 per cent of total inputs or approximately between 18 to 22 kilograms per hectare (Hauck 1971, Miller and Donahue 1995). There are two types of fixation: symbiotic and non-symbiotic.

Symbiotic fixation is an association between plants on soil bacteria which results in the plant, those that have the ability, to fix nitrogen from the air and use this nitrogen in their growth cycle. Legumes are one group of plants that have this ability. Atmospheric nitrogen supplements soil nitrogen, as most plants use both (Foth 1990).

Symbiotic fixation affects nitrogen in the soil in two ways. First, in cropping systems which include leguminous species, additional fertilizer is not always necessary or added in small amounts (Foth 1990). Second, upon harvesting of the legume. If all the crop is removed, then no additional nitrogen is added to the soil. But, if only the bean is harvested and the stems and leaves remain, nitrogen is added to the soil through plant residue (Foth 1990).

Non-symbiotic fixation, also referred to as free fixation, occurs through the actions of groups of bacteria living independently in the soil who convert nitrogen into microbial tissues which are released and available to the plant when the micro-organisms die and decompose (Foth 1990). This mainly occurs in soils with soil acidity pH levels over 6.0 (Donahue 1983). Most Prairie soils are low in acidity. This type of fixation can be a significant input in native prairie systems, but is low relative to cropping and fertilizer input systems.

4.2.2.3 Precipitation and Dry Deposition

Precipitation refers to the amount of nitrogen brought down annually by rainfall, approximately 4 per cent of total additions or approximately between 4.5 to 6.5 kilograms per hectare (Hauck 1971, Miller and Donahue 1995). This amount is usually nominal in semi-arid regions, such as the Prairies where the majority of the limited rainfall is brought in the spring (Frissel 1978). Higher amounts are found in more tropical regions, as they receive greater amounts of rainfall (Hauck 1971).

Dry deposition is the amount of nitrogen gained in transfers from the air (Frissel 1978). Again, this will be a very small amount.

4.2.2.4 Manure

The manure account would only be applicable to farm operations where producers are using manure as an additional fertilizer element on their fields or contain livestock in their operations. Nitrogen in an element within the composition of manure, with one kilogram of manure containing approximately 0.0052 kilograms of nitrogen within it (Manitoba Agriculture 1994).

4.2.3 Outputs

There are five main direct outputs of the nitrogen cycle: crop removal, leaching, denitrification, volitization and manure export.

4.2.3.1 Crop Removal

Crop removal is the largest direct output of the cycle, accounting for approximately 80 per cent of total removal from the system or approximately between 62.0 and 50.5 kilograms per hectare, depending on the amount of fertilizer added (Hauck 1971, Miller and Donahue 1995). Export of nitrogen in the plant is reflected in its protein concentration.

If a soil is nitrogen deficient, nitrogen additions will initially increase both yield and protein concentration. As nitrogen continues to be added, the yield curve will level off, but the protein level will continue to become more concentrated. Nitrogen is only one factor that can affect protein levels, weather and soil type also play significant roles (Cowell and Doyle 1993, Hay and Walker 1989).

4.2.3.2 Leaching/Nitrification

Nitrogen leaching is the movement of nitrogen from soil surface horizons to sub-surface layers where it can be transferred to the groundwater table. This accounts for approximately 3 per cent of removal from the system or approximately between 5.0 to 3.0 kilograms per hectare (Hauck 1971, Miller and Donahue 1995).

Leaching occurs as an after-effect of a process of nitrogen conversion known as *nitrification*. Nitrification is the biological process where soil bacteria oxidize soil nitrogen into an ionic form that is easily available to plants for uptake. Nitrification converts relatively immobile ammonium ions in to the mobile form and thereby increases the risk of nitrogen leaching loss. In well-aerated soils, nitrate ions move rapidly, through mass flow of water within the soil, to the plant root where it is absorbed. But, in poorly aerated soils the plant is not able to absorb all of the ions produced, and the excess is either lost to the atmosphere (denitrification) or moves downward with the water flow eventually ending up in the groundwater table (Donahue 1983, Foth 1990). The majority of the leached nitrogen ions, are nitrate ions as they are the most mobile, whereas ammonium ions are held by the soil matrix (Foth 1990).

4.2.3.3 Denitrification/Nitrification

Denitrification is the gaseous loss of nitrogen to the atmosphere that results from the conversion of nitrate ions to nitrogen gas. It accounts for approximately 14 per cent of total removal from the system or approximately between 5.5 to 4.5 kilograms per hectare (Hauck 1971, Miller and Donahue 1995). Denitrification is not a slow or constant process, but one that occurs rapidly when conditions are favourable (Donahue 1983) and it therefore difficult to obtain precise estimates of this process.

Nitrogen that is not absorbed by the plant or kept within the soil layers for use at a later date (to be discussed in section 4.2.4) accumulates as mineral nitrogen in the soil profile. Mineral nitrogen that does not downward (leaching) is potentially reduced or lost from the soil into the atmosphere. Soils that are well aerated and have a free-flow of oxygen available to the bacteria, incur small denitrification losses. Soils with poor aeration and a lack of soil oxygen (e.g., soils that are waterlogged, soils that are heavily manured or soils that are slightly warm and acidic) incur higher denitrification losses (Donahue 1983, Foth 1990). In soils where the total amount of nitrogen remains relatively constant year after year, the annual additions via fixation tend to balance the losses via denitrification (Foth 1990).

4.2.3.4 Volitization

Volitization is the gaseous loss of ammonium nitrogen (NH_3) into the atmosphere which results when ammonium is introduced into a basic solution (NH_4^+), such as from surface applications of ammonium or urea fertilizers on high carbonate content soils (Donahue 1983). Broadcast fertilizer application causes the largest losses because of the exposure of the fertilizers to the soil and its proximity to the atmosphere. Losses can be minimized by covering the fertilizer with soil after application or washing it in with rainfall or irrigation (Donahue 1983). This type of loss can contribute only traces (Frissel 1978) of additional nitrogen, or up to 15 per cent (Hauck 1971, Miller and Donahue 1995) of total losses (which would represent up to between 16.5 to 13.5 kilograms per hectare), depending on fertilizer and soil type.

4.2.3.5 Manure Export

When exposed to air and oxidized, manure will lose nitrogen at a general rate of approximately 20-30 per cent of total applied broadcast manure (Manitoba Agriculture 1994).

Table 1

Nitrogen Flow Account

Inputs (kg/ha)		Outputs (kg/ha)	
Fertilizer Input	86	Grain Export	80
PPT and Dry Deposition	4	Dentrification	14
N2 Fixation	10	Volitization	3
Manure		Manure Export	
		Leaching	3
Total Inputs	*100*	Total Outputs	*100*
Total Inputs	*100*		
Total Outputs	*100*		
Net (Im)Balance	*Balanced*		

Note: data is shown in percentage form

4.2.4 Transformation Between Soil Banks

In addition to the direct inputs and outputs of the cycle, there are also processes of transformation at work. These processes are not direct inputs to the system, but are a form of re-cycling previous additions. They will be classified here as indirect inputs, because they are producing an amount of nitrogen to be available to the plant that, without these processes at work, the plant would not have access to.

There are two holding pools of nitrogen in the soil: inorganic (or mineral nitrogen) pool and the organic pool. Nitrogen is unique in that, unlike many other nutrients, plants can absorb either its organic or inorganic form (Miller and Donahue 1995) although inorganic nitrogen is the primary form taken up by plants.

At any single time in the nitrogen cycle, the majority of nitrogen lies within the soil organic matter, accounting for in excess of 95 per cent of the total nitrogen in the soil. Soil organic matter contains within it, on average, approximately 5 per cent nitrogen (Miller and Donahue 1995). Nitrogen in the organic pool is held in a chemical form that protects it from loss (nitrification and the accompanying leaching and denitrification), but this form is largely unavailable to the plant for uptake.

The remainder of soil nitrogen lies in a chemical form that is available to the plant for uptake and compromises the, much smaller, inorganic pool (Brady 1990, Donahue 1983). These nitrogen banks are not constant and a large part of the nitrogen cycle is the additions, depletions and movements between them.

The majority of nitrogen added (direct input) into the nitrogen cycle is of the inorganic form, through fertilizer application. A small portion of this additional inorganic nitrogen is made available for plants to uptake in a nitrate ionic form, with some accompanying denitrification and leaching (as discussed in section 4.1.2) losses. The large remainder is converted and rendered unavailable to the plant, and becomes part of the organic bank. A smaller amount is added through animal wastes and plant residues, which are organic in origin and are therefore added to the organic pool.

4.2.4.1 Net Mineralization

The movement of nitrogen from an available inorganic form, to an unavailable organic form is known as *immobilization.* The majority of direct inorganic nitrogen additions become immobilized (Brady 1990, Donahue 1983, Foth 1990). The large size of the organic bank is due to these additions along with the relative stability of the organic nitrogen compounds. This also partially explains the reasoning behind why large amounts of nitrogen can reside within the soil, but not available to plants and they then may be subject to nitrogen deficiency and require fertilizer additions in following cycles (Donahue 1983).

Nitrogen within the organic pool can be converted back into a plant available inorganic form. This slow process, known as *mineralization* involves the decomposition of soil organic matter and release of organic nitrogen compounds as plant available inorganic nitrogen ions (Brady 1990). Decomposition is fastest in warm well-aerated soils, such as sandy soils and in the summer months, and slowest in clay soils and the cooler spring (Miller and Donahue 1995) and also depends upon the amount of soil organic matter as the greater the amount of soil organic matter the greater the rate of nitrogen mineralization.

