TOWARDS AN OPERATIONAL DEFINITION OF SUSTAINABILITY IN NEW ZEALAND DAIRY FARMING

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ABSTRACT

Sustainability is increasingly viewed as a desirable goal of agricultural development and environmental management. The emergence of the sustainability concept has seen a concomitant rise in the interest of its measurement. It has been suggested that through the use of sustainability indicators, the attainment of the agricultural sustainability goal can be assessed.

It is therefore the aim of this thesis to develop indicators based on the concept of agricultural sustainability. An environmental accounting model is used as the framework within which these indicators were developed and evaluated.

The agricultural sustainability concept is first examined and defined, giving significance to its economic, ecological and social dimensions. It is emphasised that the attainment of sustainability involves the balance and trade-off amongst these dimensions, which can be demonstrated through the dynamic interactions of these dimensions.

The thesis then focuses on the discussion of the methodological considerations, which are important in developing an operational framework for measuring agricultural sustainability. The ideal properties and characteristics of sustainability indicators are identified and critically examined. An evaluation of the different types of input-output models that could be used in conjunction with such indicators were discussed. Input-output models were seen to be critical in developing an operational framework, as they are capable of representing the interactions between the economic and ecological dimensions of sustainability.

The second part of the thesis concentrates on the application of the methodology to measuring changes in sustainability of New Zealand dairy farming industry. After a brief historical survey of dairy farming, a number of sustainability indicators for the industry are identified. These indicators were then operationalised using a spreadsheet-based input-output model of the New Zealand dairy farming industry. The model consisted of an eight-sector dairy farming sub-model (based on MAF farm types), connected to a 25-sector input-output sub-model of the New Zealand economy. The model focused on selected resource inputs and pollutants.

Indicators derived from the input-output model were developed to reflect the economic, ecological and social dimensions of the sustainability concept. These indicators then were evaluated by monitoring their behaviour in different scenarios for the future of New Zealand dairy farming, by using the environmental accounting method developed earlier. It is observed that the policy goal of sustainability in dairy farming generally can not be attained to the full satisfaction of all the economic, ecological and social indicators. Along the way, trade-offs and balances among these factors have to be made. It is up to the policy and decision makers to weigh the various alternatives, with the indicators providing adequate information upon which rational choices can be based.

This thesis demonstrated the possibility of formulating sustainability indicators and using them as an evaluation tool in spite of the current state of available data and methodological constraints. It is recommended that a baseline of agricultural sustainability parameters should be established and associated relevant expertise be developed, if operational measurement of the agricultural sustainability goal is to be pursued.

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Chapter One

INTRODUCTION

1.1 Background

Agriculture is one of the most vital elements in the continuance of civilised societies in the world. The majority of countries worldwide are fundamentally dependent on agriculture for their basic development. In most countries, like New Zealand, agriculture is one of the most important economic sectors. Not only does it provide a considerable opportunity for employment, it feeds the whole country as well. It is also the prime source of export earnings on which importation of basic raw materials for other major industries is made possible. The agricultural sector, therefore, plays a key role in New Zealand's continuing development, and, measured by any standard, it would be difficult to conceive of an issue that is more exigent than that of agricultural sustainability.

Agricultural sustainability seems to be a challenge to policy and decision makers. While agriculture is an essential interface between ecological and social systems (Valentine, 1991), most of its development is greatly influenced and motivated by economic considerations. Sustainable agriculture depends on the consideration of and balance between these systems, and it can only be attained if appropriate information regarding these factors is available.

The Ministry for Agriculture and Fisheries (MAF) (1991) has launched a policy proposal for the agricultural sustainability of New Zealand. Sustainable agriculture now seems to be the prime goal of New Zealand's agricultural policy, but the achievement of such a goal is not an easy task. Matters are further complicated as there is no measuring rods to evaluate progress towards this sustainability goal. Unless there is an operational definition or at least some indicators of sustainable agriculture, the effectiveness of policies towards the attainment of this goal can not be assessed (Verbruggen and Kuik, 1991). Formulating policies to achieve this goal requires rational choices that can only be made if policy and decision makers possesses adequate economic, ecological and sociological information (Brink, 1991).

Sustainable agriculture is defined by three interconnected yet separate aspects: economic, ecological and social. It is imperative, therefore, for policy and decision makers to have adequate information in all these perspectives in order to achieve a balanced and rational choice. According to Brink (1991, p72), information is 'adequate' when it:

- gives clear indicators as to whether the objective will be met;
- is information on the system as a whole;
- is of quantitative character;
- is understandable for non-scientists, and
- contains parameters which can be used for 10 - 20 year periods.

Economic data ranging from fertilizer and energy inputs, production, etc., are, in fact, available and easily accessible. However, the ecological and sociological counterparts to adequately formulate policies towards agricultural sustainability are in short supply. Therefore, decision making and policy formulation often resulted in 'non-sustainable' agricultural development particularly because of the lack of ecological and social data (Figure 1.1).

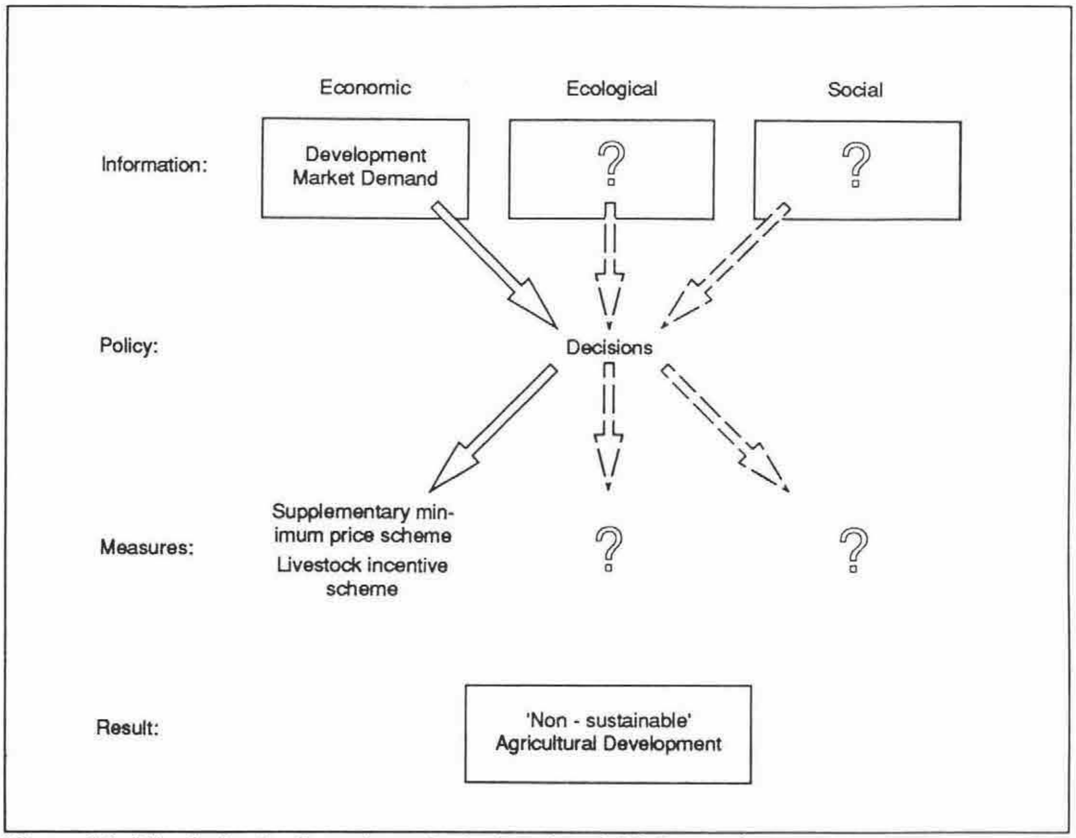

Figure 1.1 **The lack of adequate ecological and social information**
Source: Brink (1991) and MAF (1991)

In fact, ecological and social information are available in abundance. The only problem regarding this is that it appears in different formats. This information is often fragmentary, qualitative, and too detailed and contextually bounded to be of use in the formulation of macrolevel indicators. The most important problem is not so much the shortage of scientific information, but the lack of coherence and the difficulties of placing it in a practical context for use by policy and decision makers (Brink, 1991).

Statistical data regarding agriculture in New Zealand abounds, and are collated by at least three (3) different types of agencies: The Ministry for Agriculture and Fisheries (MAF), the Department of Statistics (DoS) and the different Producer Boards. Therefore it is not surprising that these data were designed for specific purposes, specially for the agencies that gather them. Besides these agency uses, the data can frequently be used directly and indirectly by policy and decision makers. It is, however, not particularly useful in its scope and content for guiding decision makers when it comes to sustainability matters. New Zealand dairy farming can be considered as a good example of the problems encountered in the availability and suitability of data when it comes to considering sustainable development. At least three agencies (MAF, DoS and the New Zealand Dairy Board (NZDB)) are monitoring the dairy farming industry. However, inspite of the array of data these agencies generate, there is often insufficient information for policy and decision-making purposes.

The sustainability of dairy farming is important, as it is one of the most important contributors to New Zealand's agricultural exports and economic wealth, and to ensure long term prosperity. Maintenance of the dairy industry production should be based on the "ecologically and economically sustainable pastoral farming" (MAF, 1991). Despite this official recognition of the importance of sustainability, pastoral farming in New Zealand still remains dependent on energy and nutrient inputs from external sources. Furthermore, the continued use of energy and nutrients are depleting finite resources, causing global warming, and eutrophication to some New Zealand lakes. The indefinite availability of these inputs is uncertain and their continued use have serious environmental repercussions giving doubts to pastoral farming sustainability in the long run. It is, therefore, important that these phenomena and other relevant factors be monitored and appropriate indicators developed if sustainable dairy farming is to become a reality.

1.2 Thesis Goal

The goal of this thesis is to analyze the sustainability concept and then to develop an operational methodology, based on indicators, for measuring the sustainability of the dairy farming industry.

1.3 Thesis Objectives

The objectives of this thesis are:

(1) to investigate various concepts of sustainability as it relates to New Zealand dairy farming;

(2) to develop indicators of sustainability and associated environmental accounting models based on these concepts, using the presently available statistical data; and

(3) to critically assess the methodology developed in (2), and recommend how it can be improved upon in the future.

1.4 Thesis Outline

The thesis is divided into three main parts: Part One - Theory and Methodology (Chapters Two to Four); Part Two - Application to New Zealand Dairy Farming

(Chapters Five to Eight), and Part Three - Review and Concluding Comments (Chapter Nine).

Chapter One begins with the argument stressing the importance of agricultural sustainability, particularly dairy farming in New Zealand. It then explains the importance of generating adequate information for policy and decision makers if the goal of sustainability is to be pursued. Consequently, it states the goal for measuring sustainability through the use of indicators, and the objectives of how this goal can be attained.

The second chapter starts with the overview of the on-going debate on the meaning of the concept of sustainability. It reviews the sustainable development concept from social, economic and ecological perspectives. Consequently, it defines sustainable agriculture, emphasising the fact that agricultural sustainability, like sustainable development, can only be achieved through the realisation of its three aspects: social, economic and ecological considered together. It then expresses the idea that trade-offs have to be made in order to attain sustainability.

Chapter Three explores the idea of measuring sustainability through the use of the two elements of State of Environment Reporting (SER): indicators and the environmental/resource accounting method. The idea of a sustainability indicator is defined and its 'ideal' qualities expounded. Such indicators can be developed in the context of an environmental accounting approach, which places particular emphasis on the environment-economy interactions.

Input-output analysis as a basis for accounting methodology is proposed in Chapter Four as one practical way of assessing these environment-economy interactions. Previous input-output models which incorporate the environment are then reviewed.

A profile of the New Zealand Dairy Industry as whole is briefly presented in Chapter Five. In particular, cooperative dairying and the role of the New Zealand Dairy Board is reviewed and New Zealand dairy farming is briefly described. Farm production features, costs and returns are explained, and the importance of dairy farming international competitiveness and sustainability in the long run, is stressed.

Chapter Six deals with the identification of sustainability indicators for dairy farming, with a more detailed look at dairy farming. Ecological implications of various farming inputs and outputs are examined. The economic and social environment are likewise explored. A number of sustainability indicators are suggested, based on this analysis. Subsequently, these indicators are preliminarily evaluated against the qualities of indicators as stated in Chapter Three.

An environmental accounting model, in the form of input-output table, is developed in Chapter Seven. The model is divided into four (4) quadrants. Quadrant I describes the economic commodities for the eight dairy farm models representing the eight dairying regions of New Zealand. Quadrant II quantifies the 25-sector New Zealand economy. The ecological commodities for these farm models and the New Zealand economy are indicated in quadrants III and IV respectively. The spreadsheet construction of the model is described.

Chapter Eight deals with the evaluation of sustainability indicators using the environmental accounting model. Basically, the aim of the analysis is to demonstrate how the proposed indicators will behave in various future situations. Scenarios were first developed and then translated into the model, and the resultant indicator values are recorded for each scenario. These values were finally examined according to economic, ecological and social perspectives of sustainability.

The last chapter discusses the outcome of the study. The strength and weaknesses of the model are assessed. Conclusions are made along with recommendations for the establishment of a baseline for agricultural sustainability parameters and for the development of associated expertise.

Part One

THEORY AND METHODOLOGY

Chapter Two

CONCEPTUALISATION OF SUSTAINABILITY

2.1. Sustainable Development: The Different Perspectives

The last few years have shown a transformation in the environment-development debate. It was known that environment and development could be seen as complementary, for the condition of one is of importance to the other. Development can not be maintained in a deteriorating environment. Economic activity is dependent on a clean and properly functioning environment for raw materials and energy resources. While environmental enhancement and conservation are given consideration, it is apparent that development can be maintained. But other developmental trends do not take this into consideration. The present crisis in food and resource scarcity in some countries, pollution and environmental degradation have served the case for policy makers and decision makers. It was realised that for development to be continuous over time, it should be self-conserving and, therefore, should take account of its resource base - the environment.

Thus the notion of sustainable development has been the latest development catchphrase. But, in spite of its apparent global acceptance as a new development paradigm (Braat, 1991; Toman, 1992) the term is a subject of continuing debate. Sustainable development means many things to different people and can be used in reference to a number of different issues (Toman, 1992 p2). Both the terms sustainability and development have been subjected to a number of examinations and interpretations (Redclift 1987, Toman 1992, Lele 1991 to name a few). Sustainable development invokes a concept of preservation and nurturing over time. Or, taken literally, it would simply mean 'development that can be continued indefinitely or for the implicit time period of concern' (Lele, 1991 p608). Nonetheless, the World Commission on Environment and Development (known popularly as the Bruntland Commission) has the most widely quoted definition. In its 1987 report, *Our Common Future*, it defined sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987 p43). Thus, sustainability involves some notion of respect for our descendants' interests. But beyond this point, however, various perspectives arise. Sustainable development is a value laden term, its meaning often depending on the one who defines it.

It is crucial to obtain a clear picture of the sustainability concept[1]. To attain this, it is necessary to delve into the various dimensions of sustainability. So far, the literature is composed of three complementary views: social, economic and ecological perspectives.

2.1.1. The Social Concept of Sustainable Development

The social concept of sustainable development is comparatively qualitative, which, if viewed from the objectives of this paper is difficult to relate. Nevertheless, the whole picture of sustainable development is not complete without it.

Barbier (1987), defines social sustainability as the ability to maintain desired social values, traditions, institutions, cultures and other characteristics. Similarly, it recognizes

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[1] Sustainable development and sustainability will be treated as being synonymous throughout this thesis and will, therefore, be used interchangeably.

as its goal the survival of the human species, and the realization of an acceptable quality of life for each individual in present and future generations (Pearce *et al*, 1989; Redclift 1987). Moreover, according to O'Riordan in Turner (1988), 'this implies a much broader phenomenon, embracing the ethical norms to institutions responsible for ensuring that such rights are fully taken into account in policies and actions'. In other words, social sustainability pertains to intergenerational equity. According to IUCN, UNEP and WWF, (1990), it is an equitable distribution of 'goods' and 'bads' of resources use, and environmental management by present and future generations, not only within but between countries.

For human survival to be long term, it must make reference to the means and limits of its environment. This implies the stabilization of human population; for the 'north' to maintain their standard of living and minimize resource consumption and pollution; for the 'south', to improve welfare and minimize environmental degradation. There is a great difficulty in achieving this goal. According to World Conservation Strategy (1987), this can be done through global cooperation and trade restructuring at an international level; the political will to formulate policies for decentralization and for a new era of economic growth, one that must be based on policies that sustain and expand an environmental resource base at the national level, and community empowerment in decision making and resource use at the local level.

As the concept described above is too broad to be operational, further elaboration is considered to be beyond the scope of this study. Nevertheless, some of the relevant points will be expounded in later parts of this paper.

2.1.2 The Economic Concept of Sustainable Development

So far, the economic interpretation of sustainable development has received considerable attention. It is reported in varied and diverse expositions that sustainable development is used interchangeably with sustainable growth, which, if taken explicitly, has a different meaning. Daly (1990), Pearce *et al* (1989) and IUCN, UNEP and WWF (1991) elaborate the meaning of both terms. The difference could be determined by dictionary distinction of the words *growth* and *development.* Growth means to 'increase naturally in size by the addition of material through assimilation or accretion' (Daly, 1990 p1). Hence, sustainable growth can be seen to be a contradiction in terms, as 'nothing physical could grow indefinitely' (IUCN, UNEP, and WWF, 1991 p10), especially in the world economy with its finite resources. To develop means to 'expand or realize the potentialities of; bring gradually to a fuller, greater or better state' (Daly, 1990 p1). In contrast to the quantitative nature of sustainable growth, sustainable development is qualitative improvement of unfolding potentialities. Daly (1990, p1) further clarified that 'an economy can grow without developing, or develop without growing or do both or neither'.

Sustainable development means many things to economists. For some, it means 'to increase in social welfare' (Lele, 1991 p609), or 'sustainable utility' (Pearce *et al*, 1989 p32), or, for others, it is simply to increase material consumption and production.

All these facets rely mainly on the requirement that the stock of capital that one generation passes on to the next be maintained or enhanced. Further, this stock of capital is seen by some to comprise two elements: manufactured capital and natural capital. The extent to which these are believed to be substitutes or complements is subject to debate. As it is considered to be of relevance to this paper, a brief examination of these views are dealt with further.

2.1.2.1. Neoclassical Economics

The neoclassical economic paradigm of sustainable development is apparently optimistic. According to this concept, 'sustainability can be achieved even if production and consumption deplete a natural resource faster than it regenerates if:

- the resource can be continuously substituted for capital,
- or if there is resource-saving technological progress (Klaassen and Opschoor, 1991 p111).

Therefore, it is assumed that sustainability can be attained through capital substitution and technological progress. This assumption appears to be unrealistic because, firstly, all natural resources can not be substituted in all of their capital functions (eg, the role of air as input to industrial machinery), while other services rendered to the economy can not be substituted (eg, waste assimilation capacity, etc.). Nevertheless, according to Victor (1991, p195), 'it is important for those who believe in sustainable development to consider the role of substitution in alleviating the pressures of a diminishing resource base'. Secondly, there are well known physical thermodynamic limits to technological progress. For example Slesser (1978, p17) expounds Carnot's Theorem: the maximum amount of work one can obtain from a quantity of heat depends only on the temperature of the heat and the temperature of the surroundings and has *nothing to do with* *technology* or substance used[2]. In other words, for every work there is always an energy irretrievably lost regardless of the technology used. Technology can only minimize loss, not completely eliminate it.

2.1.2.2. Ecological Economics

The ecological economic perspective can be classified as restrained. This paradigm is more cautious in dealing with the natural resources and environment to the point that the rate of its exploitation and use should be maintained or even minimize as suggested by Daly (1973) in his steady state economics. The importance of the maintenance of environmental and natural resources is due to the significance of their role in the economic process. Sustainable development is viewed as an evolutionary process in the dynamic interaction between the environment and the economy.

Pearce *et al* (1990), at the London Centre for Environmental Economics, advocate the 'maintenance-of-natural-capital stock' concept, implying the limitations of capital substitutability. According to Victor (1991, p201), Pearce and Turner (1989) differentiate natural and manufactured capital:

- manufactured capital is not independent of natural capital. The later is often needed to make the former;
- natural capital fulfils other economic functions, including basic life support; and is multi-functional to an extent not shared by manufactured capital; and,

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[2] Emphasis added.

- because of the above, it is not always possible to substitute manufactured capital for natural capital.

Furthermore, the role of the natural environment to economic activity and the effects of economic activity on the environment are still uncertain. Compounding this is the fact that the repercussions of human activity on the environment is irreversible and can not be matched by manufactured capital (Victor, 1991 p202). Therefore, by taking account of uncertainty and irreversibility through the maintenance of the natural environment, sustainability is further insured.

2.1.2.3. Economics and the Laws of Thermodynamics

In the previous sections it was discussed, briefly, how sustainable development is viewed under different paradigms, from optimistic (neoclassical) to restrained (ecological). In this section sustainability is viewed as unrealistic. This paradigm, otherwise named as 'thermodynamic' by Victor (1991) explicitly incorporates the laws of physics, particularly thermodynamics, to economics.

According to the first law of thermodynamics, economic activity can not create or destroy energy, it can only be transformed from one form to the another (Victor, 1991 p206). Similarly, matter can not be created nor destroyed, except under nuclear processes. Known particularly in economics as 'materials-balance-approach', this simply means that, baring accumulation in the production process, all matter and energy entering economic activity is ultimately returned to the environment in the form of services, products, wastes and heat.

The significance of this first law of thermodynamics to the environmental-economic relationship is that for every resource entering the economic process, transformation into corresponding product and waste occurs. In other words, this paradigm explicitly emphasizes the significance of waste or pollution economic activity generates. Unlike in the neoclassical model, where pollution is considered as an externality, ecological economics explicitly emphasizes its significance. It is in the treatment of this 'undesired product' of economic activity that the second law of thermodynamics is more important to economics according to Georgescu-Roegen (Georgescu-Roegen, 1975 as cited by Victor, 1991).

If the first law is the transformation of energy, the second law explicitly states that this transformation of energy always involves the degradation of energy from high quality forms of higher economic value to low quality forms of lower economic value. The second law of thermodynamics demonstrates that 'economic activity takes low entropy matter/energy [which can be thought of as highly organized materials and energy flows] and converts it into high entropy matter/energy (highly disorganized materials and energy)' (Victor, 1991 p207)[3]. According to Georgescu-Roegen (1975 pp351-3 as cited by Victor, 1991), 'thermodynamics ... recognizes the qualitative distinction which economists should have made from the outset between the inputs of valuable resources (low entropy) and final outputs of valueless wastes (high entropy)'.

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[3] Peet (1992, p36) points out that the Second Law of Thermodynamics can be stated in the following theoretically equivalent ways:

- In any transformation of energy, some of it is always degraded
- It is not possible to convert a given quantity of heat (thermal energy) into an equal amount of useful work (mechanical energy)
- Heat will not of itself flow from a colder body to a warmer body
- The availability of a quantity of energy can be used only once

Thus, all economic activity in the long-term is transforming matter into valueless waste and valuable energy into valueless energy. It also implies that 100% recycling is impossible without extra energy inputs, since recycling a certain product into its former state requires energy infusion. Considering the fact that the world is a closed system in material terms[4] and open in energy terms (although sunlight is a form of high entropic energy), energy can be seen as the ultimate constraint on the supply of material resources (Peet and Baines, 1986; Slesser, 1978).

2.1.3. The Ecological Concept of Sustainable Development

The last decade saw the realization that past development policies and programs are after all, not adequate for long-term human economic development (Horsley, 1989). Rapid economic growth was, then, the most basic and the main goal for planners and decision makers, with other related factors such as environment and natural resources not accounted for. According to Horsley (1989), 'basic economic concepts become narrowly defined and are used without consideration of their wider social and ecological context'.

The resulting environmental repercussions of these narrowly focused economic growth programs became evident. Pollution, environmental destruction due to resource exploitation, and the consequent climatic variations became globally apparent, suggesting that this economic trend was gradually destroying its own resource base.

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[4] In strict terms, matter enters the biosphere in the form of meteorites. However, this is negligible.

It is on this premise that the World Conservation Strategy (WCS) was prepared. This document indicates that development can only be sustained by conserving the living resource on which it depends by the integration of development and conservation.

The strategy stressed three main objectives for living resource conservation:

- maintain essential ecological processes and life support system;
- preserve genetic diversity (ie, the range of genetic material found in the world's organisms); and
- ensure the sustainable utilization of species and ecosystems (notably fish and other wildlife, forests and grazing lands) (WCS, 1980).

Ecologically sustainable development requires the establishment of resource-use limits. Economic development, according to this paradigm, can not be pursued through increased material and resource exploitation alone. It requires balance between economic development and environmental conservation. The natural environment is needed for other services that can not be provided by economic growth and technological progress, and implies that the economic system is only a part of a bigger ecosystem. In the end, ecological sustainability means a way of life within the laws of nature.

2.2. Sustainable development: The Concept

Section 2.1, and its subsequent subsections, have briefly elaborated the various dimensions of sustainability. Each dimension tends to emphasise a particular set of objectives: ecologically, it emphasizes genetic diversity and biological productivity and environmental conservation; economically, it stresses sustainable welfare and increasing production and consumption, while socially, it means maintenance of desired social values, traditions and cultures.

It is apparent that some of these concepts of sustainability are complementary to each other, while in some instances economic, ecological and the social dimensions are, apparently, in conflict with one another. Commercialised or industrial agriculture attains high production but tends to simplify ecosystems reducing genetic diversity. Sometimes social values and traditions may be ignored to increase welfare at the same time sacrificing diversity. A concrete example of this phenomenon is the shift from traditional rice agriculture in South-East Asia to modern agriculture employing high energy and resource input to increase production and improve welfare. In the process, agricultural diversity, due to monocropping, was reduced.

Given these potential trade-offs among policy objectives, 'a choice must be made as to which objectives should receive priority and thus greater weight in overall development strategy' (Barbier, 1987 p104). Taking into account limitations within each of the dimensions (maintenance of capital stock for economic and ecological dimensions, for example), sustainability could, therefore, be considered as the optimum satisfaction of policy objectives across these dimensions. One of the common features of these different sustainability dimensions, however, is its apparent anthropocentric welfare optimization theme (Braat, 1991).

However, this concept is still too broad to be operational. Wright (1991, p2) stressed that 'there is a tension between keeping sustainable development wide enough to incorporate all these concerns and narrow enough to have some chance of making the concept workable'. The common approach in making the concept workable is to view sustainability purely in quantitative terms[5]. One way of doing this is to examine the sustainability of one of the world's renewable resources: agriculture.

2.3. Sustainable Agriculture

Like sustainable development, sustainable agriculture is subject to a number of interpretations. As such, it assumed different names: low-input agriculture, organic agriculture, biological agriculture, alternative agriculture, ecological agriculture, resource-efficient agriculture, natural agriculture, biodynamic agriculture, regenerative agriculture and permaculture (Gips, 1987 p69). Inevitably, these generate various meanings for different people.

According to Conway and Barbier (1990), sustainable agriculture is multi-faceted:

- For agriculturists, it embodies a desire to consolidate and build upon the achievements of the green revolution. For them, sustainability is food sufficiency, and sustainable agriculture embraces means toward an end (Barbier and Conway, 1990, p9).

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[5] Quantitative measures tend to emphasise economic and ecological dimensions (eg, Gross Domestic Products (GDP), raw material resources - tonnes of iron ore, etc.), and may not capture all social dimensions like equity, and provision of desired social values which are difficult to quantify. Nevertheless, in the later part of this thesis, some measures will be presented to at least represent this social dimension.

- For environmentalists, though, the means are crucial. Sustainable agriculture represents a way of providing sufficient food and fibre that complements, and indeed, enhances our natural resource endowment. For them, sustainability means a responsibility for the environment - a stewardship for our natural resources (Barbier and Conway, 1990, p9).

- For economists, sustainability is a facet of efficiency, not short-run efficiency alone, but efficiency in the use of scarce resources in such a fashion as to benefit both present and future generations (Barbier and Conway, 1990, p9).

- Finally, sociologists see sustainable agriculture as a reflection of social values, and define it as a developmental path that is consistent with traditional cultures and institutions (Barbier and Conway, 1990, p10).

While these perspectives are different from one another, some are contrasting. In recent years, there seems to be a coalition of interest in promoting sustainable agriculture as a development goal. However, little effort was given to clarifying this concept (Barbier and Conway, 1990, p10), which tended to blur the concept and definition. This has given rise to very general definitions of sustainable agriculture, which have typically encompassed the following development objectives:

- highly efficient and stable production;
- low inexpensive inputs, in particular making full use of the techniques of organic farming and indigenous traditional knowledge;

- food security and self-sufficiency;
- conservation of wildlife and biological diversity;
- preservation of traditional values and small family farms;
- help for the poorest and the disadvantaged (in particular those on marginal land, the landless, women, children and tribal minorities); and
- a high level of participation in developmental decisions by the farmers themselves (Barbier and Conway, 1990 p10).

All these goals are considered to be desirable, but hardly fully attainable. As it is clear that there will be trade-offs in the process, it is important to develop a concept that will encompass and evaluate these goals. For an agricultural system to be sustainable, it must have the following principles: ecological suitability, economic viability and social justice (Gips, 1987 p64).

2.3.1. Ecological Suitability

The notion of ecological suitability in sustainable agriculture came from the view that sustainability is long-term food sufficiency without destroying the resource base. For agriculture to be sustainable, it must be ecologically sound, whole and in good condition (Gips, 1987 p65). Aldo Leopold (1949, pp224-5) sums up this concept quite simply: 'A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise'. Indeed, agriculture is so dependent on ecological principles that, according to Williams (1990, p92), 'ecological constraints are the ultimate determinants of sustainability'.

There are two components that could be considered necessary in order to achieve an ecologically sustainable agricultural system, both of which are based on basic biological processes in nature: self-regulation and resource efficiency (Harwood 1985). The achievement of self-regulation and resultant stability requires soil with minimum erosion and contamination, and diversity of the surrounding flora and fauna (Gips 1987). Furthermore, according to Gips (1987), an ecologically suitable agriculture must be resource efficient in order to conserve precious resources, avoid system toxicity and decrease inputs.

One way of achieving resource efficiency is by having a system of closed resource cycle loops so that resources can be recycled and not lost, while energy requirements should emphasize renewable resources that allow greater self-reliance (Gips 1987). Although the prospects for a 100% recycling of waste residuals are still only a technical impossibility, it is essential to ensure that the resulting impact on the environment and its resources are as minimum as possible (Barbier and Conway, 1990 p106).

In addition to this, Barbier and Conway (1990) stress that dependence on external resources is not only frequently costly, it also tends to make the system more vulnerable to external stresses and shocks such as changes in the costs and supply of resources. Additionally, it is also widely believed that applying non-renewable resources to natural systems will eventually decrease productivity. This is either because too many non-renewable resources are used which generate pollutants, and other outcomes that impair the vitality of the biological resources, or because too rapid application of non-renewable resources may cause society to raise population and consumption levels unsustainably, leading to a crisis breakdown (Douglas, 1984 p13). Although this later may sound a little unrealistic, the former is credible. It is believed that there are natural and physical limits on our capacity to grow food - limits based on finite supplies of natural resources, production capacity, and waste assimilation capacity.

Based on the discussion above, ecologically sustainable agriculture will encompass elements of the following properties:

- increased recycling;
- minimal use of non-renewable resources;
- exploiting non-renewable resources at a rate less than their natural rate of 'ecologically safe' regeneration;
- reduced waste generation levels to well within the assimilative capacity of the environment; and
- maximum resource-use efficiency within the production process (Conway and Barbier, 1989 p106).

2.3.2. Economic Viability

The second test of a sustainable agriculture is that it be economically viable, or able to prosper (Guralnik 1978 in Gips 1987 p65). A viable economy is one that is workable and likely to survive. Such an economy must be able to maintain itself and grow over both the short and long-term.

A key element of economic viability is profitability (Neidig, 1990), and for industrialized agriculture this is the most essential component. After all, the sustainability of industrialized agriculture relies on being commercially competitive, to generate profit to sustain its survival (Ikerd, 1990 p18).

According to the neoclassical prescription, the degree of profitability should be balanced to sustain it for a long period. As there are instances where too much profitability is attained at a considerable loss to the environment, profitability should be optimized in order not to generate too many negative externals, while benefit and cost analysis should be considered with due regard to environmental repercussions.

