EFFECTS OF GOVERNMENT PROGRAMMES ON SUSTAINABLE AGRICULTURE IN THE PEACE RIVER REGION OF BRITISH COLUMBIA: A LINEAR PROGRAMMING ANALYSIS

by

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ABSTRACT

Land is an essential resource for most types of agricultural production. Its continued productivity forms a significant part of the deliberations about sustainable agriculture. While discussing sustainable agriculture, this thesis focuses on government agricultural programmes that have influenced agricultural land use in the Peace River region of British Columbia. The general aim is to point out the relevant programmes that impede sustainability of agriculture.

We assume that farmers are continually making decisions about the optimal allocation of land so as to maximise present value of net farm incomes. A linear programme (LP) is one of the techniques of mathematical programming that can be used to maximise farm incomes. It is this technique that we employed to analyze effects of government agricultural programmes on land use as it pertains to crop and forage production in the Peace River region, where forages are assumed to be a derived demand for livestock production. Cultivation practices of summerfallow and continuous cropping are examined.

Parametric linear programming (PLP) is subsequently used to analyze other optimal land use scenarios by varying the LP's objective function coefficients. As well, other cases including the elimination or halving of government subsidies are also simulated and discussed. Furthermore, an attempt was made to simulate two other scenarios that deal with the removal of grains and summerfallow from lower quality land. The region's soil erosion problem was also simulated.

It was found, among other things, that four government agricultural programmes--Western Grain Stabilization Act, Special Canadian Grain Programme, Crop Insurance and Chemical Rebates--encouraged cultivation of marginal lands, which are more susceptible to erosion. For example, some 26% (comprising wheat and summerfallow) of the total farm acreage occurred on classes 4 and 5 land. Consequently, these programmes, as presently constituted, adversely impact on Peace River region's sustainable agriculture.

Cultivation of grains on only good quality lands resulted in a significant reduction of summerfallow and more intensive cropping, which will lead to less soil degradation in the region. This alternative programme also was observed to increase a farmer's income by about 4%, which can add a total of over $259,000 to the region's economy. As well, it can increase pasture to feed more than 15,600 beef cows, which will be a boon to the livestock industry in the region.

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LIST OF ACRONYMS, ABBREVIATIONS AND EQUIVALENTS

ALR	Agricultural Land Reserve
BCMAFF	B.C. Ministry of Agriculture, Fisheries and Food
CC	Continuous Cropping
CCNG	Continuous Cropping with No Government Subsidy
CCSG	Continuous Cropping with Some Government Subsidy
CLI	Canada Land Inventory
CWB	Canadian Wheat Board
FAO	United Nations Food and Agricultural Organization
FGMDP	Food Grain Market Development Programme
GNP	Gross National Product
GRIP	Gross Revenue Insurance Program
GSP	Gross Sustainable Productivity
IFOAM	International Federation of Organic Agriculture Movement
ISEW	Index of Sustainable Economic Welfare
LP	Linear Programming
NG	No Government Subsidy
NOG	No Grains on Land Classes 4 - 5
NOSF	No Summerfallow on Land Classes 4 - 5
NNW	Net National Welfare
PLP	Parametric Linear Programming
PRSCA	Peace River Soil Conservation Association
SCGP	Special Canadian Grains Programme
SG	Some Government Subsidy
SOE	State of the Environment

UN	United Nations
UNEP	United Nations Environment Programme
WCED	World Commission on Environment and Development
WGSA	Western Grain Stabilization Act

1 ACRE = 0.405 HECTARE

1 IMPERIAL TON = 0.907 METRIC TONNES

1 TON/ACRE = 2.242 TONNES/HECTARE

1 POUND = 0.454 KILOGRAM

1 FOOT = 0.305 METRES

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DEDICATION

To my beloved ma

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture plays a major role in British Columbia's economy; in 1988, for example, total farm cash receipts exceeded one billion dollars. A notable feature of B.C.'s agriculture is its diversity--over 80 different commodities are produced, including grains in the Peace River Country (*Quick Facts About British Columbia* 1989, p.20). About half of all agricultural products consumed by British Columbians is locally produced.

The Peace River region's agriculture plays a significant role in B.C.'s economy, a fact that influenced our decision to select the Peace River as the area for this study. Grains and oilseeds, mostly produced in the Peace River area, contributed $25.2 million and $24.9 million to B.C's farm cash receipts of $1,063.3 million and $1,178.8 million in 1987 and 1988, respectively (*B.C. Ministry of Finance and Corporate Relations* 1989, p.72).

In British Columbia, and thus in the Peace River region, farms are generally classified as either part-time or commercial, with the benchmark separating them set at gross sales of $25,000 (Agriculture Canada 1988, p.8). In 1981, part-time farms contributed only one percent to the average $30,000 family income (*ibid.*). Commercial farms (27 percent of B.C.'s farms) contribute some 74 percent to the province's farm cash receipts. Overall, the number of farms in the province is declining as monoculture and mechanization engender relatively larger farms, some of which gross over $250,000 annually (*ibid.*, p.9).

In this century, agriculture has generated surpluses that facilitated the growth and expansion of the economies of more developed countries (MDCs) such as Canada. In recent decades, however, agriculture has become largely characterized by monoculture (i.e., specialization) and intensive energy use.

Moreover, as Berry (1978) succinctly points out, "modern" agriculture has narrowly linked farm productivity to profits. Invariably, this has induced the view that the farm is like a factory, such that the land is "mined" instead of treated as a natural habitat. Consequently, traditional notions about farming have all but disappeared, leaving us with increasing land degradation instead of land nurturing.

This new phase of agriculture is "maintained by a highly complex system of farm implement and agrochemical industries, a highly developed marketing system, and government institutions" (Norgaard 1984, p.162). Examples of such institutions in Canada, as in many other more developed countries, are crop insurance, transportation subsidies, and other income support schemes.

Needless to say, "modern" agriculture also has been spurred by unprecedented technological innovations, some of which engendered more dependence on agrochemicals. For example, Brown and Young (1990) point out that between 1950 and 1989, world fertilizer use "increased from a meagre 14 million tons to an estimated 143 million tons" (p.67). Simultaneously, the public has increasingly been exposed to many chemicals, the side effects of which are hardly known by the scientific community. Some of these chemicals are toxic substances causing genetic damage (mutagens), birth defects (teratogens) and cancer (carcinogens).

Problems such as soil erosion and degradation, contamination of water tables, and hazards posed to consumers, farmers and farm-workers by farm chemicals have, in the wake of public concern for the environment, stimulated the concept of sustainable development. In part, this has been a reflection of humanity's failure to appropriately relate to the environment (van Kooten 1987). British Columbia is not immune to these problems. Chlorinated organics along with dioxins and furans from bleaching pulp mills, for example, have contributed to the deterioration of B.C. fish habitats. In fact, as a province deriving its livelihood from its natural resources, sustainable development is imperative.

Agriculturally, sustainable development often refers to low-input or eco-agriculture (Batie 1989). Underlying this approach is the conviction that humankind should change its relationship with the environment from that of "conquest and exploitation to that of co-operation and coexistence" (*ibid.*, p.1088). Many incidents and factors underscore the need for sustainable development. For example, agriculturally it has been documented that, due to lack of care or inappropriate treatment of land, 14.8 million acres world-wide are lost beyond reclamation, and a further 49.4 million acres annually become so impoverished that they are unprofitable to farm or graze (Postel 1988).

1.2 Problem Statement

This thesis focuses on government agricultural programmes that have encouraged and shaped the agricultural land use practices in the Peace River region. The general aim is to point out relevant programmes that encourage land degradation and adversely affect agriculture's sustainability.

We assume that farmers are continually making decisions about the optimal allocation of land so as to maximise the present value of net farm incomes subject to personal (e.g., survival, risk) and institutional (e.g., Canadian Wheat Board System) constraints. A linear programme (LP) is one of the techniques of mathematical programming that can be used to maximise farm incomes. The optimization tool of a linear programme (LP) model is, thus, formulated to examine effects of government agricultural programmes on land use as it pertains to crop and forages production in the Peace River region, where forages are assumed to be a derived demand for livestock production. Cultivation practices of summerfallow in crop rotations versus continuous cropping are examined.

Parametric linear programming (PLP) is subsequently used to analyze other optimal land use scenarios by varying the LP's objective function coefficients. This will shed light on issues such as what happens to optimal land use as government subsidies are cut or halved. Furthermore, an attempt is made to simulate two other scenarios: the removal of grains and summerfallow from lower quality land classes.

1.3 Outline of Thesis

The second chapter is devoted to a review of the literature, and is followed by a description of the study area: the Peace River region (Chapter 3). Chapter 3 focuses, among other things, on agriculture and land use in the region. Moreover, it examines the government programmes that have impacted on B.C.'s agriculture, with particular reference to the Peace River area. Chapter 4 begins with a brief description of linear programming (LP), followed by a discussion of previous LP applications to the Peace River region. Subsequently, an empirical LP model is formulated for the Peace River area. In Chapter 5, we present and examine the results of this LP model, along with the PLP simulated scenarios. Finally, Chapter 6 offers a summary and some concluding remarks.

CHAPTER 2

LITERATURE REVIEW

2.1 Background to Sustainable Agriculture

Agricultural research has come under increasing pressure to respond to the environmental concerns of the public, as well as farmers eager to reduce farm operating expenses by resorting to low-input farming methods. Sustainable agriculture has, thus, become an emerging area of intense research. Although environmental protection is not a new phenomenon, the 1980s did particularly focus attention on agriculture's sustainability. Indeed, this concern is no longer subsidiary to short-term economic calculations.

Precipitating this interest in sustainability issues is the realization that agriculture's resource base--the physical environment of land, water, and air--is in peril and, in spite of modern agriculture's "successes", it has over-simplified the complex natural ecosystem that it evolved from, which has caused many environmental problems. For instance, it has increased the incidence of recognized pests and diseases (Hodges and Scofield 1983).

Furthermore, agricologenic (farmer-induced) diseases along with soil erosion and salinization have intensified. Reasons given for these problems include introduction of foreign factors into the ecosystem through, for example, the application of synthetic pesticides, and the tendency of farms to "bypass many of the processes that are normally associated with soil fertility" (Hodges and Scofield 1983, p.20).

Concern for ecological balance, if any, becomes a secondary issue in calculations of farm productivity or profitability. For example, van Kooten, Weisensel and Chinthammint (1990) concluded from their study of soil conservation in Saskatchewan that, though farmers profess interest in soil stewardship, changes in agronomic practices to achieve it were not observable yet.[1] This is in spite of their finding that stewardship requires only a minimal (less than 5 percent) decrease in net returns (*ibid.*, p.112).

Environmental quality and conservation have been the topics of numerous international conferences. Four such conferences were organized under the auspices of the International Federation of Organic Agriculture Movement (IFOAM), which exists primarily to promote the goal of eliminating inorganic fertilizers and synthetic pesticides in favour of dependence on organic materials and natural pest controls.[2]

The IFOAM conferences considered various ways to make agriculture sustainable through efficient resource use, lower production costs and enhanced environmental protection.

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[1]Stewardship connotes using soil without decreasing its long-term productivity.

[2]The first conference was held at Sissach (Switzerland) in 1977, with subsequent ones held at Montreal in 1978, Brussels in 1980 and Massachusetts in 1982.

Nevertheless, no one single practice was recommended as a panacea but suggestions made included integrated pest management as an alternative to widespread use of insecticides. Moreover, polycultures, involving crop rotations and intercropping, were recommended to improve current practices. Andow (1983) indicated that crop diversification is "promising as polycultures often yield better than monocultures per unit of land area" (p.94), for reasons that include reduced incidence of diseases and better usage of the natural soil variability.

At a 1978 conference in Prince Edward Island (PEI), Hill (1978) rightly pointed out the need to understand that "any species including our own survives on the basis of nature. It is our biology and our interaction with the supporting environment that determines our survival" (p.175). Unfortunately, farm productivity hardly distinguishes farm practices that degrade from those that sustain the ecology. As a result, modern agricultural indicators show growth without any acknowledgement of its environmental costs such as soil erosion.

In the U.S., where there is not as much dearth of soil erosion research, 2.2 billion tons of topsoil was estimated in 1983 to have been lost from croplands (Soule, Carre and Jackson 1990). It is further noted that "the average *official* tolerable losses of 5 tons/acre for deep soils and of 1 ton/acre for shallow soils were violated," (*ibid.*, p.167).[3] Overall, the U.S. is said to have lost

[3]See van Kooten and Furtan (1987) for an overview of the pertinent U.S. studies, along with Canadian ones.

at least a third of its cropland top soil, while the world is losing 14.1 billion tons per annum (Tivy 1990, p.244).

In Canada, concern for diminishing arable land and soil degradation were the bases of a study commissioned by the Canadian Environmental Advisory Council in 1983. The resulting report by Bentley and Leskiw (1985) pointed out, among other things, that soil erosion with its associated sediment pollution in water and air, salinization, and soil compaction are causing the destruction of the country's most productive farmlands. In the Prairies, for example, millions of acres of once-cultivated land have been abandoned as farmlands (*ibid.*, p.1). Agriculture's sustainability is thus a major concern.

It must be borne in mind, however, that there is no consensus among researchers on the severity of soil degradation (van Kooten and Furtan 1987).

2.2 Concepts and Definitions

World concern for the environment was apparent in the 1970s, as the 1972 U.N. Conference on the Environment and the subsequent genesis of the U.N. Environment Programme (UNEP) attest. A world conference was also convened at Nairobi in 1977 to discuss degradation of agricultural lands. The Food and Agriculture Organization (FAO) at its 21st Session in 1982 followed up by adopting a World Soil Charter, with provision to implement a World Soils Policy. This involves, for example, the adoption of good land husbandry encouraged by a sound institutional framework.

It was not until 1983, however, that the worsening situation prompted the United Nations General Assembly to ask for a World Commission to propose long-term strategies to achieve sustainable development by the year 2000 and beyond. With the release in April 1987 of the report of the World Commission, chaired by Gro Harlem Brundtland, Prime Minister of Norway, sustainable development became a popular concept.

The World Commission on Environment and Development (WCED) averred that "the environment does not exist as a sphere separate from human actions, ambitions, and needs..." (p.xi). In other words, environment and development are inseparable. Pointing out that many of the development paths of now industrialized countries are unsustainable, the Commission proposed sustainable development as an alternative. This concept was defined as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (p.8). Such development requires that countries pursue policies that will, for instance, develop agriculture along ecological principles.

Knowing that this might well become political rhetoric, the WCED called for action by proposing many legal principles, amongst which was the Principle for Conservation and Sustainable Use:"

> States shall maintain ecosystems and ecological processes essential for the functioning of the biosphere, shall preserve biological diversity, and shall observe the principle of optimum sustainable yield in the use of living natural resources and ecosystems (p.348).

In November 1987, the General Assembly of the UN adopted the *Environmental Perspective to the Year 2000 and Beyond*, which was prepared by the Intercessional Intergovernmental Preparatory Committee of the Governing Council of UNEP along with WCED. This exercise signalled a political acknowledgement of the inseparability of economic development from the environment. It meant, as the World Conservation Union (1989) rightly noted, that the "discussion is no longer about the importance of environmental [sic], but rather how development can be implemented within the limits of sustainable use of resources" (p.14).

Sustainable development is a descriptive term that captures the growing conviction that development must not be at the expense of the environment. It is a conviction that not only many political leaders of different stripes are articulating, but many programmes the world over (including those of international organizations, such as the World Bank) are incorporating.

The federal government of Canada released a *Green Plan* in 1990 that acknowledges sustainable development as a goal that Canadians should collectively strive to achieve. Described by the then Federal Minister of the Environment, Robert de Cotret, as "the most important environmental action plan ever produced in Canada" (p.3), the Green Plan commits the federal government to an environmental expenditure of $3 billion over a period of five years, in addition to the annual budget of $1.3 billion.