In general, in an agricultural system, the amount of mineralization exceeds the amount of immobilization. This is referred to as a state of *net mineralization*. This net process determines the amount of nitrogen available to the plant for use in its growth cycle each year from the nitrogen banks residing within the soil. This is traditionally a very small amount, only approximately 1-3 per cent of the total amount held in the soil banks (Brady 1990, Donahue 1983).

As an indirect input available to plants, net mineralization can account for up to 40 per cent of total inputs in agricultural systems (Hauck 1971, Miller and Donahue 1995). Quantitative estimations of these processes require complex scientific studies and can not be done per farm unit. General estimates attribute approximately 80 kilograms per hectare immobilized and 67 kilograms per hectare mineralized (Frissel 1978, Manitoba Agriculture 1994, Racz 1995).

4.2.2 The Nitrogen Stock Accounts

The cycling of nitrogen, as presented in the discussion of the cycle's inputs, outputs and processes of transformations, are only half of the accounts of nitrogen in the soil. As mentioned in the transformation discussion, not all nitrogen in the soil is used by the plant and large residual amounts. These are the various holding cells or forms of nitrogen within the soil. These can be referred to the assets of nitrogen in the soil as they all represent positive amounts.

These accumulations of nitrogen can be separated and accounted for by the environmental accounting system by isolating each form into a sub-account. Nitrogen will have 7 sub-accounts: plant, animal, manure, inorganic nitrogen in the rooting zone, organic nitrogen in the rooting zone and nitrogen in the sub-rooting zone.

The following section will discuss each sub-account and provide a general guide to its quantitative estimation (Hauck 1971, Miller and Donahue 1995, Racz 1995, Norwest 1995). All of these sub-accounts totalled together comprise the total amount of nitrogen within the soil. The first three accounts to be presented; plant, animal and manure, reflect information that most producers are currently aware of. The last three accounts; the three forms of nitrogen in the soil zone, reflect information that many producers are not aware of and is important in the crop input decisions.

4.2.2.1 Plant

This is a short-term cycle, one year, where the plant is seeded, grows and takes nutrients from the soil, dies and then returns some nutrients to the soil. The net change for this account would reflect changes in plant standing biomass through an estimate of plant yield and plant tissue analysis. This involves analysis of the plant leaves for nutrient content. Under normal conditions, the amount of plant biomass remaining in the field is on par with the amount typically removed by the crop (Morrison 1995).

Typical plant contents (in terms of total plant biomass) of nitrogen are approximately 2 per cent for cereals and approximately 4 per cent for oilseeds (Cowell and Doyle 1993, Norwest 1995). To use an average cereal as an example, this translates into approximately 16 kilograms per hectare (Norwest 1995), which compares favourably to the average cereal crop removal rate of 20 kilograms per hectare (Cowell and Doyle 1993).

The net change figure for this account will be negligible as the plant will contain relatively the same amount of nitrogen within its make-up each year. Large changes would only occur if the plant were to undergo some adverse growth conditions. This sub-account is of minor magnitude, but it still a holding cell is therefore included in the asset accounts.

4.2.2.2 Animal

This account is mainly attributable to livestock producers and reflects a short-term cycle in reference to the size of a herd kept. The account is calculated as the size of the herd multiplied by the nitrogen content a live animal carries within it. This can be tabulated in number of animals or in animal units (to differentiate between age and size).

Changes in the herd size depend on the economics of an operation and may or may not vary from year to year. If the herd size is kept relatively constant, the net change would most likely be zero. If the herd size has changed during the year the net change figure would reflect the additions/depletions in herd size. For example, the average hog contains 36 per cent nitrogen within its internal components or approximately 6.1 kilograms (kg) of nitrogen (Frissel 1978).

4.2.2.3 Manure

This account is also mainly applicable to livestock producers. This refers the nitrogen content of manure excreted by the animals. The amount of manure is based on herd size and if herd size is relatively constant then the amount of manure excreted and stored would also be relatively constant. This account could be recorded in slurry, or lagoon, volume or by the average amount of animal excretions per day or year. For instance, in keeping with the hog example, the average hog excretions contain approximately 2.5 kg of nitrogen per year (Frissel 1978). Or, the average hog excretes 7.4 kg of manure per day with an associated nitrogen content of 0.0052 per kg (Farm Practices Guide Book 1994).

No breakdown will be done of phosphorous spread onto fields as fertilizer as this would be reflected in the direct input accounts of the flow statement and the nitrogen loss from the fertilizer would be recorded there.

4.2.2.4 Inorganic Nitrogen

This reflects a short-term cycle of nitrogen in the soil in a form available to plants for uptake in their growth cycle. Changes in this bank are reflective of their residual component of direct fertilizer additions (the net change from the flow statement) the and additions through the process of mineralization - which will include losses from immobilization (available to unavailable) and gains from mineralization (unavailable to available).

Estimates of the size of this bank can be obtained from a standard soil tests, reflected as the amount of available nitrogen, performed at the beginning and end of each season. No intermediate entries will be made to this bank to distinguish between residual fertilizer additions and processes of mineralization, or other microbial activities. The processes, in aggregate, will be reflected in the soil test value each season. The dis-aggregation of the net change figure is a complex process beyond the scope of this exercise.

The net change of this cycle will be zero or very small as the plant will use all nitrogen it can from this pool. The residual nitrogen the plant can not use is accounted for the following two stock accounts.

4.2.2.5 Organic Nitrogen in the Rooting Zone

This is an important account for producers to monitor (many are unaware of this information) as it can be crucial to the future productivity of the soil. Organic nitrogen is the large pool of residual and naturally occurring nitrogen held in the sub-soil rooting zone. This nitrogen is not readily available for plant use and is only slowly converted to an inorganic form (a form that is available), through mineralization. The majority of nitrogen in the soil is attributed to this storage bank.

Initial estimation will be based on average Manitoba site data as obtained through local field studies (Norwest 1995). Historically, these banks have been substantially drawn down as agriculture has become more intensive since the turn of the century. With the use of fertilizers in the last thirty years, the size of these banks is slowly increasing (Cowell and Doyle 1993).

Changes in this account are reflected on a long term basis. This is largely a reflection of the mineralization process (additions through immobilization and depletions through mineralization) with minor losses also occurring from leaching of soluble inorganic nitrogen through this zone and into the sub-rooting zone. Standard soil tests can provide estimation on the size of this bank as the amount of total nitrogen in the rooting zone (0-2 feet) minus the amount that is available within this depth (used in the calculation of the available bank) with the organic composition being the residual. Or, the estimate from the soil organic matter content could be used. No intermediate entries will be made as the net change processes will reflected in the changes of the aggregate figures of the standard soil test data.

4.2.2.6 Sub-Rooting Zone Nitrogen

This account is the account that will monitor the leaching movement of nitrogen—mainly nitrate. This account will have two components: nitrogen residing in the soil and nitrogen leached through to the groundwater. Nitrogen in the sub-rooting zone will eventually either move downward into the water or become accessed by a deep rooted plant for uptake in the growth cycle.

1. Nitrogen in the soil—this amount can be determined by either core test analysis or a series of soil tests. Core analysis is a very specific type of soil test that takes soil samples at very deep depths, similar to geological core samples. The other option is a series of standard soil tests, one performed at 0-2 feet and the other at 2-4 feet or deeper. This method will help to determine a farm specific measure of nitrate movement if the amount of nitrate in the deeper soil test continually increases.

2. Nitrogen in the groundwater—the initial balance of this account will be determined through the use of a water sample test. The first year closing balance, and all subsequent balances, can also be determined through water sample tests as this method is easily available for producers to use. Other more complex methods, such as building a well field, may yield more exact results but are beyond the needs of most producers.

   The net change may be very large in the first year (as zero is the starting point), but in subsequent years it will stabilize to provide more accurate reflections. This is a good indicator of the beyond the farm gate effects of nitrogen. Continual increases in this account will highlight both a problem with soil structure, weak structures allow rapid nutrient movement, and an environmental concern for those using the groundwater.

Table 2

Nitrogen Stock Account

Plant	opening balance	p
	closing balance	p
	net change	*P*
Animal	opening balance	a
	closing balance	a
	net change	*A*
Manure	opening balance	m
	closing balance	m
	net change	*M*
Inorganic Bank in Rooting Zone	opening balance	i
	closing balance	i
	net change	*I*
Organic Bank in Rooting Zone	opening balance	o
	closing balance	o
	net change	*O*
Sub-Rooting Zone in Soil	opening balance	s
	closing balance	s
	net change	*S*
Sub-Rooting Zone in Groundwater	opening balance	g
	closing balance	g
	net change	*G*
Net Change of Capital Assets *(P+A+M+I+O+S+G)*		*Balanced*

4.2.3 Summary of Nitrogen

Nitrogen is a key element in crop production. Ensuring an adequate supply is crucial to economically efficient production. Examination of the nitrogen cycle provides useful information on the status of nitrogen in the soil and with the use of this information a producer can determine if they need any adjustments in the input decisions (both crop selection and fertilizer application).

The nitrogen cycle can be broken down into separate sections, or accounts, and these are used as the basis for construction of a nitrogen flow account. The forms, assets or stocks, in which nitrogen resides in the soil can also be tabulated and these are used in the constructing the stock accounts of nitrogen. The transfer of these developed accounts, flows and stocks, onto the accounting statements will be presented in chapter five, where construction of all the statements is shown.