2.3.3. Social Justice

It can be argued, historically, that traditional systems have had a mixed pattern of social justice (Gips, 1987 p68). While many people were denied basic human rights, they did incorporate certain aspects of social justice, including community decision making, shared labour, and access to common land. However, with the incursion of outside influences, control was taken by corporations, governments and wealthy elites.

This trend is prevalent in industrialized agriculture. Small family farms are slowly being displaced by corporations. Gips (1987) stresses that the examination of social justice within conventional or industrialized agriculture shows that in many countries, national farm policy is designed to eliminate small family farms while providing subsidies to large corporate farms. Farmers and consumers have little influence on commodity pricing policies or agribusiness boards. Clearly, industrialized agriculture does not meet a just social criteria for sustainability.

2.3.4. Trade-Offs

From the sustainability criteria discussed above, it is imperative that trade-offs have to be made. As Ikerd (1990 p23) points out, 'trade-off is the key to sustainability of farming systems'. Any criterion should not be maximized at the expense of another, thus systems must be chosen to consider trade-offs between resource conservation and environmental soundness on the one hand, and productivity and competitiveness on the other, or between social equity and productivity.

Similarly, trade-offs must be made between short-term profitability and long-term survival. Systems that are most profitable in the short-term, maybe most vulnerable in the long-term. There are potential losses in short-term profitability that must be weighed against the benefits of long-term sustainability (Ikerd, 1990 p23), who further states that economics has a great potential in balancing these trade-offs. But to ensure a more sustainable agriculture, there must be limits/thresholds, beyond which sustainability can not be regained. In other words, within any economic analytical framework a natural resource base should be conserved to ensure a sustainable agriculture.

2.3.5. The Meaning of Sustainable Agriculture

It must be pointed out that as the purpose of this thesis is the 'measurement' of the sustainability of an agricultural system, the operational aspects of the definition are most important. One step in the process of operationalising this concept is to cite 'unsustainable' activities which can be related to agriculture, which:

- require continued inputs of nonrenewable resources;
- use renewable resources faster than their rate of renewal;
- cause cumulative degradation of the environment;
- require resources in quantities that could never be available for people everywhere; and
- Lead to extinction of other life forms (Guidepost Project 1991 in Wright 1991, p2).

Moreover, it should be recognised that in addition, to these quantifiable aspects, sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources (FAO 1989). Furthermore, it should have the ability to maintain satisfactory productivity in the face of stress or shock (eg, resource price increases or unavailability, environmental repercussions that impair productivity, or government regulatory interventions). Sustainability thus determines the persistence or durability of a system's productivity under a known, or possible condition (Conway and Barbier, 1990 p37).

Chapter Three

OPERATIONALISATION OF SUSTAINABILITY MEASURES

Chapter Two explores the different perspectives of sustainable development and sustainable agriculture. While an unanimous definition of each of these terms is still under debate, its measurement is another problem. Verbruggen and Kuik (1991) however, stress that definition and measurement will be 'mutually fertilizing', that in the end such terms will have a concrete meaning. Apparently what they mean is that measurement will provide the base upon which the definition will be made more operational. In turn, this will provide the way for a more precise measurement and monitoring. In other words, each will reciprocate to develop a more precise term.

According to Wright (1991, p3), there are three major approaches for measuring sustainability. The first involves correcting the national accounting system with the ultimate goal of calculating 'sustainable national income', while the second involves the production of supplementary environmental and natural resource accounts. Both of these approaches fall under the term environmental or natural resource accounting[6]. The third approach is through sustainability indicators.

In this thesis, both the environmental accounting and sustainability indicator approaches will be used. That is, an environmental accounting model will be constructed from which a series of identified indicators will be developed and evaluated. The environmental accounts provide a means of interlinking economic transactions with their impact on the environment, as measured by a series of sustainability indicators. Both environmental accounting and use of sustainability indicators are considered to fall within the domain of State of Environmental Reporting.

3.1 State of Environment Reporting (SER)

The consequences of economic growth and development was increasingly recognized in the late 1960s and early 1970s, and mid-80s[7]. As has been previously emphasised, economy and environment interact, putting pressure on the environment and the natural resource base. Economic growth and development resulted in environmental degradation

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[6] The literature does not distinguish between resource accounting and environmental accounting. However, according to Wright (1989), environmental accounting is more concerned with pollution and its control, and environmental conservation, while resource accounting is more concerned with natural resources, as other studies, like that of Clarke and Dragun (1989) and the New Zealand Institute of Economic Research (NZIER) (1992), have exemplified. These natural resource accounting studies were focused on resource flows and exploitation. The NZIER, however, clarifies environmental accounting as broader, incorporating welfare detracting environmental impacts of economic activity, especially in developed countries. It is in this context that this thesis will use the term environmental accounting, as this gives more emphasis to pollution rather than mere resource flows generated by agricultural activities.

[7] The early 1970s might be considered as the realisation of the first wave of environmental consciousness brought about by human economic activity. Among the publications written about this were *Limits to Growth* (Meadows *et al*, 1972), *The Entropy Law and Economic Process* (Georgescu-Roegen, 1972), *Tragedy of the Commons* (Hardin, 1968), and many others. The second wave of consciousness was heralded by the *Bruntland Report* (1987).

and depletion of natural resources, as economic decision making was narrowly focused (Serafy and Lutz, 1989). The role of the environment in economic development was treated as 'external'. It is only when environmental degradation became global (eg, acid rain and greenhouse gas) that decision makers became aware of the problem. The 'external effects' of economic growth and development on the environment has serious effects on the world ecosystem as a whole. Although this system is generally large, it is nevertheless finite, and in certain respects it is subject to great stress (Serafy and Lutz, 1989). Previous decision making did not pay particular attention or reference to the environment[8]. This trend should be minimized or arrested if sustainable development is to be pursued.

In sections 2.2 and 2.3, the conservation and preservation of the environment, in order to attain sustainability, was emphasized. It is then imperative that the state of environment be taken into consideration when economic decisions are made. According to the Department of Statistics (DoS) and the Ministry for Environment (MfE) (1990), this SER shows:

- current states of the relevant part of the environment (snapshot);
- trends in the state (history); and
- the cause-effect relationship between human action and the environment which allows projections to be made about environmental effects of the decision being considered (future scenario).

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[8] In the academic literature economic externalities were well covered by Herfindahl and Kneese *et al* in the late 60s and early 70s.

SER has three elements, namely, rules, efficiency and indicators (DoS and MfE, 1990). Accordingly, *indicators* provide knowledge about the state of the environment and/or pressures put on the environment by human activities. *Rules* stands for any of the following: objectives, standards, policies, regulations, legislations and natural laws as used in the scientific modelling of natural systems. Environmental management involves the comparison between rules and indicators. The comparison between these two elements results in *efficiency* which introduces the concepts, value for money, performance and accountability.

3.2 Indicators

The use of indicators in policy making and decision making is not new. The economic growth and development during the past three decades in the developed countries saw the necessity of measuring the multi-dimensional nature of human well-being. This can be illustrated in the social indicator development programme of the Organization for Economic Cooperation and Development (OECD) countries (see OECD, 1976). Economic growth was not made as an end in itself, but rather an instrument for creating better conditions of life. Increased attention was given to the qualitative aspects of growth, the dimensions of which were not included in economic indicators, and to the formulation of policies with respect to the broad economic and social choices involved in allocation of resources. This, in turn, gradually took notice of how this development affected the environment. The growing concern for the health of the environment necessitates adequate information about its state, and for this reason environmental indicators were formulated.

3.2.1 The Meaning of Indicators

Normally an indicator is something that acts as a sign or indication. In the case of environmental indicators, it relates to phenomena, and states of physical environment, while human well-being is mainly expressed as per capita income, life expectancy, literacy rate, etc.

The term, *indicator*, is used for empirical specification of concepts that can not be (fully) operationalised on the basis of generally accepted rules (Vos *et al*, 1985 in Kuik and Verbruggen, 1991 p1). Vos *et al* (1985, p6), argues 'it is evident that indicators contain more information than statistics'. Statistics form a collection of observed data which can be subsequently used for all sorts of applications, whereas indicators are, according to Vos *et al* (1985), 'thriftily selected data' assumed to have causal relation with a theoretical concept. Their primary function lies in simplification: indicators are a compromise between scientific accuracy and the demand for concise information in order to serve their social purpose (Wright 1991; Kuik and Verbruggen 1991), forming a cross between scientific reality and social clarity. In other words, 'reliability of measurement and validity of representation are the main criteria for the selection of indicators' (Vos *et al*, 1985 p5).

Indicators have been described in many ways. In order not to add too much confusion to this, it is important to distinguish between two commonly used indicators - environmental and sustainability indicators.

Environmental and sustainability indicators may overlap but will not be identical. While sustainability indicators may include economic, social and institutional as well as physical indicators, environmental indicators measure biophysical phenomena, although the selection of such indicators is based on social perception (Wright, 1991 p4).

Environmental indicators can be defined as quantitative descriptors of changes in either (anthropogenic) environmental pressure or changes in the state of environment (Opschoor and Reijenders 1991). In this way environmental indicators can be divided into 'pressure' (cause) indicators and environmental 'effect' indicators.

Sustainability indicators are not simply 'state indicators' but rather indicators of states *vis-a-vis* some reference situation; the later could either be some past environmental state or a future one that is regarded as more desirable than the present. Sustainability indicators are thus more than mere state descriptors; they are normative measures of 'distance(s)' between current states and the reference situation (Opschoor and Reijenders, 1991 p7). It implies, therefore, that there will be cases wherein more 'distances' are needed to express a certain indicator. Parameters in pollution emission and energy use and efficiency ratios are examples of this concept.

Braat (1991) distinguishes between two types of indicators, predictive and retrospective. *Predictive* indicators provides direct information about future states and development of relevant socioeconomic and environmental variables. This information constitutes the basis for anticipatory planning and management. *Predictive* indicators are often derived from mathematical and statistical models of man-environment systems (Braat, 1991).

Braat (1991) suggests that, scientifically, the most appropriate way to develop simulation models is to generate trajectories of future values for selected socioeconomic and environmental variables, with explicitly defined reference values. Stock, flow or ratio, can be selected as an indicator variable to track the changes in these trajectories. The selection is often based on psychological attractiveness and easy intelligibility of the indicator, rather than the scientific adequacy of the indicator.

The *retrospective* indicator includes the traditional policy evaluation and historical trend indicators, which provide information about the effectiveness of existing policies or about autonomous developments, respectively. In this way, retrospective indicators may provide indirect information about future sustainability, and are, usually, quantified by a combination of measured data and reference values (eg, historical situations, economic targets, health standards) (Braat 1991).

The *retrospective* indicator can be a useful sustainability indicator for policy performance assessment, as it is usually numerical in nature and can be compared with the reference values (sustainability indicator) to see if certain policies, in an historic period under consideration have led to welfare, environmental quality and amenity levels, or have maintained a sustainable level.

3.2.2. Qualities of an Indicator

In principle, information embodied in indicators is used in decision making. Successful indicators are, therefore, defined as indicators which are consistent in the representation of complex processes while using a format which is psychologically attractive so that they may aid decision makers rather than confuse them.

Therefore, as a special class of models, they should have the following qualities:

- *The information must be presented in an attractive format*

  As previously stated, the purpose of the indicator is essential in considering the format of the indicator. There are three main target groups, identified by Braat (1991), as users of indicators: professional analysts and scientists, policy/decision makers or politicians, and the public. The importance of an indicator to a certain group can be demonstrated in a pollution-related indicator. For the public this indicator serves mainly a communication function, simply making the public aware of changes in environmental quality (Vos *et al*, 1985).

  For the policy/decision maker or politician, this will mean something more, claiming 'indicators are often better understood if they have immediate social or political meaning' (Liverman *et al*, 1988 p137). In this instance, the particular interest is on the receptor effects or repercussions (concentration on biota and humans) caused by the pollution. This is when the planning function of the indicator becomes effective. Policy/decision makers or politicians should be able to derive information from the indicators from the appraisal of the current and prospective social problems (Vos *et al* 1985).

The professional analysts and scientists, will mainly be interested in the effects of pollution on the environment (air and water quality), thus, 'the format of the indicator might be in the form of raw data which can be analyzed statistically' (Braat, 1991 p60).

- *The indicator must be representative of the chosen system*

As thriftily selected data, it should convey completeness as much as possible, and should be able to convey the maximum information about a theoretical concept, as possible (Patterson, 1993).

- *The indicator must have a scientific basis*

The indicator must, preferably, be based on an empirically quantified, statistically tested, causal model of the system it represents. Discrepancies between this ideal and the actual empirical and theoretical basis of the indicator must be explicit: it must not be hidden by the format of the indicator.

- *The indicator must be quantifiable*

The data on the structure of behaviour of the system represented by the indicator must be available or obtainable with present technology. In addition, indicators nearly always need to be expressed as ratios, indices, percentages or in terms of arithmetical transformations (Patterson, 1993).

- *The indicator should include reference or threshold values*

  This is, of course, relevant and necessary for the identification of the degree of sustainability of a particular development, implying that the relevance and appropriateness of the reference values should be beyond doubt and dispute. Therefore, it incorporates relevant reference points in order to facilitate the comparisons of change to the indicators through time.

- *The indicator should provide information without bias*

  Sustainability indicators should not be formulated from a narrow ethical-theoretical framework. As the target group may include decision makers from various political and ethical convictions, non-compliance with this requirement makes an indicator immediately inappropriate (Braat 1991).

- *The indicator must represent reversible and manageable processes*

  From a management perspective, it is critical to identify indicators which reveal whether changes are reversible and controllable. According to Liverman *et al* (1988), the most critical changes to life support systems are those which involve a permanent and irreversible shift in conditions. Such changes might include the total removal of topsoil, destruction of rainforests, desertification and the release of non-degradable toxic materials.

- *The indicator should have predictive meaning*

  Indicators which predict or anticipate non-sustainable conditions are valuable for policy and decision makers. Liverman *et al* (1988) have suggested that time series can be used in predictive extrapolation or simulation modelling. Others, like global modellers, have used a combination of empirical estimates and theoretical assumptions to warn policy and decision makers of potential 'non-sustainable' futures (Meadows *et al*, 1972)

Using the above suggested properties, it is believed that an appropriate indicator can be developed. It is important to note, however, that all the above mentioned properties can not be found in a single indicator.

Chapter Four

ENVIRONMENTAL ACCOUNTING APPROACH

4.1 Environmental Accounting

Environmental accounting is used as a means of providing reports on the state and use of natural resources (Garnasjordet, 1980, p1), and includes the incorporation of 'true' environmental costs and benefits (eg, the role of the environment as a 'source' and 'sink' of economic activities) of economic development. Through environmental accounting 'costs' and 'benefits' can be adequately shown, distinguishing clearly between 'true' income generation and the diminishing of capital assets by resource depletion and degradation (Serafy and Lutz, 1989).

Wright (1989), stresses that environmental accounting should show the physical base of a society, determine what is physically possible, outline are the ultimate constraints, and point to impending scarcities of unpriced or underpriced environmental goods and services. Importantly, it will also point out the 'externalities' (eg, pollution and degradation) that a society or economy generates. In other words, such a set of accounts would provide better data for taking 'full account of the sustainability of natural and physical resources' (Environment Act 1986 as cited by Wright, 1989).

Merely accounting for the state of natural resources alone can not satisfy all the criteria of SER as outlined in section 3.1. It can not portray the cause-effect relationship between economic activities and the environment, nor can it express the projections how certain economic decisions can impact on the environment. Therefore, scenarios can not be simulated by mere environmental accounting alone. The adoption of input-output analysis is seen as an answer to this problem. Aside from its attribute as a basis for resource accounting methodology (Wright, 1989), it has the ability to determine interrelationships in the economy, and thus the environmental effects. Therefore, it can be manipulated to create future causal economic, environmental and social impacts of the environment-economy interaction.

4.2. Input-Output Analysis

Previous discussions have dealt with sustainable development/sustainable agriculture and how this phenomenon can be monitored and measured by means of indicators of sustainability. So far, normative indicators of sustainability have been related to maintenance of constant natural capital stock, resource-use efficiency and the minimization of the degree of pollution that certain economic activities generate.

It was also emphasized that economic activities uses natural resources as raw material inputs, and the environment as the waste sink. This man-environment or environment-economy interaction is believed to be one of the most neglected phenomenon in the area of economics (except perhaps for a few economists like H.E. Daly and Georgescu-Roegen), while it is a cause for alarm to environmentalists.

One of the most practical way of assessing the interaction between the economy and the environment is through input-output models. Input-output analysis is an accounting tool that can monitor the degree of resource use and the intensity of waste disposal to the environment. From such analyses, the sustainability of a certain economic activity can be assessed.

4.2.1 The Basic Theory of Input-Output Analysis

The convention behind the input-output model is the notion that the degree of activity in an industry is dependent upon the consumer demand. The activities within industries are considered to be interdependent: the output of one is the input of another. This interrelationship is aptly described by Victor (1972b, p56):

> The fundamental idea upon which input-output model is based in that inputs of one industry are the outputs of another and that, in general, all industries are interrelated by providing each other's inputs and using each other's outputs. Some outputs are also supplied to final consumers and it is in this 'final demand' which is the driving force of an input-output model. Once the relations among the various industries have been established, that is once estimates have been made of the input requirements per unit of output of each industry an input-output model can be used to estimate the pattern and level of industrial activity necessary to produce a specified demand for final commodities. These interindustry relations are usually estimated on the basis of data taken for single, base, year. The inputs and outputs of each industry for the base year may be used to estimate input-output coefficients, which are no more than statements of the inputs per unit output for each industry.

While it is not necessary to go into detail as to how this model records the commodities produced and used by industries and consumers, it is more important to emphasize how this model can be used to relate the interaction between the economy and the environment.

4.2.1 Input-Output and the Environment

As emphasized earlier, economic processes requires inputs from other industries to produce outputs. Similarly, it also requires inputs from the environment in the form of raw materials and 'free goods', such as air and water. Furthermore, industries also produce outputs, which are consumed by other industries and consumers, and produce wastes which are either recycled in the production process or discharged into the environment (Victor, 1972b).

It must be noted that, whatever activity industry performs, in one way or the other, the environment is always involved (ie, as the source of raw materials or capital, and as the recipient of production externalities, known as wastes). Similarly, the consumption of final services also involves the environment as air is used in the combustion of fuel and this consumptive process uses the environment as the discharge medium for the exhaust. In fact, Ayres and Kneese (1969) have stressed that pollution is an integral part of an economic activity, not an externality, as expressed by neoclassical economists (Richardson, 1972 p214). Through this relationship, the environment can be regarded as an additional industry in an input-output model, performing, as usual, its above mentioned role.

A number of input-output models that explicitly take account of natural resources and the environment have been developed. These are briefly outlined and discussed in the following subsections of this thesis.

4.2.1.1 The Cumberland Model

It is generally regarded that Cumberland (1966) attempted the first input-output model relating economic activity to environment. His approach was to add columns and rows to traditional input-output tables, to identify benefits and costs associated with economic activity, and to distribute these by sector (Richardson, 1972 p215). It is important to note that this model does not incorporate the flow into the economy from the environment, and *vice versa,* into an input-output framework in an integrated manner, since neither the column on *Cost of Environmental Restoration* nor Row R are linked to particular values for the interindustry flows between economic sectors.

The general equation structure of this model is outlined in Figure 4.2, where Row R measures the environmental effects of any development project or programme, and consists of monetary estimates of any environmental benefits by sector, as shown in Row Q, minus estimates of environmental cost by sector, Row C (ie, $R = Q - C$). The column on the *Cost of Environmental Restoration* represents the cost which would be incurred by public and private sectors of the regional economy in order to neutralise adverse environmental effects, and to restore the environment to its base period quality levels.

Figure 4.1 The Cumberland Model

<table>
<tr><td>Input-Output
Transaction
Matrix</td><td rowspan="4">Cost
of
Environmental
Restoration</td></tr>
<tr><td>Environmental Benefits (Q)</td></tr>
<tr><td>Environmental Costs (C)</td></tr>
<tr><td>Environmental Balance (Q - C)</td></tr>
</table>

Source: Richardson, 1972

It is apparent that this model was designed to facilitate environmental benefits and costs that certain economic activity generates (Richardson, 1972; Victor, 1972b). But, inspite of this being the purpose, 'the model does not address the problem of how the environment is being utilized' (ie, environmental inputs and outputs to the environment is not clearly emphasized) (Richardson 1972), nor, how these benefits and costs can be evaluated (Victor, 1972b p37). Richardson (1972) further stresses that the analysis attempts to place monetary values on environmental effects rather than measuring them in physical term. It is noted that imputing monetary values on environmental effects is difficult, and depends on the successful and valid application of non-market valuation methods.

4.2.1.2 The Isard Model

Isard's (1969) model provides a more complete picture of interaction between the economy and the environment. It deals, mainly, with material flows, and 'shows interactions both within and between the economic and environmental systems' (Richardson, 1972 p218). The model, essentially, covers four (4) types of activities: As shown in Figure 4.2, the diagonal matrices, Type I and Type III, contain the coefficients representing the internal structure of the economy and the environmental system, respectively, while the opposite diagonal matrices, Type II and Type IV illustrate the flow from the environment to the economy and *vice versa*. The apparent comprehensiveness of the model is also its weakness. The principal shortcomings lie in the enormous quantity and variety of base year data it requires. This is because part of the model consists of an input-output model of the environment itself (ie, Type IV quadrant). Although inputs and outputs of other processes like the environment-economy interaction can be determined (eg, pollution and other waste products), the resultant outputs of the ecological processes are difficult to determine. Apart from that,

Figure 4.2 The Isard Model

	Economic Process	Ecological Process	Sum of Rows
Economic Commodities	Type I	Type II	
Ecological Commodities	Type III	Type IV	

Source: Richardson, 1972

relationships in ecological processes are often not linear or near linear.

4.2.1.3 The Daly Model

Daly's (1968) model deals mainly with material and energy flows, and is similar to Isard's in that it also involves ecologic and economic processes. According to Victor (1972b, p44), 'the essential difference between the two is that Isard uses the coefficient of production directly, whereas Daly turned initially to accounting data from which he intended to derive the coefficients'.

The use of square matrices implied in the industry-by-industry and the highly aggregated process-by-process sectoring schemes are inappropriate when an ecological-economic model is intended for analytical purposes (Richardson 1972), because the assumption of one product industry is logically inconsistent with such a model. It has been repeatedly stressed that every economic process has two products, its main output and waste products. Similarly, within the ecological system, each of the processes included in the input-output table hides a wide variety of 'products' and 'outputs' which can not be normally analyzed in an industry by industry type model. Furthermore, Daly sums across the two rows of his table in order to calculate technical coefficients, involving adding together both economic and ecological outputs from the same industry. This is inappropriate since market prices can not be directly assigned to ecological outputs as these are not distributed through a market.

4.2.1.4 The Leontief Model

Leontief's (1970) model was primarily designed to consider cost effects of pollution control (Victor, 1972b p64). The approach is to incorporate pollution abatement industry in the traditional input-output model. The weakness of this method is that its bias toward the flow of materials to environment, ignoring the materials-balance-approach by not considering the flow of materials from the environment to the economy.

Figure 4.3 The Leontief Model

Inputs Inputs and Pollutant's Output	Sector 1	Sector 2	Pollution Abatement	Final Demand	Total Outputs
Sector 1	X_{11}	X_{12}	X_{1PA}	Y_1	X_1
Sector 2	X_{21}	X_{22}	X_{2PA}	Y_2	X_2
Physical Output of Pollutant	X_{1P}	X_{2P}	$-X_{PA}$	Y_P	X_P
Primary Inputs	V_1	V_2	V_{PA}	V_Y	V
Total Inputs	X_1	X_2	X_{PA}	Y	X

Source: Richardson, 1972

The distinctive feature of this input-output table is the row that represents the physical output of pollutants and the column representing the *Pollution Abatement Industry*. Since entries into this row are expressed physically, it can only be added horizontally. It is, therefore, exempted from vertical summations, since entries in the columns are expressed in monetary terms. Also, the output of *Pollution Abatement Industry* is recorded twice - in physical terms (ie, amount of pollutants eliminated = negative output of pollutants) in the pollutants output row and in monetary values in the usual fashion at the bottom of industry columns (ie, in terms of the cost of inputs from other industries and value added). This double valuation of output of *Pollution Abatement Industry* enables the monetary cost of eliminating each unit of pollutant to be estimated directly.

The table can be expressed by some simple accounting identities. Summing the column and rows of the basic input-output table (ie, leaving aside the pollutant row):

$$X \equiv X_1 + X_2 + V \equiv X_1 + X_2 + X_{PA} + Y$$

$$V \equiv Y + X_{PA}$$

$$Y \equiv V - X_{PA}$$

The introduction of *Pollution Abatement Industry*, financed from households, upsets the traditional identity of value added and final demand ($V = Y$). Sales to final demand are reduced below the level of value added by an amount equal to the expenditure of resources on pollution abatement.

The specific application of the Leontief model is to determine the level of activity in the anti-pollution sector, and the price of pollution, along with that of all other industrial sectors and prices, once final demand is specified. These data, then, can be used by the government to prescribe policies that can levy taxes on households, as expressed in the equation above, and the receipts can then be used to finance a privately or publicly operated anti-pollution industry (Victor, 1972b). Furthermore, the Leontief model can be used to estimate the effects on commodity prices of alternative anti-pollution policies.

This is done by estimating the effect of the policies on the pollution coefficients in the model and the cost of the policies, and then using the model to calculate the unique set of final goods and pollution prices that are consistent with these charges.

4.2.1.5 The Victor Model

Victor's (1972) model is a combination of some features of the above models, retaining the strengths and dropping or revising the weaknesses. The resulting model, Figure 4.4, is a compromise between a theoretical ideal and the practical requirements for empirical application. Victor drops the internal matrix of the ecological system, but retains the commodity-industry table of the Isard model. Moreover, he is able to make his analysis of ecologic inputs and outputs conform with the principles of input-output accounting by adopting the materials-balance-concept (Richardson 1972).

Figure 4.4 The Victor Model

Economic Sector	Economic Sector				Ecological Sector	
	Commodities	Industries	Final Demand	Gross Output	Outputs	Totals
Commodities		Z	Y	X	R	
Industries	U			T	Q	
Value added		V_Z	V_Y	V		
Totals	X'	T'	S	W	P	
Ecological Sector						
Inputs	N	M				L

Source: Richardson, 1972

The Victor model only includes flows of 'free goods' from the environment into the economy, and of waste products from the economy to the environment. The benefits accruing from the modest scope of this model is that it can be implemented (Richardson 1972), and this attribute establishes the characteristics of input-output in accounting by establishing identities in economic and ecological features.

These identities can be expressed through the following interpretation of the table:

(a) Economic Sector

Each element of vector — Sum of corresponding (row or column) elements of matrix (or matrices)

$T = U$

$X' = U$

$X = Z + Y$

$S = Y + V_Y$

$V = V_Z + V_Y$

$T' = Z + V_Z$

in addition

$U = U - Z$

and $W = S = V$

(b) Ecological Sector

Each element of vector		Sums of corresponding (row or column) elements of matrices	
P	=	$Q + R$	ecological outputs
L	=	$M + N$	ecological inputs
in addition			
P	=	L	materials balance equation

4.2.3 Comment on the Models

Each of the environmental input-output models, discussed in section 4.2.2, have their own strengths and weaknesses. While each has its own purpose to serve, a few points should be considered as essential factors for attention to an ideal model for this study.

The adoption of the materials-balance-approach in a model is an important factor to be considered, and the following should be regarded carefully: (1) Many of the relationships between the ecological and economic systems are non-linear, and fixed coefficient assumptions maybe less appropriate than in interindustry relations; (2) Ecological inputs and outputs are usually expressed in physical terms rather than monetary, making it difficult to incorporate them in input-output tables. (3) The use of environmental resources is considered to be common property resource usage, but assigning values to them is another problem (Richardson, 1972 p213-4).

Part Two

APPLICATION TO NEW ZEALAND

DAIRY FARMING

Chapter Five

DAIRY FARMING IN NEW ZEALAND

New Zealand, with its mild climate and topography, which is suitable for pastoral farming, is one of the world's leading agricultural countries. Despite its relative decline in the 1970s and 1980s, agriculture is still considered one of the country's main industries. According to the Ministry for Agriculture and Fisheries (MAF), the agricultural industry contributed 13% of the country's gross domestic product (GDP), and 18% of total employment, while agricultural exports contributed 58% of the country's export income (MAF,1992).

These export earnings provide the finance for the importation of commodities and raw materials required by the economy (NZDB, 1980). In the 1990-91 season, New Zealand agricultural export earnings amounted to $8.5 billion, of which 17% were dairy products (MAF, 1992). As the second largest export earner in the agricultural sector (meat and other animal products being the first at 20%), dairying is of considerable importance to economy.

5.1. The Dairy Industry Development

The advent of European settlers in the early 1800s, saw the beginning of dairy farming in New Zealand. By the mid-1800s, the stock of cattle was already providing more milk, butter, and cheese than the infant nation could consume (Rae *et al*, 1985). At that time, dairy products were mainly exported to Australia. However, with the development of refrigerated shipping, distant markets were established, particularly in the United Kingdom (UK). By the mid-1900s, the New Zealand dairy industry had established a considerable market worldwide (NZDB, 1976).

It can be argued that the development of the New Zealand Dairy Industry is due to many factors, among them are: (1) the establishment of an effective and efficient cooperative dairying system; and (2) the development of a successful marketing strategy by the New Zealand Dairy Board.

5.1.1. The Emergence of Cooperative Dairying

Though the New Zealand dairy farmer is a firm believer in the private ownership of his own farm, an extensive structure of cooperative control of manufacturing and export marketing has been established in order to keep costs to a minimum and maximize returns to the farmer (NZDB, 1980). The earliest known venture to establish a cooperative type company was formed in Auckland in the mid-1800s by a group of soldier settlers (NZDB, 1976). This attempt was unsuccessful due to failures in meeting cow payments. Consequently cooperative dairying, for the time being, was abandoned.

By the year 1871, New Zealand's first cooperative dairy factory was established on the Otago Peninsula, the first of its kind in the Southern Hemisphere and the forerunner of the many dairy cooperatives of today (NZDB, 1976). The popularity of cooperatives is primarily a result of economic viability and efficiency. Historically, government subsidy to this industry was keep to the minimum, compared with other countries, and, currently, there are no dairy farming subsidies. There has been, therefore, continued economic pressure to hold costs and increase efficiency both in the farming and processing sectors of the industry.

The cooperative dairy companies are registered under the Cooperative Dairy Companies Act of 1894. The company Board of Directors are elected by milk supplying shareholders. Shares are allocated in proportion to the quantity of milkfat supplied, and the company may require any shareholder, who in the preceding 12 months has not supplied milk or cream, to sell his shares back to the company with provision for arbitration on the value, if required. In this way, only active suppliers of milk take part in running of the cooperative.

The number of dairy cooperative companies was reduced from a total of 188 in the 1960-61 season to 54 in 1978-79 season (NZDB, 1980) to 17 in early 1990s (NZDB, 1992). However, it is important to realise that the reduction in number is not the result of company closures, but company amalgamation.

The main economic pressure behind the growth in amalgamation through the 1960s and 1970s was the need to increase efficiency by achieving economies of scale in order to maintain returns to farmers at economic levels, in the face of both near-static export purchase prices and considerable internal inflation (NZDB, 1980). Technological developments led to the use of milk tankering, and the changeover from cream to wholemilk delivery to factories.

5.1.2. Dairy Board

Today, the New Zealand Dairy Board (NZDB) has evolved from three different organizations: NZDB, the government's Marketing Department and the New Zealand Dairy Products Marketing Commission (NZDPMC). Each of these had its own function and all were aimed at the promotion of the industry's products.

It was originally planned, in 1924, through the establishment of the New Zealand Dairy Board, to have a centralized system of acquisition and marketing of dairy products. However, world prices fell in 1926, resulting in the suspicion and lack of unity within the industry (NZDB, 1980). This led to the limitation of the Board's function regarding arrangements for shipping and in farm production services. Gradually, though, the NZDB developed more power and extended its functions to policy formulation for the industry.