This comprehensive plan, supported by over 40 federal departments and agencies, recognizes the need for a concerted effort to address environmental problems. As part of the Green Plan's implementation, the federal government has introduced the

Canadian Environmental Assessment Act that obliges the government of Canada to "integrate environmental considerations into its project planning and implementation processes" (p.19). Currently, there are over 50 statutes with environmental implications in addition to legislations, with attendant regulations, by the provinces and Territories. With over 100 initiatives, the Green Plan--embodying economic incentives and stronger enforcement mechanisms--can make a significant contribution to sustainable development in Canada and, possibly, in the rest of the world.

In 1989, the U.S., Congress legislated an annual calculation of *gross sustainable productivity* (GSP), along with conventional economic indicators such as gross national product (GNP), beginning in 1990 (Brown 1990, p.9). Moreover, Careless (1990) notes that a 1988 joint study by the U.N. Environmental Programme and the World Bank proposed the notion of *sustainable income*, which expands the conventional economic definition of capital to include stocks of natural endowments. Other countries--including Indonesia--and major organizations such as the United Nations are currently revising their indices as well, while Japan and Norway initiated their revisions in the early 1970s (*ibid.*).

Generally in the revised national accounts, or what may be called *environmental accounting*, deductions are made for depreciation of environmental assets. Sustainability can (in this context) be narrowly defined as the balance between environmental depletion and investment in the environment.

Some countries, such as Canada, have resorted to periodical reports under the theme of *State of the Environment* (SOE). Of course, this underscores the realization that incorporating environmental indices into national accounts, albeit with great difficulties, has become paramount to the survival of humankind.

British Columbians have increasingly become aware that increases in the province's standard of living are threatened by environmental degradation. Consequently, the *British Columbia Round Table on the Environment and the Economy* chaired by Chuck Connaghan has been initiated to establish a framework in which environmental accounting can be commenced and sustainable development spurred.

Agriculturally, sustainable development presents challenges and opportunities for farmers, consumers and governments, not to mention academics. It compels us to re-appraise our institutions to ensure that those that hinder eco-agriculture are rectified. This re-orientation has sparked new research generally known in the agricultural economics literature as sustainable agriculture, defined by Hileman (1990) as:

> a systems approach to farming that seeks to develop a multiyear practice that takes advantage of whatever is produced or can be produced on the farm, including naturally occurring beneficial biological interactions to ensure soil fertility and to keep losses from pests, weeds, and animal diseases within acceptable levels. The aims are adequate productivity and profitability, conservation of resources, protection of the environment, and assured food safety (p.27).

It may have been noticed that different terms were used to describe sustainable agriculture. Indeed, there are many such terms that are used to denote the same idea. For example, "alternative agriculture", "low-input agriculture", "organic agriculture" and "eco agriculture" are sometimes used interchangeably with sustainable agriculture even though each may have some specific production requirements not shared with the others. None of these terms should be misconstrued as a resurrection of past or incompatible agricultural practices; rather, they signify attempts to synthesise contemporary and ancient methods to ensure that agriculture takes cognizance of the environment.

Sustainable development draws its intellectual wisdom from many disciplines including ethics and, as such, is amenable to diverse interpretations, with their concomitant disparate ramifications. As Batie (1989) rightly observes, some of its advocates even question the desirability of economic growth.

2.3 Neoclassical Economics and the Environment

Economists have attempted to incorporate the environment into the framework of neoclassical economics. For example, Turner (1988) suggests a working definition of sustainable development as "maximising the net benefits of economic development subject to maintaining the services and quality of natural resources over time" (p.352). Nonetheless, as he points out, there are two variants of economic modelling of environmental resources, "one more revisionist than the other in terms of the modifications required in the neoclassical blueprint" (p.354). The revisionists generally incorporate entropy limits into their economic analyses.

It is worth noting that neoclassical economists commonly dichotomize the focus on environment into nature (for amenity uses such as Parks), and what is imprecisely referred to as pollution (Fisher and Peterson 1976). It is the latter aspect of the environment that is the source of public exasperation, and the nucleus of this discussion.

Early economic thinkers about the environment, such as Marshall, spoke about the environment as external to production.[4] Subsequently, the notions of *private cost* and *social cost* were enunciated which, for policy purposes, implied that imposing taxes (often called Pigouvian) to equalize *marginal social cost* and *marginal private cost* will resolve the pollution problem. Hence, dealing with the "externality problem" became an extension of *price theory* in economics.

Given the collapse of major command economies in 1989 and the demise of the Soviet Union, many people believe that the efficiency of markets in allocating resources has been vindicated. Private enterprise though is found wanting in so far as resolving the increasing environmental calamity is concerned. In fact, Krutilla has indicated that "private market allocations are likely to preserve less than the socially optimal amount of the natural environment" (Fisher, Krutilla and Cicchetti 1972, pp.605-606).

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[4]See Fisher and Peterson (1976) for a survey of environment in economic analysis.

This is exacerbated by the fact that some environmental degradation is very difficult, if not impossible, to reverse. Others, including Nobel laureate Arrow (1985), have alluded to the limitations of the price system in dealing with environmental problems, while even the notion of externality has been critiqued (e.g., Scitovsky 1954 and Bator 1958).

Another major argument advanced against total reliance on private markets to solve environmental problems is the notion of *option demand*, defined by Krutilla (1967) as "a willingness to pay for retaining an option to use an area or facility that will be difficult or impossible to replace and for which no close substitute is available," (p.780). As well, there is the concept of *existence demand*, sometimes referred to as *intrinsic demand*, described by Johansson (1990) as the derivation of satisfaction from the pure fact that an asset is available for other people living now or unborn. The individual in this case may or may not utilize the asset or its services. Markets for these demands are not impeccably operational as they are bedeviled by difficulties associated with public goods such as the free rider problem.

An equally important factor, perhaps, is the fact that neoclassical economists mostly operate in the positive economics arena, with little or no reference to normative economics.

Environmental economics, with its roots in neoclassical economics, continues to grow with, as Winpenny (1991) notes, the underlying rationale of market failure due to factors such as public goods. As well environmental economists tend to accept that "the workings of markets do not always achieve the most efficient allocation of resources due, for instance, to the existence of monopolies and imperfect information among consumers" (*ibid.*, p.2).

Techniques of economic valuation such as cost-benefit analysis and cost-effectiveness analysis are grappling with environmental accounting and its complexities. These include ignorance about the effects of programmes or projects, and the task of valuation and quantification of costs and benefits even if known. The increasing use of Environmental Impact Assessment by countries, private companies and international organizations are attempts to ensure that development and the environment are not separated.

Sustainable development, albeit with its present amorphousness, means to address the need for humanity to have a harmonious relationship with the environment. It is a new thinking that requires us to eliminate the chasm between nature and humankind. This new thinking also understands, among other things, that "our economic cosmos is not one of uniform circular motion of commodities among men but one of elliptical orbits through interdependent ecological sectors" (Daly 1968, p.400). Its a new thinking that draws insights from many disciplines and accepts the premise that unfettered private enterprise does not adequately protect our environment.

2.4 Towards Sustainable Agricultural Development

The intractability of environmental problems has not prevented researchers such as Smith (1968) and Burt (1981) from grappling with optimality of intertemporal natural resource allocation, while some, including Fisher, Krutilla and Chicchetti (1972), have grappled with both theoretical and empirical questions associated with environmental preservation. Others, such as Potter and Christy (1962), and Ruttan (1971), have put their confidence in technology to redress environmental predicaments. Ruttan (1971), for instance, argues that:

> The advance of science and technology has enabled modern society to achieve a more productive and better balanced relationship to the natural world than in the ancient civilizations or in the earlier stages of Western civilization (p.708).

Acknowledging, however, that environmental deterioration had reached an alarming proportion even two decades ago, Ruttan urged that institutional and technical change should be redirected to enhance the performance of the ecosystem. This is especially pertinent in view of how our institutional web of laws and policies have undervalued the environment.

Ruttan's remedial measures include concentration on institutional changes to achieve decentralized decision-making such that property rights will be established within what he called environmental subsystems, wherein market forces will direct production and services. He also views a re-organization of the socio-political environment as imperative, since the private sector has no incentive to invest in the research needed to spur the changes required and the public sector traditionally lacks support for such research.

The need to integrate economics into an ecological paradigm is reiterated by Daly (1968), who avers that "the entire physical environment is capital on which the hierarchy of life depends" (p.397). Imploring that elements of this environment (air, water and soil) should be cared for in the same way that we care for other machines, he outlined a model he calls the "total economy", which is an extension of Leontief's input-out model that incorporates the human economy into the economy of nature. In its simplest version, his model has four quadrants representing human and non-human sectors. While Daly's model has practical problems associated with it (e.g., measuring the non-human sector), it is yet another attempt to grapple with the notion of sustainable development.

Calculation of GSP and other environmentally-oriented indices are attempts to address this problem by countries and/or organizations. For example, in Japan a *Net National Welfare (NNW)* index is calculated annually to adjust the country's GNP. NNW primarily corrects for environmental problems, such as water contamination, by making deductions for pollution and losses due to urbanization (Careless 1990, p.9). Norway, noted as the premier initiator of environmental accounting, regularly reevaluates both its renewable and non-renewable resources to take cognizance of environmental degradation and resource enhancement in the national accounts.

Synthesizing Daly's 1968 ideas, Daly and Cobb (1989) developed yet another model that defines a welfare index based on social, economic and environmental considerations, which they called the

Index of Sustainable Economic Welfare (ISEW). This index appraises many factors including automobile use and loss of valued habitats (e.g., wetlands). Though their index is a remarkable one, its complexity and scope makes it difficult, if not impossible, to practically compute; hence, it may never be conjectured in environmental accounting.

With respect to agriculture, Hileman (1990) notes that there are a variety of methods that contribute to sustainability of agriculture, including crop rotations, biological pest controls, and an amalgam of livestock and crops. The appeal of crop rotations is that they help to control pests and diseases. In the State of Washington, where some farmers actively practice alternative agriculture, Hileman notes that wheat root pathogens, for example, have been eliminated with three-year rotations involving barley and peas or lentils.

As well, she observes that "grain yields following a legume are usually greater than yields of grain planted as a continuous monoculture, no matter how much fertilizer is applied" (Hileman 1990, p.33). Manure and forage legumes also reduce water and wind erosion, while non-native predator pests and/or sterilized insect pests are part of integrated pest management programmes.

In recognition of the viability and the need for sustainable agriculture, the 1990 U.S. Farm Bill includes proposals, dubbed "positive incentives," to eliminate restrictions on polycultures, and give farmers the flexibility needed to grow different crops without loss of government benefits (Hileman 1990).

Contending that mechanical philosophy leaves the impression that technology, whether existing or not, will redeem us, van Kooten (1987) argues for a public philosophy for agriculture, which he integrates into a notion of stewardship, akin to coevolutionary development as enunciated by Norgaard (1984). This, he says, is the only relevant solution to our environmental degradation. He builds this notion into a socio-economic model for prairie agriculture, that encompasses religious communalism and requires what he calls "Agricultural Practices Councils" to be established in agricultural regions. These would have authority to enforce sustainable agriculture guidelines. His suggestions, radical as they may be, attempt to operationalize the notion of eco-agriculture by encouraging decision making at the local level as opposed to provincial or national level.

Upon reviewing prairie agriculture, van Kooten and Kennedy (1990) noted that soil degradation involving soil erosion and salinity is the main problem. They suggested practices such as crop diversification, greater reliance on management (flexcropping) and other applicable methods of low-input agriculture to rectify the problem.

The Peace River region manifests prairie agriculture and its attendant erosion problems. Indeed, the B.C. Ministry of Agriculture, Fisheries and Food (BCMAFF) noted in its Annual Report of 1984 that the Peace River soils are among the most erodible in North America (p.19). Hence, sustainable agriculture in the Peace River area, and for that matter in the rest of B.C., is essential if agriculture is to continuously contribute to the growth of the economy and increase standard of living in British Columbia.

CHAPTER 3

DESCRIPTION OF STUDY AREA AND PERTINENT GOVERNMENT PROGRAMMES

As much as government programmes have encouraged what is grown in the Peace River region, the influence of the natural habitat (including climate, soils and vegetation) certainly can not be ignored. As a result, this section presents a general overview of the study area. It is also intended to familiarize readers with the area, and to present the framework for the formulation of a linear Programme model.

3.1 Geography and Climate

The Peace River region is located in the north-eastern part of the province of British Columbia. It is bounded on the north and south by latitudes 58^0N and 55^0N, respectively, while the Alberta border is the eastern boundary and the Rocky Mountains border it on the west. This tends to isolate it from the rest of British Columbia. The total land area of the region, as reported by the Statistics Canada 1986 Agriculture Census, is some 48.2 million acres. This region is interspersed with timber, rocks, lakes and rivers.

The Peace River demarcates the area into the North, with Fort St. John as the main urban centre, and the South, with Dawson Creek as the paramount urban centre. The northern plateau has an altitude not exceeding 1,000 feet above sea level in some parts, while the south is generally some 2,500 feet above sea level (Graham and Lopez 1976, p.9).

Climatically, the area resembles much of the Prairies, but it has generally milder summers and relatively colder winters. During the winter warm Chinook winds that blow can lead to snowmelt and, consequently, soil erosion problems; cold arctic air may also induce frosts in the summer. The frost-free period varies significantly amongst areas; for example, Dawson Creek and Fort St.John have 78 days and 115 days, respectively, as Table 3.1 shows.

Table 3.1 Average Frost-Free Period in Selected Towns of the Peace River Area

Station	Height (feet above M.S.L.)	Frost-Free Period (Days)
Dawson Creek	2,148	78
Fort Nelson	1,253	106
Fort St. John	2,280	115

Source: Environment Canada (1982). Canadian Climate Normal, Volume 6, Frost: 1951 - 1980.

Total precipitation in the region shows that summer is the wettest, with July having an average precipitation of over 70 mm in Dawson Creek, Fort Nelson and Fort St. John (see Table 3.2). The region is classified as having moderate precipitation. The principal streams and rivers are inaccessible due to deep valleys and so obtaining water for even domestic use could be a problem.

The farming community therefore tends to depend on dams or "dugouts".

Considering the Peace River region's climate, it has been observed that the three main climatic factors--rainfall, temperature and wind--vary significantly within and between years. Hence, agricultural production is more uncertain relative to most other regions in British Columbia (Graham and Lopez 1976, p.12).

Table 3.2 Average Total Precipitation 1951-80 in Selected Towns of the Peace River Area (mm)

	Dawson Creek	Fort Nelson	Fort St. John
January	36.1	24.9	35.6
February	28.9	19.5	27.3
March	30.6	24.4	29.7
April	19.0	16.7	21.5
May	35.2	41.7	38.9
June	72.8	69.1	68.0
July	70.8	84.3	77.1
August	68.9	61.2	60.3
September	41.5	41.6	39.2
October	30.9	24.3	27.7
November	29.6	22.7	31.2
December	39.4	21.4	36.1
Year	503.7	451.8	492.6

Source: Environment Canada (1982). Canadian Climate Normals, Volume 3, Precipitation: 1951-1980

3.2 Soil and Vegetation

Many soils are found in the region. Classification of these soils at the Great Group Level include Dark Gray Solod and Orthic Gray Luvisol (see Agriculture Canada 1986). The soils generally have moderate drainage capabilities but rapidly drained ones such as Neumann soil are also present in the region. Soil formation in the area is low due partly to the region's cold climate and the fact that the soils generally are shallow.

Indigenously, the Peace River's vegetation consists of Park or Woodland. The wooded areas have an undergrowth that is excellent for grazing livestock in the summer months. There is a dense forest containing merchantable white spruce and lodgepole pine in the South. Through burning, vegetation in a significant part of the open areas has become typical prairie.

Soil erosion, especially that by water and wind, bedevil the area. This is due in part to the impervious subsoil. Sheet and gully erosion are present even on the slightest slopes of the summerfallowed lands. In fact, the area has been identified as having "the highest erosion risk in all reporting regions in British Columbia" (Van Vliet and Hall 1991, p.2). Consequently, the area's T-value (tolerable soil loss) is low; it is about 2 tons/acre. Largely as a result of this problem and other non-land sustaining practices, the Peace River Soil Conservation Association (PRSCA) was established in 1986 by some grain farmers in the area.