4.3 The Phosphorous Account

4.3.1 The Phosphorous Cycle and the Flow Accounts

Phosphorous is the second key element in plant growth, and the second most often deficient nutrient (Miller and Donahue 1995). Phosphorous plays a dual role in the plant growth process; as itself essential to plant growth and as a regulator in a plants' ability to efficiently uptake other nutrients.

In its first role, phosphorous is an essential component of the plant and aids in controlling cell division and growth and influences maturity, fruiting and seed production (Donahue 1983). Plants require the majority of their moderate phosphorous needs in the early growth stages (Donahue 1983). Beyond this moderate amount necessary for growth, additional phosphorous is not shown to have a significant effect on either yields or crop quality (Cowell and Doyle 1993).

In its second role, that of a regulator, phosphorous acts as a component of various compounds, which affect the ability of plants to successfully transform energy. Phosphorous has a positive effect on plant respiration and photosynthesis. This aids plant effectiveness in their uptake and transport of other nutrients, especially nitrogen (Brady 1990). Figure 3, located at the back of this chapter, summarizes these relationships.

4.3.1.1 The Phosphorous Problem

In most soils the amount of total phosphorous is low, estimates range between 0.5 to 0.1 percent by soil mass weight (Donahue 1983, Miller and Donahue 1995). Within this, the amount available in a soluble form available for plant uptake is critically small, seldom greater than 0.01 percent (Brady 1990) of total phosphorous. When additional phosphorous is added to the cycle, through fertilizer application, is rapidly "fixed" or changed to an unavailable form. This fixation leads to what is commonly known as the phosphorous problem.

Although plants only need a moderate amount of phosphorous for growth, approximately one tenth of nitrogen needs (Miller and Donahue 1995) they can not typically obtain this amount because soil phosphates are primarily held in forms of low solubility. Plants utilize nutrients in soluble forms. Phosphates initially added are in a soluble form, available for plant use, but they are rapidly fixed (through chemical processes in the soil to be discussed in section 4.3.4) within the soil to a insoluble (or low soluble) form the plant is not able to utilize. Only after time and natural processes (to be discussed in section 4.3.4) does the phosphorous become insoluble and available once again (Donahue 1983, Brady 1990).

The following discussion of the phosphorous cycle will be centred around the phosphorous use issue, in particular its accumulation to unavailable forms and slow transformation back to an available form. The phosphorous cycle involves inputs, outputs and transformations. The inputs will be used to construct positive flow accounts, the outputs to construct negative flow accounts and the processes of transformation can be used as direct inputs and towards the stock account components. First, the inputs will be presented, then the outputs and, last, the transformation processes.

4.3.3 Inputs

There are three main direct inputs to the phosphorous cycle: fertilizer, manure and other elements. .

4.3.3.1 Fertilizer

Plants absorb soluble forms of phosphorous from both organic and inorganic compounds, in roughly equal amounts (Brady 1990). Plants have the ability to utilize from both compounds as the key to phosphorous use lies not in the origins of the compound, but it its relative ability to be broken down and become more soluble allowing it to be available to the plant.

The largest direct input is inorganic soluble fertilizer, accounting for approximately 80 per cent of total additions or approximately between 14.5 and 13 kilograms per hectare (Hauck 1971, Miller and Donahue 1995). Phosphorous use efficiency by the plant is approximately 20 percent (Cowell and Doyle 1993). The remainder of phosphorous is "fixed" and rendered into an insoluble unavailable form (Brady 1990), thus increasing the amount of secondary mineral reserves in the soil. The fixation is discussed further in section 4.3.4.

4.2.2.2 Manure

Organic soluble compounds, such as manure, are another form of fertilizer. This addition is also subject to low use efficiency and is also fixed and added to the reserve component in the soil. The manure component would only be applicable to producers who spread manure on their fields or have livestock in their operations. One kilogram has approximately of phosphorous within its constituents.

4.3.2.3 Additional Inputs

Other unspecified elements, such as erosion, account of the remaining 20 per cent of total additions or approximately 3 kilograms per hectare (Hauck 1971, Miller and Donahue 1995). These other elements are not more clearly broken down into specific categories as the phosphorous cycle is a very complex process and science in still in the process of studying these effects.

4.3.3 Outputs

The major direct output of the phosphorous cycle is through crop removal. Leaching and gaseous losses are uncommon due to the poor mobility of insoluble phosphorous in the soil and that a large portion of phosphorous in the soil is held in this form. Some phosphorous is removed through surface erosion, but this is only a concern in an area with erosion problems.

4.3.3.1 Crop Removal

The amount of phosphorous removed by the crop is reflected in its protein content. In general, oilseeds are the most efficient users of phosphorous and will have approximately twice the phosphorous content of grains. Grains are less efficient due to poor phosphorous proliferation in the root zone (Cowell and Doyle 1993). Crop removal accounts for upwards of 90 percent of phosphorous output from the system or approximately between 11 to 12 kilograms per hectare (Hauck 1971, Miller and Donahue 1995).

4.3.3.2 Other Outputs

The remainder of output from the phosphorous system, approximately less than 10 percent or approximately up to 2 kilograms per hectare is attributed to erosion, manure export or other unknown sources (Cowell and Doyle 1993, Brady 1990).

Table 3

Phosphorous Flow Statement

Inputs (kg/ha)		**Outputs (kg/ha)**	
Fertilizer Input	90	Grain Export	90
Other Deposition	10	Other Loss	10
Manure			
Total Inputs	*100*	Total Outputs	*100*
Total Inputs	*100*		
Total Outputs	*100*		
Net (Im)Balance	Balanced		

* data is shown in percentage form

4.3.4 Transformations

In addition to the direct additions and depletions, the phosphorous cycle also involves biological processes at work converting residual phosphorous in the soil to forms that are available to the plant for uptake. The processes are not direct inputs to the system, they are a re-cycling of residual phosphorous within the soil from previous input applications that have been fixed unavailable into a form that is available once again.

The phosphorous reserves in the soil can be accordingly classified to their main compound forms: soluble available and insoluble unavailable. The majority of activity in the phosphorous cycle consists of transformations and moments in these reserves. The two main transformation processes are: fixation and mineralization.

4.3.4.1 Fixation

Phosphorous fixation is the rapid process whereby soluble forms of phosphorous (added from fertilizer application) are changed into an insoluble inorganic forms. This occurs through the reaction of ortho phosphate with other elements in the soil. Specifically calcium in alkaline soils, and iron, manganese and aluminum in acidic soils (Donahue 1983). Phosphorous that has been "fixed" is no longer available for plant use and becomes part of the very large insoluble inorganic phosphorous reserve in the soil.

Fixation can occur by two processes, each having the same overall effect. Firstly, *precipitation* is the reaction of soluble phosphate into insoluble phosphate by iron and aluminum ions. This is most common is soils with pH levels around 6.0. Secondly, *adsorption* is the attachment of the soluble ions to insoluble surfaces of iron and aluminum ions in acid soils and calcium surfaces in alkaline soils (Donahue 1983). Through attachment, the soluble phosphorous is changed and no longer available to the plant.

The level of fixation depends upon several factors. Firstly, soil pH level. Optimal (the lowest amount of fixation) is a pH level near 6.5. Studies have shown this to be the level where the point of maximum availability to a plant occurs (Donahue 1983).

Related to soil pH is the relative presence of fixing cations. The higher the concentration of the cation (Calcium, Iron, Aluminum) the more enhanced is their ability to fix. For example, an alkaline soil (high pH) with an abundance of calcium (the main phosphorous fixer in alkaline soils) will fix phosphorous at a greater rate than an alkaline soil with a lower concentration of calcium. Similarly, an acidic soil (low pH) with an abundance of iron, manganese and aluminum (the main phosphorous fixers for acidic soils) will fix at a faster rate then acidic soils with lower concentrations of these nutrients. Lower concentrations reduce the extent of phosphorous fixation (Miller and Donahue 1995). It has been shown that the addition of lime to acidic soils and chemical fixation inhibitors can also aid in limiting fixation (Miller and Donahue 1995).

The level of organic matter is another factor. Additions to organic matter, from manure and plant residues, can enhance phosphorous availability as the organic matter is decomposed and becomes mineralized back into a useable form (Brady 1990).

4.3.4.2 Net Mineralization

Phosphorous held in an organic form can be transformed from an insoluble, and unavailable, form to a soluble, and available, form through a process known as *net mineralization*. This process consists of two reactions. Firstly, organic soluble phosphorous is transformed into organic insoluble phosphorous via fixation. This phosphorous becomes a component of the organisms residing within the soil. The movement of the organic ions, from their initial addition in an inorganic form, to their transformation into an organic form, is known as *immobilization*. (The large complex organic polymers are not soluble and therefore not available to the plant).

Secondly, organisms living within the soil organic matter eventually die and their decomposition releases soluble organic and inorganic phosphorous. This movement is known as *mineralization*.

The combination of these processes (immobilization and mineralization) is known as *net mineralization* (Brady 1990, Donahue 1983). Net mineralization determines the amount of phosphorous available from organic sources within the soil each season (Brady 1990, Donahue 1983). This is typically a very small amount, as previously stated approximately 0.01 per cent of total phosphorous held (Brady 1990).