In the 1930s the government's Marketing Department, now handling the Board's marketing function, proved that marketing, controlled by a non-proprietary organization, could work successfully. In the 1940s and 1950s the NZDB emerged as the leading producer and gave the industry the unity it required to takeover marketing from the government. Thus, in 1947 an agreement between the government and the NZDB established a commission, the NZDPMC, consisting of three government and three dairy industry members and a chairman, agreed to by both parties. The commission took over the government's marketing function and determined the guaranteed price, which would be backed by the government.

In the 1950s the NZDPMC developed marketing flexibility in free market conditions and established strong commercial production links with the cooperative companies. Other functions of the board are the administration of the price stabilization scheme (based on average export returns), and control of the domestic marketing of manufactured dairy products, a function which it exercises most strictly in the case of butter (Rae *et al*, 1985). In the 1960s, these three main functions were combined and integrated into one board, the present New Zealand Dairy Board.

5.1.3 Present Dairy Organisations

Rationalisation and amalgamation continue in the dairy industry. At present, there are only 17 companies (compared to 75, 20 years ago) which operate approximately 50 dairy factories for the manufacture of dairy products. Each company is governed by a board of directors who are elected by farmer suppliers. The cooperatives utilize funds supplied in the form of share capital by farmers (Department of Statistics, 1992; MAF, 1992).

Rationalisation has also applied to the town milk industry. Until 1988, liquid milk distribution was regulated by the New Zealand Milk Board (MAF, 1992). However, under the Milk Act of 1988, the New Zealand Milk Authority was established for the purpose of maintaining home delivery for milk until the expiration of the Act on the 31st of March, 1993. By then, the milk industry will be totally deregulated and there will be no administrative restrictions on liquid milk processing, distribution or price (Department of Statistics, 1992; MAF, 1992). Consequently, the town milk industry is gradually being integrated into the larger manufacturing dairy industry. At present, 19 of the 20 milk processors are now (May 1993) fully or partially owned by cooperative dairy organisations (MAF, 1992).

5.2 The New Zealand Dairy Farm

The New Zealand dairy farms of today were developed from cleared native bush and forests. Domestic cows first arrived in 1815 when Reverend Samuel Marsden imported cattle to Russell from Sydney (Holmes and Wilson, 1984). Originally intended to supply milk and milk products to missionaries, it developed to a promising farming enterprise as the demand for it increased with the arrival of European settlers towards the end of 19th century (NZDB, 1980). Since then, with the highly improved pastures and cows of high genetic merit, it evolved into one of New Zealand's prime farming industry.

At present, the typical dairy farm is owner operated with 1.6 labour units (Holmes, 1992) to manage and milk a weighted average number of 171 cows (MAF June, 1992). The farmer's family provides the majority of labour on the average farm. With such a number of cows and available labour, rapid milking systems are essential. Milking machines are used nationwide, and the use of batch type milking plants (herringbone and rotary) capable of milking more than 70 cows per milker per hour are widespread (NZDB, 1980).

5.2.2 Farm Production

The average dairy farm is 68 ha with a stocking rate of 2.40, and producing milk amounting to 24,980 kg milkfat annually (MAF June, 1992). The average cow is currently producing 148 kg MF/yr (MAF June, 1992), compared to 56 kg MF/yr in the early 1900s, and 116 kg MF/yr in the 1950s (Holmes and Wilson, 1984).

Currently, for monitoring purposes, the Ministry for Agriculture and Fisheries (1992) subdivides New Zealand into eight (8) dairying regions. The North Island has five (5) regions while the remaining three regions are located in the South Island. Most of the major dairying regions are located in the North Island: Waikato/South Auckland, Bay of Plenty, Taranaki and Manawatu are geographically located for a favourable climate, and soils for pasture production. This is evidenced by higher milk productivity per cow in these regions. Compared to the northernmost part of the North Island (Northland) and the dairying regions of the South Island, these regions are almost self-sufficient in pasture feed production. With additional nutrient application from synthetic fertilizer, they can accommodate comparatively higher stocking rates and consequently higher milkfat production.

The northernmost and southernmost dairying regions of New Zealand might be considered as, comparatively, not well suited climatically for dairying. Temperate pasture grass for dairying seems to have difficulty flourishing in the almost tropical conditions of Northland. The growth of tropical grass (which is a low quality feed) as weed aggravates the situation (MfE, 1990). The consequence for this is a lower stocking rate and milkfat productivity. The relatively cold climate in Southland makes it less appropriate for pasture production. Feed is inadequate during winter and sometimes hay has to be obtained from the North Island. This situation has forced the farmers to adopt a more conservative stocking rate (MAF, 1992). Table 5.1 summarises the main production features of these farm types.

Table 5.1

Typical Dairy Farm Production Features

Farming Region	Dairy Class	Area (ha)	Cows	Stock Rate	MF/cow Kg/cow	MF/ha (Kg/ha)
North Island						
Northland	16	78	160	2.00	121	238
Waikato/South Auckland	14	65	176	2.60	153	401
Bay of Plenty	14	63	175	2.77	140	389
Taranaki	14	62	169	2.72	152	414
Manawatu/Tui	14	68	160	2.35	159	375
South Island						
West Coast/ Nelson	17	77	140	1.82	145	273
Marlborough/ Canterbury	17	100	235	2.35	156	342
Southland/Otago		77	137	1.70	161	268

Source: Various MAF Farm Monitoring Reports (1992)

5.2.3 Farm Costs and Returns

The dairy farmer's cost depends on the methods of production used, of which feeding is the crucial element. Since dairy farming is pasture based, a significant portion of production expenses are geared toward the maintenance and enhancement of pasture productivity. Equally important as pasture production is the efficiency with which the pasture is consumed and converted into milk. How this milk is extracted from the cow is also an important factor (Holmes and Wilson, 1984). The use of milking machines to do this efficiently, and the consequent energy requirements associated with it are among the important physical inputs in dairy farming. Table 5.2 summarises these main inputs in dairy farming.

Table 5.2

Other Key Inputs in a Dairy Farm

Farming Region	Electricity (TJ)	Feeds (T DM)	Fertilizer (T DM)	Weed & Pest (L)
North Island				
Northland	169.19	17.02	78.76	230
Waikato/South Auckland	196.68	60.11	81.86	230
Bay of Plenty	218.54	78.01	68.19	190
Taranaki	187.99	64.54	87.97	40
Manawatu/Tui	150.39	44.21	67.03	100
South Island				
West Coast/Nelson	122.19	28.37	41.05	140
Marlborough/Canterbury	149.08	75.65	85.00	240
Southland/Otago	178.59	36.60	59.76	60

Source: Various MAF Farm Monitoring Reports (1992)

Holmes and Wilson (1984) estimate that approximately 25-30 kg of DM feed must be eaten to produce 1 kg of milkfat on an average dairy farm. In the 1991/92 season, the weighted average price for milkfat was $5.38 per kg (MAF June,1992). Adjusting this milkfat price to the average required amount of DM feed to convert it into 1 kg milkfat, it can be estimated that feed should be well below 19c[9] per kg DM in order that production costs can be covered and a profit realized. This simple estimate indicates that only hay[10] and pasture are the most economically feasible foods for dairy cows throughout the year, although it is more profitable to use other more expensive feed in the short term under particular conditions (Holmes and Wilson, 1992).

5.2.4 The future of Dairy Farming

It is known that the New Zealand dairy farmer is a price taker. Local milkfat prices must reflect the export prices minus the cost of manufacture, transport and storage within the industry (Holmes and Wilson, 1992). Hence, the farm gate price for milkfat is very dependent upon, and susceptible to changes in overseas markets, factors over which the dairy farmer has no control. What the dairy farmer can control are the production costs and aims to further improve production efficiency.

Therefore, it can be concluded that the future of dairy farming hinges on two main conditions:

- The maintenance and enhancement of pastures.

  The ecological viability of the farming system, taking into consideration the ecosystem upon which dairy farming is a part, this is further discussed in Chapter Six.

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[9] $5.38 divided by 27.50 kg.

[10] At an estimated cost of 18c per kg DM (Brooks 1990; Holmes, 1992 personal correspondence.

- The viability and availability of export markets.

  The economic competitiveness of New Zealand's dairy production will play an important role in determining its place in the international market. This is discussed, in part, in Chapter Eight.

Chapter Six

IDENTIFICATION OF INDICATORS

One of the distinctive features of the New Zealand Dairy Industry is its pasture-based milk production. Dairy cattle usually feed on highly productive pasture averaging according to Holmes and Wilson (1984) 12 tonnes DM/hectare annually. The combination of improved grass and clover species, and a generally temperate climate, provides the New Zealand dairy farmer with an opportunity to graze stock outdoors on a year-round basis (Williams and Haynes, 1990). These features, combined with improvements in production technology and generally increased efficiency, have sustained the New Zealand dairy farming for generations (MAF, 1991).

According to the Ministry of Agriculture and Fisheries (1991), New Zealand's pastoral based farming system is considered to be sustainable in an environmental and economic sense. This assertion is not shared by everyone. Hayward (1990), for example, argues that the sustainability of New Zealand farming systems is, at best, doubtful. This is due to the fact that pastoral farming in New Zealand is heavily dependent on energy inputs from external sources. The availability of energy, aside from being finite, is also under the influence of international politics which are very unpredictable, making the supply of energy in the future uncertain.

6.1 Pastoral Farming and the Environment

New Zealand pastoral landscape and grasslands are not natural. They were developed from forests, fern, scrub and tussock (New Zealand Agricultural Statistics, 1987). As such, most of the initial fertility of the soil needed by the introduced pasture plant species came from the humus and ashes of the forest burn. However, as soil fertility declined it became more difficult to maintain the sown pasture species. This was compounded by the fact that forest regrowth was also competing for soil nutrients. The intensive grazing employed to control secondary regrowth also needed highly productive pasture. This, in turn, could be maintained only through the application of fertilizer and lime to ensure that the soil was adequately supplied with nutrients (Williams and Haynes, 1990).

Beginning in the late 19th century, New Zealand pasture lands were regularly topdressed with fertilizer (Williams and Haynes, 1990). Since then, there has been a steady increase in the amount of fertilizer applied each year as the area of grassland increased and land use intensified. Associated with the increase in fertilizer usage has been the increase in stock numbers. In recent years, however, there has been a decrease in fertilizer usage due to decreased farm income and increasing fixed costs such as interest payments on borrowed money.

Figure 6.1 demonstrates this linkage between pastoral production and nutrient inputs via the use of fertilizers. From these data it can be implied that pastoral farming operates within an open and unstable system, where without added nutrients, pasture production levels and stock numbers would fall (Williams and Haynes, 1990 p50; Gillingham et al,

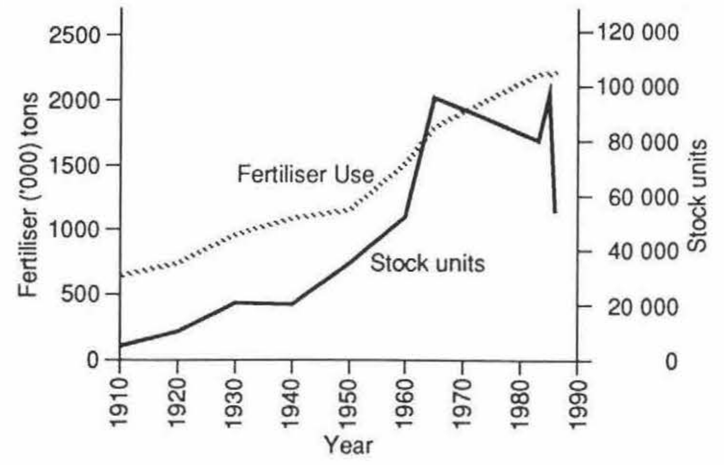

Figure 6.1 **Amount of fertilizer applied to grassland and the number of stock units in New Zealand**
Source: Williams and Haynes (1990)

1986) resulting in decreased farm outputs. Furthermore, Figure 6.1 demonstrates that pasture farming is very much dependent on the economic environment: a decline in farm income and increase in fixed costs tends to reduce farm inputs such as fertilizer.

6.1.1. Dairy Farming Inputs and the Environment

6.1.1.1. Fertilizer

More than a hundred and fifty years of pastoral farming in New Zealand have generally increased the nutrient status of the soils (Williams and Haynes, 1990). The improvement was brought about by the continuous applications of fertilizer which boosted plant growth thereby increasing soil organic matter content. Associated with this is the increase in microbial activity that enhances plant nutrient availability. Similarly, the presence of grazing animals also influences the soil nutrient status by increasing the rate at which nutrients are cycled between soil, plants and animals (Williams and Haynes, 1990).

This cycle however is not a closed system. Along the process, there are nutrient gains and losses. Gains to the system can occur from atmospheric fixation and the application of fertilizer (Williams and Haynes, 1990), while nutrient losses in the system occur through leaching, evaporation, run-off, and products and excreta of the grazing animal (Figure 6.2). The cycle through grazing animals is usually faster when compared to the dieback by pasture plants. By ingesting herbage, grazing animals encourage pasture

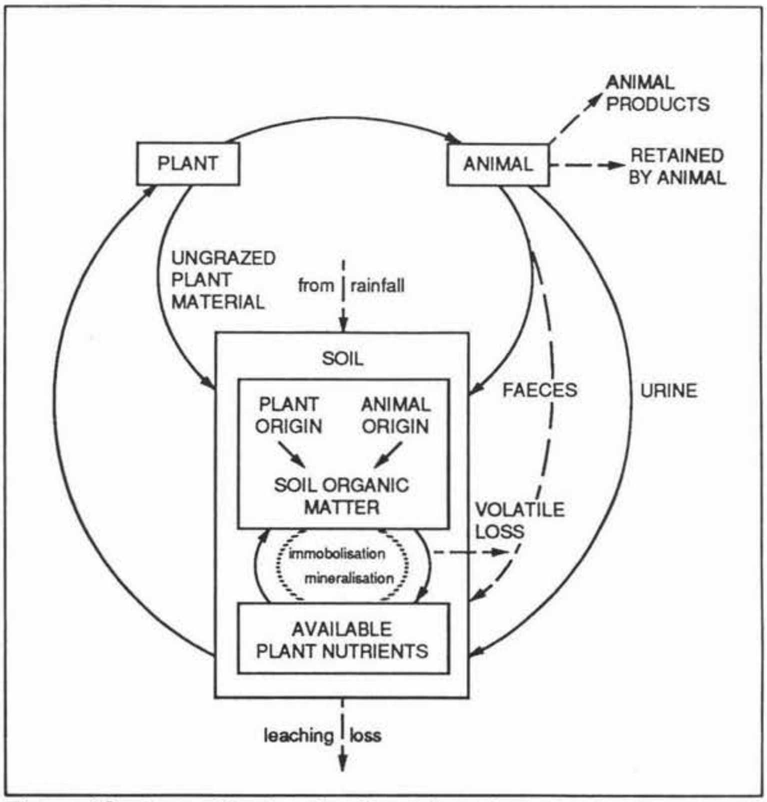

Figure 6.2 Generalised cycle of nutrients in grazed pasture
Source: Williams and Haynes (1990)

plants to grow and take-up more nutrients from the soil. The resulting animal excreta contains nutrients that are readily available for the plants. In contrast, nutrients from plant decomposition are in organic form which are not readily available for plant growth (Williams and Haynes, 1990).

The dynamics of the various nutrient cycles greatly affect the sustainability of dairy farming. According to Williams (1991) sustainability in dairy farming can only be achieved if gains and losses of nutrients balance each other.

The gain of nutrients from the atmosphere can be considered as 'free' as it is naturally acquired by pasture, while nutrient input, in the form of synthetic fertilizer, is a different story, two factors affecting its lack of sustainability: imported nature and non-renewable nature. In New Zealand dairy farming, commercial inputs are primarily potassic super and nitrogen (McChesney, 1978). As potash is not produced domestically[11], and the fact that it is a relatively 'non-renewable' resource, its continuing availability is uncertain. Aside from that, the mining, transportation and subsequent on-farm application of potash fertilizer consumes great amount of energy much of which is non-renewable fossil fuels. Similarly with the nitrogen, although it is locally available, its manufacture is from non-renewable natural gas. These two inputs alone according to McChesney (1978) account for almost 40% of dairy farm energy inputs.

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[11] Potash is imported from either USA or the former Soviet Union. While lately rock phosphate for superphosphate manufacture is from Nauru and Ocean Islands (Department of Statistics, 1990).

The grazing animal is an important contributing factor to soil nutrient loss. Loss through animal products in the form of milk, and surplus animals, is equivalent to 82 kg nitrogen (N), 13 kg potassium (K), 12 kg phosphorous (P) and 4 kg Sulphur (S) per year per hectare for a 20 stock unit (Middleton and Smith, 1978, Field and Ball, 1982 and Williams, 1988 as cited by Williams and Haynes, 1990). Through animal excreta, nutrients are redistributed throughout the farm in small areas of soil under dung and urine patches (Williams and Haynes, 1990). In most cases, however, 5% of animal excreta is concentrated around dairy sheds (Phillips, 1970), these concentrated nutrients being in excess of the plant's requirements. Wastage, therefore, occurs through seepage and leaching (Williams et al, 1989) or through run-off (Syers, 1974). Roughly following Syer's (1974) procedure, the approximate nutrient wastage from the dairy shed entering New Zealand's water system for the 1991/92 season can be estimated. From the 2.27 million dairy cattle, it can be said that 22.94 kilotonnes BOD, 0.49 kilotonnes P, 1.88 kilotonnes K and 2.95 kilotonnes N ultimately enters bodies of water. These figures would be even higher, if run-off and leaching loss from the animal excreta outside the dairy sheds (about 95% of total excreta) are included. Similarly, a study by Sharply (1977) indicates that grazing dairy cattle in swards can increase the presence of nutrient concentration in streams.

According to Wilcock (1986, p98), agricultural run-off is commonly cited as the prime contributor to water pollution in New Zealand. Various studies confirm that pastoral run-off has caused high sediment and nutrient loss resulting in widespread decline in water quality and environmental degradation. This run-off is the major source of nitrate in groundwater (McColl, 1982, White, 1982, and Quinn, 1984 as cited by Wilcock, 1986).

Similarly, Wilcock (1986) estimates that pasture is likely to have twice as much phosphorus per hectare as afforested catchment. Furthermore, given the nature of fertilizer application (topdressing) and the tendency of phosphorus fertilizer to remain in the upper 5 cm of the soil profile (Saunders, 1959 and Walker *et al*, 1959 as cited by Syers, 1974), it is more susceptible to erosion (Syers, 1974). It is, therefore, widely accepted to be one of the contributing factors to the eutrophication in several New Zealand lakes (Fish, 1969a, b. 1970, 1971 as cited by Syers, 1974).

6.1.1.2. Pesticides

The New Zealand agricultural sector is one of the major user of pesticide products. It is estimated that every dollar invested in pesticide use is equivalent to four (4) dollars in agricultural loss avoided (MacIntyre, 1989). Its use, therefore, can be justified economically. However, the continued use of pesticides in agriculture has raised other concerns, issues which are embodied in the use of pesticide: food safety, environmental contamination and public health. Some pesticides have longer residual lives and often remain in agricultural products with considerable risk to the consumers.

While the agricultural sector is a major user of pesticides as a whole, pastoral farming use is relatively minor compared to other sectors. Since the 1970 prohibition of DDT usage in pastures, most pesticides currently used in pastoral farming have short residual lives (MacIntyre, 1989; Mathews, 1974). Furthermore, there have been a recent decline in pesticide input in pastoral agriculture. During the period of 1983 - 1987, for example, sales of herbicides decline by 24% (363.80 tonnes), insecticides by 63% (18.90 tonnes) and fungicide by 40% (1.40 tonnes) on a national level (MacIntyre, 1989). These new generation pesticides often use a smaller quantity of active ingredient per hectare, are less acutely toxic to humans and leave fewer persistent residues in the environment. The trend in pesticide use in pastoral farming, therefore, is ecologically favourable.

6.1.1.3. Energy

Dairying is the most energy intensive form of agriculture in New Zealand in terms of energy input per kilogram output. According to Smith and McChesney (1979), it constitutes 30% of the overall energy required for agriculture, but is carried out on only 7% of the country's productive agricultural land. While it was mentioned above that fertilizer constitutes 40% of overall energy input, 40% of direct energy input is attributed to on-farm fuel and electricity use, while the remainder is consumed in machinery and materials production. Just under half of the petroleum fuel is used in tractors. The main energy consuming activity is the provision of supplementary feeds (hay and silage) mostly in the South Island (Smith and McChesney, 1979).

Energy therefore is a vital input in a dairy farm. Unfortunately this situation is far from stable. Significant amounts of energy consumption on a dairy farm is through imported oil and gas, which are not only finite, but are also subject to unpredictable international politics (McChesney, 1978; Smith and McChesney, 1979). This is one factor stressed by Hayward (1990) in his assessment of the sustainability of New Zealand's farming systems.

6.1.1.4. Management

Management plays a vital role in dairy farm productivity. Some of the management practices involving, fertilizer, pesticide and energy inputs, have been briefly discussed. Although these inputs play an important role in the farm productivity, stocking rate is the most significant. Stocking rate is the number of animal per unit area of grassland, irrespective of the amount of forage available (White, 1987).

Farm productivity, and hence profitability, is achieved by higher milkfat yields per hectare. Studies show that associated with higher stocking rate is the increase in milkfat yields (Holmes, 1987; Thompson, 1988). An experiment conducted on the Waemate West Demonstration Farm shows that the response of milkfat production to stocking rate is linear, from 2.5 - 4.9 cows per hectare. By increasing stocking rate by one cow per hectare, production will increase by 120 kg milkfat per hectare (Thompson, 1988). However, this increase in cow numbers per hectare has an associated decrease in production amounting to 18 kg milkfat per cow (Holmes, 1987). McMeekan and Walshe (1963, as cited by Holmes, 1987) suggested that a decrease of 11% (equivalent to 280 l) in milkfat production per cow will maximize production per hectare, but doubt if farmers can tolerate such a decrease in cow milk production. A conflict, therefore, occurs for the farmer who has to choose between production per cow and production per hectare. This leads to a dilemma in selecting the most appropriate stocking rate (Holmes, 1987).

While higher stocking rates are usually the most economic option, they may not be ecologically favourable, for associated with higher stocking rates are higher inputs, thus an added pressure on the environment. Furthermore, higher stocking rates tend to increase soil compaction in the sward affecting the condition of the pasture, which leads to excessive grazing pressure often resulting in instability of pasture community, and, sometimes, 'collapse' (White, 1987).

Grazing animals are also affected by the increase in their number. This will mean a comparatively lower food intake leading to a decrease in livewieght. Often undernutrition and the associated onset of diseases results in an increased mortality rate in the herd (White, 1987).

Some farmers seek to maximize the utility or satisfaction of their income, not their expected net profit (White, 1987). Thus risk averters will use lower stocking rates and accept lower profits for the sake of income stability and a feeling of security. White (1987) suggests that this may not be economic, stressing the fact that when the stocking rate is too low, the farmer may be unable to increase cash reserves sufficiently in a good season to survive the poor season. The choice of stocking rate on predominantly economic grounds should, therefore, involve a compromise between profit maximization and financial security (White, 1987).

Stocking rates interacts with many of the physical, biological and economic components of a farming system (White, 1987). In determining a sustainable management regime for dairy farming, the issue of stocking rate is critical and, therefore, there will be a need to balance trade-offs between these factors.

6.2 Dairy Farming and the Economic and Social Environment

6.2.1 Market

One of the basic strengths and potential problems of New Zealand dairy farming is its export-based market orientation. As such, it is readily affected by changes in world markets and international trade agreements (NZDB, 1992; Chadee and Guthrie, 1991). Overseas dairy markets are often volatile, subject to rapid change in consumer preferences, and subject to policy interference.

The ability of the New Zealand dairy industry to adapt to these rapidly changing markets is, therefore, important in maintaining long term sustainable growth, from an economic perspective. A highly diversified product range and the capability to sell into markets should enhance its adaptability and hence its sustainability in economic terms.

6.2.2 Labour on Dairy Farms

The dairy farm conversion of pasture to milk requires physical, financial and human resources. The efficient utilisation of all these resources is, therefore, important for farm overall efficiency (Holmes and Thomson, 1990).

Although the number of people working on the farms (both paid and unpaid) has not changed since the 1960s, its overall efficiency has significantly increased in a number of indicators (see Table 6.1). The increase in labour productivity can be attributed to several factors. According to Holmes and Thomson (1990), these are due to changes in shed design (from walkthrough to herringbone to rotary), changes in work routine used during milking (eg, in 1980 no legroping, no stripping, little teat washing and stimulation), and the increase in the sets of cups handled per person in the shed.

Table 6.1

Number of Cows per Herd, Total Labour per Farm,

Cows Milked per Person and Milkfat Produced per Person

Years	1930-35	1960-65	1970-75	1980-85	1985-88
Number of cows per herd	40	65	106	137	151
Total number of people working per farm (approx.)	1.8	1.6	1.6	1.6	1.6
Cows per labour unit (cows/person) (approx.)	22	41	66	86	94
Milkfat produced per labour unit (kg/person) (approx.)	2400	5300	8500	13200	14700

Source: Holmes and Thomson (1990)

However, one of the most important factors to this efficiency, aside from improved overall farm management, is the shift from human energy (labour) to mechanical and electrical energy (mechanised milking and fertilizer application) in dairy farming. It seems that labour efficiency is attributed to increased energy (mechanical and electrical) demand for most farm activities. Manual labour in milking was replaced by automated pumps while fertilizer application is becoming increasingly mechanised. In other words, behind this labour efficiency is the increased reliance on other energy forms. This relationship is shown in Figure 6.3.

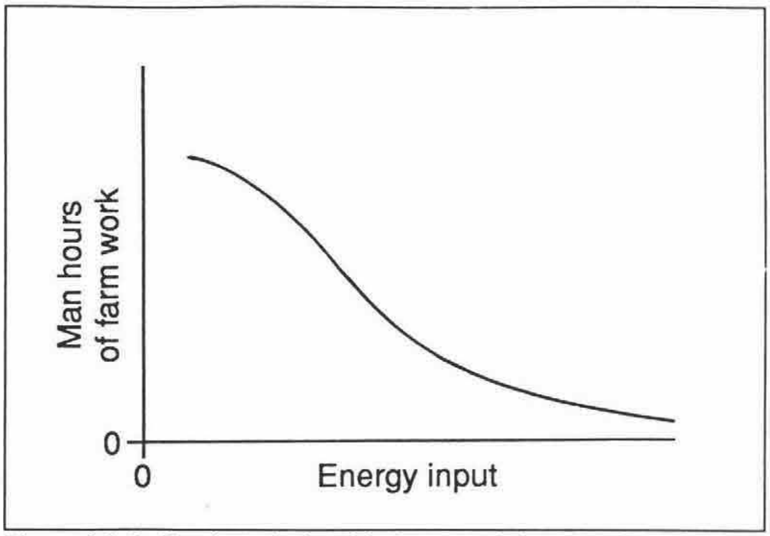

Figure 6.3 **Indicative relationship between labour, and mechanical & electrical energy requirements in dairy farms**
Based from Stienhart and Stienhart (1974)

It must be noted that sustainability in agriculture is a trade-off between three factors: social, economic and ecological considerations. Although this improvement in labour productivity is economically desirable, it may not be so desirable in ecological and social terms. Non-renewable energy inputs are often substituted for manual labour. This leads to adverse ecological effects both in terms of depleting finite stocks of energy resources, as well as leading to the release of CO_2 from their combustion. Furthermore, mechanised farming tends to favour big farmers, (Allen and Van Dusen, 1988). Mechanised and energy intensive farming is cost effective to big farmers but not so to smaller farms. The competitiveness of dairy farming, then, tends to favour those who can afford this expensive equipment. The consequences of this can be the displacement of small farmers. Manifestations of this are the increased herd size and the increase in farm size during the last decades (refer to Table 6.1).

6.3 Proposed Indicators

The above discussion pointed to the advantages and disadvantages of various farm inputs in relation to production and the environment. Progress towards sustainable dairy farming will only be made when the implications of these practices are viewed and examined as part of a bigger system. As has been emphasised, the nutrient cycle, the energy dependency and productivity will play an important part in indicating the sustainability of dairy farm.

Nutrient cycles in dairy farms tend to be open. Not only do dairy farms rely on external sources to replenish loss and maintain pasture productivity, but the loss is deposited in areas that causes harm to the integrity of the environment (eutrophication, groundwater pollution, etc.). Therefore, to achieve sustainability the dependency on external nutrient sources must be reduced, resulting in a corresponding mitigation of environmental impacts caused by loss of nutrients to the environment.

While energy demand in dairy farming cannot be avoided, progress towards sustainability can be achieved in two ways. Firstly, energy conservation and efficiency can be practised; secondly, a shift to the use of renewable energy sources. Both these measures are designed to reduce the dependency on depleting energy sources.

Productivity in the long term is a good indicator of sustainability. This can only be achieved if the three elements of sustainable agricultural systems, as elaborated in section 3.2.1, are met. Sustainable farm management, therefore, will play an important role in attaining this.

Below are some proposed equations that are likely to indicate the sustainability of a dairy farm.

6.3.1 Fertilizer Productivity

Fertilizer productivity can be expressed by the following ratio:

$$P_f = \frac{\left(\frac{MF_c}{F_c}\right)}{\left(\frac{MF_b}{F_b}\right)}$$

where:

P_f = fertilizer productivity trend ratio

F_b = total amount of fertilizer used in the base year (kg)

MF_b = total amount of milkfat production in the base year (kg)

F_c = total amount of fertilizer used in the current year (kg)

MF_c = total amount of milkfat production in the current year (kg).

A decreasing trend in the ratio (a value less than 1), measures a decrease in the efficiency of fertilizer application in producing milkfat, pointing to a possible sign of an ecological or management problem. Oppositely, an increasing trend in the ratio (a value greater than 1), will show that productivity is responding to fertilizer application.

6.3.2 Energy Productivity

Following the same rationale with the fertilizer used on a dairy farm, the following formula could express the relative energy productivity in milk production:

$$P_e = \frac{\left(\frac{MF_c}{E_c}\right)}{\left(\frac{MF_b}{E_b}\right)}$$

where:

P_e = energy productivity ratio

E_b = amount of energy used in the base year

MF_b = total milkfat production in the base year

E_c = amount of energy used in the current year

MF_c = total milkfat production in the current year.

Energy productivity ratio is a significant indicator of sustainable development. A value less than one means that there is more energy consumption per unit of product than the previous year. Whereas, a value more than 1 will indicate that a higher productivity was achieved per unit of energy consumed.

6.3.3 Nutrient Recycling Trend

The complete elimination of synthetic fertilizer in dairy farming will not be realized in the near future. An indicator reflecting the move to renewable fertilizer means that certain practises are moving towards sustainability. This trend can be illustrated by the following formula:

$$S_f = \frac{F_o}{(F_c + F_o)} * 100\%$$

where:

S_f = % towards the use of organic fertilizer

F_c = weight of commercial/synthetic fertilizer

F_o = equivalent weight of organic fertilizer.

The Dairy Exporter (May 1991), states that the synthetic fertilizer equivalent of effluent from a 100 cows spread on a 10 hectare farm are:

Volume	N (kg/ha)	P (kg/ha)	K (kg/ha)
117,000 litres	23	5	35

There are two of problems with data requirements. Firstly, currently published dairy farm performance indicators do not include the volume of effluent sprayed back to the farms. However, there is a high possibility that farmers who are employing this practise have records of volumes recycled to the pasture. Secondly, effluent concentrations are not uniform for every farm. There is a potential, therefore, that the data presented above will not be applicable to all situations.

6.3.4 Renewable Energy Use Trend

The use of renewable energy will lessen the reliance on rapidly depleting non-renewable energy sources, as well as lessening the detrimental environmental effects of using non-renewable energy resources (eg, CO_2 emissions). Therefore, the following ratio could be used to express the move towards the use of renewable energy in dairy farming:

$$S_e = \frac{E_r}{(E_n + E_r)} * 100\%$$

where:

S_e = % in the shift towards the use of renewable energy resources

E_n = amount of non-renewable energy used on a dairy farm

E_r = amount of renewable energy used on a dairy farm.

Most non-renewable energy consumption in dairy farming is through tractors and farm bikes or those machines that use liquid fuels (McChesney, 1978).

6.3.5 Stocking Rate

Stocking rate is a pressure indicator of the pasture and the grazing animals themselves (Section 6.1.1.4). For a sustainable grazing pressure, stocking rate should not exceed the biological carrying capacity of the pasture, - that is, the number of grazing animals a pasture can sustain at least pasture production (White, 1987). Unlike the other proposed indicators, stocking rate data are readily available in farm performance indicators. This is expressed in the following ratio:

$$SR=\frac{N_c}{A_f}$$

where:

SR = stocking rate

N_c = number of cows

A_f = area of the farm in hectares.