3.3 Agriculture and Land Use

Settlement in the Peace River region was undertaken by fur traders in the 1790s. The subsequent Klondike gold rush, coupled with the introduction of the railway and the construction of the Alaska Highway in 1942, stimulated further settlement.

Agriculture, the backbone of the region's economy, was largely subsistence prior to the first World War. Production occurred around trading posts such as Dawson Creek and consisted of fruits, vegetables, a bit of grain and livestock (B.C. Department of Lands and Forests 1952, p.15).

Livestock farming initially constituted the major land use in the area but, by 1939, grain farming (dominated by wheat until the 1970s) had become the primary activity. Since grain farming was practised by people mostly from the southern Prairies, the agronomic methods used in the Peace River region were akin to the prevailing southern prairie practices. In view of varying land fertility and climatical inconsistencies, grain quality and yield vary enormously. Wheat yields initially averaged about 30 bu/acre on the black soils of the Peace River area, and about 50 percent less in the gray-wooded (gray luvisolic) areas. In 1990, wheat yielded 40 bu/acre (Statistics Canada, Grain Trade in Canada).

Land use in the Peace River area shows that, of the region's 48.2 million acres, area in farms constituted 1.7 million acres in 1971 and 2.2 million acres in 1986 (Table 3.3). It is also shown by Table 3.3 that improved farmland increased in a decade (1971-1981) by 171,048 acres, or 22.5%, while, in the same period, unimproved land declined by 58,421 acres, or some 6.4%.[5] However,

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[5]Agriculture Canada classifies unimproved land as native pasture or hay land that had not been cultivated, grazing and waste land, rocky land, marsh, etc.

Table 3.3 Peace River Land Use: Census Years (Acres)

	1971	1976	1981	1986
Total Land Area	48,199,680	48,199,680	48,199,680	48,199,680
Improved Farmland	761,107	1,853,256	932,155	1,008,644
Unimproved Farmland	907,966	793,130	849,545	1,168,067
Area in Farms	1,669,680	1,060,126	1,781,704	2,176,711

Sources: BCMAFF (1982), pp. 16-17; BCMAFF (1980), pp. 15-16; Statistics Canada, Agriculture Census, B.C. 1986, Catalogue # 96-112.

Table 3.4 Peace River Principal Crop Acreage: 1979-90 ('000)

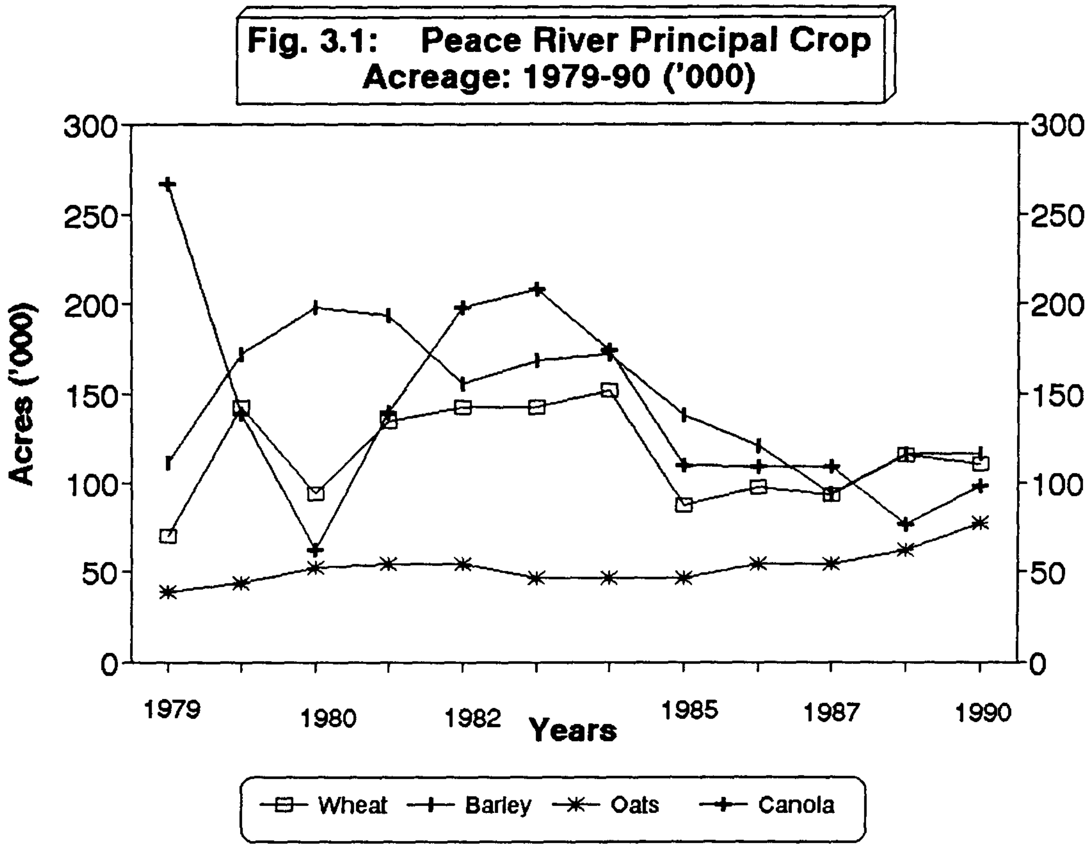
Year	Wheat	Barley	Oats	Canola	*Total*	*As % of Total Acreage*			
						W	*B*	*A*	*C*
1979	71.3	111.8	38.9	267.4	*489.4*	*14.6*	*22.8*	*8.0*	*54.6*
1980	142.5	171.9	43.8	138.7	*496.9*	*28.7*	*34.6*	*8.8*	*27.9*
1981	94.4	197.8	53.0	62.4	*407.6*	*23.2*	*48.5*	*13.0*	*15.3*
1982	134.2	193.4	54.5	139.4	*521.5*	*25.7*	*37.1*	*10.5*	*26.7*
1983	142.9	155.1	54.5	198.1	*550.6*	*26.0*	*28.2*	*9.9*	*36.0*
1984	142.9	167.9	46.8	207.9	*565.5*	*25.3*	*29.7*	*8.7*	*36.8*
1985	151.7	172.1	46.8	173.7	*544.3*	*27.9*	*31.6*	*8.6*	*31.9*
1986	88.0	138.1	46.8	110.1	*383.0*	*23.0*	*36.1*	*12.2*	*28.7*
1987	97.9	121.1	54.5	108.9	*382.4*	*25.6*	*31.7*	*14.3*	*28.5*
1988	93.5	94.6	54.5	108.9	*351.4*	*26.6*	*26.9*	*15.3*	*31.0*
1989	115.7	116.0	62.5	76.8	*371.0*	*31.2*	*31.3*	*16.8*	*20.7*
1990	111.3	116.0	78.1	99.1	*404.5*	*27.5*	*28.7*	*19.3*	*24.5*
Ave.	115.5	146.3	52.9	140.9	*455.7*	*25.4*	*32.3*	*12.1*	*30.2*

W = wheat; B = barley; A = oats; C = canola
Source: Author's calculations from B.C. figures obtained from Statistics Canada, 1986 Agriculture Census, Catalogue # 96-112; Catalogue # 22-002; Catalogue # 22-201. Based on Statistics Canada's indication that, in 1986, acreages for wheat, barley, oats and canola were 89%, 86%, 78% and 99%, respectively, of the B.C. total.

improved farmland decreased by some 49.7% from 1976 to 1981, while unimproved farmland increased by 7.1%. Between 1971 and 1986, improved and unimproved farmland increased by 32.5% and 28.7%, respectively. In this period (1971-1986) area in farms increased by 30.4%, as agriculture continues to expand into more remote areas with the support of various government programmes.

Acreage of the principal crops (wheat, oats, canola and barley) in the Peace River region is presented in Table 3.4. It shows that, between 1979 and 1990, total acreage averaged 455,700 acres. Barley had the largest average share (32.3%), of the total acreage, followed by canola (30.2%), wheat (25.4%), and oats (12.1%). Acreage for all four crops vacillated during this period (see Figure 3.1). For example, barley ranged from a high of 197,800 acres in 1981 to a low of 94,600 acres in 1988. Similarly, canola varied from its high of 267,400 acres in 1979 to a low of 62,400 acres in 1981; wheat's acreage spanned from a high 151,700 acres in 1985 to only 71,300 acres in 1979. The acreage of wheat shows the largest oscillation followed by canola, while oats exhibits hardly any swings (see Figure 3.1).

These swings may be attributable to grain prices and CWB quota incentives that encourage expansion of grain acreage (see section 3.4). Between 1979 and 1990, the largest total acreage for these four primary crops in the Peace River occurred in 1984 with the latter part of the 1980s accounting for the lowest acreages (Table 3.4). The on-going grain "subsidy war" between the U.S. and the European Community, which commenced in 1985 and has resulted in record low world grain prices certainly was instrumental in depressing grain acreages in the Peace River region.



In terms of production, barley generally ranked as the premier crop between 1979 and 1990 followed by wheat. They averaged about 148,800 tons (about 41%) and 107,290 tons (about 29%), respectively (Table 3.5). The average total production of these four crops was 368,400 tons, with the largest of 488,900 tons in 1980 and the smallest of 319,900 tons in 1981. Canola's average output was the third largest (about 16%), though it generally had the second largest average acreage (about 30%) in the region.

Table 3.5 Production of Principal Crops in the Peace River Region: 1979 - 90 ('000 Tons)

Year	W	B	A	C	*Total*	*As % Total Production* W	*B*	*A*	*C*
1979	80.1	119.7	43.8	133.7	*377.3*	*21.2*	*31.7*	*11.6*	*35.4*
1980	166.9	208.5	51.7	61.9	*489.0*	*34.1*	*42.6*	*10.6*	*12.7*
1981	85.4	167.2	42.5	24.8	*319.9*	*26.7*	*52.3*	*13.3*	*7.7*
1982	90.7	179.5	55.7	54.5	*380.4*	*23.8*	*47.2*	*14.6*	*14.3*
1983	125.6	175.4	57.6	62.2	*420.8*	*29.8*	*41.7*	*13.7*	*14.8*
1984	101.0	134.6	42.1	62.2	*339.9*	*29.7*	*39.6*	*12.4*	*18.3*
1985	80.4	109.0	31.8	31.6	*252.8*	*31.8*	*43.1*	*12.6*	*12.5*
1986	82.4	164.9	49.0	54.6	*350.9*	*23.5*	*47.0*	*14.0*	*15.5*
1987	104.0	129.9	58.5	62.2	*354.6*	*29.3*	*36.6*	*16.5*	*17.5*
1988	114.8	121.3	67.9	64.4	*368.4*	*31.2*	*32.9*	*18.4*	*17.5*
1989	122.6	138.4	70.2	37.1	*368.3*	*33.3*	*37.6*	*19.1*	*10.1*
1990	133.4	136.5	86.2	42.1	*398.2*	*33.5*	*34.3*	*21.6*	*10.6*
AVE.	107.3	148.8	54.7	57.6	*368.4*	*29.0*	*40.6*	*14.9*	*15.6*

W = wheat; B = barley; A = oats; C = canola
Source: Author's calculations from B.C. figures obtained from Statistics Canada, 1986 Agriculture Census, Catalogue # 96-112; Catalogue # 22-002; Catalogue # 22-201. We assumed that, of B.C.'s total production, Peace River accounted for: wheat 89%, barley 86%, oats 78% and canola 99%; these were the respective shares in acreage in 1986.

Table 3.6 Peace River Livestock Production: Census Years

Livestock	1971	1976	1981	1986
Dairy cows	1,692	1,999	2,699	1,669
Beef cows	11,037	25,764	31,825	31,767
Calves	9,744	21,820	28,559	29,001
Horses	4,090	4,833	7,723	8,017
Pigs	12,759	5,123	15,125	12,192
Sheep	5,672	9,807	8,256	7,028

Sources: BCMAFF (1982), pp. 36-41; BCMAFF (1980), pp. 25-28; Statistics Canada, Agriculture Census, B.C. 1986, Catalogue # 96-112.

Livestock accounts for not an insignificant amount of land use in the Peace River region. It is especially prevalent in the areas characterized by native pastures and low quality grain. Hogs initially were the major livestock raised, but beef cow production is now the main activity of the non-grain farmer. For example, in 1986, 31,767 beef cows and 12,192 pigs were raised (Table 3.6).

In view of intense pressure on farmlands, by developments in urban areas for example, "legislation was put in place in 1974 (under a New Democratic Party government) which placed the majority of the higher quality land in the province in an Agriculture Land Reserve (ALR)" (Agriculture Canada 1983, p.21). However, provision was made to allow some of the reserve land to be exempted from agriculture use upon request to the Land Commission.

The area of land in each Canada Land Inventory (CLI) class and the proportion in ALR in the Peace River region is indicated by Table 3.7. The quality of land (i.e., capability to support field crops) is inversely related to land class (see Appendix C for a description of land classes). It must be pointed out that the CLI classifications have some anomalies. For example, "the improved rating does not indicate that it is either technically or economically possible or desirable to drain or irrigate the land " (Agriculture Canada 1983, p.22). The ALR generally excludes land in CLI classes 5 - 7; this is indicated by the relatively minimal proportion of these land classes in the ALR (Table 3.7).

Based on the 1986 area in farms and the proportion of improved CLI in the ALR, the author estimated that over 500,000 acres in each of land classes 1 - 4 were under cultivation in the Peace River region in 1988 (Table 3.7). Class 5 land cultivated was 94,200 acres, while less than 15,000 acres of classes 6 and 7 land was under cultivation (Table 3.7). The "small" area of classes 5 -

7 land under cultivation stems from the "biases" in the designation of ALR noted above. More "poorer" land classes are cultivated than our calculations suggest.

Table 3.7 Area in CLI Agricultural Land Class and ALR, 1988 ('000 Acres)

Class	CLI Unimpr	CLI Impr	ALR	Cultivation*
1	9.4	9.5	8.8	515.5
2	299.2	299.0	279.9	520.6
3	902.7	925.6	832.5	500.2
4	1,239.0	1,323.3	1,250.2	525.4
5	4,162.6	4,934.4	835.8	94.2
6	1,465.1	1,412.8	38.0	14.9
7	3,705.8	2,870.3	29.7	5.9
Total	11,783.8	11,774.9	3,274.9	2,176.7

Notes: CLI = Canada Land Inventory
ALR = Agriculture Land Reserve
Impr = Improved
Unimpr = Unimproved

Improved and unimproved land each has an additional 40 million acres of water and other unclassified areas such as urban and unmapped zones, giving each a total of some 52 million acres.

* Author's 1986 Estimate. These were obtained by taking CLI improved farmland proportion in ALR, multiplied by the region's total area of farms (2.2 million acres) in 1986.

A description of the land classes is presented in Appendix C.

Sources: Agriculture Canada 1983, p.32
Agriculture Canada 1988, pp.24 - 25

In 1978, acreage by land class in the Peace River was outlined by the B.C. Select Standing Committee on Agriculture as shown in Table 3.8. It shows that grains are cultivated on classes 1 - 6 land, which suggests that some grains in the Peace River region are to be found on marginal land.

Table 3.8 Peace River Land Use by Land Class ('000 Acres)

	Land Class		
Activity	1 - 3	4 - 5	6
Grain and Forage	452.8	412.2	3.2
Grassland and Pasture	50.8	83.3	2.3
Forested range	147.1	410.0	6.8
Forested lands	460.8	1,163.0	26.0
Total	1,111.5	2,068.5	38.2

Source: Graham and Anderson (1982), p.49

Grain production has not ceased to be the mainstay of the economy of the region. In fact, most business activities in urban centres such as Dawson Creek and Fort St. John depend upon this primary activity. Nevertheless, other economic activities ranging from forestry to mining provide avenues for off-farm employment.