4.3.3 The Phosphorous Stock Accounts

Phosphorous, like nitrogen, has holding cells or assets (as the accounting aspect refers to them) in the soil. These holding cells are where the net transformation processes take place. There are four main form of the phosphorous asset: plant, animal, manure, available pool and the unavailable pool. These will hereafter be referred to as the stock accounts.

The following section will discuss each stock account and provide an approximation of its quantitative value, relative to the other stocks. As previous estimates, Manitoba specific data will be used where possible (Racz 1995, Norwest 1995) as well as data from other studies done in the Great Plains region (Hauck 1971, Miller and Donahue 1995) will also be used.

All of the stock accounts totalled together constitute the total amount of phosphorous residing in the soil at a specific point in time. This is reflected in the phosphorous stock balance sheet, of which these accounts make-up the components, which will be constructed in chapter five.

4.3.3.1 Plant

This is a short term cycle, one year, where the plant is seeded, grows and takes phosphorous from the soil, dies, and then returns some nutrient back to the soil. The net change for this account would reflect changes in the plants' standing biomass, as reflected through plant tissue analysis, of which crop removal rate can b used as a proxy (Morrison 1995). As was the case with nitrogen, this net change figure should work out to be minimal or zero, unless adverse growing conditions occur.

4.3.3.2 Animal

This account is mainly applicable to livestock producers and is based on a short—term cycle in reference to the size of the herd kept and phosphorous content of each animal. If the size of the herd did not change very much, the net change figure would be zero. If, due to economic and other reasons, the herd size considerable changes from the beginning to year end, the net change figure will reflect this.

The account would be recorded and tabulated in the same format as the nitrogen Animal stock account, except now being recorded is the amount of phosphorous per animal (or animal unit—differentiating the herd by age and size). In keeping with the hog example from the nitrogen stock accounts discussion, the phosphorous content of an average hog is 0.28 kg (Frissel 1978).

4.3.3.3 Manure

The account is also mainly applicable to a livestock producer and is dependent upon herd size. As herd size changes, this figure will change in the same direction. This account could be recorded by slurry volume readings or by the average amount of animal excretion per day, the same methodology as for the nitrogen accounts. The net change in this account is mainly dependent upon changes in herd size. In keeping with the hog example, the average hog excretion (per year) contains 1.53 kg of phosphorous (Frissel 1978).

No breakdown will be done of phosphorous spread onto fields as fertilizer as this would be reflected in the direct input accounts of the flow statement and the phosphorous loss from the fertilizer would be recorded there.

4.3.3.4 Available Inorganic Phosphorous Bank

This is the amount of phosphorous immediately available for plant use. Additions to this bank are mainly attributed to fertilizer applications and the positive effect of mineralization. The net change in this bank will be small as it is based on a short–term cycle and any residual fertilizer is quickly fixed and then added to the unavailable bank. Data for this bank is provided through standard soil tests which provide information on levels of available phosphorous in the soil.

4.3.3.5 Unavailable Phosphorous Banks

The unavailable banks are based on long–term cycles and contain the majority of phosphorous in the soil. As is the case with almost all nutrients, these banks have been substantially drawn down as agriculture has become more intensive since the turn of the century. With the use of fertilizers in the last thirty years, the size of these banks is increasing (slowly).

Estimates of these banks are not easily available. Soil tests of the total amount of phosphorous in the soil are less common in collection figures. If a reliable figure of the total phosphorous in the soil is available, then one procedure would then be to subtracting the available amount from the total amount leaving the residual amount to be the unavailable amount. Then, the balances are recorded in their appropriate accounts.

Although, when the aggregated total method is used, no distinction is made between inorganic and organic phosphorous. A producer may want this information. An additional step could be performed, if a producer was so inclined, to further dis-aggregate the total phosphorous data and obtain the information. This additional step is optional to producers, and the results of the total method alone are entirely substancial.

This method can be demonstrated with four steps:

Step One:

The total amount of phosphorous in the soil can be estimated with use of a specialized soil test. The estimation procedure is characterised by the following equation:

Formula 1:

Total Phosphorous	=	Available Phosphorous	+	Unavailable Phosphorous

The total figure is then broken down into two components: available and unavailable. The available figure is obtained through a standard soil test (as used for the stock account data in 4.2.3.4), leaving the unavailable figure to be solved for.

Formula 2:

Unavailable Phosphorous	=	Total Phosphorous	-	Available Phosphorous

Step Two:

The unavailable amount is then broken down into its organic and inorganic components. This is done by use of a generalized estimate of the phosphorous component within the soil organic matter. The total amount of soil organic matter in the soil can be determined through a standard soil test. Of this total soil organic matter, 0.05 (Miller and Donahue 1995) is a typical phosphorous composition. This amount will represent the size of the organic unavailable component. The inorganic unavailable portion will be solved for as the remainder of the total amount.

Formula 3:

Unavailable Organic Phosphorous	=	Total Soil Organic Matter	x	0.05%

Then;

Formula 4:

Inorganic Unavailable Phosphorous	=	Total Unavailable Phosphorous	-	Organic Phosphorous

The first two steps provide the opening balances of the unavailable bank accounts. The next two steps estimate the closing balances.

Step Three:

The closing balance formula for the aggregate banks is the opening balance minus the net mineralization rate of 0.01 per cent per hectare (Brady 1990).

Formula 5:

Closing Unavailable	=	Opening Unavailable	-	0.01%

Step Four:

The total unavailable closing balance (solved for in step three) can be separated into its organic and inorganic components, in order to make the appropriate adjustments to each individual sub-account. These can be assumed to be held in relatively equal portions (Brady 1990) and the total amount can be divided as such and the appropriate closing balances made. Each year, these same calculations will be repeated.

Table 4

Phosphorous Stock Statement

Plant	Opening balance	p
	Closing balance	p
	Net Change	*P*
Animal	Opening balance	a
	Closing balance	a
	Net Change	*A*
Manure	Opening balance	m
	Closing balance	m
	Net Change	*M*
Available Phosphorous	Opening balance	s
	Closing Balance	s
	Net Change	*S*
Unavailable Phosphorous	Opening balance	i
	Closing balance	i
	Net Change	*I*
Net Change of Captial Assets (P+A+M+S+I)		*Balanced*

4.3.4 Summary of Phosphorous

Phosphorous is a key element in crop production. Examination of the phosphorous cycle and the associated phosphorous use problem will provide a producer with a better idea of their phosphorous situation and the relative effects of continual fertilizer additions. One response to the phosphorous problem may be to simply apply more and more fertilizer to increase the gross amount in the soil. This is not the answer as too much phosphorous has a direct monetary cost associated with it. The key lies in monitoring the phosphorous levels currently in the soil and patterning management decisions on methods to utilize it, as the monitoring via the stock and flow accounts will show.

The developed phosphorous accounts, flows and stocks, based on the phosphorous cycle form the basis for the phosphorous environmental accounting statements. Chapter five will present the construction of these statements.

4.4 Summary of Nitrogen and Phosphorous Accounts

The environmental accounts for agriculture are based on soil quality and this is turn based on monitoring the nutrients state of nitrogen and phosphorous in the soil. These nutrients were chosen due to their importance in the plant growth process and significance in a balanced relationship with each other.

Each nutrient has a natural cycle in the soil based on inputs, outputs and biological transformations. Nitrogen and phosphorous each have independent roles to play in the plant growth process as well as working together to enhance each other's effectiveness. The combination of these nutrients, and their cycles, are one of the major determinants on plant growth and the environmental state of the soil.

The next chapter will detail the construction of the agricultural accounts in terms of the nutrient cycles and accounts for nitrogen and phosphorous (as presented in chapter four) and financial and accounting theory (chapter three).