The literature is not very explicit in the determination of stocking rates. Various MAF Monitoring Reports indicate this farm feature as either stocking rate or stocking unit. Furthermore, this is sometimes designated as effective stocking rate - the number of *milking cows* per a hectare of farm. However, in this thesis, cow numbers will mean *all* cows on a particular farm, regardless of whether the cow is milking, dry or a replacement heifer.

6.3.6 Land Productivity

Land productivity can be expressed by the following ratio:

$$P_L = \frac{MF}{A_f}$$

where:

P_L = land productivity

MF = total milkfat production in kgs

A_f = area of the farm in hectares.

Productivity of the whole farm is perhaps the best indicator of sustainability, for not only will productivity signify the profitability of the farm, but it seems to indicate the integrity of the whole system. However, careful attention should be made to this particular indicator. There might be instances where productivity is high at the expense of other farm inputs. This will mean that productivity is achieved through the intensive use of commercial fertilizer or imported energy or with very high stocking rate. This will show a productivity with values in either or both P_f and P_e less than one, and this kind of productivity will not be sustainable in the long-term. True sustainable farming will be an increase or a steady productivity with values more than one for indicators P_e and P_f.

6.3.7 Labour Trend

The growing automation of dairy farm activities is, to some extent, not desirable in ecological and economic terms, as discussed in section 6.2.2. The following ratio can indicate this trend:

$$T_l = \frac{N_{lu}}{N_{alu}}$$

where:

T_l = trend in labour requirements in dairy farms

N_{lu} = number of labour units per dairy farm (those who undertake physical work and mental work of management, paid and unpaid as specified by Holmes and Thomson, 1990).

N_{alu} = current average number of labour units per dairy farm equivalent to 1.6.

This indicator will reflect the social aspect of agricultural sustainability. A value less than 1 will indicate an approach to further automation of farm activities which is, arguably, socially and ecologically undesirable.

6.3.8 Farm Size and Number

Similarly, data showing the trend in the size and number of dairy farms in a certain area, over a given period of consecutive years, could indicate its social sustainability. An increasing farm size and a decreasing number of farms might indicate amalgamation which in turn might mean displacements of small farmers. Although this might show economic efficiency (economies of scale), it is apparently attained to the detriment of small farmers.

6.3.9 Economic Viability

One of the most obvious requirement for sustainable dairy farming is its economic viability. This can be indicatively expressed in the following ratio:

$$V_e = \frac{Income}{Expenditure}$$

where:

V_e = economic viability

Income = gross sales by the farmer (eg, milkfat sales, calves, etc.)

Expenditure = gross expenditure by the farmer (from farm expenses to tax and debt servicing).

This indicator expresses only the ratio of farm sales to the expenses incurred in farming operations. A value of more than one signifies relative viability of returns compared to expenses. However, it does not indicate the viability in terms of *internal rate of return* which is commonly used in economics.

6.4 Preliminary Indicator Evaluation

Table 6.2 presents the suggested indicators compared to the characteristics of an ideal indicator (section 3.2.2). Examined against the characteristics of an ideal indicator, they seem to fulfil these criteria. Fertilizer Productivity Trend, Energy Productivity Trend

Table 6.2

Comparison of the Suggested Indicators and the Required Characteristics of an Indicator

Characteristics of an Indicator	Fertilizer Productivity (P_f)	Energy Productivity (P_e)	Nutrient Recycling Trend (S_f)	Renewable Energy Use Trend (S_e)	Stocking Rate (SR)	Land Productivity (P_L)	Farm Trend (T_l)	Farm Size and Number	Economic Viability (V_e)
Presented in attractive format	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Representative of chosen system	No	No	No	No	No	Yes partly	No	No	Yes partly
Must have a scientific basis	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Must be quantifiable	Yes	Yes	Yes but current data is inadequate	Yes but needs more information	Yes	Yes	Yes	Yes	Yes
Include reference or threshold values	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Provide information without bias	Bias to fertilizer	Bias to energy use	Bias to fertilizer	Bias to energy use	Bias to cow number	Bias to farm output	Bias to labour	Bias to farms	Bias to economics

continuation to Table 6.2

Represent reversible and manageable processes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Should have predictive meaning	Yes, lower productivity means inefficient fertilizer use	Yes, lower productivity means energy intensification	Yes, percentage shown will mean the amount of renewable fertilizer used	Yes, percentage shown will mean the amount of renewable energy used	Yes, higher stocking rate means more pressure on the environment leading to instability of pasture community	Yes, productivity means efficiency	No	Yes continued increase in farm size and decrease in farm number means more amalgamation	Yes, viability means more competitive

to Economic Viability are expected to appeal to policy and decision makers.

However, as the table indicates, and Braat (1991) stresses, all properties of indicators can not be found in a single indicator. There might even be instances wherein these properties will contradict with each other.

The limitations of productivity indicators (*Fertilizer* and *Energy Productivity*) are very obvious. Each of them can only represent a part of the dairy farming system. Fertilizer productivity only represents the comparative efficiency of fertilizer and viability of the farming system as long as fertilizer use is concerned, while energy productivity only represents the energy efficiency of the farming system compared to the base year. It does not specify what source of energy the farm is using. Integrating such information into a single indicator might create a problem, for it might confuse the users, rather than help them.

The indicator *Renewable Energy Use Trend* (S_e) answers the question on the source of energy. It explicitly indicates to what percentage (%) such energy use is composed of - whether it is renewable or not. Current data can be obtained from MAF. While the Department of Statistics, however, does not provide this information, it is assumed that information regarding this can be easily secured.

The same limitations are attributed to the *Renewable Fertilizer Use Trend* (S_f). Nutrient recycling on dairy farms is not officially published, and if there is any, it is often fragmentary. Also, nutrient concentration in dairy shed effluent may not be the same for all farms with a recycling programme. There is a great possibility that the data on nutrient contents in section 6.3.3 may not hold for other farms, creating a problem for accurate measurement of this trend. It is also important to recognise that there can be no instance whereby a dairy farm can be viable on pure nutrient recycling alone, unless this can be 'imported' from other sources (eg, from other farms). The fact that dairy farming is an open system when it comes to the nutrient cycle, it is imperative that additional nutrients are needed from outside sources if it is to become ecologically viable. However, information like this can indicate how and to what extent a certain dairy farming system is dependent on non-renewable or renewable nutrient sources. For this particular indicator, it expresses the supply of renewable fertilizer use as a percentage (%) of the total nutrient input of the farm.

Stocking Rate does not at first, appear to indicate the state of sustainability for a given dairy system. But, literature on this provides much insight on how it affects the economic and ecological viability of the farm (see section 6.1.1.4). The only set back of this type of indicator is that there is no ideal reference for comparison. Comparing it as a ratio to the base year stocking rate might only add confusion to the policy and decision maker. This will contradict the name of the indicator itself. A current stocking rate of 3.20 cows per hectare, for example, as a ratio to a base year 2.70 will appear to be 1.19 stocking rate, which is not equivalent to 1.19 cows per hectare. However, this can be improved by expressing it as a difference. This time it will be 0.50 stocking rate. But this is still not very clear to policy and decision makers. One appropriate way to designate this is to rename the indicator as *differential stocking rate*. This will be the difference between a stocking rate of the year being measured and the base year. In the meantime, however, stocking rate will be used.

Land productivity seems to be qualifying in all the properties of an ideal indicator. However, this only represents the productivity of the farm in its pure sense. Productivity might be achieved at the expense of other farming inputs (see sections 6.3.6 and 8.4 to 8.5). Also, in the present format, it is presented without reference or threshold values, although this can easily be incorporated by expressing it as a ratio with the farm productivity of the base year.

Perhaps one of the most attractive formats as far as the decision makers are concerned, is *Labour Trend.* As unemployment is one of the New Zealand government's prime problems, this indicator will appeal most to policy and decision makers, especially politicians. Although the difficulty with this indicator is that it is not representative of the system, it does not have a scientific basis and is obviously very biased towards labour on dairy farms, but scoring well against the last two properties of the indicator (see section 6.3.7).

The indicator *Farm Size and Number* suffers the same limitations as that of *Labour Trend*, although it may not be as attractive to politicians. How it scores well against the last two indicator properties is explained in section 6.3.8.

The farm *Economic Viability* indicator fares well against the properties of an ideal indicator. The only limitations against this is that it is too biased to the economic perspective of the farm.

Chapter Seven

ENVIRONMENTAL ACCOUNTING MODEL DEVELOPMENT

As emphasised in section 2.7, one of the best ways to analyze interactions between dairy farming and the factors that influence its sustainability is through the development of an environmental accounting model. This model, basically the Isard type, is developed to account for economic and ecologic commodities. As illustrated in Figure 7.1, it is composed of four quadrants.

Table 7.1

Input-Output Model for

Dairy Farming and the New Zealand Economy

	Dairy Farming	NZ Economy
Economic Commodities	I	II
Ecologic Commodities	III	IV

Quadrant I describes the economic inputs and outputs of representative model farms from throughout the country; Quadrant II describes the interindustry transaction structure of the New Zealand economy with the specific addition of dairy farming as a sub-sector of agriculture; Quadrant III describes the ecologic inputs and outputs of dairy farming, while Quadrant IV describes a selected number of ecological inputs and outputs of sectors of the New Zealand economy including energy inputs and pollution emissions from energy use. It is recognised that, ideally, a wider range of such ecological inputs and outputs should be included in quadrant IV, but this is not possible due to the deficiencies of available data.

7.1 Quadrant I: Economic Commodities and Dairy Farming

Quadrant I represents the cash working budgets for the eight dairy farm models throughout the country. It was obtained from Farm Monitoring Reports covering the 1991/92 season. It must be noted that monetary figures are in million $, while the physical equivalent of some items is adequately provided for immediately under such items (Table 7.2). As an example, the Northland dairy farm model milkfat sales are in million $ and thousand tonnes expressed as 156.65 and 31.28, respectively. Items in each model represent the total sum for all farms under that model. Thus, the M$156.65 milkfat value is the sum total for 1,685 farms in the northland region. Most of the physical equivalents of the monetary data are estimated from *Farm Monitoring Reports* and *Financial Budget Manuals*. Appendix 1(A) shows the conversion factors from financial to physical items.

Isard's Model sign convention is followed throughout the whole input/output model. Positive (+) sign denotes output while negative (-) denotes input. Validation of the data was done by comparing the total for all these models to the product of the total number

Table 7.2

Quadrant I: Economic Commodities in Dairy Farming

(1991/92 Season)

Activity	1	1	1	1	1	1	1	1	
ECONOMIC COMMODITIES	Northland Model	South Auckland/ Waikato Model	Bay of Plenty Model	Taranaki Model	Manawatu/ Tui Model	West Coast/ Nelson Model	Marlborough/ Canterbury Model	Southland/ Otago Model	NET INPUT/OUTPUT
Milkfat ($ million)	156.65	818.73	140.89	343.27	170.65	47.93	66.37	19.79	1764.28
(1000 tonnes)	31.28	148.57	29.73	64.94	30.32	9.40	13.47	3.75	331.46
Dairy Cattle Sales ($ million)	29.99	177.84	26.26	58.61	27.58	9.19	16.24	4.07	349.78
(1000 cows)	43.94	497.45	73.46	78.15	31.52	11.48	21.65	4.79	762.44
Others ($ million)	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.95
Cattle Purchases ($ million)	-1.35	-7.98	-0.97	-3.79	-0.95	-0.20	-0.23	-0.15	-15.62
(1000 cows)	-1.98	-11.69	-1.42	-6.23	-1.56	-0.25	-0.31	-0.17	-23.61
Electricity ($ million)	-6.07	-23.85	-5.64	-10.11	-3.80	-1.16	-1.21	-0.69	-52.53
(TeraJoules)	-214.59	-843.87	-199.53	-357.58	-134.60	-41.11	-42.86	-24.47	-1858.61
Feeds ($ million)	-6.07	-72.47	-20.01	-34.49	-11.12	-2.68	-6.11	-1.41	-154.36
(1000 Tonnes Dry Mater)	-28.68	-342.65	-94.63	-64.54	-52.56	-12.68	-28.90	-6.66	-631.30
Fertilizer ($ million)	-25.61	-90.05	-15.96	-42.91	-15.38	-6.72	-6.56	-2.08	-205.27
(1000 tonnes)	-132.70	-466.60	-82.71	-222.31	-79.69	-18.35	-32.47	-10.88	-1045.71
Seeds ($ million)	-2.02	-6.84	-1.21	-0.51	-0.59	-0.31	-0.48	-0.05	-12.01
(1000 tonnes)	-0.39	-1.33	-0.24	-0.10	-0.12	-0.06	-0.09	-0.01	-2.34
Weed and Pest ($ million)	-2.19	-7.41	-1.82	-1.01	-1.19	-0.49	-0.65	-0.15	-14.91
(1000 litres)	-0.39	-1.33	-0.24	-0.10	-0.12	-0.06	-0.09	-0.01	-2.34
Animal Health ($ million)	-7.75	-38.19	-5.46	-10.36	-4.40	-1.34	-2.42	-0.70	-70.62
Breeding ($ million)	-4.72	-19.72	-5.58	-8.34	-3.92	-1.56	-1.43	-0.29	-45.56
Dairy Shed Expenses ($ million)	-4.08	-14.25	-2.43	-4.67	-2.38	-0.76	-1.56	-0.40	-30.53
Freight ($ million)	-1.35	-4.56	-1.33	-2.02	-0.80	-0.54	-0.29	-0.14	-11.03
Administration ($ million)	-14.98	-63.38	-11.52	-23.00	-12.60	-3.75	-2.33	-1.22	-132.78
Repair & Maintainance ($ million)	-11.80	-53.01	-5.46	-25.27	-11.30	-2.37	-3.82	-1.46	-114.49
Vehicles ($ million)	-12.64	-56.43	-12.13	-15.16	-8.92	-3.13	-3.63	-1.55	-113.59
Others ($ million)	-0.84	-6.84	0.00	0.00	-2.38	-0.45	-1.53	-0.09	-12.13
Wages ($ million)	-3.45	-23.60	-5.46	-1.26	-5.35	-3.13	-5.73	-0.25	-48.23
Personal Drawings ($ million)	-29.49	-136.80	-25.47	-57.87	-26.16	-7.82	-7.45	-4.19	-295.25
Tax ($ million)	-15.46	-88.58	-10.69	-38.26	-22.78	-5.87	-10.11	-2.51	-194.26
Debt Servicing ($ million)	-37.51	-170.85	-35.71	-80.52	-24.87	-9.04	-13.83	-5.71	-378.04
Capital Purchases ($ million)	0	-28.50	0.00	-25.27	-11.89	-0.89	-4.78	-1.09	-72.42

of farms for the whole country and the Dairy All Classes Cash Working Budget from *Farm Monitoring Report, 1992.*

7.2 Quadrant II: Economic Commodities and the New Zealand Economy

Interindustry transactions in the New Zealand economy are in the second quadrant (Table 7.3). Unavailability of the latest data required the conversion of the 1986/87 interindustry transactions to 1991/92. To derive an estimated 1991/92 interindustry transactions matrix, the 1986/87 dollars were converted into equivalent 1991/92 dollars using an appropriate inflation factor obtained from the *Monthly Abstract of Statistics/Key Statistics*. Then, using the ratio for GDP (Gross Domestic Product) contribution for each sector for the year 1986/87 and 1991/92, the interindustry transactions matrix was adjusted to account for changes in output of each sector. Appendix 1(B) shows an example for this conversion.

An additional column in the 25-sector interindustry transaction matrix was made in order to include accounts for dairy farming. Entries for *Dairy Farming* column were simply transferred from the *Net Input/Output* column in quadrant I. *Other Farming Activities* are simply the difference between *Agriculture* and *Dairy Farming*. Total input/output for this quadrant is the sum total for all economic sectors excluding *Agriculture*. Thus, for example, in the *Agriculture* row, the figure amounting to M$ 2653.25 is the net input/output from the columns: *Dairy Farming*, *Other Agricultural Activities*, *Fishing and Hunting* . . . to *Household Domestic Activities Sector.* This is, therefore, the horizontal summation of inputs and outputs from other economic sectors to *Agriculture.*

Table 7.3

Quadrant II:Economic Commodities and the New Zealand Economy

(in 1991/92 $ million)

Activity	1	*	*	1	1		1	1	1		
SECTOR	Agriculture	Dairy Farming	Other Agricultural Activities	Fishing & Hunting	Forestry & Logging	....	Local Government Services	Private Non-profit Services	Household Domestic Services	NET INPUT/OUTPUT	Final Domestic Demand
1 Agriculture	7946.79	-280.84	8225.73	-1.80	-30.01	....	-2.58	-18.94	0.00	2653.25	256.52
1a Dairy Farming	0.00	2098.44	0.00	0.00	0.00	....	0.00	0.00	0.00	2098.44	1.39
2 Fishing & Hunting	-24.27	0.00	-24.27	691.72	0.00	....	0.00	-1.35	0.00	309.61	6.93
3 Forestry & Logging	-2.86	0.00	-2.86	0.00	2180.32	....	-1.29	0.00	0.00	1727.57	0.00
4 Mining & Quarrying	-9.99	0.00	-9.99	0.00	-5.30	....	-173.11	0.00	0.00	462.49	19.41
5 Food, Beverage & Tobacco	-112.79	-77.18	-189.97	-7.19	-7.06	....	-11.63	-97.39	0.00	9554.68	4193.03
6 Textiles, Apparel & Leather	-29.98	0.00	-29.98	-14.37	0.00	....	-6.46	-20.29	0.00	1709.46	1263.18
7 Wood & Wood Products	-27.13	0.00	-27.13	0.00	-5.30	....	-2.58	-2.71	0.00	989.98	414.59
8 Paper, Products & Printing	-65.68	0.00	-65.68	-1.80	-1.77	....	-28.42	-40.58	0.00	708.73	557.41
9 Chemicals, Petrol, Rubber, etc	-756.70	-220.18	-536.52	-14.37	-54.73	....	-43.92	-35.17	0.00	139.20	1321.42
10 Non-metallic Mineral Products	-8.57	0.00	-8.57	0.00	0.00	....	0.00	-1.35	0.00	-164.58	44.37
11 Basic Metals	0.00	0.00	0.00	0.00	0.00	....	0.00	0.00	0.00	1350.22	12.48
12 Fabricated Metal Products	-137.06	0.00	-137.06	-53.90	-49.43	....	-34.88	-10.82	0.00	922.52	1602.89
13 Other Manufacturing	-1.43	0.00	-1.43	0.00	0.00	....	-1.29	-5.41	0.00	153.87	91.51
14 Electricity, Gas & Water	-135.64	-52.53	-83.11	0.00	-1.77	....	-59.43	-33.82	0.00	1062.11	985.86
15 Construction	-359.79	0.00	-359.79	-5.39	-12.36	....	-539.99	-73.05	0.00	3125.08	74.88
16 Trade, Restaurants & Hotels	-478.29	-12.01	-466.28	-23.36	-30.01	....	-58.13	-102.81	0.00	13231.73	10786.24
17 Transport & Storage	-252.71	-124.62	-128.09	-206.62	-79.45	....	-31.00	-37.88	0.00	2994.49	736.28
18 Communication	-47.12	0.00	-47.12	-1.80	-1.77	....	-31.00	-39.23	0.00	1967.90	547.70
19 Finance, Insurance, etc	-559.67	-132.78	-426.89	-41.32	-42.37	....	-173.11	-148.80	0.00	4643.37	3369.40
20 Owner-occupied Dwellings	0.00	0.00	0.00	0.00	0.00	....	0.00	0.00	0.00	0.00	5306.46
21 Community, Social Services, etc	-266.99	-70.62	-196.37	-5.39	-12.36	....	-45.21	-78.46	0.00	3199.81	3387.43
22 Central Government Services	-27.13	0.00	-27.13	0.00	-1.77	....	-3.88	-8.12	0.00	9734.31	11073.27
23 Local Government Services	-5.71	0.00	-5.71	-1.80	-5.30	....	1880.94	-4.06	0.00	1435.07	1534.95
24 Private Non-profit Services	-17.13	0.00	-17.13	0.00	0.00	....	-6.46	1573.19	0.00	1291.85	1281.20
25 Household Domestic Services	0.00	0.00	0.00	0.00	0.00	....	0.00	0.00	0.00	0.00	48.53
Compensation of Employees	-930.89	-48.23	-882.41	-66.48	-287.77	....	-706.64	-661.47	-47.34	-36305.23	0.00
Operating Surplus	-2709.85	-673.29	-2036.56	-145.53	-683.23	....	0.00	0.00	0.00	-21615.69	0.00
Commodity & Non-com. Indirect Taxes	-376.92	-194.26	-182.66	-44.92	-38.84	....	-51.67	-64.93	0.00	-4083.03	0.00
Commodity Subsidies	-8.57	0.00	-8.57	0.00	0.00	....	0.00	0.00	0.00	-8.57	2943.72
Non-commodity Subsidies	45.69	0.00	45.69	0.00	12.36	....	0.00	0.00	0.00	434.27	0.00
Consumption of Fixed Capital	-642.48	-72.42	-570.06	-46.71	-44.14	....	-16.79	-82.51	0.00	-6175.97	0.00
Second Hand Asset	-7.14	0.00	-7.14	-7.19	-1.77	....	-6.46	-4.06	0.00	-608.39	0.00
Import Duty	-7.14	0.00	-7.14	0.00	0.00	....	-1.29	-1.35	0.00	-376.38	0.00
Contribution to GDP	*	988.20	3648.85	310.83	1043.39	....	782.85	814.32	47.34	68830.37	452.03
Total GDP		68739.24									
Balance of Trade		13144.36									

Net Exports, entered under the column *Balance of Trade*, is the difference between the total input/output and total domestic demand of each sector. The final domestic demand was adjusted from 1987 to 1992 using the same inflation adjustment indices. Final demand was updated using the national population ratio of 1992 and 1987.

7.3 Quadrant III: Ecological Commodities and Dairy Farming

Quadrant III describes the inputs and outputs for the Dairy Farming Sector. Most of these ecological commodities are directly related to dairy cattle inputs and outputs, oxygen inhaled, excreta, and nutrient outputs phosphorus, potassium and nitrogen were estimated from dairy cow excreta. Similarly, the carbon dioxide (CO_2) and methane (CH_4) "emissions" are results calculated from cow exhalations and expelations. While it is understood that farm fertilizers are not totally absorbed by pasture grasses, it is difficult to accurately assess these quantities and record them in the model. Similarly, the amount of pesticide lost to the environment is difficult to quantitatively assess.

7.4 Quadrant IV: Selected Ecological Commodities and the New Zealand Economy

Quadrant IV is the ecological counterpart of the New Zealand interindustry transactions (Table 7.5). In this selective example, only energy requirements (in terajoules) needed to run the economy and energy-related atmospheric emissions are taken into account. Although energy is only approximately 5.15% of the overall farm expenses, it is an essential and ubiquitous constituent. A reduction in the supply of energy inputs will significantly affect dairy farm production and efficiency levels. Although energy requirements for New Zealand agriculture is only partially dependent on foreign sources,

Table 7.4

Quadrant III: Ecologic Commodities in Dairy Farming

(1991/92 Season)

ECOLOGIC COMMODITIES	Northland Model	South Auckland/ Waikato Mode	Bay of Plenty Model	Taranaki Model	Manawatu/ Tui Model	West Coast/ Nelson Model	Marlborough/ Canterbury Model	Southland/ Otago Model	NET INPUT/OUTPUT
Activity	1	1	1	1	1	1	1	1	
Wastes (Kilotonnes of BOD)	124.90	466.75	98.28	249.25	110.08	37.53	53.20	14.73	1154.72
Phosphorus (Kilotonnes)	2.68	10.00	2.11	5.34	2.36	0.80	1.14	0.32	24.75
Potassium (Kilotonnes)	10.26	38.34	8.07	20.47	9.04	3.08	4.37	1.21	94.84
Nitrogen (Kilotonnes)	16.06	60.01	12.64	32.05	14.15	4.83	6.84	1.89	148.47
CO2 Exhaled (Gegalitres)	446.06	1666.96	351.00	890.16	393.15	134.04	189.99	52.59	4123.95
CH4 Emission (Gegalitres)	247.81	926.09	195.00	494.53	218.42	74.46	105.55	29.22	2291.08
Land (1000 has)	-131.43	-370.50	-76.42	-156.67	-80.85	-34.42	-38.20	-14.01	-902.50
Cows to Calve (1000 cows)	-269.60	-1003.20	-212.28	-427.06	-190.24	-62.58	-89.77	-19.11	-2273.84
Other Cattle (1000 cows)	0.00	0.00	0.00	-108.66	-47.56	-18.77	-25.59	-12.74	-213.32
Land Production (MT Dry Mater)	-1.58	-4.45	-0.92	-1.88	-0.97	-0.41	-0.46	-0.17	-10.84
Cow Dry Mater Intake (KiloTonnes)	-1.48	-5.54	-1.17	-2.76	-1.22	-0.41	-0.59	-0.15	-13.32
Oxygen Inhaled (Megalitres)	-446.06	-1666.96	-351.00	-890.16	-393.15	-134.04	-189.99	-52.59	-4123.95

Table 7.5

Quadrant IV: Selected Ecological Commodities and the New Zealand Economy

(Year 1991/92)

Activity	1	*	1	1	1		1	1	1	
SECTOR	Agriculture	Dairy Farming	Other Agricultural Activities	Fishing & Hunting	Forestry & Logging	......	Local Government Services	Private Non-profit Services	Household Domestic Services	NET INPUT/OUTPUT
DIRECT ENERGY INPUTS (TeraJoules)										
Electricity	-2145.63	-1858.61	-287.02	-26.47	0.00	......	0.00	0.00	-33806.54	-99795.39
Fuel Oil	0.00	0.00	0.00	0.00	0.00	......	0.00	0.00	-298.94	-13546.82
Diesel	-6743.14	-2153.66	-4589.48	-3722.15	-856.26	......	0.00	0.00	0.00	-61458.71
Petrol	-10261.25	-2931.38	-7329.87	0.00	-383.06	......	0.00	0.00	-35166.01	-77174.02
Aviation Fuel	-221.92	-179.47	-42.45	-2.65	0.00	......	0.00	0.00	-7.97	-18752.43
Natural Gas/CNG	-162.92	0.00	-162.92	0.00	0.00	......	0.00	0.00	-7899.89	-35149.10
LPG	0.00	0.00	0.00	0.00	0.00	......	0.00	0.00	-990.50	-4664.00
Coal	0.00	0.00	0.00	0.00	0.00	......	0.00	0.00	-3395.00	-68719.41
Wood & Black Liqour	0.00	0.00	0.00	0.00	0.00	......	0.00	0.00	-6405.37	-12224.45
Geothermal	0.00	0.00	0.00	0.00	0.00	......	0.00	0.00	-69.75	-5749.75
EMISSIONS (KiloTonnes)										
Carbon Monoxide	85.40	25.37	60.03	0.73	3.24	......	0.02	0.00	283.17	805.72
Carbon Dioxide	220.47	79.61	140.86	0.37	7.01	......	1.99	0.00	1226.27	5840.85
Nitrogen Oxide	8.86	2.73	6.13	2.60	0.75	......	0.00	0.00	17.19	103.32
Sulfur Oxide	1.18	0.37	0.81	0.47	0.12	......	0.00	0.00	2.32	26.86
Particulates	2.78	0.88	1.90	1.29	0.31	......	0.01	0.00	15.00	172.39
Hydrocarbons	10.20	3.09	7.11	1.60	0.63	......	0.00	0.00	25.01	95.82
INDIRECT ENERGY (TeraJoules)										
Coal		-335.05								
Natural Gas		-925.78								
Oil		-1463.62								
Electricity		-590.74								
Gas		-238.06								
EMISSIONS (KiloTonnes)										
Carbon Monoxide		0.04								
Carbon Dioxide		114.01								
Nitrogen Oxide		0.54								
Sulfur Oxide		0.74								
Particulates		0.88								
Hydrocarbons		0.02								

present production levels can not be achieved without it. On the other hand, energy production generates pollution, the most important of which is CO_2 emission from combusting fossil fuels, which may be responsible for causing accelerated global warming.

These two factors (energy and related emissions) are, therefore, critical in evaluating the sustainability of dairy farming. Through this model, energy availability at different levels (increase or decrease in energy demand and availability) and reduction or increase in pollutant emissions, can be simulated.

As with quadrant II, energy data was updated since the best available at this time (May, 1993) was for 1987. To have a uniform conversion factor, the same updating calculation used in quadrant II, was applied to this quadrant.

Emissions from the industries were computed through tables A1-3 and A1-4 in Appendix 1(D). For every terajoule of energy input in each sector of the economy, there is a corresponding emission factor in tonnes or kilograms of pollutants. Although data given in Table A1-3 is in an Australian setting (James, 1987), it is believed that New Zealand's economic sector emission will not be significantly different.

7.5 Model Formulations

7.5.1 Algebraic Description

The entire resource accounting model can be described by a system of simultaneous linear equations. Thus for quadrant I, milkfat sales will have the linear equation:

$$156.65*1 + 818.73*1 + \ldots\ldots\ldots\ldots + 66.73*1 + 19.79*1 = 1764.28$$

(Northland) (S. Auckland) (Marlborough) (Southland) (Total Sales)

In a more general format:

$$a_{1\,1}x_1 + a_{1\,2}x_2 + \ldots\ldots\ldots\ldots + a_{1\,7}x_7 + a_{1\,8}x_8 = y_1$$

where:

$a_{1\,1}$ = technical coefficient of milkfat sales for Northland

$a_{1\,2}$ = technical coefficient of milkfat sales for South Auckland

$a_{1\,7}$ = technical coefficient of milkfat sales for Marlborough

$a_{1\,8}$ = technical coefficient of milkfat sales for Southland

x_1 = level of activity for Northland

x_2 = level of activity for South Auckland

x_7 = level of activity for Marlborough

x_8 = level of activity for Southland

y_1 = total milkfat sales.

Similarly, for subsequent simultaneous linear equations:

$$a_{2\,1}x_1 + a_{2\,2}x_2 + \dots\dots\dots + a_{2\,7}x_7 + a_{2\,8}x_8 = y_2 \qquad \text{(for milkfat sales in 1000 t)}$$

$$\begin{array}{ccccc} . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \end{array}$$

$$a_{29\,1}x_1 + a_{29\,2}x_2 + \dots\dots\dots + a_{29\,7}x_7 + a_{29\,8}x_8 = y_{29} \qquad \text{(for debt servicing)}$$

It must be noted that quadrant III has a similar level of activities to quadrant I. Being so, coefficient and variable notations will follow from that of quadrant I. Therefore, the last linear equation for quadrant III will be:

$$a_{41\,1}x_1 + a_{41\,2}x_2 + \dots\dots\dots + a_{41\,7}x_7 + a_{41\,8}x_8 = y_{41} \qquad \text{(for oxygen inhaled)}$$

Quadrants II and IV have similar conventions to that of quadrants I and III. In the whole model, these simultaneous linear equations can be expressed compactly in matrix notation:

$$\mathbf{Ax} = \mathbf{y}$$

where:

A = matrix (n x m) describing economic and ecological commodities in either the farm model (in quadrants I and III) or economic sector (in quadrants II and IV). An input of commodity is denoted by a negative entry and an output of a commodity is denoted by a positive entry.

$\mathbf{x}$ = vector ($m \times 1$) describing level of activity in each of the farm models and economic sectors.

$\mathbf{y}$ = vector ($n \times 1$) describing the net input/output of economic and ecological commodities in the model.

m = number of sectors or farm models (columns).

n = number of commodities (rows).

7.5.2 Spreadsheet Construction

The entire input/output model was operationalised using spreadsheet package "Quattro-Pro", effectively achieving a systematic manipulation of data.