Summerfallow accounts for a large acreage in the Peace River region; it averaged over 200,000 acres (about 21%) between 1974 and 1982. Newly broken land averaged about 21,000 acres during the same period (Agriculture Canada 1983B). Large family farms dominate grain production in the region. Of the 700 grain farms, 35 percent were over 960 acres and they account for 75 percent of total output (Mcguire 1985, p.4).

3.4 Government Programmes Affecting Peace River Agriculture

Under Canada's constitutional provisions, both the federal and provincial governments have jurisdiction over agriculture. The government of British Columbia, through its Ministry of Agriculture, Fisheries and Food, administers 37 Acts (see Appendix B), while Agriculture Canada oversees 47 Acts (see Appendix A) on behalf of the federal government (Agriculture Canada 1988, p.48). Other provincial and federal ministries or departments, such as the B.C. Ministry of Forestry and Lands and Environment Canada, also offer programmes that impact on agriculture.

Federal programmes tend to focus on support services for agriculture and production efficiency, in addition to sustaining farms across the country. However, the federal government offers financial programmes, such as crop insurance, to protect farmers against losses due to factors including natural hazards and market conditions. Mortgage credit is even extended to farmers through the Farm Credit Corporation.

The federal government has sometimes also given out money in an ad hoc fashion. A case in point is an announcement in November 1991 of $800 million--farmers want at least double that amount--to help farmers cope with an on-going "subsidy war" started in 1985 between the US and the European Community (EC), which has resulted in record low grain prices. Since 1985 the federal government has contributed $12.6 billion to support farmers, while since 1986 the EC and the US government have paid $182 billion and $285 billion to their respective farmers (*The Vancouver Sun*, 1 November 1991, A15).

Provincial programmes are similarly oriented, and range from overseeing marketing boards and agencies, regulations to maintain high quality, extension services and financial assistance to facilitate farm investment and development.

Furthermore, joint federal and provincial institutions are occasionally established. A major recent example is the five-year (1985 - 1990) $40 million Agri-Food Regional Development Subsidiary Agreement (ARDSA), consisting of programmes for productivity enhancement, resource development and commodity development (Agriculture Canada 1988, p.47).

In the next section, we examine the major programmes of both levels of government that have shaped or developed the Peace River region's agriculture. As noted earlier, the Peace River area is the primary domain for the cultivation of cereals and oilseeds in B.C. As one of B.C.'s ten major commodities, grains accounted for some four percent of the province's total farm cash receipts in 1986. The total production of grains in the Peace River constitutes only two percent of western Canada's output of the four major grain crops--wheat, oats, barley and canola (Agriculture Canada 1988, p.74).

In the Peace River region, there was an annual acreage increase of some 21,000 acres that apparently came from marginal or unimproved land (see section 3.3). Government programmes have been largely responsible for the conversion of land into the production of grains, and the continued financial viability of grain farms in the Peace River region. Wheat grown in the Peace River region tends to be one grade lower in terms of quality relative to the rest of the prairies, but average yields are comparable. About 80 percent of the output in the region is sold through the Canadian Wheat Board (CWB). Since the primary mode of transport for the grains is rail, changes to the Crow Rate transportation scheme will impact on Peace River's grain production and expansion.

3.5 Review of Pertinent Government Programmes

Since its inception in 1935 and its designation in 1943 as the sole purchaser of prairie grains, the CWB has operated with a quota scheme that encourages conversion of unimproved land into grain production. As van Kooten and Kennedy (1990) point out, "CWB quota allocations are tied to the amount of improved land, thereby encouraging farmers to improve marginal land and increase the amount of grain they are permitted to deliver to the marketing system" (p.748).

The CWB system discourages grain producers from selling directly to the domestic feed market. In fact, livestock farmers had to pay premiums as high as $40/ton, until the 1974 new Feed Grains Policy was enacted to make feed grain competitive with corn in Montreal (Agriculture Canada 1983B). This policy favoured Eastern Canada over Western Canada, but it did not last long, being replaced by other forms of feed assistance to eastern livestock producers (e.g., Feed Freight assistance). Coupled with the fact that grain fed to livestock is excluded from calculations for government benefits under the 1949 Agricultural Stabilization Act, diversification of farms to include livestock for example and contribute to practices of sustainable agriculture has been hindered, if not discouraged.

Besides delivery of grains to the CWB, growers can sell directly to feed users, with assistance from the Livestock Feed Board of Canada's administered Feed Freight Assistance Programme (FFAP). With the exception of the Peace region itself, all areas of B.C.'s regional feed grain market qualify for assistance, and this assistance was extensively used in the early 1980s. Of the total expenditures of the feed freight subsidy programme, B.C.'s share increased from 18% in 1976/77 to 39% in 1981/82 (*ibid.*, p.5). Livestock production in the Peace River region was hampered by the Feed Freight Assistance Programme.

These increased expenditures for the provincial government were due largely to the relaxation of inter-provincial sales of feed grains. Factors such as the superior quality of prairie feed grains have adversely affected sales of the Peace River region's grains, the feed freight subsidy not withstanding. For example, more than 220,460 tons moved to southern B.C. from the Peace region prior to 1972, but, since 1974/75, the average has only been about 33,069 tons (*ibid.*, p.6). In response to the declining use of provincial feed grains, the B.C. government introduced the Feed Grain Market Development Programme (FGMDP), which provides an extra payment per ton for grain sold locally as feed. In 1989, about $1.8 million was paid under this scheme, an increase of some $20,000 over 1988 payments. While FGMDP may have boosted more consumption of local grains, it may also have supported grain production on marginal lands.

The provincial government also subsidizes B.C. Rail movement of grains from the Peace River region, comparable to the Crow Rate. A direct result is high farm gate prices for grain producers and an inherent inducement to cultivate unimproved land, which potentially subjects more areas to land degradation.

Another government programme that has encouraged grain production and cultivation of marginal land is the Western Grain Stabilization Act (WGSA) of 1976, which paid a net high of $5.2 million in 1986 to grain producers in B.C. (see Table 3.9). This Act, intended to stabilize net income, was amended in 1988 to cover an additional nine crops, including sunflower, but not leguminous crops that can also enhance soil fertility. It has now been replaced by the Gross Revenue Insurance Programme (GRIP).

The WGSA's implications for sustainable agricultural development were grim, since it not only fostered cultivation of unimproved land (van Kooten 1990), but no sustainable production practices of good husbandry such as grains cum legume rotation were recognized. Crops covered under this scheme induced the farmer to cultivate monoculturally. Moreover, the WGSA hampered diversification of farms. In the Prairies, for example, payments of WGSA alone skew production costs against diversifying wheat farms even though such an effort can be profitable.

In addition, the 1986 introduction of the Special Canadian Grains Programme (SCGP) to offset low international grain prices paid over $966 million country-wide in 1987, of which $5.5 million went to B.C., mostly to the Peace River area; the corresponding payments for 1988 were $1.1 billion and $6.6 million, respectively (see Table 3.9). This programme also stimulates extensive and intensive cultivation irrespective of any underlying calamitous environmental consequences.

Table 3.9 Net Direct Payments to B.C. Producers By Programme: 1971-89 ($ '000)

Year	WGSA	CI	CR	FUEL	SCGP
1971	0	787	82	0	0
1972	0	669	153	0	0
1973	0	75	73	0	0
1974	0	218	4	0	0
1975	0	-242	4	0	0
1976	-150	-604	6	84	0
1977	-168	235	3	895	0
1978	522	-265	6	986	0
1979	1,410	1,779	7	824	0
1980	-488	464	0	642	0
1981	-570	3,843	0	513	0
1982	-386	3,773	0	521	0
1983	-438	5,690	0	426	0
1984	1,188	7,878	0	443	0
1985	3,116	10,132	0	748	0
1986	5,217	10,871	0	1,287	0
1987	7,702	4,895	0	856	5,500
1988	3,222	3,004	0	1,010	6,612
1989	130	7,638	0	724	2

Notes: WGSA = Western Grain Stabilization Act;
CI = Crop Insurance; CR = Chemical Rebates;
SCGP = Special Canadian Grain Programme

Source: Agriculture Canada (1990). Farm Income and Financial Conditions and Government Expenditures.

The Crop Insurance Act was enacted in 1959 to provide all-risk coverage to farmers throughout the country. It undoubtedly precipitates reliance on monoculture, as it reduces risks associated with single-crop farming. Indeed, monoculture cropping practices have become more widespread in the last 10 to 15 years in the Peace River region (Van Vliet and Hall 1991). By providing coverage for monoculture involving summerfallow practice, it indirectly hastens land deterioration, since fallow speeds up soil erosion by wind, snowmelt and rain, and could contribute to soil salinity.

Moreover, crop insurance stimulates farmers to cultivate eligible crops on unimproved lands. Coverage was at 70 percent and is now 80 percent of average yields. The limited number of crops that are insurable do not include crops that can assist in soil nurturing, and so such crops have high risks associated with their cultivation. Hence, only little amounts of soil-enriching crops are cultivated in the Peace River region. Consequently, crop insurance (as presently constituted) has had profound adverse implications for eco-agriculture in British Columbia's grain belt.

In 1989, the federal government established a Federal-Provincial Agricultural Committee to propose terms of reference for agricultural policy in Canada. Following this committee's report, which proposed four Policy Principles including increased environmental sustainability, another committee has suggested two new programmes to stabilise income for grain farmers: the Gross Revenue Insurance Program (GRIP) and the Net Income Stabilization Account (NISA). However, as Gray *et al* (1990) point out, GRIP has the potential of becoming the most important Agricultural Legislation, yet it does not cover forage and pasture land. As constituted, GRIP will not foster sustainable agriculture; in fact, GRIP will inhibit it not withstanding the committee's proposal to limit "total seeded acreage for each producer at 110 percent over the previous three year average" (*ibid.*, p.35).

The government programmes examined above are only some of the multifarious institutions that have shaped agriculture in the Peace River area. Whether ad hoc or not, these programmes have tended to thwart the practices of alternative agriculture, a problem that some programmes are occasionally instituted to resolve. A case in point is the Prairie Pothole Project intended to foster conservation of the natural habitat for waterfowl. As well, Agriculture Canada recently (1989) introduced the Permanent Cover Programme (PCP) with a budget for the first phase of $19.5 million. This has helped more than 4,000 farmers in the prairies to convert some 300,000 acres of "marginal" lands into permanent cover such as grass, according to Agriculture Canada's Prairie Farm Rehabilitation Administration.

Instead of such ad hoc attempts to spur sustainable agriculture, what is needed is a re-appraisal of existing government programmes or institutions to make them friendly to the environment. This is imperative because current land degrading agricultural practices in the Peace River region manifested by an escalation of monoculture and an increasing usage of unimproved marginal lands, are largely the result of government programmes that, among other things, inadvertently engender land deterioration.

CHAPTER 4

MODEL OF INSTITUTIONS AND LAND USE

4.1 Introduction to Linear Programming

Optimization techniques, in both their static and dynamic aspects, have been widely applied to problems in many disciplines including agriculture. These problems are divided into those with constraints (equality and inequality) or without constraints. Solving unconstrained optimization problems was assisted by calculus expounded by Newton and Leibnitz in the seventeenth century (Hazell and Norton 1986). Lagrange found solutions to equality-constrained problems in the eighteenth century, while it was not until the 1940s that Neumann and Dantzig outlined procedures to solve inequality-constrained optimization problems (*ibid.*).

Equality constrained optimization problems are often solved by converting them to unconstrained ones using the Lagrangean method. The associated Lagrange multipliers--referred to as shadow prices by economists--indicate by how much the objective function will increase or decrease with a unit relaxation of the constraint. Thus, an unbinding constraint has a zero shadow price.

Optimal solutions must satisfy the necessary condition (i.e., the first derivative vanishes), and the sufficient condition (i.e., the Hessian matrix is negative (positive) semi-definite for a maximum (minimum)). Satisfaction of the former but not the latter leads to a saddle point (i.e., the solution is neither a maximum nor a minimum). Furthermore, the optimal solution must satisfy the non-negativity constraint.

Resource allocation problems are usually analyzed by economists using optimization methods. In terms of linear programming, both the objective function and constraints must be linear. Mathematically, this is often expressed as:

$$(4.1) \quad Max\ Z = \sum_{j=1}^{n} C_j X_j \qquad s.t.$$

$$(4.2) \quad \sum_{j=1}^{N} A_{ij} X_j \leq B_i$$

$$(4.3) \quad X_j \geq 0$$

where: $i = 1, \ldots, M$

$j = 1, \ldots, N$

In such a formulation, Z is the objective function and $C_1, \ldots, C_n$ are the objective constants, while $X_1, \ldots, X_n$ are referred to as the instruments; A_{ij} are the technical constant coefficients; $B_1, \ldots, B_m$ are the available levels of the resource. Underlying this expression are three quantitative aspects: an objective function that can either be maximized or minimized, different ways to achieve the desired objective, and limited availability of resources (Heady and Chandler 1958, p.2). The opportunity set--the set of instruments satisfying the MN non-negative constraints (4.2 and 4.3)--is defined by the following closed convex set (Intriligator 1971, p.74):

$$(4.4) \qquad X=\{X \in E^n | AX \le B, \quad X \ge 0\}$$

By the Weierstrass theorem, there exists a boundary solution if this opportunity set is compact.[6] However, this does not mean that there is always a unique solution; there could be many solutions. Some of the assumptions underlying such a model are:

1) the problem is deterministic (i.e., C_j, A_{ij}, and B_i coefficients are known constants);
2) resources employed are homogeneous;
3) activities are additive; and
4) inputs have perfectly elastic supply.

Since its inception in 1947 by Dantzig as a method to plan the activities of the U.S. Air Force (Dorfman, Samuelson and Solow 1958), LP has become a major research tool in agricultural economics. It enables researchers to empirically discuss problems related to farm management and spatial location.

4.2 Applications of Linear Programming to Peace River Agriculture

Linear programming has been used to analyze Peace River agriculture in various ways. Nisbet (1962) applied LP to probe resource use in the area and Craddock (1970) used LP to examine the economic efficiency of grain production in Canada, which necessarily included the Peace River region. Using 1966 as the

[6] This theorem says that a continuous function defined over a compact set attains a maximum over the set.

base year, he selected wheat, oats, barley, rye, mixed grain and corn (where applicable) as the crops in his model.

There were eight versions of Craddock's model; models 1 to 3 presumed an annual Canadian wheat export demand of 420 million bushels, 350 million bushels, and 300 million bushels, respectively; model 4 was similar to model 2 except corn imports were not allowed; models 5 and 6 were the same as models 1 and 2, respectively, but for the assumption that there was no federal feed freight subsidy; models 7 and 8 were characterized by the assumption that acreage adjustments, because of low demand for wheat, are made only on the Prairies.

Unfortunately, Craddock (1970) generally lumped the entire Peace River region with Alberta for the simple reason that farming in the region bears greater resemblance to the Prairies than British Columbia. Nevertheless, his models 1 and 4 suggested that 56 percent of Peace River region's land was inefficient in producing cereals; models 5 and 6 showed that land in British Columbia and Eastern Canada were competitive in the production of grains vis-a-vis the Southern Prairies (*ibid.*, p.22).

Holtby (1972) discussed the most profitable use of agricultural resources for the median farmer. His analysis considered fifteen different activities: four crop rotations; four feedlot activities; conventional rearing of lambs; confinement rearing of lambs; cow-calf; cow yearling; pasture finishing of beef; farrow to finish swine; and finishing swine. He imposed the following restrictions: 480 acres of cultivated land, financial capital of $70,000 (minus cost of land), and 780 hours of labour divided into quarterly periods. In spite of data limitations, his model suggested pasture finishing of beef, rather than crop production, as the most profitable activity.

Livestock was found to be a viable activity that farmers could incorporate into their enterprises in a farm planning study by Awmack (1974). Graham and Lopez (1976) embodied uncertainty in their analysis to determine an optimum income plan for the Peace River farmer. They found generally that "a combination of crop and livestock enterprises are (sic) more stable than an optimum plan which is diversified in crop enterprises only" (p.96).