Figure 2

The Nitrogen Cycle

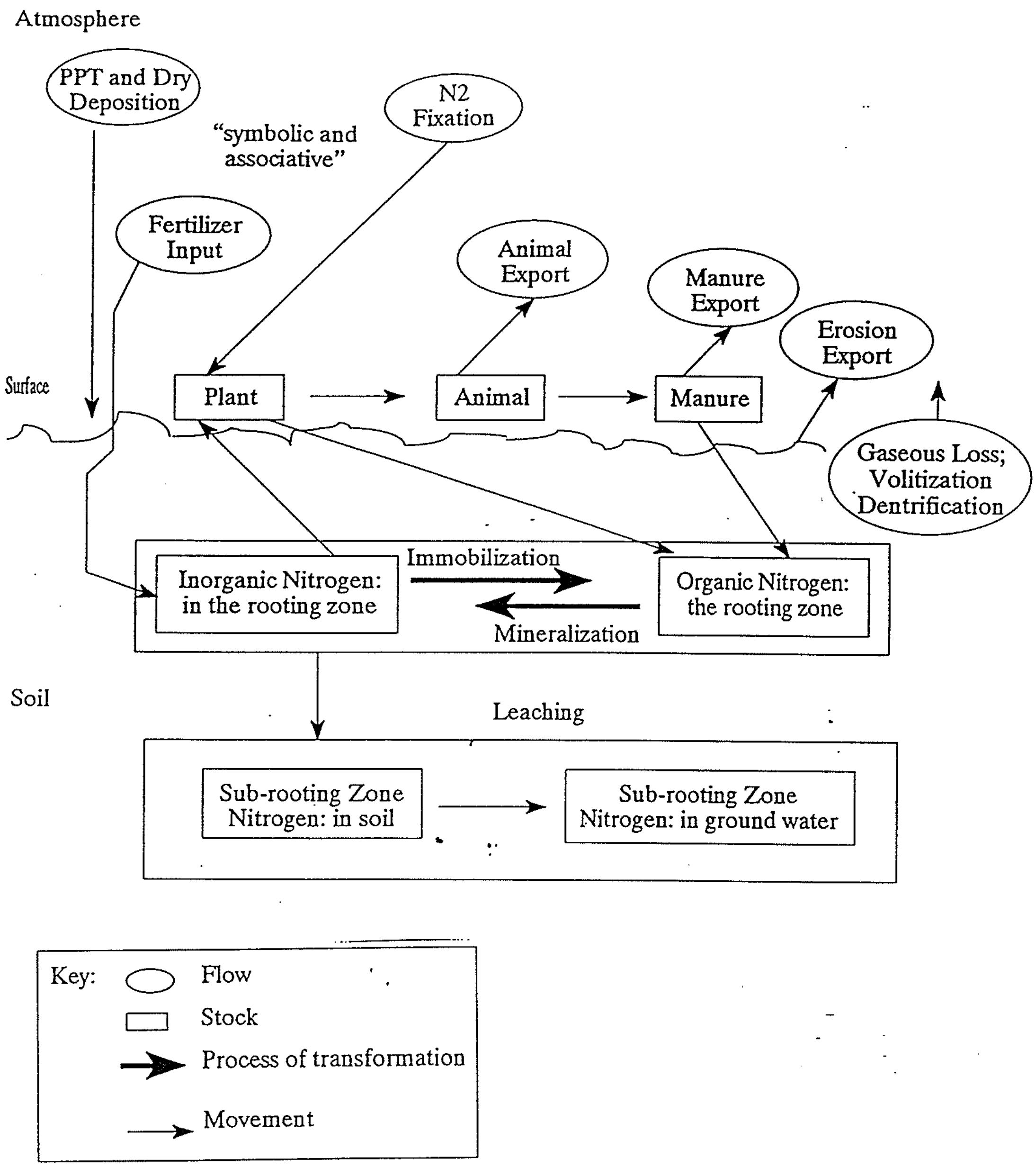
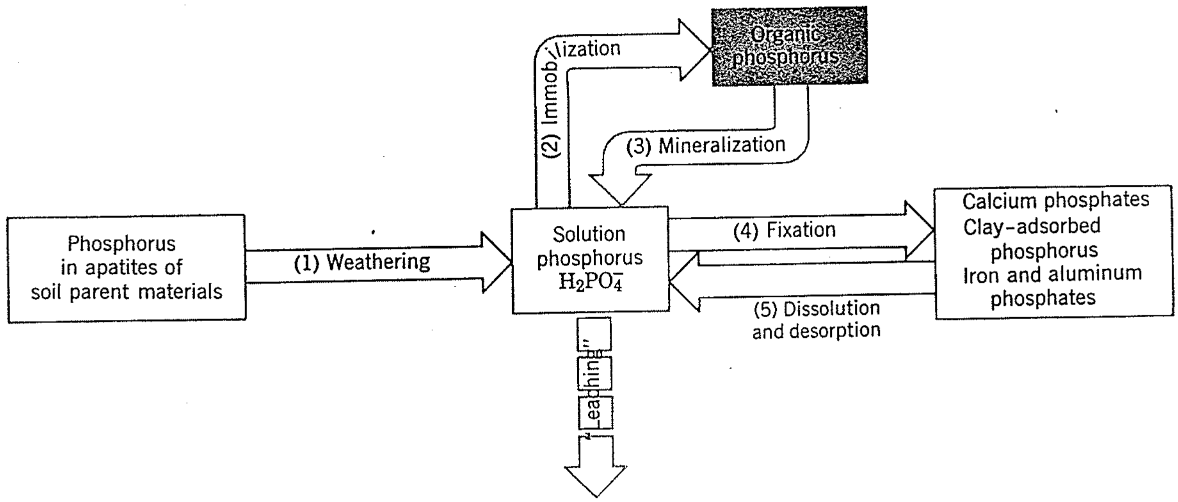


Figure 3

The Phosphorous Cycle



Chapter Five: The Agriculture Environmental Statements

5.0 The Agricultural Environmental Accounts and Statements

The environmental agricultural statements (presented here in chapter five) are based on the framework of standard financial statements (presented in chapter three) and utilize physical unit data from the nutrient cycles (presented in chapter four). The statements can be maintained independently or attached to a the regular set of financial statements in an appendix. Links between nutrients can be made through general implications as to their relationships with each other and on overall soil productivity.

This chapter will demonstrate the construction of the environmental statements in terms of nitrogen and phosphorous, with five statements per nutrient. Although the statements will be constructed for the specific chosen nutrients, the basic methodology can be used to construct similar statements for other nutrients.

After a brief discussion of the methodology, the construction of the statements will be shown. First, the flow statements, followed by the stock statements and then the reconciliation procedure. To demonstrate the relevance of the gathered information, analysis and implications of the statements will be discussed. This will take two forms: construction of comparative statements and presentation of a general framework for use of the results in future management decisions.

5.1 Preparation of the Statements

The structure of the statements in a similar format to standard accounting statements was done to promote a high degree of continuity between interpretation of the results of a financial statement and interpretation of the agricultural statements. It is hoped this similarity will enable producers with a greater degree of comfort in their practical use of the statements and recognition of the results.

The information obtained from the nutrient cycles will be adapted onto two main statements: flow statement and stock statement. These will then be enhanced into three additional statements: comparative flow statement, comparative stock statement and reconciliation flow statement. This will give the producer both a static and dynamic picture of their nutrient situation.

The statements are designed as a tool for individual producers. The results are farm specific and as such the statements (or results) from one farm can not be interpreted as a generalized statement for all farms or be compared against each other. It is up to each individual producer to decide on the value and use of the information, and incorporate this into their production decisions.

With the framework of the statements in place, the next step is to transfer the data to the appropriate places. For the purposes of demonstration, the statements will be constructed for a grain farm with no livestock component. The data used originates from the same variety of sources as used in the accounts of chapter four (Frissel 1978, Hauck 1971, Miller and Donahue 1995, Racz 1995, Norwest 1995) and, except where otherwise is stated, all units are in kilograms per hectare. A compilation of sources was necessary as a complete producer based data set for Manitoba was not available for this study.

Although the following numerical tables are based on a compliation of different sources, the exersize can be duplicated by a producer by using data from the following sources: generalized soil science estimations (for plant uptake and crop removal rates, atmospheric contibutions and losses, rates of fixation and net mineralization rates) standard soil tests (available and inorganic levels of nutrients), specific soil tests (to determine organic and unavailable and total nutrient levels and levels of nutrients beyond the rooting zone), plant tissue analysis (plant stock account), and chemical water analysis (groundwater leaching).

By using soil data for an average soil, the value of the exercise becomes grounded in the "how to" component. The numerical estimates are provided for illustration only with the purpose of providing a rough outline to the format of the statements. As the data in not Manitoba specific, caution should be taken in translating the attached figures to a particular Manitoba based farm or community. They should merely be viewed as one possible senario. Therefore, analysis of them will also be presented in general terms as to changes in thier relative levels and not taken to a more specific level of analysis of rotations and remedies for possible inconsistencies and problems. This fits with the objective of the study as the development of a framework that can is easily adaptable and not only applicable to one site in particular.

5.2 Construction of the Statements

5.2.1 The Flow Statement

The flow statement shows the net change of additions and depletions in the nutrient over one recording period. Data, in terms of inputs and outputs, is based on the nutrient cycle. The processes of transformation are not included on the flow statement as they represent a re-cycling of previous additions and are themselves not a new direct source. The transformations will be reflected in the stock accounts.

The format is to separate the (gross) positive amounts and the (gross) negative amounts. Tabulation of the net change figure is straightforward as the negative amounts are subtracted from the positive amounts. This figure is expected *a priori* to be positive, due to the trend of small accumulations of nutrient additions into the soil (Cowell and Doyle 1993).

5.2.1.1 The Nitrogen Flow Statement

The Nitrogen Flow Statement consists of three positive and four negative entries, corresponding to the nitrogen cycle. The positive entries are: fertilizer, fixation and precipitation/dry deposition, and the negative entries are: crop removal, leaching, denitrification and volitization.

Table 5

Nitrogen Flow Statement (kg/ha)

Inputs (kg/ha)		Outputs (kg/ha)	
Fertilizer Input	73	Grain Export	56
PPT and Dry Deposition	6	Dentrification	5
N2 Fixation	20	Volitization	15
Manure		Manure Export	
		Leaching	4
Total Inputs	*99*		
		Total Outputs	*80*
Total Inputs	*99*		
Total Outputs	*80*		
Net (Im)Balance	*19*		

5.2.1.2 The Phosphorous Flow Statement

The Phosphorous Flow Statement includes two positive entries, fertilizer and other inputs, and two negative entries, crop removal and other outputs. The net change figure is expected *a priori* to be largely positive, due to the associated phosphorous problems of fixation and accumulation.

Table 6

Phosphorous Flow Statement (kg/ha)

Inputs (kg/ha)		Outputs (kg/ha)	
Fertilizer Input	13	Grain Export	10
Other Deposition	3	Other Loss	1
Total Inputs	*16*	Total Outputs	*11*
Total Inputs	*16*		
Total Outputs	*11*		
Net (Im)Balance	5		

5.2.2 The Stock Statement

The stock statement records and tabulates the various asset forms, or holding cells, of the nutrient. Being assets, all entries are positive amounts. The initial data estiamtes are based on Manitoba (type) soils, but subsequent balances (to be shown on the comparative statements) will be based on generalized guidelines.