7.5.2.1 Commodities and Dairy Farming

Quadrants I and III are composed of ten columns, representing the commodities itself (first column), the farm models (the following eight columns) and the net input/output (final column). The entries from the second through to the final column can be illustrated through the following spreadsheet formula:

2nd Column (Northland Model)	3rd Column . . . . (S. Auckland Model)	9th Column (Otago Model)	10th Column (Net Input/output)
156.65 * D2	+ 818.73 * E2 + ...	+ 19.79 * K2	= @SUM(D8..K8)
31.28 * D2	+ 148.57 * E2 + ...	+ 3.75 * K2	= @SUM(D9..K9)
.	.	.	.
.	.	.	.
.	.	.	.
-446.06 * D2	- 1666.96 * E2 -	- 52.59 * K2	= @SUM(D53..K53)

where:

156.65, 31.08 and -446.06, are milkfat sales in $ million, 1000 tonnes and oxygen inhaled in megalitres, respectively, in the *Northland Model* (2nd column).

818.73, 96.18 and -1666.96 are milkfat sales in $ million, 1000 tonnes and oxygen inhaled in megalitres, respectively, in the *South Auckland Model* (3rd column).

19.79, 3.75 and -52.59 are milkfat sales in $ million, 1000 tonnes and oxygen inhaled in megalitres, respectively, in the *Southland Model* (9th column).

These numeric entries are equivalent to **A** matrix in the algebraic expression of the model and expresses economic and ecological commodities. As usual, an input of a commodity is denoted by a negative entry, and an output of a commodity is denoted by a positive entry.

D2, E2 and K2 are sector activity of each farm model or column. This is equivalent to **x** in the algebraic expression of the model.

@SUM(D8..K8), @SUM(D9..K9) and @SUM(D53..K53) are the net input/outputs for milkfat sales in $ million, 1000 tonnes and megalitres of oxygen inhaled, respectively. This is equivalent to **y** in the algebraic expression of the model.

7.5.2.2 Commodities and the New Zealand Economy

The spreadsheet construction for quadrants II and IV follows the same procedure as that of the preceding section. The only difference is that it has more columns and rows, and the column 4, column R in the spreadsheet (*Dairy Farming Sector*) is basically 'imported' from quadrant I, as shown in Table 7.6.

Quadrants II and IV are composed of 31 columns. The first column is the sequence number of each economic sector, the second is the various economic sectors themselves, and column 3 through to 29 are the individual economic sectors. Column 30 is the net input/output for each sector while the final column is the domestic consumption sector.

Columns 3, 6 through 29 represent the different economic sectors and are basically similar to the entries in quadrant I, except that, this time, they represent economic sectors not farm models. As in quadrant I, they have the algebraic equivalent of **Ax**. Thus, formulae in these columns can be illustrated as:

3rd Column . . . . . 6th Column . . . . 29th Column

(Agriculture) (Fishing and Hunting) (Household Domestic Services)

7946.79 * Q2 + . . . - 1.80 * T2 . . . . - 0 * AQ2

-24.27 * Q2 - . + 691.72 * T2 . . . . - 0* AQ2

. . .

. . .

. . .

10.20 * Q2 + . . . + 1.60 * T2 . . . . + 25.01 * AQ2

where:

7946.79, -24.27 and 10.20 are outputs for *Agriculture Sector* to *Agriculture* itself, input of *Fishing and Hunting Sector* to *Agricultural Sector* and hydrocarbon emission for *Agricultural Sector* (in kilotonnes), respectively.

-1.80, 691.72 and 1.60 are inputs for *Fishing and Hunting Sector* to *Agriculture*, self-consumption for *Fishing and Hunting Sector* itself, and hydrocarbon emission (in kilotonnes) for *Fishing and Hunting Sector*, respectively.

0, 0 and 25.01 are the inputs for *Agriculture* and *Fishing and Hunting Sectors* to *Household Domestic Services Sector* and hydrocarbon emission (in kilotonnes), for *Household Domestic Services Sector,* respectively.

Q2, T2 and AQ2 are the levels of activity in *Agriculture*, *Fishing and Hunting Sector* and *Household Domestic Services Sector,* respectively.

As demonstrated in the preceding section these entries are equivalent to the algebraic expression **Ax.**

Table 7.6

Relationship Between Quadrant I and Quadrant II

Quadrant I (10th Column)		Quadrant II (4th Column)		
Commodity	Cell Address	Sector	Formulae	Quantity
Others(Output)	L14	Agriculture	L14 + 0.50*L17 + L26 + L27 + L30 + L32	-278.93
Feed[12]	L17			
Breeding Expenses	L26			
Dairy Shed Expenses	L27			
Repair and Maintenance	L30			
Others	L32			
Milkfat Sales	L8	Dairy Farming	L8 + L10 + L12	2098.44
Cattle Sales	L10			
Cattle Purchases	L12			
Feed	L17	Food, Beverage and Tobacco	0.50*L17	-77.18
Fertilizer	L19	Chemicals, Petrol, Rubber, etc.	L19 + L23	-220.18
Weed and Pest	L23			
Electricity	L15	Electricity, Gas and Water	L15	-52.53
Seeds	L21	Trade, Restaurants and Hotels	L21	-12.01
Freight	L28	Transport and Storage	L28 +L31	-124.62
Vehicles	L31			
Administration	L29	Finance, Insurance, etc.	L29	-132.78
Animal Health	L25	Community, Social Services, etc.	L25	-70.62
Wages	L34	Compensation of Employees	L34	-48.23
Personal Drawings	L35	Operating Surplus	L35 + L37	-673.29
Debt Servicing	L37			
Tax	L36	Commodity and Non-commodity Indirect Taxes	L36	-194.26
Capital Purchases	L38	Consumption of Fixed Capital	L38	-72.42

---

[12] It was assumed that feed expenses will be for supplementary purposes like hay or silage during the winter season, and commercial feed for calves during the calving season. Hence, feed expenses were halve, between the *Agricultural Sector* (silage or hay from other farmers) and commercial feed from *Food, Beverage and Tobacco Sector*.

Columns 4 and 5 in quadrant II are directly related to quadrant I. Entries in column 4 (*Dairy Farming Sector*) are directly imported from the total input/output in quadrant I, while entries in column 5 (*Other Agricultural Activities*) are the difference between columns 3 (Agriculture Sector) and 4.

The importation of entries from quadrant I, 10th column in particular is illustrated in Table 7.6.

These relationships (ie, the determination of equivalence between quadrants I and II) were facilitated through the use of the New Zealand Standard Industrial Classification (Department of Statistics, 1987).

It must be noted that columns 4 and 5 do not have levels of activity. This is because column 4 is directly related to the level of activity in quadrant I (ie, in the dairy farm models). Column 5 is directly dependent to the level of activity in column 3.

Column 30 (*Net Input/output*) is the equivalent of **y** in the algebraic expression of the model for quadrants II and IV. This is the summation of all sectors except *Agriculture*. This is to avoid double counting the entries in agriculture since quantities in *Dairy Farming* and *Other Agricultural Activities* all sum to the entries in *Agriculture*. In the spreadsheet, this column has the following (spreadsheet) formula:

Column 30

(Net Input/output)

@SUM(R8..AQ8) = Total output of the *Agricultural Sector*

@SUM(R10..AQ10) = Total output of the *Fishing and Hunting Sector*

.

.

.

@SUM(R67..AQ67) = Hydrocarbon emission (kilotonnes) of the New Zealand economy

Other entries which are worth mentioning are the *Contribution to Gross Domestic Product* (GDP). GDP is simply the sum of primary inputs in each economic sector (compensation of employees, operating surplus . . . . to import duty). These total the absolute value for the algebraic addition of primary inputs.

Thus, under the *Dairy Farming Sector* for example, contribution to GDP can be illustrated in spreadsheet formula as:

|-R35| + |-R36| + |-R37| + |-R38| + |-R39| + |-R40| + |-R41| + |-R42|

Basically, the energy and pollutant emission for quadrant IV follows similar procedure with the economic counterpart in quadrant II. The only difference is that only one entry is imported from quadrant I, electricity in physical quantity (terajoules). This entry is reflected under *Dairy Farming Sector*. However, since energy inputs other than electricity are used in dairy farming, but are not physically accounted for in the farm monitoring reports, other sources of information were necessary[13]. Using the estimates made by the Massey University Agronomy Department (1983), other energy inputs in the form of petrol, diesel and aviation gas were obtained[14].

7.5.3 Refinements to the Model

There are certain simulations in the model wherein the activity level does not change. These simulations need some 'connective' factors so that the resulting data the model will generate is as realistic as possible, for example, the possibility of increasing the stocking rate in the model, all other commodities remaining constant. The simplest way to do this is to multiply the row for *Cows to Calve* and *Other Cattle* with a certain factor to arrive at a desired number of cows. As far as the cow numbers are concerned, this seems to be alright. But associated with increased stocking rate is the increase in animal waste generation. It is in this instance that the model lacks the necessary provision to reflect this situation. However, by multiplying each cell in the row for animal waste (*BOD*, P,. . .CH_4) by the each factor: (D49 + D50)/269.60 . . . (K49 + K50)/31.85, this effect can be automatically reflected in the model. D49, D50 up to K49 and S50 are the cell addresses for the commodities *Cows to Calve* and *Other Cattle,* respectively, in each farming type, 269.60 . . . to 31.85 are the total number of cows (in thousands) in each farm type at base year. By increasing the cow numbers (D49 and D50 for example), the waste generation emission is automatically increased.

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[13] Quantities of other energy inputs are incorporated, financially, in the expenses for *Freight, Repair and Maintenance, Vehicles and Others* as depicted in Table 7.2.

[14] See Appendix 1 for the calculation.

To avoid double counting, however, all animal waste emission is not multiplied by the activity level, since they are already linked to the cow numbers, which, in turn, is multiplied by the activity level. Similarly for Quadrant II, it is assumed that for every electricity expenditure in the shed there is a corresponding energy consumption in the form of petrol, diesel and aviation gas in the field[15]. To interconnect this item to dairy farming activity, it was multiplied by the factor (L15/-1858.61)[16]. Through this relationship, values for this item will proportionately increase or decrease in conjunction with the fluctuations of the dairy farm activities. Similarly, indirect energy and indirect emission under dairy farming were interconnected to direct energy and emission, using the same factor.

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[15] In the absence of relevant information about the relationship between electricity consumption and other energy sources (petrol, diesel and aviation gas) it was assumed to be proportional.

[16] L15 is the cell for total electricity (in terajoules) in quadrant I, while -1858.61 is the electricity consumption for all farm models for the 1991/1992 base of year.

Chapter Eight

SUSTAINABILITY INDICATORS AND THE ENVIRONMENTAL ACCOUNTING MODEL

Chapter Six explored some possible sustainability indicators in the context of a static one-year *snapshot* of the dairy farming sector. But sustainability in an agricultural system is the ability to maintain production for long periods of time. It can be viewed as a long term guiding goal, or a process, the attainment of which can be dynamic as the values and priorities of society change with prevailing conditions, or, it might be gradual as society slowly adjusts to attain these objectives. In this context, sustainability indicators are not mere 'state indicators' but rather indicators of state in relation to some 'reference situation' (Opschoor and Reijnders, 1991). These referenced situations might be a past condition considered to be sustainable, a present favoured condition, or a future condition which is regarded as more desirable.

Thus, in order to evaluate and develop the suggested sustainability indicator, it is necessary to look at the past, present and future trends in New Zealand dairy farming.

8.1 Historical Growth of Dairy Farming

While Chapter Three has dealt with dairy industry in New Zealand as a whole, this section will have a closer look at the historical development of a typical dairy farm. Figure 8.1 shows the trend in the components of net farm income from 1921 to 1990.

These components are total milk sold (kgs), milk price ($/kg) and on-farm costs of producing milk ($/kg).

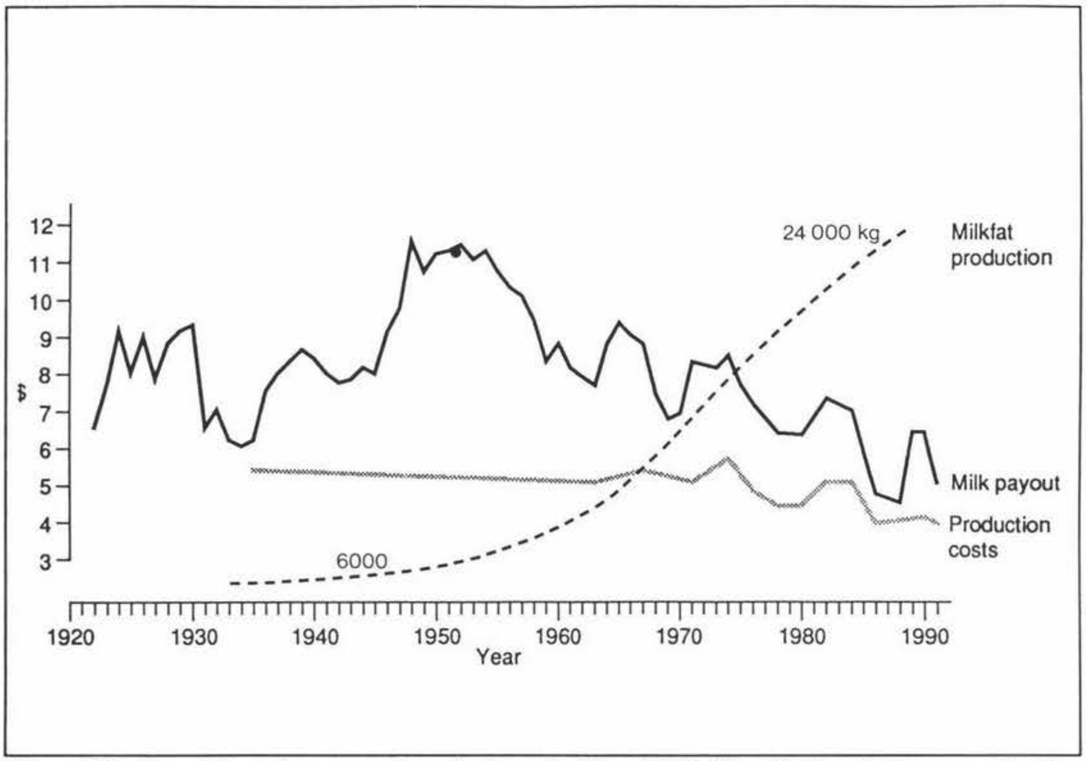

Figure 8.1 **Trend in dairy payout, cost of production (1990 $/kg MF), and farm production (kg MF/farm) 1922-91**
Source: Maughan and Holmes (1992)

It can be observed from Figure 8.1 that production costs have remained relatively constant, while production per farm has increased significantly as the price ($/kg) declined from the 1950s to 1992 (Maughan and Holmes, 1992). The figure can raise concern for the future. The declining trend in monetary payout (in real terms) may not be upset by a continuous increase in milk production or the overall productivity of the farm in order for it to be economically viable.

Table 8.1 presents data which provides further evidence to confirm this trend. With a declining payout from $9.00 in 1960 to $6.50 in 1990, farmers will have to increase

Table 8.1

Trends in the New Zealand Dairy Industry (1960-1990)

	1960 -65 (average)	1989 -90
Price of MF received by farmers (1989 $/kg)	9.00	Actual 6.50 Trend 5.50
No. of dairy farmers	25,000	13,500
Area in dairying	1.20 m ha	1.00 m ha
Average farm size	50 ha	100 ha
Average cows per farm	82	156
Cows per person	50	100
Yield of MF		
kg per cow	130	154
kg per hectare	190	350
kg per person	7300	16000
No. of dairy companies	?	18
No. of dairy factories	coop. 250	50
No. of product specifications	few	200 +
No. of overseas outlets - owned by New Zealand	few (2 in UK)	25
No. of countries to which produce is exported	few (mainly UK)	100 + (UK and Europe only 18%)

Source: Maughan and Holmes (1992)

productivity per person, per hectare and to a lesser extent per cow, just to remain in the industry (Maughan and Holmes, p92). Farmers have to increase their stocking rate, increase milk production per cow and milk as many as twice the number of cows as in the 1960s, just to have a reasonable income. Inspite of this increased productivity and efficiency Maughan and Holmes (1992) suggest that almost half of the farmers have had to leave the industry, as is shown by the figures in Table 8.1. The increase in individual farm area by about 50% was contrasted by a decrease in total dairying area for the whole country by about 0.20 million ha. Those who can not economically cope up with the declining milkfat price have had to quit the industry.

8.2 Possible Future Patterns of Growth

There are four (4) possible future patterns of growth the New Zealand Dairy Industry, in general, is expected to develop, and are formulated according to the themes: Bussiness as Usual, Successful GATT, Emergence of a Green Market and several equally significant factors that may affect the future of dairy farming. These scenarios are considered to have equal possibilities of occurring in the future.

Scenarios are possibilities not probabilities. This is a feature of a scenario which distinguishes them from a forecast. According to Schnaars (1987), *scenario* differs from *forecast* for two different reasons. Firstly, it provides a more qualitative and contextual description of how the present will evolve into the future. Secondly, a scenario usually tries to identify a set of plausible but not assured futures. This combination of offering more than one forecast and offering it in the form a narrative, is deemed to be a more reasonable approach than trying to predict what *will* happen in the future.

Some researchers (Carlson and Umble, 1980) term scenario as a set of multiple forecasts, and this idea of providing a forecast has become the cornerstone in scenario development. According to Schnaars (1987), it is an explicit recognition of the frailty of forecasting, and the importance of underlying assumptions, suggesting that a forecast is only as accurate as the underlying assumptions, and that it makes more sense to consider all plausible assumptions, rather than a single one which may later turn out to be incorrect. This is, therefore, one of the reasons why this thesis has formulated a number of possible future patterns of growth for the New Zealand Dairy Industry.

8.2.1 Business as Usual

If the conclusion for the GATT talks results in no substantial benefits for New Zealand agricultural trade, the New Zealand Dairy Industry will probably follow its current downward trend. Figure 8.1 and Table 8.1 suggest such a scenario: a continued pressure on the real milk price that will either remain static or in decline, and, at the same time, even more expensive production costs. According to Maughan and Holmes (1992), there will be on-farm pressure to either:

(1) "to milk many more cows per person and increase milk per cow". This will mean a high cost automated milking system, and adoption of more intensive farming methods[17]. If it is still economically viable, increase supplementary feeding through the use of commercial feeds.

(2) "to milk many more cows with less milk per cow". This is an attempt to lessen cost by practising a once-a-day milking system. The expected decline in production per cow can be compensated by increasing the stocking rate.

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[17] As Tillman and Gregg (1992) point out, 'on the majority of farms, where there is still considerable scope for increasing production, profitability would be enhanced by greater, rather than lesser, expenditure on fertilizer'.

These on-farm developments will exert more pressure on smaller farmers, forcing some to leave the industry (Maughan and Holmes, 1992).

Table 8.1 can provide some clues to off-farm developments. According to Maughan and Holmes (1992), to take advantage of economies of scale, factories will get bigger and investment overseas will increase. There will be a point in time where returns from these investments are more profitable than selling overseas low-cost New Zealand milk products. This happens when New Zealand owned companies overseas have to source their products from countries other than New Zealand.

This will be compounded by developments in other major milk producing countries irrespective of the outcome of GATT talks. Recent developments in biotechnology can substantially increase milk production, according to Chadee and Guthrie (1990). If this technology is adopted, the resulting surplus will significantly distort world markets, since this surplus would ultimately be traded internationally.

8.2.2 Successful GATT

The subsequent increase in real milk price is expected to encourage New Zealand dairy farmers to produce more milk. On-farm, this will led to either:

(1) "increase stocking rates to produce more milk". Associated with the increase in stocking rate is a possible increase in farm inputs: automation, fertilizer and supplementary feeds.

(2)"influx of farmers to the industry". The profitability of dairy farming might trigger the return of some dairy farmers to the industry. There will be some conversion, of other farming types, to the industry, resulting in a larger portion of agricultural land being devoted to dairy farming.

(3) "additional *environmental costs* to the farmer". The expansion of dairying will raise concern for local authorities, as measures to minimize environmental repercussions, due to animal waste and wasted farm inputs, will incur additional costs to the farmers, and involve local government expenditure.

However, the initial advantage short lived. The rising profitability of the world dairy trade will encourage other major milk producing countries to change unfavourable policy environments (quotas in the EC and, to a lesser extent, the 1990 Farm Bill in the US) and to be more competitive in international market.

The GATT talks are dominated by two major players, the United States of America and the European Community, with negotiations mostly related to grain trade since grain is the major export. The successful GATT talks are seen as resulting in cheaper grain, some of which is animal feed, thus, comparatively lower feed costs for US and EC dairy farmers. Developments in biotechnology will complement their grain-fed system of dairy production, while the introduction of Bovine Somatotropin (a growth hormone that, if injected, can increase cow milk productivity), coupled with nutritious feeds are seen to significantly increase milk production per cow at a relatively lower cost to farmers.

However, the increase in real price also, may not be always advantageous. A significant portion of the growing New Zealand export market will include developing countries, and higher milk product prices will force these countries to minimize consumption, or to develop their own dairy industry.

Considering all these possibilities, the benefits that can be expected from GATT negotiations will be lower than most optimistic assumptions (Chadee and Guthrie, 1990).

These two scenarios have the same effect for the New Zealand dairy industry in increasing pressure from overseas competitors. This will force the dairy industry to be more efficient and continuously look for new *niches* in the international market. One of these is the so called *green* consumers.

8.2.3 Emergence of a 'Green' Market

Under this scenario, the growing concern for environmental problems involves a shift for some dairy consumers towards *green products*. Grown basically from organic farming systems, these green products seems to suit New Zealand's pastorally-based dairy industry. Although small in quantity when compared to the current market, such products usually commands a premium price. The NZDB will, under these circumstances, encourage farmers to met this demand.

On-farm, this new opportunity will translate into a shift from inorganic (commercial) to organic fertilizers. Nutrient recycling will become the theme in fertilizer application, and effluent will be sprayed back to the fields. The use of synthetic fertilizer will decline significantly, and the cost for additional fertilizer will be diverted to costs in spraying effluent. The consequent decline in grass growth, due to lesser nutrients[18], will force farmers to adopt lower stocking rates, and production per farm will decline.

However, not all farmers will accept this new challenge. The prospect of reduced production will make them apprehensive. Although the milk price will be almost 30% higher (FTNZ, 1990) compared to the traditional method of production, some farmers will resort to a 'wait and see' attitude.

Off-farm, the NZDB will continue to seek market niches. Product diversification will be enhanced to counter uncertainty in markets. Research and development programs will be directed to develop 'healthy' (less fat) products. This will be the result for the demand of 'healthy food' among consumers, especially in the UK and the EC traditional markets.

8.3 Other Factors That May Affect the Future of Dairy Farming

The three scenarios explored were mainly based on themes. However, there is a possibility that two or more themes might simultaneously influence the future development of the New Zealand Dairy Industry (ie, successful GATT negotiations and the emergence of a green market may both eventuate). Similarly, other variables not mentioned in the scenarios might come into play.

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[18] Although effluent supplies significant amount of nutrients, it is insufficient to meet normal maintenance requirements (Tillman and Gregg, 1992)

8.3.1 Energy and Dairy Farming

Since dairy farming is energy dependent, energy self-sufficiency might be an issue in the future. New Zealand is dependent on uncertain energy imports (McChesney, 1978). Even the supply of renewable energy sources can not be guaranteed, as demonstrated by the power crisis of 1992. Although it is not yet known if the industry was severely affected, energy in dairy farming is still a crucial factor for its sustainability. Direct electricity in dairy farming is used by milking equipment, and for heating and chilling of milk. Other farming inputs such as fertilizer and feeds accounts for indirect energy use. Nitrogenous fertilizer requirements in pasture is reliant on the biological fixation on nitrogen by clover grass species. In this respect, it appears that dairying is not indirectly dependent on other energy inputs. In fact, nitrogenous fertilizer only constitutes about 5% of the total energy input, compared to 20% in the UK (Leach, 1975 as cited by Pearson and Corbet, 1980). But, the nutrient requirement to stimulate clover production is provided by superphosphate, a fertilizer which must be imported. Hence, production, transportation and ultimately pasture application requires significant amounts of energy. Accordingly, overall energy requirements associated with fertilizers in New Zealand is high, amounting to 33% (Pearson and Corbet, 1980). Energy, in New Zealand dairy farming remains a vital input, whose supply is not guaranteed and may be dependent on sustainability constraints.

8.3.2 Climate Change

According to Maunder (1988), global warming will have a profound effect on all ecosystems, including agricultural based ecosystems. A 1990 study by the Ministry for the Environment indicates that pasture productivity will increase by about 10% - 15%, as the forecasted warmer weather will permit the expansion of pasture lands in the South Island. But, this potential increase in pasture area in the south will be off-set by an increase of subtropical grass species in Northland, which is not desirable due to its poor feed value, and its gradual southward incursion will be a nuisance. Also, other kinds of weeds are expected to become comparatively significant throughout the country. Similarly, the warmer climate is expected to increase winter production of pasture on the east coast of both islands, a beneficial effect that might be neutralized by decreased production due to summer droughts.

This study also indicates that the overall effect of the climatic change would be a dairying move to the South Island, because increased pasture production during summer in the North Island will be more than outweighted by feed shortages and management problems in the winter-spring, while dairying in the Southland would be encouraged by warmer temperatures and less wind.

However, the expected 'drier' summers and 'wetter' winters (Mosley, 1988) may cause floods increasing farming costs. Furthermore, increased droughts might again disrupt power supplies to farms, or at least force a greater use of fossil fuels to ensure short-term security. This may ensure electricity supplies in the short-term, but the use of fossil fuels in electricity production does not enhance the long-term sustainability of such an operation due to CO_2 emission.

8.3.3 Shift to Intensive Labour

The rising cost of energy supplies may prompt dairy farmers to employ additional farm labourers. That is, labour may substitute for energy inputs, reversing the historical trend. According to Stienhart and Stienhart (1974, p315), 'even small increases in energy costs may make it more profitable to increase labour input to food production'. Such reversal of the 50-year trend toward energy-intensive agriculture would also lead to environmental benefits. This possible labour for energy substitution was analyzed by the New Zealand energy scenarios study (Boshier *et al*, 1986), which found that labour for energy substitution resulted in a lower level of economic production for the New Zealand economy. It is likely that dairying production would also decrease given a shift back to increased labour inputs.

8.4 Scenario Results[19]

Using a 10-year span of projection, the model was run according to the assumptions presented in section 8.3 (see Table 8.2). The following are the results in the context of sustainability indicators. Only the *fertilizer* and *energy productivity trend* indicator, *stocking rate* and *land productivity*, as identified in sections 6.3.1, 6.3.2, 6.3.5 and 6.3.6 using the year 1992, as the base year were monitored, because, among the indicators proposed in section 6.3, only these four can be directly monitored using the data generated by the model.

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[19] See Appendix 1 and Appendix 2 for the Scenario results in Table and Graphical Forms, respectively.

Table 8.2

Trends and Possible Effects

on the Environmental Accounting Model

Trends	Effect on the Model	Remarks/Comments
Business as Usual		
1. Scenario 1-A: To milk many more cows per person with more milk per cow	*increase milk production by 1/2 of 1% annually *increase the following farm inputs by 1% annually: electricity fertilizer feeds weed and pests *constant wage	The continued improvement in productivity is brought about by additional farm inputs and automation. Labour expenses (wages) remain constant.
2. Scenario 1-B: To milk many more cows with less milk per cow	*without increasing the stocking rate decrease milkfat production by 1/2 of 1% annually decrease the following by 1% annually: electricity fertilizer feeds	Without increasing the stocking rate, it is assumed that present manpower can compensate for the decline in the use of other energy sources (energy needs for automation). However, the expected lesser efficiency in milking (as some might resort to manual milking) will result a decline in milk

continuation of Table 8.2

	weed and pests repair and maintenance vehicle	production per cow. Similarly, repair and maintenance of milking machines, vehicle use for fertilizer application together with other farm inputs are expected to decline.
Scenario 1-C	*increasing the stocking rate constant milk production increase cows to calve (milking cows) by 1% annually increase wages annually by 1% decrease the following by 1/2 of 1% annually: electricity dairy shed expenses repair and maintenance	To maintain the present milk production with reduced cow productivity, farm inputs and other expenses, it is necessary to increase the stocking rate. Consequently, additional manpower is needed to handle/milk additional milking cows.
Scenario 1-D	*increasing the stocking rate with additional farm inputs constant milk production increase cows to calve (milking cows) by 1% annually increase wages by 1% annually increase the following by 1/2 of 1% annually: fertilizer feeds weed and pests	Additional farm inputs (fertilizer, etc.) are necessary to compensate for the increased stocking rate.

continuation of Table 8.2

	decrease the following by 1/2 of 1% annually: electricity repair and maintenance dairy shed expenses	
Successful GATT		
1. Scenario 2-A: Increase activity level	*basically increase the activity level for all farm types	
2. Scenario 2-B: Increase activity level with additional environmental costs to farmers	*increase activity level for all farm types *increase by 1% annually the following: dairy shed expenses administration repair and maintenance vehicles and others	Additional expenses are for pollution abatement and control
Other Factors		
1. Scenario 3-A: High cost of energy and shift to labour intensive production	*financially increase the following by 1% annually: feeds fertilizer weed and pests	Energy insufficiency partially blamed on global warming (causing droughts), has led the dairy farming system to be more labour intensive. Similarly, this energy scarcity has pushed other farming input prices up.

continuation of Table 8.2

	administration	
2. Scenario 3-B: Technology development	*increase the following by 1/2 of 1% annually: milk production dairy shed expenses repair and maintenance *decrease the following by 1% annually: electricity fertilizer feeds weed and pests	Technology development has led the dairy farming sector to produce more milk with relatively lesser farming inputs, though there is a slight increase in repair and maintenance expenses associated with this development.

The 1991/92 dairy season was selected as the base, because this was the latest data available at the time of writing. Section 9.1.1 further explains this choice.

8.4.1 Business as Usual

Scenario 1-A operates on the premise that the present trend will continue. The pressure to be more competitive in international markets and to compensate for the declining real milk price have led farmers to be more intensive in farming practice. They will continue to rely on intensive use of energy and other farming inputs. Milk productivity will continue to improved by 1/2 of 1% annually. But, the increase in productivity will have little effect on the economic viability (the ratio between total income and the overall expenditure) of the farm. In the 10-year projected period, the economic viability indicator increased by 0.02, from 1.07 to 1.09. This can be reflected in the *land productivity trend* ratio, the ratio of farm productivity (kg MF/ha) of the present year to the base year of 1991/92, which only recorded an increase of 0.04 for the 10-year period. However, these slight improvements in economic performance and farm productivity were attained at the expense of energy and fertilizer efficiency. Their productivity trend ratios (P_e and P_f for energy and fertilizer, respectively) declined from 1.00 in the first year to 0.95 in the tenth year. This means that more fertilizer and energy was consumed per kg of milkfat produced, compared to the base year. Considering the ecological implications 'cow' waste to product ratio improved from 2.24 kg of BOD per kg of milkfat to 2.13 at the end of 10 years.

Scenario 1-B accounted for some innovations adopted by farmers to compensate declining real milk price. It was based on the possibility that farmers will milk more cows with less milk per cow. This attempt to minimize production costs by practising a once-a-day milking system, and reducing farm inputs, have a favourable response with regard to the proposed sustainability indicators. *Energy* and *fertilizer productivity* trend ratios show a consistent improvement from 1.01 in the first year to 1.08 in the tenth year, indicating less energy and fertilizer requirements per kg of milkfat produced. Consequently, less energy means less emissions both from the direct and indirect sources. Since there was no increase in stocking rate, and the milkfat produced per cow was lesser, the BOD generated per milkfat produced was higher than the scenario 1-A. This is 1.55 kg per milkfat more than the first scenario, though overall, the volume generated remains the same. The fact that there was no increase in stocking rate and the cows produced less milk due to a decline in milking efficiency (milking were generally manual), caused milk production per farm to decline. This is reflected in the *land productivity trend* indicator which was recorded at 1.00 in the first year, 0.98 in the tenth year. However, there seems to be a slight improvement, in economic performance as measured by the *economic viability* indicator which increased from 1.07 to 1.08 in the 10-year period. Declining milkfat production might have been financially compensated for by minimized farm inputs.

Scenario 1-C was based on the possibility of maintaining milkfat production with less energy input. It was necessary to increase the stocking rate to compensate for less milk productivity per cow. The *economic viability* and *fertilizer productivity* indicators were maintained (1.07 and 1.00, respectively) for the 10-year period. While *the energy productivity* indicator improved from 1.01 to 1.05, farm productivity was maintained but animal waste generation increased due to higher stocking rate. Similarly, under this condition, cow productivity declined from 143.96 kg milkfat to 132.18 kg of milkfat per cow. Two reasons might account for this. Due to increased stocking rate, without additional farm inputs (fertilizer), dry matter productivity of the farm declined, causing the DM intake per cow to decrease and the subsequently milk productivity to drop. The second reason might be due to a decline in milking efficiency.