Graham and Anderson (1982) used LP to formulate a regional development model of the Peace River region that focused largely on grains, forage and livestock. Their study was done in the context of "developing proposals for a long-term agricultural development plan for B.C. agriculture" (*ibid.*, p.1), a project initiated by the B.C. Ministry of Agriculture in 1976. However, their objective was not to evaluate sustainable development in the region.

The criterion they used to evaluate the alternative strategies considered in the study was net farm income; their objective was to maximize net farm income. The alternatives they considered were the following:

1) double stockers in the region (from 8,000 to 16,000);
2) backgrounding with lower feeder and calf prices;
3) double beef cow herd size;
4) expand cow herd and cultivated acreage;

5) increase land under cultivation by an extra 60,000 acres, while other activities are held constant (i.e., an examination of acreage increases only);

6) increase cultivated acreage by an extra 100,000 acres (i.e., examine potential impacts of cultivating more marginal lands);

7) increase the number of yearlings sold off pasture in the fall;

8) expand feedlots; and

9) increase the dairy herd size.

In their analysis, alternative 1 increased net income per rancher by $1,500.00, with a net gain to the region as a whole of $135,000.00 (see Table 4.1). For alternative 2, high prices of livestock were crucial for profitability; when lower prices were assumed (relative to 1978 prices), a net loss of $3.2 million was calculated for the region, as against a profit of $3.5 million for the base case.

The beef sector is a major contributor to the Peace River economy. Consequently, when beef prices were depressed, the region "suffered and showed a negative aggregate net return for the total agricultural economy" (Graham and Anderson 1982, p.121). An increase in net return from $3.5 million to $4.9 million was associated with a doubling of beef herd size. However, this required an additional 48,775 acres of classes 4 and 5 land. (See Appendix C for land class description). Furthermore, increased use of 4,147 acres of class 6 land was needed, in addition to more usage of crown range. Profitability of the livestock sector in the region means grain farmers may convert their marginal land to forage and diversification of farms to include livestock may become an attractive venture; either practice augurs well for sustainable agricultural development in the region.

When they simultaneously doubled beef herd and increased cultivated acreage (alternative 4), the researchers calculated an increase in net return of over $1.63 million. By assuming an average farm size of 1,000 acres per new farmer, 60 new farmers were capable of achieving a net return of $155,000. This alternative also required bringing classes 4 and 5, and even class 6, land into production (see Table 4.1). Nevertheless, Graham and Anderson found this alternative to yield the highest return. Of course, its ecological implications were not taken into account.

Alternative 5 resulted in a volume increase of all grains (except oats) and a significant decrease in alfalfa sales, a reduction they linked to the imposition of a stagnated beef herd size. They also found cultivating more marginal land (alternative 6) lucrative since the required additional capital investment of $5 million had a return of 13 percent. Though not stated, this alternative's profitability may be partly attributable to government programmes (see section 3.4) that support grain production on marginal land.

Expansion of feedlots (alternative 8) to increase net farm income in the Peace River region was not profitable according to the Graham and Anderson study. Alternative 9, on the other hand, had the effect of increasing the net benefit to the region by $102,000 (Table 4.1). However, this led to the reduction in the

Table 4.1 Summary Results of the Graham and Anderson 1982 Study

Alternative Plan	Increase in Peace River's Net Income ($'000)	Prerequisite
1	135	additional 4,000 acres of hay land.
2	-3,200	low prices of livestock cause loss.
3	1,400	increase class 4 and 5 land by 48,775 acres; increase class 6 land by 4,147 acres.
4	1,600	additional 60,000 acres; cultivate land class 6.
5	178	increase class 4 and 5 land by 25,685 acres; reduction of improved hay land by 34,486 acres.
6	259	39,000 acres of class 6 land.
7	-98	high price structure needed to expand yearling production.
8	-2,260	decline in sales of oats, barley, and alfalfa.
9	102	double dairy herd size to 750 cows.

sale of grains (oats and barley) and alfalfa, due to the extra feed requirements.

Though these other studies indicate that sustainable practices are viable in the Peace River region, none looked at the implications of farming methods in the area--shaped by government programmes--for sustainable agricultural development. This is what the current study attempts to do.

4.3 Structure of Empirical Model

The LP model formulated for this study is designed to primarily examine the effects of government agricultural programmes on land use in the Peace River region which, in turn, will shed some light on sustainable agriculture in the area.

Recall that it was argued in section 1.2 that land use and its attendant issues, such as land degradation, are essential factors in a critical analysis of agriculture's sustainability. Indeed, a notable factor in the world's growing sustainability concerns is land degradation due, not insignificantly, to "poor" agricultural land use. Hence, sustainable agriculture necessarily includes alleviating, if not eliminating, land use practices that lead to land degradation including soil erosion rates that are above a region's T-values (tolerable soil loss). In the Peace River area, for example, the T-value is 2 tons/acre (see section 3.2).

The model is a partial equilibrium one, with the coefficients of the objective function determined exogenously. The commodities endogenous in the model are the main crops (wheat, oats, barley, and canola) and forage (fescue) cultivated in the region. Envisaged by the model is a crop farmer who may not produce any livestock directly. Nevertheless, forage production is undertaken by the farmer as a derived demand by the livestock sector of the Peace River economy, and to contribute to sustainability by decreasing soil erosion. The other side of the farming coin in the Peace River area are farmers who engage in livestock production, with little or no crop production. This dichotomous farming practice accounts for at least 90 percent of the farming activity in the region (Graham and Lopez 1976, p.40).

Crop production is undertaken on classes 1 - 5 land. The land classes were assumed to decline in their capabilities to support field crops as the class number increases, akin to the CLI classes described in Appendix C. Production should take place only on classes 1 - 3 land, but government programmes have made land classes 4 and 5 marginally cultivable. A land class constraint is imposed to ensure that land use does not exceed the available acreage.

Some of the activities in the model were constrained using the guidelines enunciated in *Guide to Farm Practice in Saskatchewan (1987)*. For example, it suggested a lower bound for grains at 60 percent of the cultivated acreage, and an upper bound of 30 percent for summerfallow. Fixed proportions for other activities were also stipulated. Thus, the model specified at least a joint product activity, if not a multicrop activity.

Crop rotation is a sustainable farm practice that farmers often follow to control weeds and soil erosion. Since grains have similar soil requirements, forages and legumes are usually cultivated by farmers to enhance soil fertility and/or increase income. To reflect this approach to farming, we built proportional rotations into the model. However, no particular rotation was built into the model *a priori*. Any rotation options would be discerned from the model's results. Underlying this representation is the assumption that acreage available to the rotational crops is not fixed; for example, unbroken land can be broken to increase acreage for any or all crops by the farmer.

The CWB delivery quota system was reviewed in 1970 and 1978 to give farmers flexibility over land use for their crops and an equitable share of the delivery opportunities. Concomitantly, this was to enable the CWB to efficiently bring into country elevators at the right time the quantity and quality of all the kinds of grain required to compete effectively in the market (Wilson 1979, p.238). Delivery quotas, expressed by CWB as bushels per acre, are included in the model using a calculated acreage of total assignable quota comprised of total acreage of grains (wheat, oats, barley and canola), summerfallow and forage.[7] Given the non-emptiness of the constraints, there exists an optimal solution that is also a global one (Meister, Chen and Heady 1978).

4.4 The Basic Empirical Model

The model posits the maximization of returns to wheat, oats, barley, canola, forage, summerfallow, and unbroken land for a

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[7] The Canada Grains Council (Statistical Handbook 1985, p.184) indicates that assignable quotas are determined using a 4-part formula as follows: (1) land seeded to wheat, oats, barley, rye, flaxseed and canola; (2) summerfallow; (3) miscellaneous crops; (4) perennial forage (up to 1/3 of the area in the other three classifications). Though using this formula, the quota in the model is defined without (3) as well as rye and flaxseed.

farmer with 1,400 acres comprised of land classes 1 to 5. Forage is assumed as a derived demand by the livestock sector, while unbroken land allows the phenomenon of new breaking and its attendant cultivation of marginal land to occur. Production of grains on such marginal land facilitates unsustainability of agriculture in the region. As well, expansion of grains at the expense of forage (e.g., fescue) in crop rotations enhances soil erosion that adversely impacts on sustainable agriculture. This is a practice that is increasingly becoming a feature of the region (Van Vliet and Hall 1991).

Mathematically, the model's objective function can be expressed as equation (4.5).

$$(4.5) \qquad Max \sum_{j=1}^{5} R_{ij} X_j$$

where:

R_{ij} is the gross margin of i^{th} instrument on j^{th} land class; and the instruments are wheat, oats, barley, canola, forage, summerfallow and unbroken land. In other words, the above objective function was specified as follows (equation 4.6):

$$(4.6) \qquad \begin{aligned} Max\ & R_{w1}W_1 + R_{w2}W_2 + R_{w3}W_3 + R_{w4}W_4 + R_{w5}W_5 + R_{a1}A_1 \\ & + R_{a2}A_2 + R_{a3}A_3 + R_{a4}A_4 + R_{a5}A_5 + R_{b1}B_1 + R_{b2}B_2 \\ & + R_{b3}B_3 + R_{b4}B_4 + R_{b5}B_5 + R_{c1}C_1 + R_{c2}C_2 + R_{c3}C_3 \\ & + R_{c4}C_4 + R_{c5}C_5 + R_{f1}F_1 + R_{f2}F_2 + R_{f3}F_3 + R_{f4}F_4 \\ & + R_{f5}F_5 + R_{sf1}SF_1 + R_{sf2}SF_2 + R_{sf3}SF_3 + R_{sf4}SF_4 \\ & + R_{sf5}SF_5 + R_{u1}U_1 + R_{u2}U_2 + R_{u3}U_3 + R_{u4}U_4 + R_{u5}U_5 \end{aligned}$$

where:

W = wheat; A = oats; B = barley; C = canola; F = forage;

SF = summerfallow; U = unbroken land;

$R_{w1},....,R_{w5}$ = gross margin of wheat on land classes 1 - 5;

$R_{a1},....,R_{a5}$ = gross margin of oats on land classes 1 - 5;

$R_{b1},....,R_{b5}$ = gross margin of barley on land classes 1 - 5;

$R_{c1},....,R_{c5}$ = gross margin of canola on land classes 1 - 5;

$R_{f1},....,R_{f5}$ = gross margin of forage on land classes 1 - 5;

$R_{u1},....,R_{u5}$ = gross margin of unbroken land on land classes 1-5;

$R_{sf1},...,R_{sf5}$ = gross margin of summerfallow on land classes 1-5;

$W_1,....,W_5$ = wheat on land classes 1 - 5;

$A_1,....,A_5$ = oats on land classes 1 - 5;

$B_1,....,B_5$ = barley on land classes 1 - 5;

$C_1,....,C_5$ = canola on land classes 1 - 5;

$F_1,....,F_5$ = forage on land classes 1 - 5;

$SF_1,....,SF_5$ = summerfallow on land classes 1 - 5; and

$U_1,....,U_5$ = unbroken land on land classes 1 - 5.

This acreage is typical for a representative farmer in the Peace River area, with net income in the $50,000 - $99,999 category. There were some 106 such farmers in 1981, while some 75 farmers in the net income category of $100,000 - $249,999 had an average farm size of over 2,300 acres; another 24 farmers, making over $250,000 cultivated an average farm size of over 5,000 acres (BCMAFF 1984, p.97). The average farm size in 1981 was about

836.62 acres. In 1986, the corresponding numbers (of wheat farmers alone) were 91, 98, and 44, respectively (Agriculture Canada 1988, p.18).

In order to take account of land quality differences in the Peace River area, the 1,400 acres was disaggregated--using percentages calculated from Table 3.7--into the following:

(a) land class 1 = 331.52 acres;

(b) land class 2 = 334.88 acres;

(c) land class 3 = 321.72 acres;

(d) land class 4 = 337.96 acres;

(e) land class 5 = 60.62 acres;

(f) land class 6 = 9.66 acres; and

(g) land class 7 = 3.78 acres.

The acreage of land classes 1 and 4 were entered as equations (4.7) to (4.10) in the model. The remaining land (equation (4.11)) was assumed to be class 5.

$$(4.7) \qquad W_1 + A_1 + B_1 + C_1 + F_1 + SF_1 + U_1 \leq 331.52$$

$$(4.8) \qquad W_2 + A_2 + B_2 + C_2 + F_2 + SF_2 + U_2 \leq 334.88$$

$$(4.9) \qquad W_3 + A_3 + B_3 + C_3 + F_3 + SF_3 + U_3 \leq 321.72$$

$$(4.10) \qquad W_4 + A_4 + B_4 + C_4 + F_4 + SF_4 + U_4 \le 337.96$$

$$(4.11) \qquad W_5 + A_5 + B_5 + C_5 + F_5 + SF_5 + U_5 \le 74.06$$

The following constraints also were added based on discernible farm practices in the area or, in some cases, on the agriculture of the Southern Prairies (when Peace River information was not available). The Peace River region has similar farm practices as the prairies (see Chapter 3).

Summerfallow is at least 20 percent of the grains cultivated (equation 4.12):

$$(4.12) \qquad \sum_{i=1}^{5} SF_i - 0.2\,(W_i + A_i + B_i + C_i) \ge 0$$

Grains constitute at least 60 percent of total farm acreage (TFA) (equation 4.13).

$$(4.13) \qquad \sum_{i=1}^{5} 0.4\,(W_i + A_i + B_i + C_i) - 0.6\,(SF_i + F_i + U_i) \ge 0$$

Grains produced by Peace River farmers are deliverable to the CWB on quota basis. This works out to be an assignable quota (see section 4.3) of at least 530 acres in our model (equation 4.14).

$$(4.14) \qquad \sum_{i=1}^{5} W_i + A_i + B_i + C_i + F_i + SF_i \geq 530$$

Wheat is at least 25 percent of acreage planted to grain as the historical acreage shows in Table 3.4 (equation 4.15).

$$(4.15) \qquad \sum_{i=1}^{5} 0.75W_i - 0.25(A_i + B_i + C_i) \geq 0$$

Oats acreage is not less than 11 percent of total grains acreage based on historical data from Table 3.4 (equation 4.16).

$$(4.16) \qquad \sum_{i=i}^{5} 0.89A_i - 11(W_i + B_i + C_i) \geq 0$$

Barley is at least 29 percent of grains acreage (see Table 3.4) (equation 4.17).

$$(4.17) \qquad \sum_{i=1}^{5} 0.71B_i - 0.29(W_i + A_i + C_i) \geq 0$$

Canola's lowest bound is not less than 24 percent of grains acreage as shown in Table 3.4 (equation 4.18).

$$(4.18) \qquad \sum_{i=1}^{5} 0.76C_i - 0.24(W_i + A_i + B_i) \geq 0$$

Forage is not less than nine percent of grains and forage acreage (equation 4.19).

$$(4.19) \qquad \sum_{i=1}^{5} 0.91F_i - 0.09(W_i + A_i + B_i + C_i) \geq 0$$

In accordance with farm practices, grains were also specified to be at least equal to summerfallow on each land class to ensure that the latter's acreage does not exceed that of the former.

Crop and labour relationships in the Peace River region suggest that a quarterly breakdown of demand for labour is reasonable. However, gross margins specified in the objective function make deductions for labour costs; hence, no labour restraints are imposed on the model.

Gross margins (GM), as indicated by BCMAFF, allocates money for interest payments, overhead and other indirect costs as well as some return for the farmer. The GMs per acre in 1989 for wheat, barley, oats, and canola--all on summerfallow--were given by Saskatchewan Agriculture and Food (1989) as \$53.64, \$84.76, \$66.15 and \$105.18, respectively, while the cost of maintaining an acre of summerfallow was stated as \$25.82. The GMs for wheat, barley, canola, and oats--on stubble--were \$40.52, \$53.45, \$60.10 and \$48.68, respectively. For forage, the BCMAFF's GM for fescue over a 6-year period was converted to a net present value, with a discount rate of 15%; this gave us a GM of \$52.50 per acre. Unbroken land was valued at one-half of the GM for forage on land class one (i.e., $26.25 per acre) (see Weisensel, Rosaasen and Schoney 1991).