The format is similar to the asset side of a standard financial balance sheet. Each form of the nutrient is tabulated separately, with each account consisting of an opening and closing balance. No intermediate entries are made as movement between forms is picked up in the changes in the individual account net balances. Tabulation of the net figure for the accounts is simply the opening balance minus the closing balance. The closing balance is carried forward onto the statement of the next year to represent its opening figure. The net change for the entire statement is the addition of the individual account net change figures.

5.2.2.1 The Nitrogen Stock Statement

The Nitrogen Stock Statement consists of seven accounts: plant, animal, manure, inorganic nitrogen pool, organic nitrogen pool in the rooting zone, sub-rooting zone nitrogen in soil and sub-rooting zone nitrogen in groundwater.

The *a priori* expectation for the statement is a positive net change figure. This is based on the assumption of residual fertilizer moving to either the organic bank or being leached into the sub-rooting zone. Sub-rooting zone nitrogen is still considered an asset because a deep rooted plant may be able to access it and it has not leached beyond the bounds of the system.

A positive net figure, for an individual account or the entire statement, is not necessarily indicative of a positive situation. Mores than a positive balance, the important indicator to look at is the degree of movement between the asset forms, specifically from organic to inorganic and leaching. This movement determines the ability of the system to retain available nitrogen and keep it within the access of most cereal and oilseed crops. These types of relationships will be expanded upon in the implications discussion (section 5.3).

5.2.2.2 The Phosphorous Stock Statement

The Phosphorous Stock Statement consists of six accounts: plant, animal, manure, inorganic available phosphorous, organic available phosphorous and organic unavailable phosphorous.

The *a priori* expectation for the statement is a positive net change figure. This is based on the assumption of continual accumulation in the soil as a result of the low fertilizer efficiency use rate. The majority of the increase is expected to be reflected in the unavailable bank, due to the rapid fixation of residual fertilizer and low leaching level (phosphorous has poor soil mobility). The level of phosphorous is slowly being restored in Prairie soils, as intensive agriculture had previously depleted the stocks, but this is a long-term process (Cowell and Doyle 1983, Brady 1990, Foth 1990).

Table 7

Nitrogen Stock Statement (kg/ha)

Plant	opening balance	56
	closing balance	56
	net change	*0*
Animal	opening balance	0
	closing balance	0
	net change	*0*
Manure	opening balance	0
	closing balance	0
	net change	*0*
Inorganic Bank in Rooting Zone	opening balance	47
	closing balance	34
	net change	*-13*
Organic Bank in Rooting Zone	opening balance	3992
	closing balance	4005
	net change	*13*
Sub-Rooting Zone in Soil	opening balance	103
	closing balance	105
	net change	*2*
Sub-Rooting Zone in Groundwater	opening balance	0
	closing balance	0
	net change	*0*
Net Change of Capital Assets		*2*

Table 8

Phosphorous Stock Statement (kg/ha)

Plant	Opening balance	13
	Closing balance	13
	Net Change	*0*
Animal	Opening balance	0
	Closing balance	0
	Net Change	*0*
Manure	Opening balance	0
	Closing balance	0
	Net Change	*0*
Available Phosphorous	Opening balance	27
	Closing Balance	23
	Net Change	*-4*
Unavailable Phosphorous	Opening balance	1100
	Closing balance	1106
	Net Change	*6*
Net Change of Captial Assets		*2*

5.2.3 Reconciliation Procedure

The reconciliation procedure is the last step in the generation process. This procedure compares the net change of the flow statement to the net change of the stock statement. The purpose is to verify the residual amounts from the flows of the system have been accumulated by one of the forms of stocks within the soil structure, and thus nothing has been missed. With this step, all inputs, outputs and residual accumulations will have been accounted for.

A reconciliation entry is necessary each time the statements are generated, as the net change amounts between flows and stocks are bound to differ. Systems' modelling is a dynamic process and the accounts chosen to represent these process are only the main elements. There could be numerous smaller processes at work, and an accountants' modelling is bound not capture all possible effects.

The reconciliation figure, calculated in the appropriate amount to equate the statements per nutrient, is recorded on the flow statement. This produces a revised version, called the Adjusted Flow Statement.

For example, let (Z) denote the net change of the flow statement and (D) denote the net change of the stock statement. The possible reconciliation adjustments are as follows:

1. If; $Z=D$

   Then; all elements have been accurately estimated and accounted for. No reconciliation in the flow account is needed. This result is not expected due to the a-fore-mentioned difficulties in modelling an ecosystem.

2. If; $Z>D$

   Then; losses to the system are being reflected. A reconciliation entry in the flow account is necessary to balance the system. This result is most frequently expected, as it is the magnitude of these losses this exercise is designed to monitor.

3. If; $Z<D$

   Then; gains to the system are being reflected. A reconciliation entry in the flow account will balance the system. This result is not expected. This situation can be attributed to overestimates of either the stock or flow accounts and the data should be re-checked. If the balance is verified, a possible net addition to the system is being highlighted and this should be checked against future data.

With the reconciliation, calculations for the periodic statements are complete and the system is adequately captured. We now move beyond the "how to" of construction and into the "how to" of interpretation and what to do with the information.

Table 9

Nitrogen Adjusted Flow Statement (kg/ha)

Inputs (kg/ha)		**Outputs (kg/ha)**	
Fertilizer Input	73	Grain Export	56
PPT and Dry Deposition	6	Dentrification	5
N2 Fixation	20	Volitization	15
Manure		Manure Export	
		Leaching	4
Total Inputs	*99*	Total Outputs	*80*

Total Inputs	*99*
Total Outputs	*80*
Flow Statement	19
Stock Statement	2
Reconcillation Adjustment	17
Net (Im)Balance	*0*

* adjustment from stock statement

Table 10

Phosophorous Adjusted Flow Statement (kg/ha)

Inputs		**Outputs**	
Fertilizer Input	13	Grain Export	10
Other Deposition	13	Other Loss	1
Total Inputs	*16*	Total Outputs	*11*
Total Inputs	*16*		
Total Outputs	*11*		
Flow Statement	*5*		
Stock Statement	*2*		
Reconcillation Adjustment*	3		
Net (Im)Balance	*Balanced*		

* adjustment from stock statement

5.3 Evaluating the Information of the Statements

There can be two, complementary, methods of how to approach performing an analysis of the information gathered and how these valuable insights can be factored into future management decisions: quantitative and qualitative. The quantitative method addresses the information by structuring it into a set of comparative statements to highlight trends and changes. The qualitative method is process, or framework, in which to interpret the value of the information. The following section will discuss each method.

5.3.1 Comparative Statements

The comparative statements reflect the transfer of information from a number of periodic statements onto one synopsis-type statement. These can be constructed for flow and stock accounts. Information is tabulated in a format that allows for trends in the relative flows of the cycle and relative accumulations of the stocks to be highlighted. These types of changes are important not only in defining quantity aspects of the nutrient (relative volume changes), but they can also be extended to note quality considerations (relative changes in the forms, availability and movements).

5.3.1.1 Comparative Flow Statements

The comparative flow statement compiles information from the periodic flows. The relative figures are not expected, *a priori*, to change very much assuming fertilizer input levels remain relatively constant. The underlying scientific processes of the nutrient cycle do not, on their own, widely vary in the short-term. This leaves fertilizer as the key input variable of change. The effects of a change in fertilizer practice is predominately a short-term event and would be clearly distinguished in comparison from other years of normal applications.

Comparative statements provide the producer with one tool to monitor soil quality. General soil quality is not something that is usually apparent (except in the more severe cases) to the naked eye. Soil quality shows itself more indirectly through fertilizer requirements and crop yields.

For instance, in the following nitrogen and phosphorous comparative flow statements, a rotation including a legume is proposed. Through looking at the tables some general observations can be made. For example, the relative input levels are affected in that less nitrogen fertilzer is required (as the legumes can utilize large amounts of nitrogen through fixation) but, more phosphorous is used as legumes are heavy phosphorous feeders. Other observations would include the increase in gasseous nitrogen losses, in conjunction with increased fixation activity, and increase in the grain output component. The legumes' effects are immedietly eflected in the current years' tabulations, but they will also affect nutrient needs and levels in the upcoming year. This type of information allows a producer to effeciently track the effects of a particular rotation on the nutrients in the soil.

Now, the next step is to look at the comparative stock statement and determine how these types of production decisions are being reflected in the soil. This will aid the producer in determining the effects of the decisions, and if the decisions are working towards building soil health. A healthy soil being one that retains and releases nutrients with little leaching activity to produce optimal yields.