However, associated with the increase in stocking rate is the possible additional expenditure on other farm inputs, especially fertilizer, to boost grass growth. This scenario is explored in Scenario 1-D.

Energy productivity and animal waste generation were basically the same as in Scenario 1-C. Also, similar to Scenario 1-C, labour expenses increased in order to compensate for milking the additional stock. An increase in total wages lead to increased GDP, leading to an upward movement in the dairy industry's contribution to GDP. However, unlike in Scenario 1-C, economic performance of the farm, as indicated by *economic viability,* declined by 0.01 in the 10-year period. Constant milk production, with increased stocking rate and fertilizer input, caused the *fertilizer productivity* to decline from 1.00 in the first year to 0.95 in the tenth year. Compared to the base year of 1991/92, fertilizer input per kilogram of milkfat produced, was higher. More manual labour in place of other energy inputs resulted to an improved *energy productivity*, increasing from 1.01 to 1.05 during the 10-year period.

8.4.2 Successful GATT

There were two possible scenarios explored under the assumption that the successful conclusion of the GATT negotiations will be favourable to farmers. The first one (Scenario 2-A) is that all activity levels in all farm models throughout the country will increase by 1% annually. There were no significant changes though in the indicators *fertilizer* and *energy productivities*, *economic viability* and *land productivity*, because all increases in outputs has a corresponding increase in inputs. In ratio terms, it was basically, the same as that of the base year.

However, taking the overall implications of increased activity, the situation is different. Since activity has risen, economic and ecological consequences are worth noting. In economic terms, dairy farming production increased, resulting in 'multiplier effects' on supporting industries, as well as downstream processing industries. As the land area increases under this scenario, conflict might arise between dairy farming and other farming types. The total amount of agricultural lands is finite. As the activity increases, the land required for dairy farming also increases, this will lead to conflict with other types of land use. Economic viability might be the deciding factor determining which farming type is most appropriate and competitive. Economies of scale might be the guiding rule. But, social implications may not be encouraging, as the smaller farms might be disadvantaged, and will be pressured to be more competitive or otherwise be displaced. Ecologically this will mean additional pressure to the environment, as more fertilizer, energy and other farm inputs are required to sustain this level of activity. Total generation of animal waste and emissions from intensive energy consumption will likewise increase.

This ecological implications are considered in Scenario 2-B. To minimize these impacts, measures were introduced that imposed additional costs on farmers. This has made the economic performance of the farms in terms of the *economic viability* indicator to decline from 1.07 to 1.04 in the 10-year period.

8.4.3 Other Factors

8.4.3.1 High Costs of Energy and Shift to Manual Labour

The growing energy prices was explored in Scenario 3-A. Higher energy costs led the dairy farming system to be less energy intensive, gradually resorting to labour intensive production. This energy scarcity led other farming inputs to be comparatively expensive. Although the physical quantity of the inputs (fertilizer, feeds, etc.) remained constant, farm expenditure on these items increased. Economic performance in terms of the *economic viability* indicator then declined from 1.07 to 1.05 in 10-year period. Other indicators remained the same as those of the base year, while *energy productivity* recorded a significant increase from 1.01 to 1.10, because milking, fertilizer application and other farming activities were done manually. Consequently, wages rose and the contribution to GDP by the dairy farming sector increased from M$ 989.16 to M$ 997.85 in the 10-year period.

8.4.3.2 Technology Development and Green Market

In the context of sustainability, the best result so far has been achieved through developments in dairy farming technology (Scenario 3-B). Milking was undertaken with less energy inputs, fertilizer efficiency was greatly enhanced by demands from green markets, and dairy cow waste was increasingly recycled. Additional costs were compensated by the decrease in demand for synthetic fertilizer. Overall, fertilizer expenditure, including waste recycling costs, gradually declined. The increasing milk productivity and relatively lower farm energy requirements, coupled with the decline in synthetic inputs, made dairy farming more economically viable. The *economic viability* indicator increased from 1.08 to 1.14 in 10-year period, while the energy and fertilizer productivity ratios increased from 1.02 to 1.17, and *land productivity* increased from 1.01 to 1.05. Milkfat production was attained at lesser generation of emissions in energy consumption and animal waste.

8.5 Sustainability Implications from the Scenario Results

The scenarios explored provide different perspectives under which the suggested indicators behaved. Grouped under the three perspectives of sustainability, Table 8.3 shows how such perspectives were met under the different scenarios. It must be noted that the social indicator, *labour trend,* as identified in section 6.3.7, was not reflected in the environmental accounting model. However, assuming that wages were to remain constant throughout the time projection of the model, variability in wage expenditure can indicate fluctuations in labour inputs on dairy farms. Also, total land area was included as an indication of dairy farm size (see section 6.3.8). Figures, therefore, in the columns under *Labour Trend* and *Farm Size and Number* are data from the commodities *Wages* and *Land* in the model, respectively.

Table 8.3

Scenarios and the Sustainability Indicators

	Sustainability Indicators						
	Economic			Ecological		Social	
Scenario	Economic Viability (V_e)	Land Productivity (P_L)	Stocking Rate (SR)	Fertilizer Productivity (P_f)	Energy Productivity (P_e)	Labour Trend (T_l)	Farm Size and Number
1-A	+	+	0	-	-	0	0
1-B	+	-	0	+	+	0	0
1-C	0	0	+	0	+	+	0
1-D	-	0	+	-	+	+	0
2-A	0	0	0	0	0	+	+
2-B	-	0	0	0	0	+	+
3-A	-	0	0	0	+	+	0
3-B	+	+	0	0	+	+	+

where:

+ = increasing

- = decreasing

0 = maintain or same as the base year of 1991/92

8.5.1 Economic and Ecological Trade-offs in Sustainable Dairy Farming

Table 8.3 apparently demonstrates the incompatibility between the economic and ecological dimensions of sustainability in the scenarios explored. Scenario 1-A demonstrates the circumstance wherein *economic viability* was attained at the expense of *fertilizer* and *energy productivity*. While scenario 1-C exhibited an increase in the indicators *energy productivity* and *labour trend*, it was at the expense of increasing the *stocking rate* with no economic advantage as there is no relative increase in the *economic viability* and *land productivity* of the farm.

These trade-offs between economic and ecological considerations for sustainable dairy farming seem to be prominent in almost all the scenarios explored but one. Unless there is a development in technology that will minimize inputs (energy and other farming inputs) and abate pollution generation in dairy farming, ecological and economic objectives tend to conflict with each other. However, if such technology is realized, as exemplified in scenario 3-B, both improvements in economic and ecological perspective can be achieved at the same time. Technology development, therefore, remains one of the hopes for, at least, partially achieving sustainability in dairy farming.

8.5.2 Social Consequences in Sustainable Dairy Farming

One of the implications of technology development is the apparent displacement of farm labours in dairying. As some of the scenarios have indicated, improvements in dairy productivity was attained while maintaining the 1.6 average number of farm labour units. In reality, however, this is not always the case. A good example of this phenomenon can be seen in the development of milking machines. Since this adoption, a farmer can milk more cows more efficiently than using the traditional manual method, in fact, with such machines the farmer has doubled his capacity without the expense of another farm labourer. This is not to imply that the development of milking machines was detrimental to the employment of other farm workers. Rather, it points out how technology developments can negatively affect the social perspective of sustainability.

Another by-product of technology development is the growing mechanisation of fertilizer and pesticide application, now mostly done by using an aircraft. According to Stienhart and Stienhart (1974, pp313-314), hand application of these inputs is more labour intensive, but the energy consumption is reduced from 18000 to 300 Kilocalorie per acre. Manual application therefore has more advantages in the context of sustainability, not only will it minimises resource depletion and pollutant emission, it will increase employment opportunities. In the case of pesticide, manual application will be more efficient since it can be directly applied to its intended target, a fact which is both socially desirable and ecologically appropriate.

The intensification of activity levels in successful GATT scenarios (2-A and 2-B) also have some social implications. The expansion of dairy farming areas in the model means either further farm amalgamation or conversion of other farm types to dairying. Farm amalgamations are advantageous, economically, increasing efficiency through economies of scale. Socially it is a different story, for this means the displacement of smaller farmers, which is one of so many causes of rural depopulation (Pearson and Corbett, 1980; Stienhart and Stienhart, 1974).

Part three

REVIEW AND CONCLUDING COMMENTS

Chapter Nine

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

9.1 Discussion

A recent study (Dialogue Consultants, 1992) has asserted that operationalising indicators of sustainability is a near impossibility given the current situation in New Zealand[20]. The study concluded that the development, design and implementation of sustainability indicators needs a 'new policy development to procure the necessary financial resources and build up of expertise'. It was argued that this will involve a large sum of money, and efforts. This author agrees that lack of data, expertise, financial and methodological problems all make it difficult to construct meaningful sustainability indicators in the agricultural sector. However, this study has shown that reasonable results can be obtained, although, admittedly, some of the data has to be estimated using less perfect data. Nevertheless, indicators can be developed which can serve as a guide in policy analysis, and more accurately indicators can be developed in the future if necessary. Sensitivity analysis can be used to establish if and when more accurate data is required. As Verbruggen and Kuik (1991) state, indicators are a compromise between scientific

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[20] Dialogue's argument is addressed to the whole economic sector of New Zealand. However, they have implied that the Agricultural Sector has the advantage of having the 'relevant constituencies' that can facilitate the initial three steps in indicator development (Dialogue, 1992 p80). Apparently, MAF's (1991) policy proposal has facilitated the emergence of these constituencies.

accuracy and the demand for information.

9.1.1 Uses and Limitations of the Environmental Accounting Approach

The input-output method of conducting environmental accounting in evaluating sustainability indicators has encountered several operational problems. This is not surprising since environmental accounting is a relatively new approach to providing an operational measure of sustainable development. Furthermore, the methodology has not been widely used. Although input-output analysis was first established in the 1960s and 1970s as a technique to examine the environment-economy relationship, there have been relatively few reported applications since then. Perhaps several reasons were behind this, as demonstrated by this study.

One common problem with using quantitative method of analysis is the adequacy and availability of data, and this study is no exception. Even though data requirements for dairying are readily available, sometimes consistency in the data series was a problem. For example, for farm productivity (kg/ha) data from MAF Monitoring Reports, Department of Statistics and the New Zealand Dairy Board are all available. However, such data was often inconsistent. Values for the same item from these publications often did not tally. Further, at the time of writing (September 1992), the latest available data for New Zealand inter-industry transactions matrix (input-output table) was for the year 1987, involving a great number of computations to convert it into the desired year of 1992. Similarly, for other ecological inputs, some of them had to be estimated through information from personal interviews.

The prime purpose of the model was to evaluate the achievements of the policy goal of sustainable development via the suggested indicators. Due to data and time constraints, only a number of sustainability indicators were selectively used under different scenario assumptions. These evaluations were limited to the commodities that could readily be expressed in terms of a relative indicator (eg, fertilizer productivity). Other indicators, like the shift to renewable fertilizer and energy, were not able to be monitored as data for estimating these were not adequate, and were not incorporated in the model. Data regarding animal waste recycling were scarce and fragmentary, such data often representing only a portion of a certain region. Extrapolating these data to represent the whole country did, inevitably, led to significant discrepancies in the quantities and the percentages generated by the model. The suggested socially relevant indicators *Labour Trend* and *Farm Size and Number*, could only be used to a limited extent due to data availability problems. *Labour Trend* was only represented in the model as wages, while *Farm Size and Number* are similarly represented by the commodity *Land*. It was assumed that changes in the land area in the model during scenario simulations would represent change in farm sizes and numbers.

Data availability also restricted the usefulness of the operational models in examining some of the other aspects of sustainability in the dairy farming sector. How the different scenarios will affect biodiversity (although in dairy farming, biodiversity is not much of an issue) were hardly examined. The social perspective of sustainability (as described above) was only slightly evaluated through the commodities *Wages* and *Land*, both of which have limited interpretative value. Perhaps this is due to the fact that social values, and hence perspectives, can best be evaluated qualitatively.

The environmental accounting model was formulated on the basis a linear relationship between inputs and outputs. Richardson (1972) has, however, pointed out that many of the relationships in economic and ecological systems are not linear. To take a simple example, animal waste generation (BOD, N, P, K, etc.) may not be a linear function of cow numbers. Animal waste is also dependent on the type of feed and the mix of feeds, which may vary as cow numbers increase, thereby leading to a non-linear increase in the waste generated. Fortunately in New Zealand, however, linearity, in this case, can be assumed to be valid, since cows mostly feed on grass without any major feed supplements.

It must be noted that one of the prime purpose of this study is to provide the policy and decision makers with information upon which rational choice can be made. This model describes some of the more important economic and environmental interactions a certain agricultural system can have, thereby providing an understanding of the interactions which are often useful in policy analysis deliberations. It should be recognised that the model of these interactions is very much a simplification of the real world situation. Nevertheless, at best, it gives an approximate picture of these interactions, which, for most of the time are neglected.

The adoption of materials-balance principle is one of the factors which make the picture of an economic-ecologic interaction clearer, and ensures the model conforms to one of the basic physical principles - the law of conservation of matter. This law states that *in* *all physical and chemical changes, atoms are not created nor destroyed*[21]*. It can only be rearranged into different spatial patterns (physical changes) or different combinations (chemical changes).* These transformations are considered and accounted for in the materials-balance principle. What enters the model as input (eg, air, dry matter feed, energy, etc.) ultimately exits as output (eg, milk, other animal products, excreta, emissions, etc.). In other words, this principle can be interpreted in the context of this model, in terms of the catchphrase "there is no such thing as a free lunch" from the environment.

The model can be used for policy analysis particularly in assessing the environmental implications of agricultural policies. Policies that will encourage production can be simulated to find out how this will impact on the use of farm inputs (fertilizer, energy, etc.); the subsequent impact on the environment (pollution emission of energy use, animal waste, etc.); the economic viability of the farm (profitability, productivity, etc.); and related social implications (increased employment opportunities, amalgamation, etc.). Thus, one of the basic questions that can be answered by the model is, what are the economic, environmental and social (to a limited degree) implications of policies that will affect dairy farming?

As a policy analysis tool, therefore, the model has much to offer. The policy implications for various scenarios, can be obtained from interpreting the model results. Scenarios are the likely answers to the questions *what if?* There can be many

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[21] According to Miller (1993), it is accepted in modern physics that a tiny amount of matter is converted into energy when a chemical reaction takes place. However, the amount is so minute that it cannot be detected by even the most sensitive measuring devices.

combinations of imagined plausible events which can be simulated in the model, although in some instances only approximately. Various policy implications can be evaluated using the model, albeit within the limitations of the assumptions of the model.

The model could be improved to more explicitly take account of pollution abatement technology. Once emissions and waste are generated and disposed off in the environment, they are considered as detrimental to the environment, when, in fact, current energy consumption emissions can be minimised through the use of anti-pollution devices and technology. Actual amounts of the emissions used in this study were based on figures obtained from James (1982), and these were based on average emission generations. However, the type of energy, fuel mixture and type of engine used can also affect the quantity of emission generated. These factors, together with anti-pollution devices or technology employed, can significantly reduce pollution emission. In reality therefore, it is most likely that actual emission is less.

Similarly, not all animal wastes (BOD, N, P, K, etc.) reach the water system where they have the maximum environmental impact. As previously emphasised in section 6.1.1.1, only 5% of these are directly wasted and disposed into the environment. Although 95% are directly returned to the fields, a significant proportion will ultimately enter the natural water systems via run-off. Others, in the form of dung gasses, are evaporated into the atmospheric environment.

In other words, pollution generated by dairy farming activities should not be treated as pollution *per se*. Effective policy evaluation can not be guaranteed, if only the quantities of potential pollutants are described by the model. What will appeal most to policy and decision makers is how these pollutants will affect the environment. In short, the actual environmental damage caused by pollutants is critical. Such damage could be assessed by the model by including ecological processes within the model (as in the quadrant IV of a typical Isard Model). But the appropriate data is often unavailable. Nevertheless, in the absence of such data, the best approach was to provide the total amounts of pollutants.

All scenario projections were based on linear trends of input variables over time. Milkfat production, for example, was assured to increase by linear increments of 1/2 of 1% yearly for a 10-year model projection. Such linear increases are unlikely to occur. For example, fluctuations in farm production are clearly demonstrated in Figure 8.1 for the period 1922-1991. A stochastic modelling approach could have been used to allow for random fluctuations in the input variables.

The use of the environmental accounting approach in this study has raised more questions than it answered. Perhaps this is expected, as this is a relatively new technique with no explicit procedural guidelines. A similar approach, although different, natural resource accounting has encountered procedural and practical problems as well, in studies both locally and abroad. It is not surprising that this study encountered similar problems. However, environmental accounting offers a promising area for research. As demonstrated by the model, it is a good tool for policy analysis, if the weaknesses can be minimised.

The choice of a base year is arbitrary, for this problem needs to be examined in an historical context. Pastoral farming in New Zealand is considered to be sustainable (MAF, 1990) on the basis that for more than a century, it has been maintained in one way or the other. However, this assertion is contested by Hayward (1990) and recently by the Dialogue Consultants (1992). Hayward points out the reliance of pastoral farming systems on outside sources of energy and fertilizer inputs, while the later stresses the point that farming system in the mid-19th century (at the start of European settlement in New Zealand) were radically different from today. The fact that farming systems have changed indicates that they are not sustainable. A possibility might be that the current farming systems are also not sustainable. In the light of this uncertainty, sections 6.1 to 6.2.2 have elaborated various factors, and any past year can be selected as a reference point. For this particular study, 1992 was arbitrarily chosen.

9.1.2 Sustainability Issues and the Future of New Zealand Dairy Farming

Agriculture is governed primarily by ecological principles. This might be ignored in the short-term, to the detriment of system, later. Although technology can influence agriculture for man's benefits, this will be achieved only through the constraints of, and utilization of, ecological principles (Smith and McChesney, 1979). Ecology, therefore, has a great influence on the sustainability of farming systems. A healthy environment with a proper functioning natural ecosystems ensures that ecological properties are not yet disturbed to an alarming degree. Although dairy farming in New Zealand has transformed the natural environment to a certain degree, this 'improved' ecosystem (pasture ecosystem) can still be maintained and considered sustainable. Maintenance of this condition depends on a number of factors.

Nutrient movement in dairy farming should be a closed cycle as much as possible, in order to achieve sustainable management of the industry. Though this can not be avoided, due to export of animal products (milk and meat), and the importation of nutrients. To improve the sustainability of dairy farming, nutrient recycling should be maximized. Excessive nutrient input leads to wastage, and unrecycled nutrients are also wasted which becomes a liability on the environment. Environmental repercussions of wastage have already been discussed in section 6.1.1.1. However, the effect of excessive nutrient import is not yet fully recognised. Not only is this ecologically detrimental, it is not efficient in economic terms. Too much nutrient, or fertilizer, input leads to soil toxicity and pollution of water systems. Dairy farming is also subject to the well known law of diminishing returns (Pearson and Corbet, 1980; Smith and McChesney, 1979), as production per hectare shows diminishingly small increases for each increase in nutrient input. This is particularly evident in systems which are already stretched to the limit, and where additional fertilizer input can not significantly increase productivity in an economically affordable way.

The sustainability of dairy farming is not only dependent on ecological factors; economic and social considerations also play an important part. At certain times these factors are in conflict with each other. The consideration of only one factor leads to the disadvantage of the others. The evolution of dairy farming in New Zealand to its present state, has seen the interaction of these sustainability perspectives (eg, economic, ecological and social). The amalgamation of early cooperatives, and individual farms, to be more competitive are examples of this. Although these cooperatives and farms become more competitive and survived difficult times, this was achieved at the cost of smaller farm displacement. Dairy farming, then, was sustained in an economically viable condition, but in a socially undesirable way as Table 8.1 demonstrates. In a period of 30 years (1960-1990), dairy farmers were reduced from 25,000 to 13,500. Although there were many reasons that lead to this reduction, most of those who abandoned dairy farming did not do so voluntarily. Other factors, primarily economic, forced these farmers to quit and look for a brighter future elsewhere. If this trend continues, there will come a time when there will be only a few thousand dairy farmers, mostly those who can afford to invest in modern and expensive equipment to generate a relatively higher profit. Although this is economically desirable, it is a social injustice. It is, therefore, important to monitor this trend through the indicator *Farm Size and Number*.

One of the most important questions regarding these indicators is whether they can truly reflect the sustainability of dairy farms. Can it really guide the policy and decision makers in achieving sustainability for dairy farming?

The indicators were evaluated in section 8.4 using the model. Their behaviour only confirms the suggestion that sustainability will not be attained to the satisfaction of all the perspectives. There has to be trade-offs involved. It is up to the policy and decision makers to balance these trade-offs between different policy objectives. Particular emphasis and bias could be accorded to a perspective that will satisfy a certain demand at a certain time. There are certain instances where profitability could be sacrificed in order to accommodate increased employment. This can be achieved through policies encouraging labour intensive production. Overall productivity can be stimulated by policies encouraging high technology systems inducing higher labour productivity at the same time lowering employment opportunities. These trade-offs involve political choices which must be continuously adjusted as a result of new changing social requirements or unforeseen developments in the economic and ecological systems. It is a balancing between the economic and social demands of society and the ecological state of the environment.

It is also important to recognise that these indicators are only for the dairy farm. If viewed in a wider perspective, dairy farming is at the lowest level of a hierarchy that extends to the cooperative companies, the Dairy Board, associate companies overseas and, ultimately, the customers in overseas countries. This hierarchy is very much interconnected. Changes in market preferences abroad will affect dairy farming. Competition with other countries for markets can ultimately affect farming practices. In other words, changes within and outside the hierarchy will have a profound effect on dairy farming, and will impact on its sustainability. Therefore, it can be said that the proposed indicators are inadequate in providing a comprehensive monitoring regime for all levels within the dairy industry hierarchy. A more comprehensive set of indicators for every level of the hierarchy might ensure a more sustainable dairy industry.

9.2 Conclusion

The issue of agricultural sustainability in New Zealand has only recently received attention from policy and decision makers. As a consequence, research and studies regarding this matter are limited. This study demonstrates that monitoring agricultural sustainability at farm level can be done in a limited way with current data quality and methodological knowledge, but is difficult and not without problems.

Statistical data regarding dairy farming abounds, although tailored for different purposes. Nevertheless, with these data, this study was able to develop and formulate indicators that can help operationalise sustainability in dairy farming, albeit in a limited way.

According to Conway and Barbier (1987), agricultural sustainability is the persistence and durability of the system's productivity under a known or possible condition . Hence, persistence and durability can only be maintained through the three perspectives of agricultural sustainability - economic, ecological and social considerations. Agriculture is still governed primarily by ecological principles, its development motivated by economic demands and its productivity by social necessity. Agricultural sustainability indicators must provide the necessary check and balance between these three considerations, for sustainability can not be achieved by only one or two but a balance and trade-off between all these considerations. For a time one or two perspectives can be given more consideration in order to satisfy immediate societal demands. But in the end, it is the proper balance between these three if long-term sustainability is desired.

There are a number of ways balance and trade-off can be evaluated. One of them has been used in this study. As sustainability is an elusive concept, every possible way should be explored, tested, developed and improved to operationalise it.

9.3 Recommendations

The indicators developed under this thesis are only a product of an experimental approach. Under this exploratory exercise, a number of factors were perceived to be in need of further improvement:

- *the availability of appropriate data*

Sustainability issues encompass a wide range of dimensions which should be given sufficient, and equal attention. This necessitates the availability and consistency of data regarding these dimensions. An equally important issue to be addressed is the establishment of a 'baseline' of agricultural sustainability parameters against which monitoring and interpretation of changes can be compared.

- *the development of expertise to interpret and analyze data*

The problem of sustainability can not be addressed solely by the availability and consistency of data. Expertise should be developed to utilize these data and convert them into appropriate information. A multi-disciplinary team of experts is believed to be appropriate to address the measurements and analysis of the multi-facet nature of sustainability issues. Perhaps the sociological dimension of sustainability might be given more emphasis. This study not only found these factors difficult to quantify, but sociological factors also seem to be getting lesser attention compared to the other dimensions of sustainability. Much of the sustainability debate revolves around the ecological-economic interface.

- *improved data and expertise*

The development of scenarios is very important in evaluating sustainability indicators, as they provide convenient platforms for measuring change over the very long-time periods which must, necessarily, be considered in examining changes in sustainability. Scenarios, however, must be plausible, internally consistent and based on the best possible data which is pertinent to future events. It is, therefore, recommended that such data and expertise be developed in New Zealand to assist in the improved development of scenarios.

- *more research on environmental accounting*

Environmental accounting is a relatively new technique as a tool for sustainable development planning and policy analysis. As such, there is still a large opportunity for its improvement. In this thesis, a more comprehensive coverage of ecological-process and inputs/outputs (eg, not only pollutants but the impact of these pollutants on the environment) should have been achieved in the input-output model. Likewise, a more appropriate sociological criteria should have been incorporated in the model.

Generally, however, more research and study is needed to develop environmental accounting as a more useful tool for resource management planning and policy analysis. As other studies have found (NZIER, 1992; Clarke and Dragun, 1989), environmental/resource accounting is more appropriate for studies at the national level.

Indicator formulation should not be confined to the use of the environmental accounting method. The appropriate choice of trade-offs involved in the process of pursuing sustainability can be greatly enhanced by the use of multicriteria methods of analyses.

- *more research on sustainability indicators*

Sustainability of dairy farming is dependent on many factors. As formerly emphasised, it is only a part of a hierarchy that extends from the farm to overseas markets and costumers. Indicator development, therefore, should encompass the whole range of this hierarchy, as changes in any one of these levels will ultimately affect dairy farming. Valentine (1991) has suggested the generation of a hierarchy of indicators for decision makers at farm, regional and national levels.

The process of indicator development should not be confined to the presently available data and methodology. There is a possibility that under the current method adopted by this study a number of important factors have not been considered. A more thorough research and study on indicator development process is highly recommended.

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APPENDICES

Appendix 1

Scenario Results

The scenario results were obtained by running the model according to the assumptions specified in Table 8.2. The economic and ecological commodity values were obtained from the *Net Input/output* column in quadrants I and III. These commodity values were used to derive the following indicators: *Economic Viability*, *Farm Productivity Trend*, *Stocking Rate*, *Energy Productivity* and *Fertilizer Productivity*. The formula used to calculate these indicator values are presented in section 6.3 and are also contained in the spreadsheet model on the attached diskette. The *Wages*, *Other Energy Inputs* and *Emissions* were directly obtained from the *Dairy Farmin*g column in quadrants II and IV.

Table A1-1

Scenario-1A

Business as Usual - to milk more cows per person, with more milk per cow

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1773.10	1781.92	1790.74	1799.57	1808.39	1817.21	1826.03	1834.85	1843.67	1852.49
Milkfat (KTonnes)	333.12	334.77	336.43	338.09	339.75	341.40	343.06	344.72	346.38	348.03
Electricity (M$)	-53.06	-53.58	-54.11	-54.63	-55.16	-55.68	-56.21	-56.73	-57.26	-57.78
Electricity (TJ)	-1877.20	-1895.78	-1914.37	-1932.95	-1951.54	-1970.13	-1988.71	-2007.30	-2025.88	-2044.47
Feeds (M$)	-155.90	-157.45	-158.99	-160.53	-162.08	-163.62	-165.17	-166.71	-168.25	-169.80
Feeds (KTonnes)	-637.61	-643.93	-650.24	-656.55	-662.87	-669.18	-675.49	-681.80	-688.12	-694.43
Fertilizer (M$)	-207.32	-209.38	-211.43	-213.48	-215.53	-217.59	-219.64	-221.69	-223.74	-225.80
Fertilizer (KTonnes)	-1056.17	-1066.62	-1077.08	-1087.54	-1098.00	-1108.45	-1118.91	-1129.37	-1139.82	-1150.28
Weed & Pests (M$)	-15.06	-15.21	-15.36	-15.51	-15.66	-15.80	-15.95	-16.10	-16.25	-16.40
Weed & Pests (KLiters)	-2.36	-2.39	-2.41	-2.43	-2.46	-2.48	-2.50	-2.53	-2.55	-2.57
Wages	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23
Contribution to GDP	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20
Ecologic Inputs/Outputs										
BOD (KTonnes)	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22
P (KTonnes)	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76
K (KTonnes)	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84
N (KTonnes)	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47
CO2 (KTonnes)	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95
CH4 (KTonnes)	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08
Land (1000 has)	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2175.20	-2196.73	-2218.27	-2239.80	-2261.34	-2282.89	-2304.41	-2325.96	-2347.49	-2369.03
Petrol (TJ)	-2960.88	-2990.19	-3019.51	-3048.82	-3078.14	-3107.46	-3136.77	-3166.09	-3195.39	-3224.72
Av Fuel (TJ)	-181.27	-183.06	-184.86	-186.65	-188.45	-190.24	-192.03	-193.83	-195.62	-197.42
Indirect Energy										
Coal (TJ)	-338.42	-341.77	-345.12	-348.47	-351.82	-355.17	-358.52	-361.87	-365.22	-368.57
Natural Gas (TJ)	-935.05	-944.30	-953.56	-962.82	-972.08	-981.34	-990.59	-999.85	-1009.11	-1018.37
Oil (TJ)	-1478.23	-1492.86	-1507.50	-1522.13	-1536.77	-1551.41	-1566.04	-1580.68	-1595.31	-1609.95
Electricity (TJ)	-596.69	-602.60	-608.51	-614.42	-620.32	-626.23	-632.14	-638.05	-643.95	-649.86
Gas (TJ)	-240.44	-242.82	-245.20	-247.58	-249.96	-252.34	-254.72	-257.11	-259.49	-261.87
Emissions										
CO (KTonnes)	25.62	25.88	26.13	26.38	26.64	26.89	27.15	27.40	27.65	27.91
CO2 (KTonnes)	80.41	81.20	82.00	82.79	83.59	84.39	85.18	85.98	86.77	87.57
NO (KTonnes)	2.76	2.78	2.81	2.84	2.87	2.89	2.92	2.95	2.98	3.00
SO (KTonnes)	0.37	0.38	0.38	0.38	0.39	0.39	0.40	0.40	0.40	0.41
Particulate (KTonnes)	0.89	0.90	0.91	0.92	0.92	0.93	0.94	0.95	0.96	0.97
Hydrocarbon (KTonnes)	3.12	3.15	3.18	3.21	3.24	3.28	3.31	3.34	3.37	3.40
INDICATORS										
Economic Viability	1.07	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.09
Energy Productivity	1.00	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.96	0.95
Fertilizer Productivity	1.00	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.96	0.95
Farm Productivity Trend	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05
Stocking Rate	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
OTHER VARIABLES										
Surplus (Income - Expenditure)	145.93	150.48	155.03	159.58	164.23	168.68	173.23	177.79	182.34	186.89
Productivity (kg MF/ha)	369.11	370.94	372.78	374.61	376.45	378.29	380.12	381.96	383.80	385.63
Cow Productivity (kg MF/cow)	146.13	146.85	147.58	148.31	149.03	149.76	150.49	151.21	151.94	152.67
Stocking Rate (milking cow/ha)	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53

Table A1-2

Scenario-1B

Business as Usual - to milk more cows with less milk per cow, without increasing the stocking rate