Table 4.2 Calibrated Results of Land Class Gross Margin of the Model's Instruments ($)

	Land Classes				
Instrument	1	2	3	4	5
Wheat on: fallow	53.64	52.84	33.69	21.48	13.70
stubble	40.52	39.92	25.45	16.23	10.35
Oats on: fallow	66.15	65.17	41.55	26.49	16.89
stubble	48.68	47.96	30.58	19.50	12.43
Barley on: fallow	84.76	83.50	53.24	33.95	21.65
stubble	53.45	52.65	33.57	21.41	13.65
Canola on: fallow	105.18	103.61	66.07	42.13	26.86
stubble	60.10	59.21	37.75	24.07	15.34
Forage	52.50	51.72	32.98	21.03	13.41
Unimproved land	26.25	26.25	26.25	26.25	26.25
Summerfallow	-25.82	-25.82	-25.82	-25.82	-25.82

A function was posited to determine a declining gross margin (as a function of land class) of the instruments in the model, except unimproved and summerfallowed land which were assumed not to decline with land class.[8] This function assumed that the above GMs were for land class one. Estimated GMs for other classes of land are presented in Table 4.2.

Linear programming's non-negative constraint is represented as equations (4.20) to (4.26).

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[8]The following was run using GAUSS to determine gross margin as a function of land class: X=seqa(0.1, 3.0, 10); $GM_i = Y_i$*exp(-0.15*X); where i = instruments in the model; Y = gross margin of the instruments as obtained from Saskatchewan Agriculture and Food, or from BCMAFF; GM = gross margin.

(4.20) $W_1,\ W_2,\ W_3,\ W_4,\ W_5, \geq 0$

(4.21) $A_1,\ A_2,\ A_3,\ A_4,\ A_5, \geq 0$

(4.22) $B_1,\ B_2,\ B_3,\ B_4,\ B_5, \geq 0$

(4.23) $C_1,\ C_2,\ C_3,\ C_4,\ C_5, \geq 0$

(4.24) $F_1,\ F_2,\ F_3,\ F_4,\ F_5, \geq 0$

(4.25) $SF_1,\ SF_2,\ SF_3,\ SF_4,\ SF_5 \geq 0$

(4.26) $U_1,\ U_2,\ U_3,\ U_4,\ U_5 \geq 0$

The objective function (4.6) and the constraints (4.7 to 4.26) form the study's **Base Case**. This is the scenario that depicts the Peace River's current land use practices. It is compared with the following eight simulated scenarios:

1) no government subsidy **(NG)**;

2) some government subsidy **(SG)**;

3) continuous cropping **(CC)**;

4) continuous cropping with no government subsidy **(CCNG)**;

5) continuous cropping with some government subsidy **(CCSG)**;

6) regulation of no summerfallow acreage on land classes 4 and 5 **(NOSF)**;

7) regulation of no grains acreage on land classes 4 and 5 **(NOG)**; and

8) imposition of an erosion constraint on the Base Case **(ER)**.

The **NG** case involves the elimination of the average government subsidy per acre paid to Peace River farmers through WGSA, SCGP, Crop Insurance and Chemical Rebates (see Table 3.9), which was calculated at $20.35 per acre.[9] This subsidy rate was subtracted from the GMs of the **Base Case,** except forage from which only a third of this amount was deducted (in accordance with CWB payments calculations). Similarly, for **SG** one-half of the subsidy/acre was deducted from all the gross margins, except one-sixth of the subsidy was deducted from the gross margins for forage.

Continuous Cropping **(CC)** was also simulated. This follows suggestions by soil scientists that **CC** increases output over time (e.g., Rennie 1986). The objective function coefficients of the **CC** case were varied parametrically to obtain two other cases:

[9]It was obtained by summing the average payments of these government programmes between 1979 and 1989 per grains and forage acreage in the Peace River region in 1986.

continuous cropping with no government subsidy **(CCNG)** and continuous cropping with some government subsidy **(CCSG)**; both were obtained in the same way as **NG** and **SG**, as explained above.

Simulations of soil-saving practices were made with two other scenarios. The first exercise was an imposition of a regulation on the Base Case disallowing summerfallow on land classes 4 and 5 (results under **NOSF**). The second involved another regulation that prohibited cultivation of grains on land classes 4 and 5 (results under **NOG**). These scenarios may spur conversion of marginal lands, that are more vulnerable to land degradation and have been brought under grains cultivation, into either forage or unimproved land by perhaps seeding it with permanent cover such as grass. It is worth noting, as section 3.4 indicated, that Agriculture Canada has introduced the *Permanent Cover Programme* to help farmers convert some of their land (marginal land) under crop production to permanent cover. This is an effort to enhance sustainable agriculture. However, in this study, financial incentives to seed land to permanent cover are not modelled.

In the final simulation, a soil erosion constraint was added to the Base Case model in order to address the problem of overall soil erosion in the region. This simulates regulation of soil loss to ensure that farming in the region does not unduly cause soil erosion. We assumed that wheat, oats and canola generate 3 tons/acre soil loss, while barley, summerfallow and forage (fescue) cause 3.4 tons/acre, 5 tons/acre and 2.2 tons/acre soil loss, respectively. It was further assumed that the entire farm could not lose more than 4,200 tons of soil, which supposes that each acre of the farm generated soil loss of 3 tons/acre. This value is approximately what is commonly accepted by the American Society of Agronomy as tolerable soil loss (van Vliet and Hall 1991), which is higher than the 2 tons/acre envisaged as the Peace River region's tolerable soil loss (see Section 3.2).

It must be borne in mind that estimation of individual soil loss is a complex exercise because of factors such as the difficulty of discerning the effects on current crops from previous agronomic practices. Not surprisingly, there is a dearth of research about soil loss due to particular crops. Thus, the soil losses specified above may or may not be adequate. Be that as it may, we used the above values to specify a soil erosion constraint for the entire farm acreage; it is given by equation 4.27 below.

$$(4.27) \qquad \sum_{i=1}^{5} 3(W_i + A_i + C_i) + 3.4B_i + 2.2F_i + 5SF_i \leq 4,200$$

CHAPTER 5

EMPIRICAL RESULTS

5.1 Discussion of Base Case Results

The simulations were run using an interactive software package called *LINDO*.[10] The results are presented as Tables 5.1 through 5.7 and Figures 5.1 - 5.3. They show acreage cultivated in the Peace River area for: wheat, oats, barley, canola, forage, summerfallow and unbroken land for land classes 1 to 5. The land classes were assumed to decline in their capabilities to support field crops as the class number increases, akin to the CLI classes described in Appendix C. The tables and figures also depict the simulations discussed in section 4.4.

Representation of current summerfallow production in the Peace River area is shown by the **Base Case** results. Figure 5.1 shows that canola has the largest acreage (26%), followed by barley (21.6%), wheat (18.6%) and oats (8.2%). This hierarchical order of acreage is in accordance with years such as 1983 - 85 and 1988 (see Table 3.4). Acreage for forage constituted some 7%, while summerfallow's share was about 15%. Unimproved land had the least acreage (3.4%).

As shown in Table 5.1, the **Base Case** also indicates that canola had the largest proportion (35%) of the total grains

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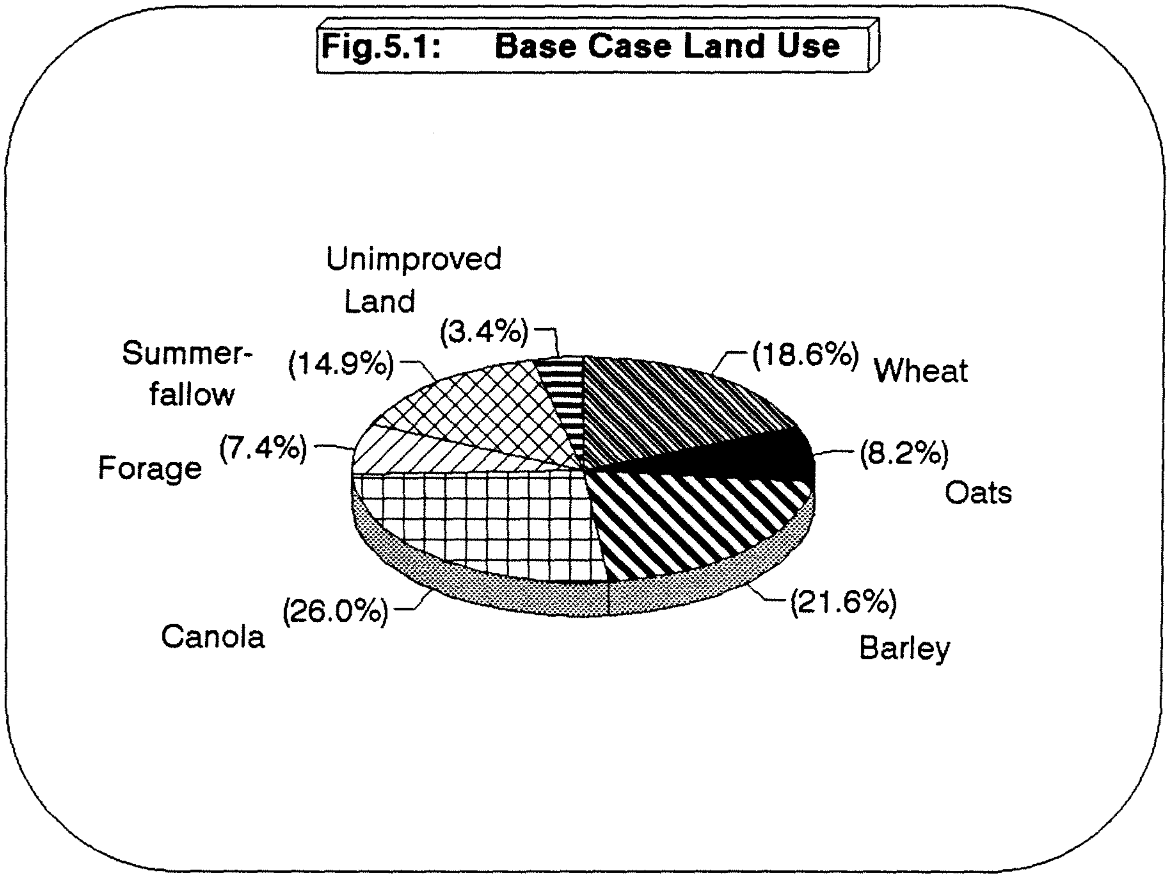
[10] LINDO is an acronym for Linear Interactive Discrete Optimizer.



acreage, followed by barley (29%), wheat (25%) and oats (11%). The total acreage of grains accounted for some 74% of the total farm acreage (TFA).

Table 5.2 shows that some 13% of Base Case grains are cultivated on land classes 4 and 5. Consequently, an equal amount (13%) of summerfallow takes place on classes 4 and 5 land. Naturally, all unimproved land occurs on land class 5; this is

Table 5.1 Effects of Government Subsidies on Agricultural Land Use in the Peace River Region

	TOTAL AS % OF GRAINS			TOTAL AS % OF TFA		
	BASE	NG	SG	BASE	NG	SG
Wheat	25.0	25.0	20.0	18.6	12.0	14.6
Oats	11.0	10.0	10.0	8.2	6.0	7.3
Barley	29.0	20.0	20.0	21.6	12.0	14.6
Canola	35.0	50.0	50.0	26.0	30.0	36.5
SF	20.0	20.0	20.0	14.9	12.0	14.6
Forage				7.4	5.9	7.2
U				3.4	22.1	5.3

	TOTAL ACREAGE		
	BASE	NG	SG
Wheat	260	168	204
Oats	115	84	102
Barley	302	168	204
Canola	364	420	511
sub-total	*1041*	*840*	*1021*
Forage	103	83	101
SF	208	168	204
U	48	309	74

TFA = Total Farm Acreage; SF = Summerfallow;
NG = No Government Subsidy; SG = Some Government Subsidy;
U = Unimproved land.

about 64% of land class 5's total acreage. The net return for the Base Case was $74,155 (see Table 5.7). This is well within the income bracket for farmers cultivating such a total farm acreage (TFA) in the region (see section 4.4).

Compared with the **Base Case**, the results for **NG** (Table 5.1) indicate that, as a percent of TFA, the acreage for wheat, oats, barley, summerfallow and forage all declined: by 35.5%, 26.8%, 44.4%, 19.5% and 20.3%, respectively. The acreage for canola increased by 15.5% and that of unimproved land increased by more than five-fold. Similarly, compared with the **Base Case**, the **SG** results (Table 5.1) show analogous directional changes for the

Table 5.2 Effects of Government Subsidies on Land Class Use in the Peace River Region (As % of TFA)

	LAND CLASSES				
	1	2	3	4	5
Wheat					
Base	0.0	0.0	5.6	12.1	1.0
NG	0.0	0.0	8.3	3.7	0.0
SG	0.0	0.0	2.5	12.1	0.0
Oats					
Base	0.0	0.0	8.2	0.0	0.0
NG	0.0	5.6	0.4	0.0	0.0
SG	0.0	0.0	7.3	0.0	0.0
Barley					
Base	0.0	21.6	0.0	0.0	0.0
NG	0.0	12.0	0.0	0.0	0.0
SG	0.0	11.1	3.5	0.0	0.0
Canola					
Base	23.7	2.4	0.0	0.0	0.0
NG	23.7	6.3	0.0	0.0	0.0
SG	23.7	12.8	0.0	0.0	0.0
Forage					
Base	0.0	0.0	7.4	0.0	0.0
NG	0.0	0.0	5.9	0.0	0.0
SG	0.0	0.0	7.2	0.0	0.0
Summerfallow					
Base	0.0	0.0	1.9	12.1	1.0
NG	0.0	0.0	8.3	3.7	0.0
SG	0.0	0.0	2.5	12.1	0.0
Unimproved land					
Base	0.0	0.0	0.0	0.0	3.4
NG	0.0	0.0	0.0	16.8	5.3
SG	0.0	0.0	0.0	0.0	5.3

TFA = Total Farm Acreage; NG = No Government Subsidy;
SG = Some Government Subsidy.

instruments in the model, albeit not in the same proportion. For example, the share for forage, as a percent of TFA, declined by only 2% while canola's acreage increased by 40%. The sub-total for grains fell by about 19% under **NG** and by 2% with **SG** as Table 5.1 indicates.

No grains were cultivated on class 5 land under both NG and SG scenarios, as shown by Table 5.2. Under the Base Case, acreage for wheat generally occupied land classes 3 and 5 as did summerfallow, perhaps suggesting wheat and summerfallow in the same rotation. In all cases (Base, NG and SG), canola's cultivation is on classes 1 and 2 land, while farming of oats and barley occurred on classes 2 and 3 land; all of forage's acreage was on class 3 land. Acreage for unimproved land occupied all class 5 land plus some 70% of class 4 land under NG.

5.2 Results of Simulations Involving Regulations

Regulations that prevent farmers from summerfallowing and cultivating grains on land classes 4 and 5 led to more than five-fold increase in the acreage of unimproved land; acreage for all the other instruments declined (Table 5.3). Total grain acreage decreased by about 19% with the former regulation (NOSF) and by 14% with the latter regulation (NOG). Prohibiting grains (NOG) on land classes 4 and 5 leads to the highest conversion of marginal lands to unimproved land, or permanent cover, and the least summerfallow: 6.4% of TFA (see Table 5.3). The decline in summerfallow and the increase in acreage for unimproved land, as a result of these regulations, are particularly welcome in the Peace River region due to the fact that it has been identified as the most erodible region in B.C. (see section 3.2).