Table 11

Nitrogen Comparative Flow Statement (kg/ha)

		Year 199a	199b	199c	Increase/ Decrease 199a-199b	199b-199c
Plant	Closing balance	56	56	90	0	34
Animal	Closing balance	0	0	0	0	0
Manure	Closing balance	0	0	0	0	0
Inorganic: Rooting	Closing balance	32	19	76	-13	57
Organic: Rooting	Closing balance	4005	4018	3961	13	-57
Sub-Rooting: in Soil	Closing balance	105	105	100	0	5
Sub-Rooting: in Groundwater	Closing balance	0	0.001	0.001	0.0001	0
Net Balance of	Capital Assets	*4198*	*4198*	*4227*	*0.0001*	*39*

Table 12

Phosphorous Comparative Flow Statement (kg/ha)

		Year 199a	199b	199c	Increase/ Decrease 199a-199b	199b-199c
Plant	Closing balance	7	7	13	0	6
Animal	Closing balance	0	0	0	0	0
Manure	Closing balance	0	0	0	0	0
Available	Closing balance	50	42	44	-8	2
Unavailable	Closing balance	2433	2446	2448	13	2
Net Change of	Capital Assets	*2490*	*2495*	*2505*	*5*	*10*

5.3.1.2 Comparative Stock Statements

The comparative stock statement compiles information from the stock accounts and contains key elements, suited towards long-term productivity implications, as it monitors the relative accumulations and movements between the different forms of the nutrient. Travel between banks provide an important indication of the productive capacity of the soil by highlighting which asset forms are retaining the nutrient, in the current cycle and beyond. The relative changes in bank sizes over time will enable the producer to indirectly determine the effects of variations in management practice on soil quality. These net outcomes will be reflected in soil productivity, crop production and ultimately net economic returns, once all benefits and costs are taken into consideration.

5.3.1.3 Nitrogen Comparative Stock Statement

The key element in nitrogen is the relative changes between the sizes of the available and unavailable banks. For instance, if the available bank is decreasing (or barely increasing) this is an indication of residual fertilizer not going into this bank and so then to look elsewhere in the system for where it is being accumulated. Most likely, it is moving downward into the unavailable banks. But then, is the nitrogen being held in the sub-rooting zone, where a deep rooted plant may access it, or has the nitrogen leached through to the groundwater table (possibly becoming an off-farm concern)? Movements of this type can be reflective of a problem with soil quality. If the soil is having difficulty retaining nutrients, then programs and practices of building soil organic matter, soil tilth and soil quality should be looked at in forthcoming management decisions.

On the other hand, if the size of the available bank is increasing, then the producer is made aware their soil can provide increasing nitrogen for plant needs. This can be factored into productivity decisions in determining how much fertilizer to apply in an upcoming year. Crop choice can also be affected in that if the available nitrogen level is high, it may be a good time to plant a heavy nitrogen user crop without having a large impact on the cycle or having to support it by large amounts of fertilizer.

For instance, in the supporting nitrogen example (as can be seen from Table 13), with the incorporation of the legume in the rotation the size of the available inorganic bank has increased (whereas with straight grains it remains relatively constant as they really neither add nor excessively draw it down) and the organic unavailable has slightly decreased while there has been no distinguishable leaching effects. This would indicate the soil is relatively healthy, or at least no significant problems are being signalled, as the nutrients are being retained within the soil structure and there is an increased amount of available nitrogen that may (a plant can not always utilize the full capasity from this bank due to scientific constraints) be available to the next crop.

Table 13

Nitrogen Comparative Stock Statement (kg/ha)

		Year			Increase/ Decrease	
		199a	199b	199c	199a-199b	199b-199c
Inputs:	Fertilizer Input	73	73	30	0	43
	PPT and Dry Deposition	6	6	6	0	0
	Manure	0	0	0	0	0
	N2 Fixation - Free	20	20	123	0	-103
	Total Inputs	*99*	*99*	*159*	0	-60
Outputs	Grain Export	56	56	90	0	-34
	Dentrification	5	5	15	0	-10
	Manure Export	0	0	0	0	0
	Volitization	15	15	trace	0	15
	Leaching	4	4	4	0	0
	Total Outputs	*80*	*80*	*109*	0	-29
Reconcillation Adjustments						
Net (Im)Balances		*19*	*19*	*50*	0	-31

Year one: cereal
Year two: cereal
Year three: legume

5.3.1.4 Phosphorous Comparative Stock Statement

The key element in phosphorous is the size of the unavailable bank relative to the available bank. Due to low fertilizer use efficiency, the size of the unavailable bank is expected to increase. But, continual application of large amounts (assumed large because the amount applied is far in excess of the small requirements of the plant) of fertilizer have a direct associated monetary cost. In the 1990s, fertilizer prices are increasing and to maximize yields and economic efficiency, producers should look at ways to utilize more phosphorous contained within the soil to save costs.

Information on phosphorous availability can impact productivity decisions in numerous ways. A producer may decide to use a chemical adaptation of a fixation inhibitor (Donahue 1983) to allow more fertilizer to remain in a plant available form. If this method is successful, the relative addition to the available bank will be increased at the expense of the amount of fertilizer going to the unavailable bank. Or, a producer may plant a crop that is a light nutrient feeder. Phosphorous would then be retained for use in the next cycle, where a heavier nutrient feeder crop may then be planted. Or, a producer may explore various management practice techniques, such as conservation tillage, to give the soil a helping hand in the regeneration process.

For instance, in the phoshorous comparative statements, the rotation shows that although fertilizer use has increased (as seen from the comparative flow statement) most of that was fixed and added to the unavailable bank and the available bank has remained relatively constant. This indicates the soil is responding to the additional fertilizer as expected, with the phosphorous fixation constraint, and the producer must then look at ways to best tap into the now increased unavailble resource in thier soil. No obvious problems or trends with phosphorous seem apparent from the three year cycle. As additional years are added, trends with availability may then emerge more clearly.

Table 14

Phosphorous Comparative Stock Statement (kg/ha)

		Year			Increaase/ Decrease	
		199a	199b	199c	199a-199b	199b-199c
Inputs:	Fertilizer Input	13	13	19	0	-6
	Other Inputs	3	3	trace	0	3
	Total Inputs	*16*	*16*	*19*	0	-3
Outputs	Grain Export	10	10	10	0	0
	Other Outputs	1	1	trace	0	1
	Total Outputs	*11*	*11*	*10*	0	1
Reconcillation Adjustments						
Net (Im)Balances		*5*	*5*	*9*	0	-4

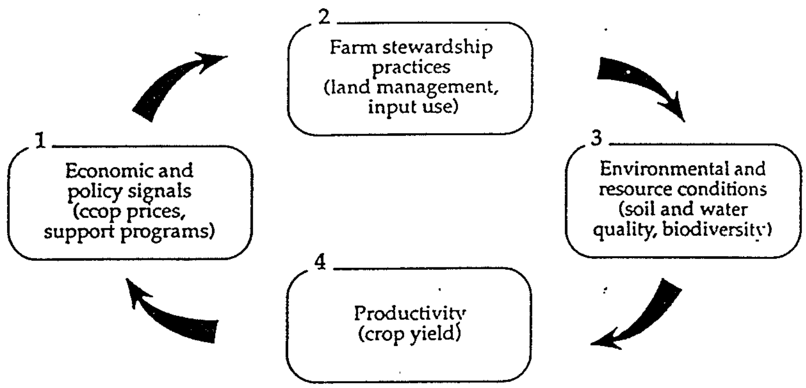
Year one: cereal
Year two: cereal
Year three: legume

5.3.2 Implications

The comparative statements are used in highlighting trends in soil movements and soil quality. The producer must then determine the value of this information and how to incorporate it into their management decisions. This is the qualitative step in statement analysis, the establishment of a framework, or process, to gauge the relative importance of the information the statements provide.

The framework developed in this study is based on four, inter-related, components a producer should factor into any management decision. These aid in making economically efficient and environmentally enlightened decisions that maximize short-term income while promoting long-term productive capacity. These are: economic and policy signals (crop prices, support programs), farm stewardship practices (land management, input use), environmental and resource conditions (soil and water quality) and productivity (crop yield) (Acton and Gregorich 1995). These can demonstrated by use of a flow chart.

Figure 4



The stewardship–state–productivity framework.

In theory, each variable should be given an equal weight of importance in maximizing short-term and long-term economic efficiency. In practice, economic policy signals and productivity factors dominate decisions and short-term economic efficiency is the main focus. Chemical application level, crop selection and management practice are the main variables of choice of these instruments and these are in turn influenced by crop price and the constant desire to increase yields. Some producers even base crop rotations and seed acreage specifically on the crop prices of the previous year. A purely price driven decision model, which is not necessarily the most economically efficient overall.

Farm stewardship and the environment often get overlooked. In part because a producer can not minimize the importance of short-term viability. But, also because stewardship and the environment are variables more subjective in nature and as such are difficult to factor into management decisions without adequate information about them on hand. The role of the environmental accounting statements is to provide this information. With these statements, the producer has access to information that can be quantified and now management practice and environmental effects can be considered directly in productivity decisions.

One main way to use information from the statements is in terms of chemical-use applications. It is widely accepted that fertilizer and pesticide applications are beneficial to crop productivity. With chemical application crop yields increase. But, this also increases the amount of residual chemical in the soil, which can cause potential environmental problems. Studies have determined the point beyond which additional chemical applications may cause groundwater contamination occurs at the same approximate level as maximum economic returns (Acton and Gregorich 1995). Producers should therefore only fertilize according to their crop needs.

Many producers over-fertilize, not aware of their specific nutrient situation. But, over-fertilization costs additional money and this is not economically efficient as the excess does not encourage plant growth and economic returns are then lowered. The chemicals may leach through the soil into the groundwater table and become an negative environmental concern (Acton and Gregorich 1995). If clean-up costs are to be incurred, this will further negate economic returns and the short-run efficiency of over-fertilization.

Producers can use this type of information in their efforts to enhance soil quality by paying closer attention to nutrient utilization through fertilization practice. This includes; properly accounting for all sources of the nutrient to be aware of the soil state, apply chemicals in the amounts suggested by soil tests, set crop yield goals that are environmentally and economically viable and seed crops in the rotation that prevent nitrate build-up after the growing season (Acton and Gregorich 1995).