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1759.87	1755.46	1751.05	1746.64	1742.23	1737.82	1733.41	1728.99	1724.58	1720.17
Milkfat (KTonnes)	330.63	329.80	328.97	328.15	327.32	326.49	325.66	324.83	324.00	323.17
Electricity (M$)	-52.00	-51.48	-50.95	-50.43	-49.90	-49.38	-48.85	-48.33	-47.80	-47.28
Electricity (TJ)	-1840.02	-1821.44	-1802.85	-1784.27	-1765.68	-1747.09	-1728.51	-1709.92	-1691.34	-1672.75
Feeds (M$)	-152.82	-151.27	-149.73	-148.19	-146.64	-145.10	-143.55	-142.01	-140.47	-138.92
Feeds (KTonnes)	-624.99	-618.67	-612.36	-606.05	-599.74	-593.42	-587.11	-580.80	-574.48	-568.17
Fertilizer (M$)	-203.22	-201.16	-199.11	-197.06	-195.01	-192.95	-190.90	-188.85	-186.80	-184.74
Fertilizer (KTonnes)	-1035.25	-2024.80	-1014.34	-1003.88	-993.42	-982.97	-972.51	-962.05	-951.60	-941.14
Weed & Pests (M$)	-14.76	-14.61	-14.46	-14.13	-14.16	-14.02	-13.87	-13.72	-13.57	-13.42
Weed & Pests (KLiters)	-2.32	-2.29	-2.27	-2.25	-2.22	-2.20	-2.18	-2.15	-2.13	-2.11
Wages	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23
Contribution to GDP	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20
Ecologic Inputs/Outputs										
BOD (KTonnes)	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22
P (KTonnes)	24.76	24.76	24.76	21.76	24.76	24.76	24.76	24.76	24.76	24.76
K (KTonnes)	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84
N (KTonnes)	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47
CO2 (KTonnes)	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95
CH4 (KTonnes)	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08
Land (1000 has)	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2132.12	-2110.59	-2089.05	-2067.52	-2045.98	-2024.44	-166.34	-1981.37	-1959.84	-1938.30
Petrol (TJ)	-2902.24	-2872.93	-2843.61	-2814.31	-2784.98	-2755.66	-226.42	-2697.03	-2667.73	-2638.41
Av Fuel (TJ)	-177.68	-175.88	-174.09	-172.29	-170.50	-168.70	-13.86	-165.11	-163.32	-161.52
Indirect Energy										
Coal (TJ)	-331.71	-328.36	-325.01	-321.66	-318.31	-314.96	-25.88	-308.26	-304.91	-301.56
Natural Gas (TJ)	-916.53	-907.27	-898.01	-888.76	-879.50	-870.24	-71.50	-851.72	-842.47	-833.21
Oil (TJ)	-1448.95	-1434.32	-1419.68	-1405.05	-1390.41	-1375.77	-113.04	-1346.50	-1331.87	-1317.23
Electricity (TJ)	-584.88	-578.97	-573.06	-567.16	-561.25	-555.34	-45.63	-543.52	-537.62	-531.71
Gas (TJ)	-235.68	-233.30	-230.92	-228.54	-226. 6	-223.78	-18.39	-219.02	-216.64	-214.25
Emissions										
CO (KTonnes)	25.12	24.86	24.61	24.36	24.10	23.85	1.96	23.34	23.09	22.83
CO2 (KTonnes)	78.81	78.02	77.22	76.43	75.63	74.83	6.15	73.24	72.45	71.65
NO (KTonnes)	2.70	2.68	2.65	2.62	2.59	2.57	0.21	2.51	2.48	2.46
SO (KTonnes)	0.37	0.36	0.36	0.36	0.35	0.35	0.03	0.34	0.34	0.33
Particulate (KTonnes)	0.87	0.86	0.85	0.84	0.84	0.83	0.07	0.81	0.80	0.79
Hydrocarbon (KTonnes)	3.06	3.03	3.00	2.97	2.94	2.90	0.24	2.84	2.81	2.78
INDICATORS										
Economic Viability	1.07	1.07	1.07	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Energy Productivity	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.07	1.08
Fertilizer Productivity	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.07	1.08
Farm Productivity Trend	1.00	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98
Stocking Rate	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
OTHER VARIABLES										
Surplus (Income - Expenditure)	142.68	143.98	145.28	146.58	147.89	148.88	150.49	151.79	153.09	154.39
Productivity (kg MF/ha)	366.35	365.43	364.51	363.60	362.68	361.76	360.84	359.92	359.01	358.09
Cow Productivity (kg MF/cow)	145.04	144.67	144.31	143.94	143.58	143.22	142.85	142.49	142.13	141.76
Stocking Rate (milking cow/ha)	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53

Table A1-3

Scenario-1C

Business as Usual - to milk more cows with less milk per cow, with increasing stocking rate

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28
Milkfat (KTonnes)	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46
Electricity (M$)	-52.27	-52.00	-51.74	-51.48	-51.22	-50.95	-50.69	-50.43	-50.17	-49.91
Electricity (TJ)	-1849.32	-1840.03	-1830.74	-1821.44	-1812.14	-1802.85	-1793.56	-1784.27	-1774.97	-1765.68
Feeds (M$)	-154.36	-154.36	-154.36	-154.36	-154.36	-154.36	-154.36	-154.36	-154.36	-154.36
Feeds (KTonnes)	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30
Fertilizer (M$)	-205.27	-205.27	-205.27	-205.27	-205.27	-205.27	-205.27	-205.27	-205.27	-205.27
Fertilizer (KTonnes)	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71
Weed & Pests (M$)	-14.91	-14.91	-14.91	-14.91	-14.91	-14.91	-14.91	-14.91	-14.91	-14.91
Weed & Pests (KLiters)	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34
Wages	-48.71	-49.19	-49.68	-50.16	-50.64	-51.12	-51.61	-52.09	-52.57	-53.05
Contribution to GDP	988.68	989.16	989.65	990.13	990.61	991.09	991.58	992.06	992.54	993.02
Ecologic Inputs/Outputs										
BOD (KTonnes)	742.22	755.83	762.63	769.43	776.23	783.04	789.84	796.64	803.45	810.25
P (KTonnes)	24.76	25.21	25.44	25.66	25.89	26.12	26.35	26.57	26.80	27.03
K (KTonnes)	94.84	96.58	97.45	98.32	99.19	100.06	100.92	101.79	102.66	103.53
N (KTonnes)	148.47	151.19	152.55	153.91	155.27	156.64	158.00	159.36	160.72	162.08
CO2 (KTonnes)	4123.95	4199.57	4237.35	4275.14	4312.92	4350.76	4388.54	4426.32	4464.16	4501.94
CH4 (KTonnes)	2291.08	2333.09	2354.08	2375.07	2396.06	2417.08	2438.07	2459.06	2480.08	2501.07
Land (1000 has)	902.50	902.50	902.50	902.50	902.50	902.50	902.50	902.50	902.50	902.50
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2142.90	-2132.13	-2121.36	-2110.59	-2099.81	-2089.05	-2078.29	-2067.52	-2056.74	-2045.98
Petrol (TJ)	-2916.91	-2902.26	-2887.59	-2872.93	-2858.26	-2843.61	-2828.96	-2814.31	-2799.64	-2784.98
Av Fuel (TJ)	-178.57	-177.68	-176.78	-175.88	-174.98	-174.09	-173.19	-172.29	-171.40	-170.50
Indirect Energy										
Coal (TJ)	-333.39	-331.72	-330.04	-328.36	-326.69	-325.01	-323.34	-321.66	-319.99	-318.31
Natural Gas (TJ)	-921.16	-916.53	-911.90	-907.27	-902.64	-898.01	-893.39	-888.76	-884.13	-879.50
Oil (TJ)	-1456.27	-1448.96	-1441.63	-1434.32	-1426.99	-1419.68	-1412.36	-1405.05	-1397.72	-1390.41
Electricity (TJ)	-587.83	-584.88	-581.92	-578.97	-576.01	-573.06	-570.11	-567.16	-564.20	-561.25
Gas (TJ)	-236.87	-235.68	-234.49	-233.30	-232.11	-230.92	-229.73	-228.54	-227.35	-226.16
Emissions										
CO (KTonnes)	25.24	25.12	24.99	24.86	24.74	24.61	24.48	24.36	24.23	24.10
CO2 (KTonnes)	79.21	78.81	78.42	78.02	77.62	77.22	76.82	76.43	76.03	75.63
NO (KTonnes)	2.72	2.70	2.69	2.68	2.66	2.65	2.63	2.62	2.61	2.59
SO (KTonnes)	0.37	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.35	0.35
Particulate (KTonnes)	0.88	0.87	0.87	0.86	0.86	0.85	0.85	0.84	0.84	0.84
Hydrocarbon (KTonnes)	3.07	3.06	3.04	3.03	3.01	3.00	2.98	2.97	2.95	2.94
INDICATORS										
Economic Viabilitiy	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
Energy Productivity	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05
Fertilizer Productivity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Farm Productivity Trend	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stocking Rate	2.78	2.81	2.83	2.86	2.88	2.91	2.93	2.96	2.98	3.01
OTHER VARIABLES										
Surplus (Income - Expenditure)	140.82	140.26	139.70	139.14	138.58	138.02	137.46	136.90	136.35	135.79
Productivity (kg MF/ha)	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27
Cow Productivity (kg MF/cow)	143.96	142.55	141.16	139.81	138.48	137.17	135.89	134.63	133.39	132.18
Stocking Rate (milkcow/ha)	2.55	2.58	2.60	2.63	2.65	2.68	2.70	2.73	2.75	2.78

Table A1-4

Scenario-1D

Business as Usual - to milk more cows with less milk per cow, with increasing stocking rate and farm inputs

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28
Milkfat (KTonnes)	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46
Electricity (M$)	-52.27	-52.00	-51.74	-51.48	-51.22	-50.95	-50.69	-50.43	-50.17	-49.90
Electricity (TJ)	-1849.32	-1840.03	-1830.73	-1821.44	-1812.14	-1802.85	-1793.56	-1784.27	-1774.97	-1765.68
Feeds (M$)	-155.13	-155.90	-156.68	-157.45	-158.22	-158.99	-159.76	-160.53	-161.31	-162.08
Feeds (KTonnes)	-634.46	-637.61	-640.77	-643.93	-647.08	-650.24	-653.40	-656.55	-659.71	-662.78
Fertilizer (M$)	-206.30	-207.32	-208.35	-209.38	-210.40	-211.43	-212.45	-213.48	-214.51	-215.53
Fertilizer (KTonnes)	-1050.94	-1056.17	-1061.40	-1066.62	-1071.85	-1077.08	-1082.31	-1087.54	-1092.17	-1098.08
Weed & Pests (M$)	-14.98	-15.06	-15.13	-15.21	-15.28	-15.36	-15.43	-15.51	-15.58	-15.66
Weed & Pests (KLiters)	-2.35	-2.36	-2.38	-2.39	-2.40	-2.41	-2.42	-2.43	-2.45	-2.46
Wages	-48.71	-49.19	-49.68	-50.16	-50.64	-51.12	-51.61	-52.09	-52.57	-53.05
Contribution to GDP	988.68	989.16	989.65	990.13	990.61	991.09	991.58	992.06	992.54	993.02
Ecologic Inputs/Outputs										
BOD (KTonnes)	742.22	755.83	762.63	769.43	776.23	783.04	789.84	796.64	803.45	810.25
P (KTonnes)	24.76	25.21	25.44	25.66	25.89	26.12	26.35	26.57	26.80	27.03
K (KTonnes)	94.84	96.58	97.45	98.32	99.19	100.06	100.92	101.79	102.66	103.53
N (KTonnes)	148.47	151.19	152.55	153.91	155.27	156.64	158.00	159.36	160.72	162.08
CO2 (KTonnes)	4123.95	4199.57	4237.35	4275.14	4312.92	4350.76	4388.54	4426.32	4464.16	4501.94
CH4 (KTonnes)	2291.08	2333.09	2354.08	2375.07	2396.06	2417.08	2438.07	2459.06	2480.08	2501.07
Land (1000 has)	902.50	902.50	902.50	902.50	902.50	902.50	902.50	902.50	902.50	902.50
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2142.90	-2132.13	-2121.36	-2110.59	-2099.81	-2089.05	-2078.29	-2067.52	-2056.74	-2045.98
Petrol (TJ)	-2916.91	-2902.26	-2887.59	-2872.93	-2858.26	-2843.61	-2828.96	-2814.31	-2799.64	-2784.98
Av Fuel (TJ)	-178.57	-177.68	-176.78	-175.88	-174.98	-174.09	-173.19	-172.29	-171.40	-170.50
Indirect Energy										
Coal (TJ)	-333.39	-331.72	-330.04	-328.36	-326.69	-325.01	-323.34	-321.66	-319.99	-318.31
Natural Gas (TJ)	-921.16	-916.53	-911.90	-907.27	-902.64	-898.01	-893.39	-888.76	-884.13	-879.50
Oil (TJ)	-1456.27	-1448.96	-1441.63	-1434.32	-1426.99	-1419.68	-1412.36	-1405.05	-1397.72	-1390.41
Electricity (TJ)	-587.83	-584.88	-581.92	-578.97	-576.01	-573.06	-570.11	-567.16	-564.20	-561.25
Gas (TJ)	-236.87	-235.68	-234.49	-233.30	-232.11	-230.92	-229.73	-228.54	-227.35	-226.16
Emissions										
CO (KTonnes)	25.24	25.12	24.99	24.86	24.74	24.61	24.48	24.36	24.23	24.10
CO2 (KTonnes)	79.21	78.81	78.42	78.02	77.62	77.22	76.82	76.43	76.03	75.63
NO (KTonnes)	2.72	2.70	2.69	2.68	2.66	2.65	2.63	2.62	2.61	2.59
SO (KTonnes)	0.37	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.35	0.35
Particulate (KTonnes)	0.88	0.87	0.87	0.86	0.86	0.85	0.85	0.84	0.84	0.84
Hydrocarbon (KTonnes)	3.07	3.06	3.04	3.03	3.01	3.00	2.98	2.97	2.95	2.94
INDICATORS										
Economic Viability	1.07	1.07	1.07	1.07	1.07	1.06	1.06	1.06	1.06	1.06
Energy Productivity	1.01	1.01	1.02	1.02	1.03	1.03	1.03	1.04	1.05	1.05
Fertilizer Productivity	1.00	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.96	0.95
Farm Productivity Trend	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stocking Rate	2.78	2.81	2.83	2.86	2.88	2.91	2.93	2.96	2.98	3.01
OTHER VARIABLES										
Surplus (Income - Expenditure)	138.95	136.52	134.08	131.65	129.22	126.79	124.36	121.92	119.49	117.66
Productivity (kg MF/ha)	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27
Cow Productivity (kg MF/cow)	143.96	142.55	141.16	139.81	138.48	137.17	135.89	134.63	133.39	132.18
Stocking Rate (milkcow/ha)	2.55	2.58	2.60	2.63	2.65	2.68	2.70	2.73	2.75	2.78

Table A1-6

Scenario-2B

Successful GATT - with Pollution Abatement and Control

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1781.22	1799.57	1817.21	1834.85	1852.49	1870.14	1887.78	1905.42	1923.07	1940.71
Milkfat (KTonnes)	334.77	338.09	341.40	344.72	348.03	351.35	354.66	357.98	361.29	364.61
Electricity (M$)	-53.06	-53.58	-54.11	-54.63	-55.16	-55.68	-56.21	-56.73	-57.26	-57.78
Electricity (TJ)	-1877.20	-1895.78	-1914.37	-1932.95	-1951.54	-1970.13	-1988.71	-2007.30	-2025.88	-2044.47
Feeds (M$)	-155.90	-157.45	-158.99	-160.53	-162.08	-163.62	-165.17	-166.71	-168.25	-169.80
Feeds (KTonnes)	-637.61	-643.93	-650.24	-656.55	-662.87	-669.18	-675.49	-681.80	-688.12	-694.43
Fertilizer (M$)	-207.32	-209.38	-211.43	-213.48	-215.53	-217.59	-219.64	-221.69	-223.74	-225.80
Fertilizer (KTonnes)	-1056.17	-1066.62	-1077.08	-1087.54	-1098.00	-1108.45	-1118.91	-1129.37	-1139.82	-1150.28
Weed & Pests (M$)	-15.06	-15.21	-15.36	-15.51	-15.66	-15.80	-15.95	-16.10	-16.25	-16.40
Weed & Pests (KLiters)	-2.36	-2.39	-2.41	-2.43	-2.46	-2.48	-2.50	-2.53	-2.55	-2.57
Wages	-48.78	-49.19	-49.68	-50.16	-50.64	-51.12	-51.61	-52.09	-52.57	-53.05
Contribution to GDP	988.08	1007.96	1017.85	1027.73	1037.61	1047.49	1057.37	1067.26	1077.14	1087.02
Ecologic Inputs/Outputs										
BOD (KTonnes)	749.64	757.06	764.49	771.91	779.33	786.75	794.18	801.60	809.02	816.44
P (KTonnes)	25.00	25.25	25.50	25.75	26.00	26.24	26.49	26.74	26.99	27.23
K (KTonnes)	95.79	96.74	97.69	98.63	99.58	100.53	101.48	102.43	103.38	104.32
N (KTonnes)	149.95	151.44	152.92	154.41	155.89	157.38	158.86	160.35	161.83	163.32
CO2 (KTonnes)	4165.18	4206.40	4247.69	4288.91	4330.14	4371.37	4412.65	4453.88	4495.11	4536.33
CH4 (KTonnes)	2313.98	2336.89	2359.82	2382.73	2405.63	2428.53	2451.47	2474.37	2497.28	2520.18
Land (1000 has)	-911.53	-920.55	-929.58	-938.60	-947.63	-956.65	-965.68	-974.70	-983.73	-992.75
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2175.20	-2196.73	-2218.27	-2239.80	-2261.34	-2282.89	-2304.41	-2325.96	-2347.49	-2369.03
Petrol (TJ)	-2960.88	-2990.19	-3019.51	-3048.82	-3078.14	-3107.46	-3136.77	-3166.09	-3195.39	-3224.72
Av Fuel (TJ)	-181.27	-183.06	-184.86	-186.65	-188.45	-190.24	-192.03	-193.83	-195.62	-197.42
Indirect Energy										
Coal (TJ)	-338.42	-341.77	-345.12	-348.47	-351.82	-355.17	-358.52	-361.87	-365.22	-368.57
Natural Gas (TJ)	-935.05	-944.30	-953.56	-962.82	-972.08	-981.34	-990.59	-999.85	-1009.11	-1018.37
Oil (TJ)	-1478.23	-1492.86	-1507.50	-1522.13	-1536.77	-1551.41	-1566.04	-1580.68	-1595.31	-1609.95
Electricity (TJ)	-596.69	-602.60	-608.51	-614.42	-620.32	-626.23	-632.14	-638.05	-643.95	-649.86
Gas (TJ)	-240.44	-242.82	-245.20	-247.58	-249.96	-252.34	-254.72	-257.11	-259.49	-261.87
Emissions										
CO (KTonnes)	25.62	25.88	26.13	26.38	26.64	26.89	27.15	27.40	27.65	27.91
CO2 (KTonnes)	80.41	81.20	82.00	82.79	83.59	84.39	85.18	85.98	86.77	87.57
NO (KTonnes)	2.76	2.78	2.81	2.84	2.87	2.89	2.92	2.95	2.98	3.00
SO (KTonnes)	0.37	0.38	0.38	0.38	0.39	0.39	0.40	0.40	0.40	0.41
Particulate (KTonnes)	0.89	0.90	0.91	0.92	0.92	0.93	0.94	0.95	0.96	0.97
Hydrocarbon (KTonnes)	3.12	3.15	3.18	3.21	3.24	3.28	3.31	3.34	3.37	3.40
INDICATORS										
Economic Viability	1.07	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.05	1.04
Energy Productivity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fertilizer Productivity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Farm Productivity Trend	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stocking Rate	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
OTHER VARIABLES										
Surplus (Income - Expenditure)	137.54	133.61	129.56	124.42	121.16	116.81	112.35	107.79	103.12	98.35
Productivity (kg MF/ha)	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27
Cow Productivity (kg MF/cow)	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40
Stocking Rate (milking cow/ha)	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53

Table A1-5

Scenario-2A

Successful GATT - increasing activity of Dairy Farming

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1781.22	1799.57	1817.21	1834.85	1852.49	1870.14	1887.78	1905.42	1923.07	1940.71
Milkfat (KTonnes)	334.77	338.09	341.40	344.72	348.03	351.35	354.66	357.98	361.29	364.61
Electricity (M$)	-53.06	-53.58	-54.11	-54.63	-55.16	-55.68	-56.21	-56.73	-57.26	-57.78
Electricity (TJ)	-1877.20	-1895.78	-1914.37	-1932.95	-1951.54	-1970.13	-1988.71	-2007.30	-2025.88	-2044.47
Feeds (M$)	-155.90	-157.45	-158.99	-160.53	-162.08	-163.62	-165.17	-166.71	-168.25	-169.80
Feeds (KTonnes)	-637.61	-643.93	-650.24	-656.55	-662.87	-669.18	-675.49	-681.80	-688.12	-694.43
Fertilizer (M$)	-207.32	-209.38	-211.43	-213.48	-215.53	-217.59	-219.64	-221.69	-223.74	-225.80
Fertilizer (KTonnes)	-1056.17	-1066.62	-1077.08	-1087.54	-1098.00	-1108.45	-1118.91	-1129.37	-1139.82	-1150.28
Weed & Pests (M$)	-15.06	-15.21	-15.36	-15.51	-15.66	-15.80	-15.95	-16.10	-16.25	-16.40
Weed & Pests (KLiters)	-2.36	-2.39	-2.41	-2.43	-2.46	-2.48	-2.50	-2.53	-2.55	-2.57
Wages	-48.78	-49.19	-49.68	-50.16	-50.64	-51.12	-51.61	-52.09	-52.57	-53.05
Contribution to GDP	988.08	1007.96	1017.85	1027.73	1037.61	1047.49	1057.37	1067.26	1077.14	1087.02
Ecologic Inputs/Outputs										
BOD (KTonnes)	749.64	757.06	764.49	771.91	779.33	786.75	794.18	801.60	809.02	816.44
P (KTonnes)	25.00	25.25	25.50	25.75	26.00	26.24	26.49	26.74	26.99	27.23
K (KTonnes)	95.79	96.74	97.69	98.63	99.58	100.53	101.48	102.43	103.38	104.32
N (KTonnes)	149.95	151.44	152.92	154.41	155.89	157.38	158.86	160.35	161.83	163.32
CO2 (KTonnes)	4165.18	4206.40	4247.69	4288.91	4330.14	4371.37	4412.65	4453.88	4495.11	4536.33
CH4 (KTonnes)	2313.98	2336.89	2359.82	2382.73	2405.63	2428.53	2451.47	2474.37	2497.28	2520.18
Land (1000 has)	-911.53	-920.55	-929.58	-938.60	-947.63	-956.65	-965.68	-974.70	-983.73	-992.75
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2175.20	-2196.73	-2218.27	-2239.80	-2261.34	-2282.89	-2304.41	-2325.96	-2347.49	-2369.03
Petrol (TJ)	-2960.88	-2990.19	-3019.51	-3048.82	-3078.14	-3107.46	-3136.77	-3166.09	-3195.39	-3224.72
Av Fuel (TJ)	-181.27	-183.06	-184.86	-186.65	-188.45	-190.24	-192.03	-193.83	-195.62	-197.42
Indirect Energy										
Coal (TJ)	-338.42	-341.77	-345.12	-348.47	-351.82	-355.17	-358.52	-361.87	-365.22	-368.57
Natural Gas (TJ)	-935.05	-944.30	-953.56	-962.82	-972.08	-981.34	-990.59	-999.85	-1009.11	-1018.37
Oil (TJ)	-1478.23	-1492.86	-1507.50	-1522.13	-1536.77	-1551.41	-1566.04	-1580.68	-1595.31	-1609.95
Electricity (TJ)	-596.69	-602.60	-608.51	-614.42	-620.32	-626.23	-632.14	-638.05	-643.95	-649.86
Gas (TJ)	-240.44	-242.82	-245.20	-247.58	-249.96	-252.34	-254.72	-257.11	-259.49	-261.87
Emissions										
CO (KTonnes)	25.62	25.88	26.13	26.38	26.64	26.89	27.15	27.40	27.65	27.91
CO2 (KTonnes)	80.41	81.20	82.00	82.79	83.59	84.39	85.18	85.98	86.77	87.57
NO (KTonnes)	2.76	2.78	2.81	2.84	2.87	2.89	2.92	2.95	2.98	3.00
SO (KTonnes)	0.37	0.38	0.38	0.38	0.39	0.39	0.40	0.40	0.40	0.41
Particulate (KTonnes)	0.89	0.90	0.91	0.92	0.92	0.93	0.94	0.95	0.96	0.97
Hydrocarbon (KTonnes)	3.12	3.15	3.18	3.21	3.24	3.28	3.31	3.34	3.37	3.40
INDICATORS										
Economic Viability	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
Energy Productivity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fertilizer Productivity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Farm Productivity Trend	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stocking Rate	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
OTHER VARIABLES										
Surplus (Income - Expenditure)	141.62	141.84	142.03	142.20	142.35	142.47	142.57	142.65	142.71	142.78
Productivity (kg MF/ha)	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27
Cow Productivity (kg MF/cow)	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40
Stocking Rate (milkcow/ha)	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76

Table A1-7

Scenario-3A

Energy Insufficiency and Shift to Intensive Labour

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28	1764.28
Milkfat (KTonnes)	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46	331.46
Electricity (M$)	-52.00	-51.48	-50.95	-50.43	-49.90	-49.38	-48.85	-48.33	-47.80	-47.28
Electricity (TJ)	-1840.02	-1821.44	-1802.85	-1784.27	-1765.68	-1747.09	-1728.51	-1709.92	-1691.34	-1672.75
Feeds (M$)	-155.90	-157.45	-158.99	-160.53	-162.08	-163.62	-165.17	-166.71	-168.25	-169.80
Feeds (KTonnes)	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30	-631.30
Fertilizer (M$)	-207.32	-209.38	-211.43	-213.48	-215.53	-217.59	-219.64	-221.69	-223.74	-225.80
Fertilizer (KTonnes)	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71	-1045.71
Weed & Pests (M$)	-15.06	-15.21	-15.36	-15.51	-15.66	-15.80	-15.95	-16.10	-16.25	-16.40
Weed & Pests (KLiters)	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34
Wages	-49.19	-50.16	-51.12	-52.09	-53.05	-54.02	-54.98	-55.95	-56.91	-57.88
Contribution to GDP	989.16	990.13	991.09	992.06	993.02	993.99	994.95	995.92	996.88	997.85
Ecologic Inputs/Outputs										
BOD (KTonnes)	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22
P (KTonnes)	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76
K (KTonnes)	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84
N (KTonnes)	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47
CO2 (KTonnes)	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95
CH4 (KTonnes)	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08
Land (has)	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2132.12	-2110.59	-2089.05	-2067.52	-2045.98	-2024.44	-2002.91	-1981.37	-1959.84	-1938.30
Petrol (TJ)	-2902.24	-2872.93	-2843.61	-2814.31	-2784.98	-2755.66	-2726.36	-2697.03	-2667.73	-2638.41
Av Fuel (TJ)	-177.68	-175.88	-174.09	-172.29	-170.50	-168.70	-166.91	-165.11	-163.32	-161.52
Indirect Energy										
Coal (TJ)	-331.71	-328.36	-325.01	-321.66	-318.31	-314.96	-311.61	-308.26	-304.91	-301.56
Natural Gas (TJ)	-916.53	-907.27	-898.01	-888.76	-879.50	-870.24	-860.98	-851.72	-842.47	-833.21
Oil (TJ)	-1448.95	-1434.32	-1419.68	-1405.05	-1390.41	-1375.77	-1361.14	-1346.50	-1331.87	-1317.23
Electricity (TJ)	-584.88	-578.97	-573.06	-567.16	-561.25	-555.34	-549.43	-543.52	-537.62	-531.71
Gas (TJ)	-235.68	-233.30	-230.92	-228.54	-226.16	-223.78	-221.40	-219.02	-216.64	-214.25
Emissions										
CO (KTonnes)	25.12	24.86	24.61	24.36	24.10	23.85	23.59	23.34	23.09	22.83
CO2 (KTonnes)	78.81	78.02	77.22	76.43	75.63	74.83	74.04	73.24	72.45	71.65
NO (KTonnes)	2.70	2.68	2.65	2.62	2.59	2.57	2.54	2.51	2.48	2.46
SO (KTonnes)	0.37	0.36	0.36	0.36	0.35	0.35	0.34	0.34	0.34	0.33
Particulate (KTonnes)	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.79
Hydrocarbon (KTonnes)	3.06	3.03	3.00	2.97	2.94	2.90	2.87	2.84	2.81	2.78
INDICATORS										
Economic Viability	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.05	1.05	1.05
Energy Productivity	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10
Fertilizer Productivity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Farm Productivity Trend	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stocking Rate	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
OTHER VARIABLES										
Surplus (Income - Expenditure)	137.00	132.63	128.25	123.87	120.82	116.08	110.74	106.37	101.99	97.61
Productivity (kg MF/ha)	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27	367.27
Cow Productivity (kg MF/cow)	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40	145.40
Stocking Rate (milking cow/ha)	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53

Table A1-8

Scenario-3B

Technology Development

COMMODITIES	92	93	94	95	96	97	98	99	2000	01
Economic Inputs/Outputs										
Milkfat (M$)	1773.10	1781.92	1790.74	1799.57	1808.39	1817.21	1826.03	1834.85	1843.67	1852.49
Milkfat (KTonnes)	333.12	334.77	336.43	338.09	339.75	341.40	343.06	344.72	346.38	348.03
Electricity (M$)	-52.00	-51.48	-50.95	-50.43	-49.90	-49.38	-48.85	-48.33	-47.80	-47.28
Electricity (TJ)	-1840.02	-1821.44	-1802.85	-1784.27	-1765.68	-1747.09	-1728.51	-1709.92	-1691.34	-1672.75
Feeds (M$)	-152.82	-151.27	-149.73	-148.19	-146.64	-145.10	-143.55	-142.01	-140.47	-138.92
Feeds (KTonnes)	-624.99	-618.67	-612.36	-606.05	-599.74	-593.42	-587.11	-580.80	-574.48	-568.17
Fertilizer (M$)	-203.22	-201.16	-199.11	-197.06	-195.01	-192.95	-190.90	-188.85	-186.80	-184.74
Fertilizer (KTonnes)	-1035.25	-2024.80	-1014.34	-1003.88	-993.42	-982.97	-972.51	-962.05	-951.60	-941.14
Weed & Pests (M$)	-14.76	-14.61	-14.46	-14.13	-14.16	-14.02	-13.87	-13.72	-13.57	-13.42
Weed & Pests (KLiters)	-2.32	-2.29	-2.27	-2.25	-2.22	-2.20	-2.18	-2.15	-2.13	-2.11
Wages	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23	-48.23
Contribution to GDP	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20	988.20
Ecologic Inputs/Outputs										
BOD (KTonnes)	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22	742.22
P (KTonnes)	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76	24.76
K (KTonnes)	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84	94.84
N (KTonnes)	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47	148.47
CO2 (KTonnes)	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95	4123.95
CH4 (KTonnes)	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08	2291.08
Land (1000 has)	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50	-902.50
Other Energy Inputs										
Direct Energy										
Diesel (TJ)	-2132.12	-2110.59	-2089.05	-2067.52	-2045.98	-2024.44	-2002.91	-1981.37	-1959.84	-1938.30
Petrol (TJ)	-2902.24	-2872.93	-2843.61	-2814.31	-2784.98	-2755.66	-2726.36	-2697.03	-2667.73	-2638.41
Av Fuel (TJ)	-177.68	-175.88	-174.09	-172.29	-170.50	-168.70	-166.91	-165.11	-163.32	-161.52
Indirect Energy										
Coal (TJ)	-331.71	-328.36	-325.01	-321.66	-318.31	-314.96	-311.61	-308.26	-304.91	-301.56
Natural Gas (TJ)	-916.53	-907.27	-898.01	-888.76	-879.50	-870.24	-860.98	-851.72	-842.47	-833.21
Oil (TJ)	-1448.95	-1434.32	-1419.68	-1405.05	-1390.41	-1375.77	-1361.14	-1346.50	-1331.87	-1317.23
Electricity (TJ)	-584.88	-578.97	-573.06	-567.16	-561.25	-555.34	-549.43	-543.52	-537.62	-531.71
Gas (TJ)	-235.68	-233.30	-230.92	-228.54	-226.16	-223.78	-221.40	-219.02	-216.64	-214.25
Emissions										
CO (KTonnes)	25.12	24.86	24.61	24.36	24.10	23.85	23.59	23.34	23.09	22.83
CO2 (KTonnes)	78.81	78.02	77.22	76.43	75.63	74.83	74.04	73.24	72.45	71.65
NO (KTonnes)	2.70	2.68	2.65	2.62	2.59	2.57	2.54	2.51	2.48	2.46
SO (KTonnes)	0.37	0.36	0.36	0.36	0.35	0.35	0.34	0.34	0.34	0.33
Particulate (KTonnes)	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.79
Hydrocarbon (KTonnes)	3.06	3.03	3.00	2.97	2.94	2.90	2.87	2.84	2.81	2.78
INDICATORS										
Economic Viability)	1.08	1.08	1.09	1.10	1.10	1.11	1.12	1.12	1.13	1.14
Energy Productivity	1.02	1.03	1.05	1.06	1.08	1.10	1.11	1.13	1.15	1.17
Fertilizer Productivity	1.02	1.03	1.05	1.06	1.08	1.10	1.11	1.13	1.15	1.17
Farm Productivity Trend	1.01	1.01	1.01	1.02	1.03	1.03	1.04	1.04	1.05	1.05
Stocking Rate	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
OTHER VARIABLES										
Surplus (Income - Expenditure)	153.75	166.11	178.48	190.85	203.21	215.58	227.95	240.32	252.68	265.05
Productivity (kg MF/ha)	369.11	370.94	372.78	374.61	376.45	378.29	380.12	381.96	383.80	385.63
Cow Productivity (kg MF/cow)	146.13	146.85	147.58	148.31	149.03	149.76	150.49	151.21	151.94	152.67
Stocking Rate (milking cow/ha)	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53

Appendix 3

Graphical Illustrations of Some Indicator Behaviour in Different Scenarios

These figures graphically depict the numerical data contained in Appendix 1. The indicators *Farm Labour*, *Farm Size and Number* and *Stocking Rate* were not included since their values were too "high" (ie, including them in the figures would diminish the graphical significance of the other indicators). Nevertheless, notes are provided to indicate the behaviour of these higher-value indicators.