Table 5.3 Effects of Regulations on Land Use in the Peace River Region

	TOTAL AS % OF GRAINS			TOTAL AS % OF TFA			
	BASE	NOSF	NOG	BASE	NOSF	NOG	ER
Wheat	25.0	25.0	25.0	18.6	15.0	16.1	17.3
Oats	11.0	11.0	11.0	8.2	6.6	7.1	7.6
Barley	29.0	29.0	29.0	21.6	17.4	18.6	20.1
Canola	35.0	35.0	35.0	26.0	21.0	22.4	24.3
SF	20.0	20.0	10.0	14.9	12.0	6.4	13.9
Forage				7.4	5.9	6.4	6.9
U				3.4	22.1	23.1	10.1

	TOTAL ACREAGE			
	BASE	NOSF	NOG	ER
Wheat	260	210	225	242
Oats	115	92	99	106
Barley	302	244	260	281
Canola	364	294	314	340
sub-total	*1041*	*840*	*898*	*969*
Forage	103	83	89	96
SF	208	168	90	194
U	48	309	323	141

TFA = Total Farm Acreage; SF = Summerfallow; U = Unimproved land;
NOSF = No Summerfallow on Land Classes 4 - 5;
NOG = No Grains on Land Classes 4 - 5; ER = Erosion Regulation.

Agriculture Canada's Prairie Farm Rehabilitation Administration (PFRA) suggests that 160 acres converted from marginal lands to permanent cover provides pasture that can feed 100 beef cows. Since this pasture will last only three to five months, there will be a need to conserve feed which may have to be produced from land classes 5 and 6.

This means that NOG's conversion of 275 acres to unimproved land (see Table 5.3) can help feed about 172 cows, with possible further grazing on class 6 rangelands. For the entire region, 25,025 acres can be converted to unimproved land and help feed 15,640 beef cows. This will be a boost to the region's livestock industry--which Graham and Anderson found to be a major contributor to the Peace River economy (see section 4.2)-- and, perhaps, farm diversification. This is not done voluntarily, perhaps, because government payments skew production costs against diversifying grain farms to include livestock; farmers may also not like inconvenience of cattle.

As well, the NOG scenario indicates that there could be a 3.8% increase in farmers' income (Table 5.7). Under the NOSF scenario, however, income falls by about 12% (see Table 5.7), but the long-term benefits from reduced erosion and the attendant sustainability of farms will more than likely compensate farmers even if governments do not offer financial incentives to spur the necessary change in farming practices. It is worth noting that on-farm costs of water erosion alone in the region were estimated to be about $9 million in 1984 (noted by Van Vliet and Hall 1991, p.2).

Another effect of NOG and NOSF is that forages acreage shifts from class 3 land to class 4 land and, with all the unimproved land accumulated on classes 4 and 5 land (see Table 5.4), sustainable agriculture seems to be better enhanced with these types of regulations. Summerfallow acreage switches to land classes 1 and 3 under the NOG and NOSF scenarios, with the latter appearing to establish some rotational relationship between barley and summerfallow on class 2 land. However, NOSF still leaves about 2.4% of the total grain acreage on land class 4 (see Table 5.4 below).

Table 5.4 Effects of Regulations on Land Class Use in the Peace River Region (As % of TFA)

	LAND CLASSES				
	1	2	3	4	5
Wheat					
Base	0.0	0.0	5.6	12.1	1.0
NOSF	0.0	0.0	13.6	1.4	0.0
NOG	0.0	0.0	16.0	0.0	0.0
ER	0.0	0.0	7.6	9.7	0.0
Oats					
Base	0.0	0.0	8.2	0.0	0.0
NOSF	0.0	0.0	6.6	0.0	0.0
NOG	0.0	6.5	0.5	0.0	0.0
ER	0.0	3.3	4.3	0.0	0.0
Barley					
Base	0.0	21.6	0.0	0.0	0.0
NOSF	2.6	12.0	2.8	0.0	0.0
NOG	0.0	1.2	17.4	0.0	0.0
ER	0.0	20.1	0.0	0.0	0.0
Canola					
Base	23.7	2.4	0.0	0.0	0.0
NOSF	21.0	0.0	0.0	0.0	0.0
NOG	22.5	0.0	0.0	0.0	0.0
ER	23.7	0.6	0.0	0.0	0.0
Forage					
Base	0.0	0.0	7.4	0.0	0.0
NOSF	0.0	0.0	0.0	5.9	0.0
NOG	0.0	0.0	0.0	6.4	0.0
ER	0.0	0.0	6.9	0.0	0.0
Summerfallow					
Base	0.0	0.0	1.9	12.1	1.0
NOSF	0.0	12.0	0.0	0.0	0.0
NOG	0.0	0.0	6.4	0.0	0.0
ER	0.0	0.0	4.2	9.6	0.0
Unimproved land					
Base	0.0	0.0	0.0	0.0	3.4
NOSF	0.0	0.0	0.0	16.8	5.3
NOG	0.0	0.0	0.0	17.8	5.3
ER	0.0	0.0	0.0	4.8	5.3

TFA = Total Farm Acreage;
NOSF = No Summerfallow on Land Classes 4 - 5;
NOG = No Grains on Land Classes 4 - 5;
ER = Erosion Regulation.

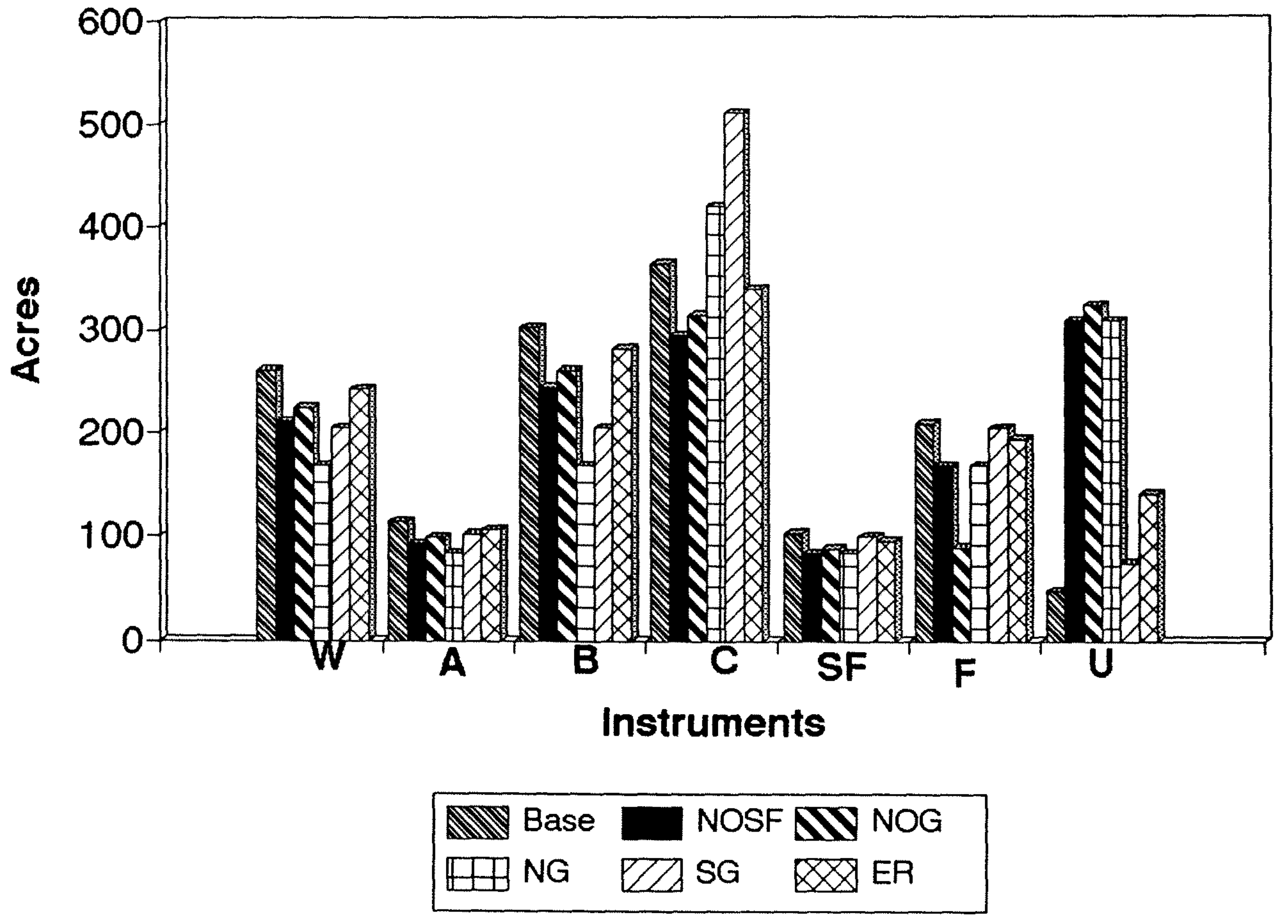
As a result of the erosion regulation (ER) imposed on the Base Case model, acreage for all the grain crops and summerfallow declined by an average of 7% and 6.7%, respectively. Acreage for forages also decreased by 6.8%, but that of unimproved land increased by about 193.8% (Table 5.3). This means ensuring that soil loss in the region was tolerable resulted in perhaps the most erodible lands under cultivation being converted to permanent cover. Thus, there is more pasture to support the region's livestock industry, and yet less need for forages.

Net returns fell by 1.1% with the erosion regulation (Table 5.7). However, less erosion also means a reduction in the costs associated with erosion; this can compensate farmers in addition to making the farms environmentally sustainable. Note that, as pointed out earlier, on-farm costs of water erosion alone in the region were estimated at $9 million in 1984.

Comparison of all six scenarios (Base Case, NG, SG, NOG, NOSF and ER) shows that canola had the highest acreage under the first three cases (see Figure 5.2). Unimproved land had the highest acreage under NOG and NOSF, but it accounted for the least acreage under the Base Case.

In summary, the simulations indicate that farmers can reduce the amount of marginal land under cultivation and foster sustainable agriculture. Regulations such as disallowing grains on poorer lands were found to decrease acreage for summerfallow and grains, which various government programmes had encouraged on marginal lands in the first place, in favour of unimproved land.

Fig. 5.2: Effects of Gov't. Subsidies on Peace River Land Use



5.3 Results of Simulations Involving Continuous Cropping

In Tables 5.5, 5.6 and Figure 5.3, we compare the Base Case with Continuous Cropping **(CC)**, Continuous Cropping with no government subsidy **(CCNG)** and Continuous Cropping with some government subsidy **(CCSG)**. **CCNG** and **CCSG** were obtained in the same fashion as NG and SG (see section 4.4).

Table 5.5 Effects of Government Subsidies on Peace River Agricultural Land Use Under Continuous Cropping

	TOTAL AS % OF GRAINS			TOTAL AS % OF TFA			
	CC	CCNG	CCSG	BASE	CC	CCNG	CCSG
Wheat	25.0	25.0	25.0	18.6	16.6	15.0	15.0
Oats	11.0	11.0	11.0	8.2	7.4	6.6	6.6
Barley	24.0	24.0	24.0	21.6	16.0	14.4	14.4
Canola	40.0	40.0	40.0	26.0	26.6	24.0	24.0
SF				14.9	NA	NA	NA
Forage				7.4	4.0	9.2	10.6
U				3.4	29.4	30.8	29.4

TOTAL ACREAGE	BASE	CC	CCNG	CCSG
Wheat	260	233	210	210
Oats	115	103	92	92
Barley	302	224	202	202
Canola	364	373	336	336
sub-total	*1041*	*933*	*840*	*840*
Forage	103	55	129	148
SF	208	NA	NA	NA
U	48	412	431	412

TFA = Total Farm Acreage; SF = Summerfallow;
CCNG = Continuous Cropping with No Government Subsidy;
CCSG = Continuous Cropping with Some Government Subsidy;
U = Unimproved land; CC = Continuous Cropping;
BASE = Base Case; NA = Not Applicable.

As a percent of TFA, acreage for each grain crop diminishes under **CC, CCNG** and **CCSG**. Forages decrease under **CC,** but increase under **CCNG** and **CCSG**. Indeed, forages attain their overall highest

Table 5.6 Effects of Government Subsidies on Land Class Use in the Peace River Region Under Continuous Cropping (As % of TFA)

	LAND CLASSES				
	1	2	3	4	5
Wheat					
Base	0.0	0.0	5.6	12.1	1.0
CC	0.0	0.0	16.7	0.0	0.0
CCNG	0.0	0.0	15.0	0.0	0.0
CCSG	0.0	0.0	15.0	0.0	0.0
Oats					
Base	0.0	0.0	8.2	0.0	0.0
CC	0.0	1.0	6.3	0.0	0.0
CCNG	0.0	0.0	6.6	0.0	0.0
CCSG	0.0	0.0	6.6	0.0	0.0
Barley					
Base	0.0	21.6	0.0	0.0	0.0
CC	16.0	0.0	0.0	0.0	0.0
CCNG	0.0	14.4	0.0	0.0	0.0
CCSG	0.0	14.4	0.0	0.0	0.0
Canola					
Base	23.7	2.4	0.0	0.0	0.0
CC	23.7	3.0	0.0	0.0	0.0
CCNG	23.7	0.3	0.0	0.0	0.0
CCSG	23.7	0.3	0.0	0.0	0.0
Forage					
Base	0.0	0.0	7.4	0.0	0.0
CC	0.0	4.0	0.0	0.0	0.0
CCNG	0.0	9.2	0.0	0.0	0.0
CCSG	0.0	9.2	1.4	0.0	0.0
Summerfallow					
Base	0.0	0.0	1.9	12.1	1.0
CC	-	-	-	-	-
CCNG	-	-	-	-	-
CCSG	-	-	-	-	-
Unimproved land					
Base	0.0	0.0	0.0	0.0	3.4
CC	0.0	0.0	0.0	24.1	5.3
CCNG	0.0	0.0	1.4	24.1	5.3
CCSG	0.0	0.0	0.0	24.1	5.3

TFA = Total Farm Acreage;
CC = Continuous Cropping;
CCNG = Continuous Cropping with No Government Subsidy;
CCSG = Continuous Cropping with Some Government Subsidy;

acreage, as a percent of TFA, of 10.6% under **CCSG**, as shown in Table 5.5. Acreage for unimproved land expanded more than seven-fold under all the three continuous cropping simulations, achieving its overall highest acreage of 30.8% of TFA under **CCNG** (Table 5.5; see also Figure 5.3). This means that continuous cropping, which soil scientists argue for (e.g., Rennie 1986), reduces the amount of marginal land cultivated and fosters sustainable agriculture.

In terms of specific land class acreage, the pattern under the continuous cropping simulations seem to be similar. No grains occur on land classes 4 and 5, while unimproved land naturally occurs mostly on classes 4 and 5 land (see Table 5.6). Without any government subsidy **(CCNG)**, continuous cropping results in a further 1.4% of TFA on land class 3 .

Of all this study's simulations, removing the subsidy per acre of $20.35 under continuous cropping **(CCNG)** led to the largest conversion of marginal land to unimproved land. Halving the subsidy per acre **(CCSG)** impacted on forages to the largest extent. Both cases give the greatest boost to the livestock industry since some 40% of TFA is in forage and unimproved land. This can assist the feeding of another 320 beef cows in the Peace River area.

However, the net return, given by the Objective Function Value in Table 5.7, declines in both the **CCNG** and **CCSG** cases relative to the Base Case; the former by 47.5% and the latter by 35.2%. It is worth noting that all the simulations show a decline in net return, with the exception of **NOG** which increases its net return by 3.8%.