Numerous other options to incorporate information from the environmental statements are also available, keeping the four variable framework in mind. For instance, the information could be used as a tool of prevention. As previously stated, environmental factors are not dominant in crop selection in lieu of the price factor and tangible net returns, specifically crop prices. But, price is a short-term tool that is not always right. The supply/demand fundamentals in one year that set a price, do not necessarily carry over into the next year, no matter what an analyst may predict. Short-term profits, based on price, are necessary in order to remain financially solvent. But, in the long-term, viability will be stressed if decreases in soil productivity, through weakened soil quality, require more and more chemicals to achieve adequate yields. Additional chemicals cost money, which ties the discussion back to the over-fertilization discussion, and these fertilization costs are increasing. If the decreases in productivity and increases in costs can be prevented through awareness and alternative production practices, the producer is better off in both the long-term and short-term.

The information from the statements can also be used in conjunction purely with the price factor. A producer specifically incorporating stewardship and environmental effects can determine their rotation options by looking at the current market prices of the various alternatives. Using crop prices and the information on the current state of their soil, they can then decide on how to afford taking care of the piece of land in question. With many farms being multi-sectioned, the returns from other sections could be used to supplement lower returns from one particular section. The next year the section that was under maintenance will be able to perform better and yields off it will be stronger. These results can be monitored in both crop output and the environmental accounts as reflected in the flows (fertilizer use) and the stocks (bank sizes). Economics, prices and the environment can be complementary.

In evaluating the information from the statements, the producer should look at their short-term and long-term economic position. The dominant short-term factors (price and policy) are influenced in coming years by the longer-term factors (management practice and environmental concerns). The agricultural statements can help to enhance and monitor these relationships. Under the guise of economic efficiency, the producer will be in a better position to make decisions to benefit the total economic value (quantitative and qualitative) of their operation. Simply put, the better the quality of the soil, the better able it is to produce maximum yields at minimum economic cost (particularly input costs). But, a weak soil requires more chemical additions to promote adequate plant growth and a higher per unit economic cost. Maintenance of soil health is an important economic goal. Information from the agricultural statements will aid in incorporating soil quality into future management decisions, whereas previously this information was not available in a format that could be easily adapted or in a framework that to evaluate it.

5.4 Summary of the Agricultural Environmental Statements

The agricultural environmental statements are constructed similar to standard financial accounting statements and use quantitative data from the eco-cycles of the soil nutrients, along with scientific testing and estimates of processes and accumulations in the soil. Two main types of statements are constructed for each nutrient, a flow and a stock statement. These are constructed on an annual basis to show a current position, and then reconciled to adequately capture any shortfalls in the estimation system.

Information from the statements is valuable only if the producer is able to utilize it. Comparative statements and a framework of analysis to incorporate the information into future management decisions were developed to fill this need. The comparative statements highlight trends in soil use and accumulations. This shows the producer of weaknesses in the soil and highlight areas that need closer attention. The four variable framework for analysis of these trends is essential for producer to be able to easily factor this information into their management decisions.

The bottom line of all productive units is always profit. Maintenance of soil quality will foster more productive crops showing that economics and the environment do not have be at opposite (short-term versus long-term) ends of the spectrum. Ultimately, the fate of the soil system depends on societies' (or in this case the agricultural producer) willingness to enter these concerns into the marketplace and forego some of the short-term benefits that accrue from mining the soil so that quality and fertility can tained over the long-term (Acton and Gregorich 1995).

Chapter Six: Summary and Conclusions

6.0 Summary

The objective of this study was to develop a set of environmental accounts, farm level, that could be used to monitor the relationship between soil quality, productivity and management decisions. The accounts were developed on the basis of nutrient cycles and a standard financial accounting format. Illustrative construction was done for nitrogen and phosphorous, although the procedure was developed such that it could be applied to any nutrient.

Two types of accounts were shown, flow accounts (to account for movements) and stock accounts (to account for accumulations). The accounts were then adapted into financial-type statements and a framework of analysis of the information the statements highlighted was discussed to link the statements back to the producer level in terms of information that could be used in a practical manner.

6.1 Viability

The accounts were developed at the producer level to be farm specific, with the intent of being producer friendly and easy to use. This was the reasoning behind the adoption of a standard financial framework to present the soils information within. On the whole, the accounts are straightforward as their calculations simply involve placing numbers in appropriate slots on the statements, with the exception of the phosphorous stock account which involves some minor manipulation, and then performing additions and subtractions.

To construct the accounts the producer needs access to the relevant information. Various look-up tables could be obtained for the flows of the system with little effort or cost, as generalized estimates are currently available. The stock accounts, however, require consistent soil testing at various depths and locations. Many producers are less than consistent with their diligence in soil testing and in order to provide the accounts with the information they need, a producer must commit to accumulating the data. The average soil test costs CDN $21, and the average plant tissue test costs CDN $45 (but, as stated previously, crop removal rates can be taken as a proxy for plant tissue tests). Rates for the necessary specialized soil tests may be slightly higher.

The producer can use the information from the accounts to influence two factors which have the greatest effects on overall returns: crop selection and management practice. Crop selection impacts the net returns through crop prices and affects soil quality throughout its cycle in relation to next crop in the rotation. Management practices can improve or degrade a given situation.

The agricultural accounts aid in the crop selection decision from an economic and environmental standpoint. If, the accounts indicate a problem with soil structure or low levels of the available nutrient in the soil, a producer can now include this information into their crop input choice. The producer may want to seed a legume, to increase nutrient levels; especially nitrogen (hence more nutrients available for the next crop).

Or, they may want to choose high density crops that would provide good surface coverage and retain more soil organic matter on the surface (again increasing the level of future nutrients).

Or, if neither of these is economically viable in terms of crop prices and net returns, a third option is to choose a crop that is a light feeder of nutrients on the soil (spring cereals) over heavier feeders (winter cereals). Still another option is the use of "catch crops". These are crops planted in the fall after the main high value crop has been harvested, which can reduce the amount of leached nitrogen by using up any leftover nitrogen and water in the soil during the fall season after harvesting and in spring before re-planting (Action and Gregorich 1995).

Management practices are also important in promoting the building of soil organic matter, which contains the bulk of the nutrients in the soil and has a direct link to soil health and its productive ability. Techniques to promote soil quality are: conservation tillage, residue management, extending crop rotations (including use of winter cover crops) and proper chemical usage. The effects of these techniques will show up in the agricultural accounts and this will enable the producer to better determine the effects their practices are having on their soil situation.

6.2 Limitations

There are two main limitations to the accounts, in their present form, scientific estimations and producer diligence. Nutrient cycles are complex scientific processes that are still being researched and all paths of the nutrient flows are yet known.

Quantification of the paths that are known, these being what the agricultural accounts are built on, can require a combination of science and creativity in providing the estimations. Soil science is rapidly researching these effects and determining various ways in which to monitor overall soil quality, but these are still in the process stage. Therefore the accounts are limited by the scientific foundations upon which they are based. The reconciliation procedure attempts to factor this in, but at some point it is necessary to determine what effects underlie the differences.

A third limitation is also present in regards to the methodology behind the accounts. The accounts are qualitative in nature in that monetary figures are not attached to the estimates. A direct monetary accessment of soil quality can not then be made. Monetary measures enter the economic equation through indirect monetary measures of soil quality, specifically through chemical application levels.

If the net results of the accounts and the effects on soil quality could be multiplied by a constant figure or converted easily into a dollar amount, the accounts would truly become financial accounts. But, as a definitive soil quality index is currently being developed and many of the relationships between the economic (and financial) costs are benefits are still being explored, the quantitative link is not yet possible.

A qualitative framework of evaluation, as presented in this study, is the best tool at this time. It does require more effort from the end-user, to piece together soil-economic-management-environmental relationship and look for the results through the accounts for validity, but, if diligent, certain trends are bound to emerge and the producer will obtain a much clearer picture of their soil situation and how their production activities affect it (short-term and long-term).

6.3 Further Research

In terms of theory, additional research is needed, as discussed above, in scientific estimations and quantitative determinations. These are not simple tasks and it may be many years before enough research in conducted to provide more accurate figures.

In terms of application, the next step in environmental accounting for agricultural producers is to undertake a number of producer case studies over a three to five year period. This will determine the applied costs and benefits of using the accounts. An actual case study will take the accounts from an illustrative framework, as presented in this study, to an applied model whereby attempts to isolate the elements in control of the producer that affect soil quality and productivity can be monitored and isolated.

6.4 Conclusion

Sustainable agriculture is an important issue in agriculture in the 1990s. Agriculture awareness of soil quality concerns have come a long way—from intensively depletion the nutrient reserves up to the 1950s (chemical fertilizer was not used back then) to beginning to replace these lost reserves in the 1990s. With no definitive method of measure soil quality or soil productivity, the door is open for a number of different and complementary method to be used. Environmental accounting is one such method that focuses on monitoring and highlighting use-patterns of nutrients in the soil.

Environmental accounting is only one tool. Numerous others can also exist. Some are very complex, such as soil tilth index's, and others more basic, such as visual inspection of the soil. Each tool yields different levels of results. The key element, in all tools, is their use as a devise for the prevention of further soil productivity and environmental degradation through the provision of information a producer can use to access their situation and make appropriate changes to ensure the long-term viability of their soil asset.

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