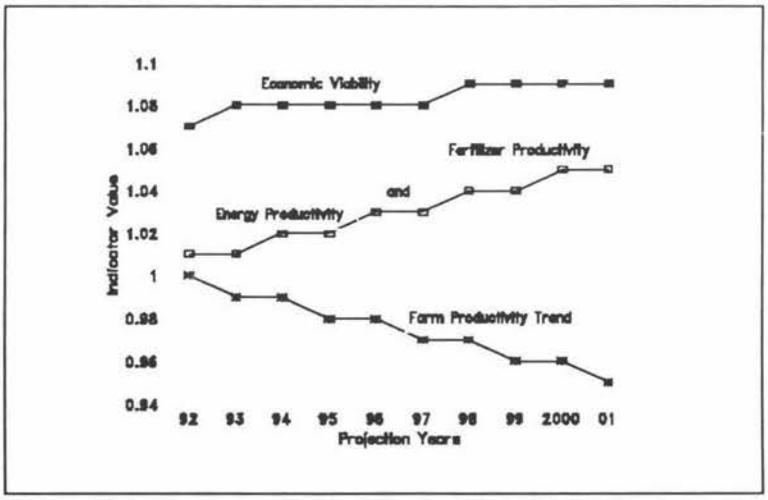

Figure A2-1 **Scenario-1A Business As Usual - to milk more cows per person, with more milk per cow**

Note: The indicators *Farm Labour*, *Farm Size and Number* and *Stocking Rate* were constant.

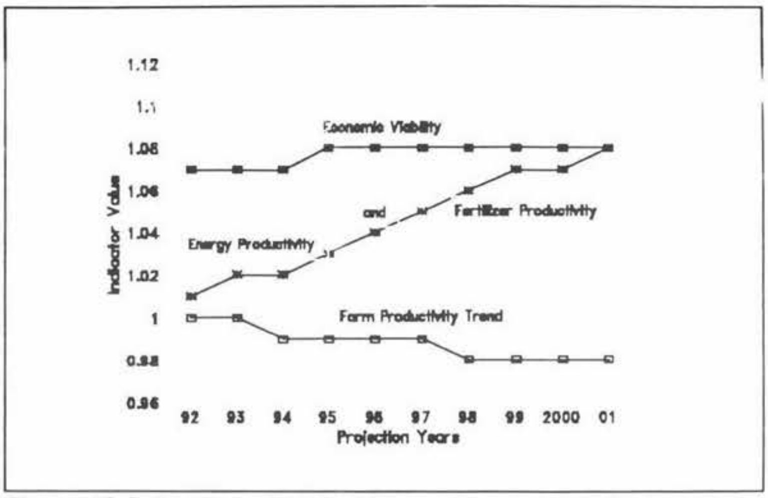

Figure A2-2 **Scenario-1B Business as Usual - to milk more cows, with less milk per cow without increasing the stocking rate**

Note: The Indicators *Farm Labour, Farm Size and Number* and *Stocking Rate* were constant.

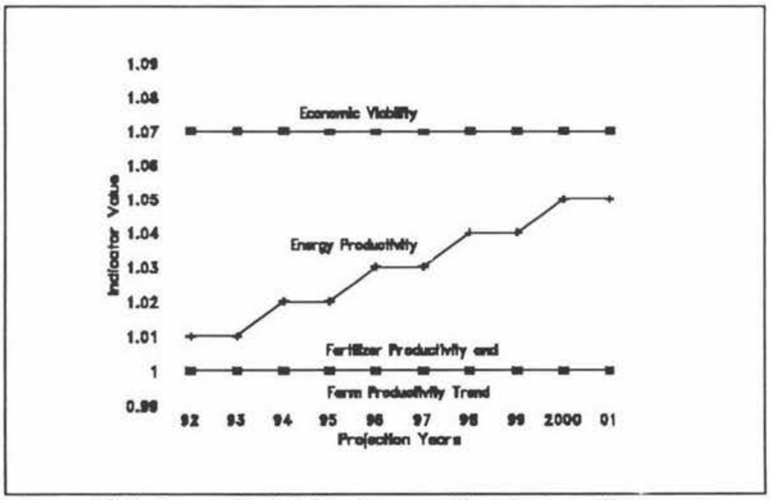

Figure A2-3 **Scenario-1C Business as Usual - to milk many more cows, with less milk per cow with increasing stocking rate**

Note: The indicators *Farm Labour* and *Stocking Rate* were increasing, while the *Farm Size and Number* remained constant.

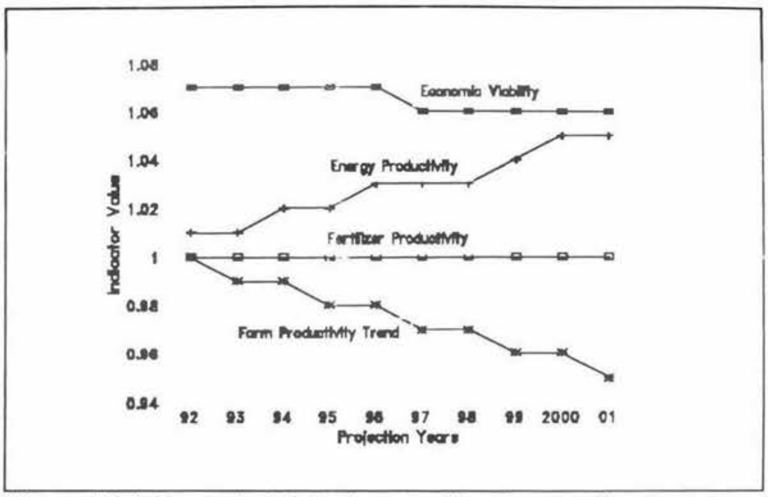

Figure A2-4 **Scenario-1D Business as Usual - to milk many more cows, with less milk per cow with increasing stocking rate and farm inputs**

Note: The indicator *Farm Labour* and *Stocking Rate* were increasing, while the *Farm Size and Number* was constant.

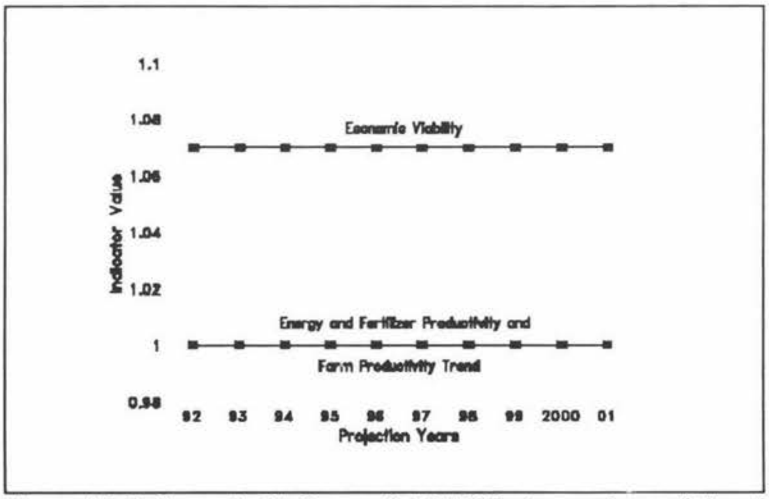

Figure A2-5 **Scenario-2A Successful GATT - increasing activity of Dairy Farming**

Note: The indicators *Farm Labour,* and *Farm Size and Number* were increasing, while *Stocking Rate* was constant.

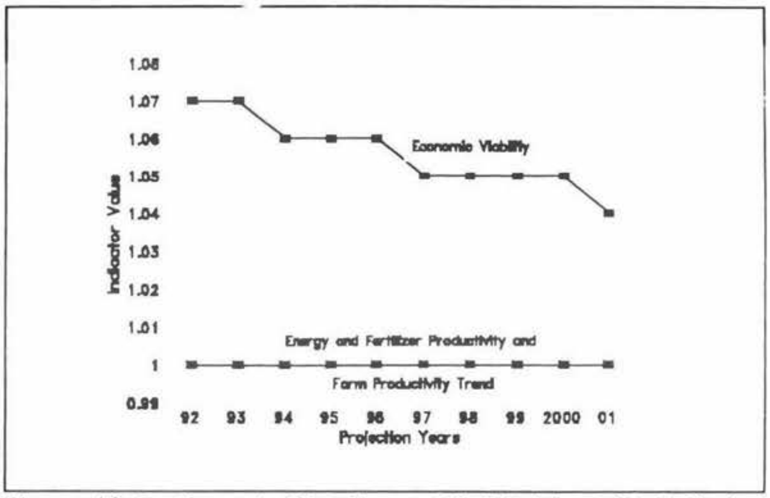

Figure A2-6 Scenario-2B **Successful GATT - with Pollution Abatement and Control**

Note: Both the indicators *Farm Labour* and *Farm Size and Number* were increasing, while the *Stocking Rate* was constant.

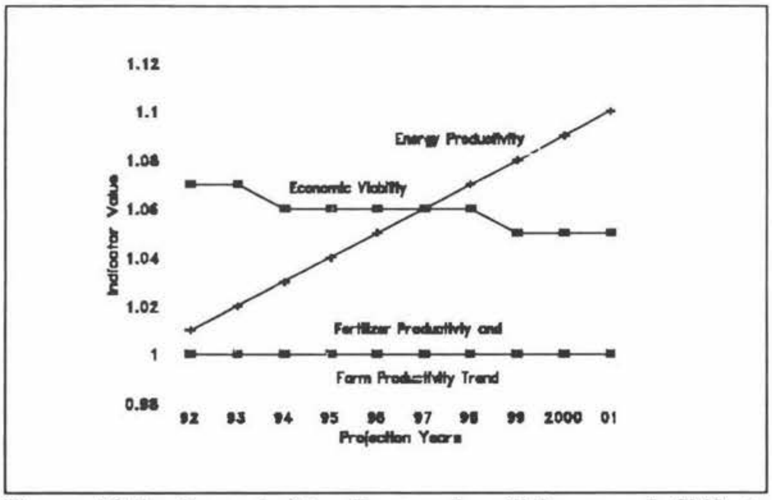

Figure A2-7 Scenario-3A **Energy Insufficiency and Shift to Intensive Labour**

Note: The indicator *Farm Labour* was increasing, while the *Farm size and Number* and *Stocking Rate* remained constant.

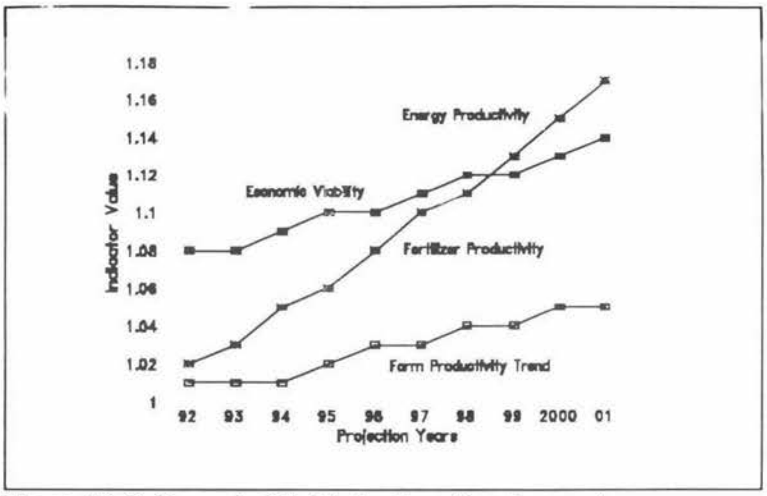

Figure A2-8 **Scenario-3B Technology Development**

Note: The indicators *Farm Labour*, *Farm Size and Number* and *Stocking Rate* remained constant.

Appendix 3

CONVERSION FACTORS AND COMPUTATIONS FOR THE INPUT-OUTPUT MODEL (Table 7.1)

Much of the data used in the Input-output model were not directly obtained from farm monitoring reports and data published by the Department of Statistics. Some data needed to be manipulated into a form suitable for inclusion in the Input-output model. This particularly applied to the physical data included in the Input-output, much of which needed to be estimated from data contained in the financial accounts of dairy farms and the New Zealand economy.

A. Conversion Factors for Quadrant I

Monetary entries in quadrant I of the Input-output model were directly obtained from Table A3-1. Whereas, the physical data in quadrant I of the model such as tonnes of fertilizer, were estimated from the monetary data. Table A3-2 summarises the conversion factors used to convert the monetary data into physical data. These conversion factors were calculated in the following way:

a - Cattle Sales for Mixed Aged Cows for Waikato Region[1]:

= 1/4($750.00 + $800.00 + $580.00 + $600.00)

= $682.50/head

---

[1] This formula calculates the mean of the four values for the price of cows as reported in the Financial Budget Manual (FBM). Similar calculations were undertaken for *b* to *f*.

Table A3-1

Financial Inputs in a Typical New Zealand Dairy Farm

	Northland Model	South Aucklan Waikato Mode	Bay of Plenty Model	Taranaki Model	Manawatu Tui Model	West Coast/ Nelson Model	Canterbury Model	Southland/ Otago Model
OUTPUTS								
Milkfat Sales	92970.00	143637.00	116150.00	135841.00	143525.00	107220.00	173745.00	108755.00
Dairy Cattle Sales	17796.00	31200.00	21650.00	23195.00	23195.00	20553.00	42500.00	22360.00
Others	500.00	0.00	0.00	0.00	0.00	0.00	0.00	600.00
Total Outputs	111266.00	174837.00	137800.00	159036.00	166720.00	127773.00	216245.00	131715.00
INPUTS								
Physical Inputs								
Cattle Purchases	800.00	1400.00	800.00	1500.00	800.00	450.00	600.00	800.00
Electricity	3600.00	4185.00	4650.00	4000.00	3200.00	2600.00	3172.00	3800.00
Feeds	3600.00	12714.00	16500.00	13650.00	9350.00	6000.00	16000.00	7740.00
Fertilizer	15200.00	15799.00	13160.00	16979.00	12936.00	15043.00	17170.00	11414.00
Seeds	1200.00	1200.00	1000.00	200.00	500.00	700.00	1250.00	300.00
Weed & Pest	1300.00	1300.00	1500.00	400.00	1000.00	1100.00	1700.00	800.00
Services								
Animal Health	4600.00	6700.00	4500.00	4100.00	3700.00	3000.00	6345.00	3840.00
Breeding	2800.00	3460.00	4600.00	3300.00	3300.00	3500.00	3750.00	1600.00
Dairy Shed Expenses	2420.00	2500.00	2000.00	1850.00	2000.00	1700.00	4085.00	2200.00
Freight	800.00	800.00	1100.00	800.00	675.00	1200.00	750.00	750.00
Administration	8890.00	11120.00	9500.00	9100.00	10600.00	8400.00	6100.00	6700.00
Wages (Labour)	2050.00	4140.00	4000.00	500.00	4500.00	7000.00	15000.00	1400.00
Repair & Maintainance	7000.00	9300.00	4500.00	10000.00	9500.00	5300.00	10000.00	8000.00
Vehicles	7500.00	9900.00	10000.00	6000.00	7500.00	7000.00	9500.00	8500.00
Others	500.00	1200.00	0.00		2000.00	1000.00	4000.00	500.00
Total Farm Expenses	72379.00	85718.00	77810.00	72379.00	69561.00	63993.00	99422.00	58344.00
Debt Servicing	22263.00	29973.00	29442.00	31862.00	20919.00	20217.00	36217.00	31360.00
Development	0.00	0.00	0.00	0.00	5000.00	0.00	0.00	0.00
Capital Purchases	0.00	5000.00	0.00	10000.00	10000.00	2000.00	12500.00	6000.00
Reinvestment	0.00	5000.00	0.00	10000.00	15000.00	2000.00	12500.00	6000.00
New Borrowing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Off-Farm Income	1000.00	0.00	0.00	0.00	900.00	0.00	0.00	0.00
Capital Introduced	1000.00	0.00	0.00	0.00	900.00	0.00	0.00	0.00
Current Account	17624.00	54146.00	30548.00	44795.00	62140.00	41563.00	68106.00	36011.00

a. Data are from various Farm Monitoring Reports covering the 1991/92 season.

Table A3-2

Conversion Factors from Financial into Physical Input and Output in a Dairy Farm

Description	Unit	Northland Model	South Auckland/ Waikato Model	Bay of Plenty Model	Taranaki Model	Tui Model	West Coast/ Nelson Model	Canterbury Model	Southland/ Otago Model
Dairy Cattle Sale	$/cow	682.50 a	357.50 b	357.50	750.00 c	875.00	800.00 d	750.00 e	850.00 f
Dairy Cattle Purchase	$/cow	682.50 a	682.50 a	682.50 b	608.33 c	608.33	800.00 d	750.00 e	850.00 f
Fertilizer (g)	$/tonne	193.00	193.00	193.00	193.00	193.00	366.44 h	202.00	191.00
Seeds (i)	$/kg	5.15	5.15	5.15	5.15	5.15	5.15	5.15	5.15
Feeds (j)	$/bale	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Weed and Pest (k)	$/l	11.15	11.15	11.15	11.15	11.15	11.15	11.15	11.15
Productivity (l)	t/ha/yr of DM	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
DM Consumption (l)									
Lactating	kg/day/cow	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Dry	kg/day/cow	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
DM Wastes (m)									
Lactating	kg/day/cow	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Dry	kg/day/cow	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Oxygen Intake (l)	l/day/cow	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00
CO2 Exhaled (l)	l/day/cow	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00
CH4 Emission (l)	l/day/cow	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00

Note:

a. From Financial Budget Manual (FBM) 1992, p A-33, in the absence of available data, average for the Waikato Region was used.
b. Average price from MAF Farm Monitoring Report (FMR) North, p 16.
c. Computed average price for cows in the area. Value taken from FBM 1992, p A-34.
d. Average price of Otago and Canterbury, from FBM 1992, p A-34.
e. Average price from FBM 1992, p A-34.
f. From FBM 1992, p A-34, in the absence of available data average for the Canterbury Region was used.
g. Taken from Energy Prices and Taxes 1989, International Energy Agency OECD Paris, 1990.
h. Data from FBM 1992, p B-47, assuming a superphosphate fertilizer.
i. Average for Nitrogen-based fertilizer ($41.60 is added per tonne for fertilizer in bag). Data from FBM 1992, p B-48.
j. Data from FBM 1992, p B-67. Value is from the average price for Ryegrass and Clover White grass.
k. Assuming that bales of hay are used for feed supplement - personal communication with C.W. Holmes, Animal Science Department, MU.
l. Estimated value from FBM 1992 for MCPA and 2,4-D, the most commonly used weedicide and pesticide according to A.I. Popay (1985).
m. Estimated value from Brookes (1990) and personal interview with C.W. Holmes, Animal Science Department, M.U.

b - Prices for Cull Cows:

= 1/4($370.00 + $420.00 + $265.00 + $375.00)

= $357.50/head

c - Dairy Herd Clearing Sales:

= 1/4 ($650.00 + $700.00 + $800.00 + $850.00) (winter 91 & 92)

= $750.00/head

d - Average for cows in Canterbury and Southland

= 1/2($750.00 + $850.00)

= $800.00/head

f - Mixed Age Friesian Cows

= 1/2($900.00 + $800.00)

= $850.00/head

h - Average Price for Fertilizer:

average (for fertilizer in bags):

= 1/2($588.00 + $645.00) + $41.60

= $658.10/tonne

total average (taken in bulk purchase):

= 1/7($658.10 + $251.00 + $242.00 + $283.00 + $274.00 + $408.00 + $448.00)

= $366.44/tonne

i - Pasture Seeds:

Ryegrass + White Clover

= 1/4($1.20 + $4.00 + $4.80 + $10.60)

= $5.15/kg

r - Estimated value for MCPA and 2,4-D, the most commonly used weedicide according to Popay (1985)

From FBM (1992) pp B-73 to B-74

2,4-D amine (40) = $178.00/20 litre

2,4-D butyl ester (72) = $192.00/litre

2,4-D butyl ester (72) = $193.00/litre

2,4-D (20) = $21.00/litre

average = $12.29/litre

MCPA (20) = $306.00/20 litre

MCPA (37.5) = $94.00/20 litre

average = $10.00/litre

total average:

= 1/2($12.29 + $10.00)

= $11.15/litre

B. Conversion Factors for Quadrant II

Conversion of the 1987 interindustry transactions matrix into the year 1992 involves the following computations:

All figures in the 1987 New Zealand inter industry transactions were updated according to the following procedure:

1. Convert to $1986/87 -> $1991/92

Table A3-3 is used as a reference in the following conversions:

Using the GDP figures (in million $)

	Constant $82/83	Current	Inflation since 1982
1986/87	34,824	55,088	1.5818975[2]
1991/92	34,140	73,312	2.1473931[3]

Inflation since 1987 = 2.1473931/1.5818975

Inflation since 1987 = 1.3574793

By multiplying all the figures in the inter industry transaction by the value 1.3574793, all the $ values will now be in 1991/92.

2. Scale up the 1986/87 Inter Industry Transaction Table (now in $1991/92) to 1991/92

---

[2] from 55,088/34,824

[3] from 73,312/34,140

Table A3-3

Contribution to Gross Domestic Product
at Constant 1982-83 Prices by Production Group

	Production Group	Year Ended March		
		1979	1987	1992
1	Agriculture	1594	2589	2723
2	Fishing and Hunting	60	102	135
3	Forestry and Logging	284	376	489
4	Mining and Quarrying	349	577	755
5	Food, Beverages and Tobacco	1769	2176	2099
6	Textiles, Apparel and Leather	661	841	587
7	Wood and Wood Products	399	469	409
8	Paper, Printing and Publishing	739	1044	1000
9	Chemicals, Petroleum, Plastic	653	803	706
10	Non-metallic Mineral Product	299	424	246
11	Basic Metal Industries	276	307	521
12 + 13	Machinery, Metal Products, Misc.	1617	1980	1423
14	Electricity, Gas and Water	831	1139	1149
15	Building and Construction	1644	1804	1199
16	Trade, Restaurants and Hotels	6199	6452	6176
17	Transport and Storage	1631	1962	2127
18	Communications	745	1232	1676
19	Finance, Insurance, etc.	3151	4600	4990
20	Owner-occupied Dwellings	1128	1321	1454
21 + 24 + 25	Community and Personal Services	1389	1704	1698
22 + 23	General Government Services	3947	4075	3878
	Gross Domestic Product	28759	34824	34140

Source: Department of Statistics (1992 pers. comm.)

Each column should be multiplied by the factor:

$$\frac{\text{GDP Sector Contribution (1991/92)}}{\text{GDP Sector Contribution (1986/87)}}$$

As a general example, take the output of agriculture to agricultural sector itself which is equivalent to $M5566 in the 1986/87 inter industry transactions table. In order to update it into 1991/92 equivalent taking into account the inflation, it should be multiplied by the factors 1.3574793[4] and (2723[5]/2589[6]) (see footnotes 3,4 and 5).

In other words $5566 in the 1986/87 inter industry is equal to:

= 5566 * (1.3574793) * (2723/2589)

= $M7946.79 in 1991/92 inter industry transactions

Other columns (ie, sectors) should be multiplied by their corresponding GDP sector contributions.

C. Conversions in Quadrant III

These computation were made to estimate the ecological inputs and outputs in a typical New Zealand dairy farm.

1. Computation for BOD (Biological Oxygen Demand) in a typical dairy cattle:

From Taiganides (1987) p96, BOD for dairy cattle is equal to 0.18 kg/APU-d (kilogram per Animal Production Unit per day). For a typical New Zealand dairy

---

[4] inflation since 1987

[5] 1992 GDP contribution of Agriculture in constant 1982 $

[6] 1987 GDP contribution of Agriculture in constant 1982 $

cattle with a livewieght of 450.00 kgs:

$BOD = 0.18 * 4.50$ kg/cattle/day

$BOD = 0.81$ kg/cattle/day

2. For Phosphorous (P) in Cattle Excreta

$P = 0.006 * 4.50$ kg/cattle/day

$P = 0.027$ kg/cattle/day

3. For Potassium (K) in Cattle Excreta

$K = 0.023 * 4.50$ kg/cattle/day

$K = 0.1035$ kg/cattle/day

4. For Nitrogen (N) in Cattle Excreta

$N = 0.036 * 4.50$ kg/cattle/day

$N = 0.162$ kg/cattle/day

As a typical example computation for the BOD in the Northland Region for the Season 1991/92:

$BOD = (a + b + c) * d *$ (365 days/year) $* e * 1/1000$

where:

a = number of cows to calve

b = other cattle in the farm

c = cattle purchase

d = BOD in cattle excreta in Kg/day

e = number of farms in the region in thousand

therefore,

BOD = (160 + 0 + 1.17) * 0.81 * 365 * 1.685 *1/1000

BOD = 88.87 kilotonnes

Computations for other nutrients (eg, P,K and N) follow similar procedure. Also, dairy cow 'emissions' of CO_2 and CH_4 which has a corresponding value of 4,500 and 2,500 litres/day respectively can be computed following the same procedure.

D. Computations for Quadrant IV

These involve the energy inputs and resultant emission from the New Zealand economy.

1. Energy Inputs in New Zealand Economy

Energy consumption for the New Zealand economy of 1987 was obtained from Massey University's (1992) End-Use Database. To update this into the 1991/92 base year, each sector was also multiplied by the ratio of its GDP contribution for the year 1991/92 and GDP contribution for the year 1981/82. Thus in the agricultural sector for example, for the year 1982, it consumed 2040.04 terajoules of electricity equivalent to 2040.04 * (2723/2015) = 2756.84 terajoules in the year 1992.

2. Energy requirements in Dairy Farming

a) Direct Energy

From Patterson and Earle (1985, p8), dairy farming energy requirements (TJ/yr) in the year 1978/79 were,

	Fuel	Electricity	Other	Total
Factory Supply	2742	934	100	3776
Town Supply	642	154	18	814
Total	3384	1088	118	4590

Fuel and Others = 3384 + 118

Fuel and Others = 3502

convert to 1992 level using the GDP in Agriculture (refer to Table A3-3).

Electricity = 1088 (2723/1594)

Electricity = 1858.61 TJ/yr

Fuel and Others = 3502 (2723/1594)

Fuel and Others = 5982.40 TJ/yr

Using the percentage composition for fuel and others by Massey University Agronomy Department (1983):

Petrol = 49% (5982.40)

Petrol = 2931.38 TJ/yr

Diesel = 36% (5982.40)

Diesel = 2153.66 TJ/yr

Aviation Gas = 3% (5982.40)

Aviation Gas = 179.47 TJ/yr

b) Indirect Energy

Using data from Baines and Peet (1989):

Coal = 2098.44[7] * (1/2.38)[8] * (0.38)[9]

Coal = 335.05 TJ

Natural Gas = 2098.44 * (1/2.38) * (1.05)

Natural Gas = 952.78 TJ

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[7] Output of dairy farming in M$.

[8] Inflation adjustment factor.

[9] Indirect energy consumption coefficient for 1981/82 in MJ/$.

Electricity = 2098.44 * (1/2.38) * (0.67)

Electricity = 590.74 TJ

Oil = 2098.44 * (1/2.38) * (1.66)

Oil = 1463.62 TJ

Gas = 2098.44 * (1/2.38) * (0.27)

Gas = 238.06 TJ

3. Emissions resulting from the Energy Consumption

Emissions for the New Zealand Economy were computed from the following table.

Table A3-4

Emission Factors (tonnes/petajoule)

Fuel	Carbon Monoxide	Nitrogen Oxide	Sulfur Oxides	PParticulates	Hydro-carbons
Coal	56.13	268.54	258.80	2381.97	17.93
Crude Petroleum	1034.35	4.76	39.64	4.61	16.61
Wood (Black Liquor)	61.73	308.66	46.30	848.83	61.73
Natural Gas	0	92.50	0	0.04	0.08
Town Gas	11.21	239.49	3.52	14.20	8.42
Automotive Gasoline	8025.00	394.28	31.40	41.87	697.84
Automotive Diesel Oil	189.11	698.64	126.07	346.70	428.12
Furnace Oil	12.35	203.58	741.28	66.77	8.11
Heating Oil	13.14	214.17	156.80	47.34	9.21
Aviation Gasoline	8025.00	394.28	31.40	41.87	697.84
Refinery Fuel (LPG)	7.20	59.32	27.79	7.89	1.43
Electricity	0	0	0	0	0

Source: James (1982)

Table A3-5

Carbon Dioxide Emission Factors

Fuel	Emission (kg CO_2/gigajoule)
Natural Gas (reticulated)	15.00
Oil Products (average)	19.00
Coal	25.40
Electricity	
Gas (New Plymouth)	54.30
Coal (Meremere)	107.90
Oil (Marsden)	69.70
LPG (includes flaring)	18.60
Petrol	18.30

Source: Ministry for the Environment (1990)

As a particular example, take the case of Carbon Monoxide and Carbon Dioxide emissions for the Agricultural Sector:

$$\begin{aligned}\text{Carbon Monoxide emission} = {} & [(a/1000 * b) + (c/1000 * d) + (e/1000 * f) + \\ & (g/1000 * h) + (i/1000 * j) + (k/1000 * l) + (m/1000 * n) + \\ & (o/1000 * P) + (q/1000 * r) + (s/1000 * t)]\ 81/1000\end{aligned}$$

where:

a = CO emission factor for electricity (tonnes/PJ)

b = electricity consumption (TJ)

c = CO emission factor for crude petroleum (fuel oil) (tonnes/PJ)

d = fuel oil consumption (TJ)

e = CO emission factor for diesel oil (tonnes/PJ)

f = diesel oil consumption (TJ)

g = CO emission factor for automotive gasoline (tonnes/PJ)

h = petrol consumption (TJ)

i = CO emission factor for aviation gas (tonnes/PJ)

j = aviation gasoline consumption (TJ)

k = CO emission for natural gas (tonnes/PJ)

l = natural gas consumption (TJ)

m = CO emission factor for LPG (tonnes/PJ)

n = LPG consumption (TJ)

o = CO emission for coal (tonnes/PJ)

p = coal consumption (TJ)

q = CO emission for wood (black liquor) (tonnes/PJ)

r = wood fuel consumption (TJ)

s = CO emission factor for CNG (tonnes/PJ)

t = CNG consumption (TJ)

therefore,

Carbon Monoxide = [(0/1000 * 2756.84) + (0/1000 * 0) + (189.11/1000 * 8664.02) + (8025/1000 * 13184.31) + (8025/1000 * 285.14) + (0/1000 * 209.35) + (7.20/1000 * 0) + (56.13/1000 * 0) + (61.73/1000 * 0) + (0/1000 * 0)] * 1/1000

Carbon Monoxide = 109.73 kilotonnes

Carbon Dioxide emission will be:

Carbon Dioxide = [(77.30[10] * 2756.84) + (19.00 * 0) + (25.40 * 0) + (15.00 * 209.35) + (18.60 * 0) + (18.30 * 13184.31)] * 1/1000

Carbon Dioxide = 457.52 kilotonnes

The computations for other emissions follow similar procedure.

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[10] Average for electricity consumption.