Fig. 5.3: Effects of Govt. Subsidies on Continuous Cropping Land Use

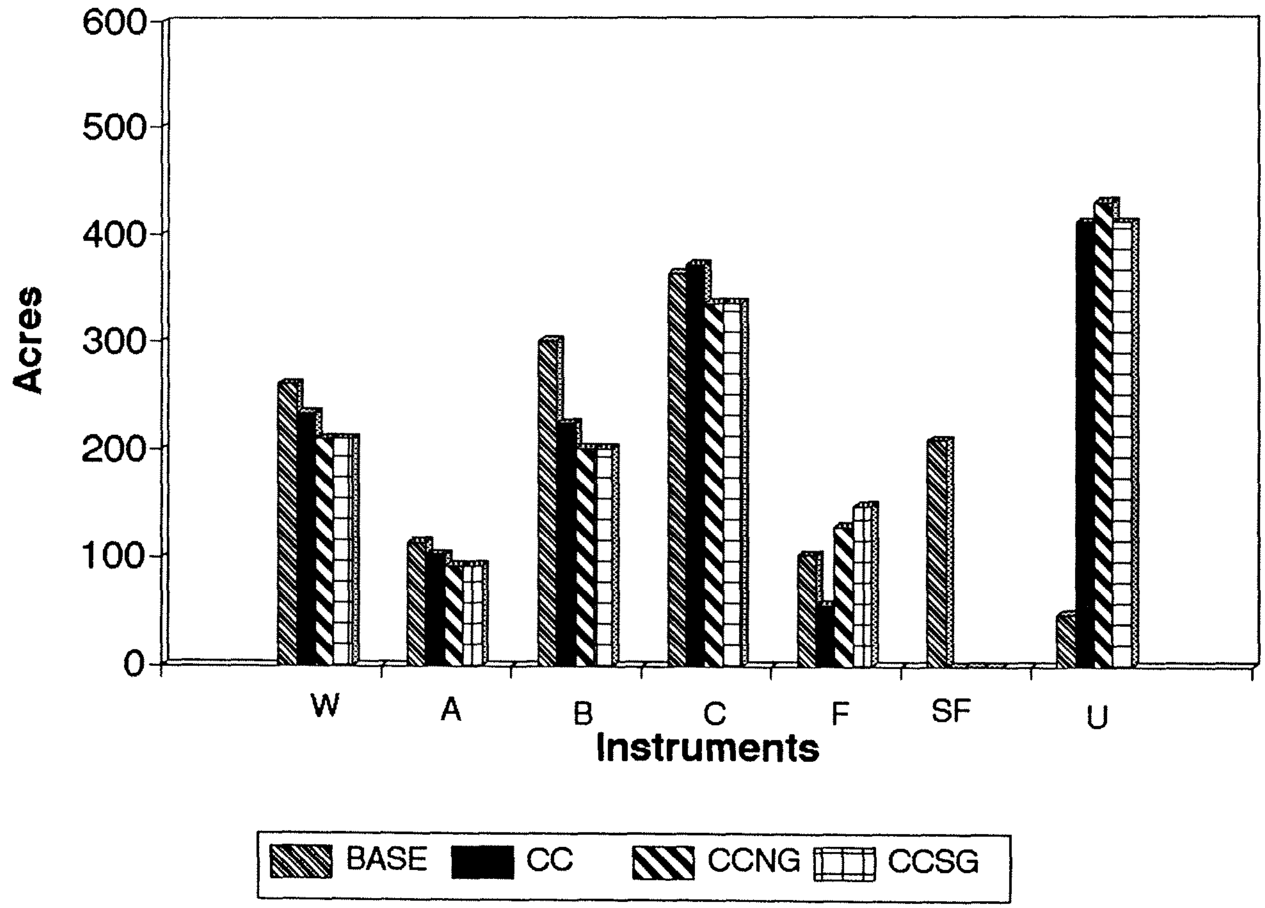


TABLE 5.7 Net Income of Various Simulations

SIMULATION	OBJECTIVE FUNCTION VALUE ($)	AS % OF BASE CASE
BASE CASE	74,155	100.0
NG	53,876	72.7
SG	65,245	88.0
NOSF	66,611	89.8
NOG	77,001	103.8
CC	57,169	77.1
CCNG	38,990	52.6
CCSG	48,043	64.8
ER	73,323	98.9

NG = No Government Subsidy; SG = Some Government Subsidy;
NOSF = No Summerfallow on classes 4 and 5 land;
NOG = No Grains on classes 4 and 5 land;
CCNG = Continuous Cropping with No Government Subsidy;
CCSG = Continuous Cropping with Some Government Subsidy;
CC = Continuous Cropping;
ER = Erosion Regulation.

5.4 Duality and Sensitivity Analyses

Duality enables economic analyses of constrained resources to be made and sensitivity analyses evaluate modifications to the model instruments and their impact on the optimal solution; this explains why some analysts prefer the term post-optimality analyses. Sensitivity analyses can be made for: (1) varying the right hand side values, B_j, (2) varying the objective function coefficients, (3) varying the constrained coefficients, A_{ij}, (4) including a new constraint(s), and (5) including a new instrument (Lee, Moore and Taylor 1985).

Simulations **NG, SG, CCNG** and **CCSG** represent sensitivity analyses with respect to the objective function coefficients, while **NOSF** and **NOG** depict the cases involving new constraints. This section covers sensitivity analyses as they pertain to issues such as Reduced Costs and Dual Prices. The discussion focuses on only the Base Case model. The associated results for all the simulations, including those of the Base Case, are presented in Appendix D. .

For the Base Case, the GMs for wheat on classes 1 and 2 land needed to increase by at least $11.82 per acre (i.e., the reduced cost) before it can enter the optimal solution, while for oats it was about $7.18/ac; unimproved land, $45.74/ac; summerfallow, $31.77/ac.

The dual prices for the Base Case show that an increase by an acre of any of the land classes will increase net return; class 1 land, for example, generates an extra return of $71.44 (the highest) and class 5 land only an additional $30.22, or 58% less. Similarly, the respective shadow prices for one percent increase in the minima for oats, barley, wheat, and forage were $98.0, $104.87, $93.35, and $60.45.[11] Furthermore, a unit percent increase in the minimum for summerfallow, as a function of grains (equation 4.12), will result in a decline of net return by $66.04.

The Base Case dual prices also indicate surpluses, with respect to equations 4.13, 4.14 and 4.18. In respective order, this means that the minimum of 60% TFA specified for total grain acreage was increased to 72%; the minimum acreage for CWB assignable quota was surpassed by about 61%, perhaps reflecting the fact that Peace River grain farmers are dependent upon and

[11]Assumed for their respective class 1 land only.

influenced by CWB operations and policies; the minimum designated for canola, 24% of total grain acreage, increased to 35%, making canola the dominant field crop.

The sensitivity analyses of the Base Case show, with respect to land class 1 GMs for the instruments, that the ranges for which the optimal solution will remain unaffected were: wheat, from $0 to $65.47; oats, from $0 to $73.33; barley, from $0 to $85.07; canola, $104.87 and beyond; forage, from $0 to $64.76; unimproved land, from $0 to $71.99; summerfallow, up to $5.96.

Similarly, the ranges of the acreages for the five land classes were: class 1 (306 to 378 acres); class 2 (309 to 381 acres); class 3 (274 to 348 acres); class 4 (290 to 364 acres); class 5 (26 to 409 acres). This means the Base Case can cover even Peace River farmers who have at least some 1,205 acres.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Undoubtedly, sustainability of agriculture has become an issue of major concern the world over. Debate about sustainable development has largely moved from the kingdom of rhetoric to discussions about strategies. Some research stations and institutes have been created to foster it and many countries, including Canada, along with multilateral organizations and institutions have made it a priority. Moreover, activism and campaigns to change laws and policies (and also to enact new tougher regulations) by various environmental movements around the world have intensified.

British Columbia is not unaffected by the environmental consciousness that is widely taking root in every corner of the world. In fact, it has been the catalyst for some government initiatives including the formation of a Round Table on the Economy and the Environment in B.C. to outline approaches that can facilitate sustainable development in the province.

Concerns about larger and global sustainability issues, such as depletion of the ozone layer, deforestation and non-renewable resources, have trickled down to agriculture. Plagued by "soil-mining" farming practices that depend excessively on chemicals, energy and subsidies, agriculture has come under pressure to resolve its sustainability issues such as land degradation.

Consequently, many researchers have grappled with the notion of sustainable agriculture. This thesis attempted a similar exercise by focusing on British Columbia's grain belt, the Peace River region, using the optimisation tool of Linear Programming.

6.1 Methodology

After a review of the sustainable development literature, it was observed that many countries have resorted to measures that may generally be termed as environmental accounting as a way of integrating environmental considerations into development programmes. In Canada, for example, the federal government's Green Plan released in 1990 is an attempt in this direction supported by over 100 initiatives and an extra $3 billion in spending over five years.

The notion of sustainable development, with all its conceptual and definitional imprecisions, was averred as a necessary step in the direction that can establish a harmonious relationship between humanity and the environment.

The Peace River region was noted as having the most erodible lands in B.C., a problem accentuated by low soil formation. Hence, averting farm practices that lead to land degradation was imperative to ensure sustainable agriculture in the region.

The LP model used in this study has some data limitations including lack of uniform gross margins; in some cases extrapolation was required. Discrepancies were also found with available data, which were not identical to extrapolated results in Tables 3.4, 3.5 and 3.7. These factors may have unduly affected the results of the models. Nevertheless, the Base Case model reasonably replicated the general situation for some years in the region.

Given adequate information and data, some of the constraints may be differently specified; of course, that will impact on the results. Notably, the regulation pertaining to soil erosion can be refined given appropriate assessment of soil loss due to individual crops and tolerable soil loss. Since the region is B.C.'s grain belt and that the area's sustainable agricultural development can be better enhanced by research, the dearth of field and applied research in the region needs to be addressed. This study is intended to be a contribution in that regard.

The livestock sector can also be directly incorporated into the model. The impact of alternative agricultural programmes--as investigated in this study, for example--on this important sector in the Peace River region can then be better analyzed.

6.2 Summary of Results

Relevant government agricultural programmes were found to have largely contributed to current farm practices that involve cultivation of grains and the summerfallow of some marginal lands. In some cases, new programmes have been introduced to mitigate existing programmes' adverse impact on the environment. The recently introduced GRIP was noted as impeding sustainable agriculture even though GRIP was meant in part to foster it.

By eliminating subsidies entailed in four government agricultural programmes (WGSA, SCGP, Chemical Rebates and Crop Insurance) that inadvertently encourage cultivation of grains on "poorer" lands, our results **(NG)** indicated a more than five-fold increase in acreage for unimproved land; but it led to a 27.3% decline in net return. It was found that another alternative programme **(NOG)** can convert enough acreage to unimproved land to help feed 15,640 beef cows in the Peace River region. This result supports initiatives such as the Permanent Cover Programme recently introduced in the prairies by Agriculture Canada.

Table 6.1 summarizes the impact of alternative programmes on the Base Case. It shows that with the exception of regulations **SG** and **ER**, all the other simulated programmes resulted in a more than five-fold increase in unimproved land. Only **CCNG** and **CCSG** led to an increase in acreage for forage.

Regulating against grains on poor lands **(NOG)** led to a 57% decline in acreage for summerfallow, a major catalyst for soil erosion, with its attendant detrimental consequences; this was the largest impact. **NOG** also increased net return by 3.8%. A direct regulation against summerfallow on the region's poor land **(NOSF)** decreased summerfallow by 19.2% and it affected a 10.2% slump in farmers' income. But benefits associated with less soil erosion may nullify the immediate income loss; all the other alternative programmes resulted in a decrease of net return ranging from 1.1% to 47.4%.

Table 6.1: Summary of Alternative Programmes' Impact on Base Case

Alternative Programme	Percent Change in Base Case				
	Grains	Summerfallow	Forage	Unimproved Land	Net Return
NG	-19.3	-19.2	-19.4	543.8	-27.3
SG	-1.9	-1.9	-1.9	54.2	-12.0
NOSF	-19.3	-19.2	-19.4	543.8	-10.2
NOG	-13.7	-56.7	-13.6	572.9	3.8
CC	-10.4	NA	-46.6	758.3	-22.9
CCNG	-19.3	NA	25.2	797.9	-47.4
CCSG	-19.3	NA	43.7	758.3	-35.2
ER	-6.9	-6.7	-6.8	193.8	-1.1

NG = No Government; SG = Some Government; NA = Not Applicable;
NOSF = No Summerfallow on Land Classes 4 and 5;
NOG = No Grains on Land Classes 4 and 5;
CC = Continuous Cropping;
CCNG = Continuous Cropping with No Government Subsidy;
CCSG = Continuous Cropping with Some Government Subsidy;
ER = Erosion Regulation.

6.3 Conclusions

Sustainable agriculture in the region requires a revamping of relevant government programmes such as WGSA and crop insurance to discourage cultivation of marginal lands and monoculture practices, which are increasing in the region. These programmes (including GRIP) should be modified to provide the right incentives to those who opt to diversify their farms and practice sustainable agriculture. For example, at present, CWB does not count wheat used in feeding livestock towards a farmer's quota benefits; and GRIP does not cover forage and pasture land, both important factors in mitigating soil erosion.

Other measures that can facilitate sustainable agriculture in the region include support for a wide range of applied research to expand knowledge and disseminate relevant information to farmers. Integrated pest management as an alternative to widespread use of insecticides, suggested by the IFOAM for example, can be investigated and, if feasible, applied in the region. More research into erosion to adequately determine the region's T-value and individual crop soil loss and the appropriate ways, involving cropping practices and different types of vegetation, to help farmers keep erosion rates within sustainable levels are also needed. These endeavours may require collaborative efforts of governments, farmers, universities and research institutions and the private sector. At the universities, for example, interdisciplinary research teams should be fostered to bridge the chasm between the physical scientists and others, including in particular agricultural economists.

It would be worthwhile also to investigate the impact of sustainable agricultural practices on factors such as yields. Such an exercise can also assist public and private policy makers make informed decisions, in addition to alleviating paranoia about food security often associated with an alternative agriculture.

BIBLIOGRAPHY

Agriculture Canada (1983). Development of the Agri-Food Sector in British Columbia: A Provincial Profile, Regional Development Branch, Victoria, B.C. (October).

_______________ (1983B). Development of the Agri-Food Sector in British Columbia: Commodity Profile, Regional Development Branch, Victoria, B.C. (October).

_______________ (1986). Soils of the Fort St.John-Dawson Creek area, British Columbia, Report # 42, British Columbia Soil Survey, Research Branch.

_______________ (1988). Agriculture and Food in British Columbia: A Look at the Industry and its Prospects for Development, Agriculture Development Branch, B.C. (Summer).

_______________ (1990). Farm Income and Financial Conditions and Government Expenditures (Farm Finance and Taxation Division)

Andow, D. (1983). "Effect of Agricultural Diversity on Insect Populations," in William Lockeretz (ed). Environmentally Sound Agriculture, (New York: Preager Publishers, 1983), pp.91-115.

Arrow, K.J. (1985). "The Potentials and Limits of the Market in Resource Allocation," in George R. Feiwel (ed.) Issues in Contemporary Microeconomics and Welfare, (London: MacMillan Press Ltd., 1985), pp.107-24.

Awmack, W.D. (1974). Farm Planning Under Certainty as Applied to the Peace River Block of British Columbia, B.A. Thesis, Dept. of Agricultural Economics, U.B.C., Vancouver.

Batie, Sandra, S. (1989). "Sustainable Development: Challenges to the Profession of Agricultural Economics," American Journal of Agricultural Economics, 16, pp.1083-1101.

Bator, F. (1958). "The Anatomy of Market failure," Quarterly Journal of Economics, 72, pp.351-79.

Barnett, H.J. and C. Morse (1963). Scarcity and Growth: The Economics of Natural Resource Availability, (Baltimore: The Johns Hopkins Press)

B.C. Ministry of Agriculture and Food (1984). Agricultural Statistics Profile 1984, (Victoria, B.C., November 1985).

_______________ (1982). Census of Agriculture Statistics: B.C.: 1971 & 1981, (Victoria, B.C.)

________________ (1980). Census of Agriculture Statistics: B.C.: 1971 & 1976, (Victoria, B.C.)

B.C. Ministry of Finance and Corporate Relations (1989). British Columbia: Economic and Statistical Review, (Victoria, B.C., October 1989).

Bentley, C.F. and L.A. Leskiw (1985). Sustainability of Farmed Lands: Current Trends and Thinking, Canadian Environmental Advisory Council, Report # 15, (Ottawa: Minister of Supply and Services Canada).

Berry, Wendell (1978). "The Commercial Imperative and the Decline of the Family Farm," in Martha M. Pratt (ed.) Proceedings of the P.E.I. Conference on Ecological Agriculture, (Charlottetown: The Institute of Man and Resources/The Ark Project).

Brown, L.R. (1990). "The Illusion of Progress," in Lester R. Brown, A. Durning, C. Slavin, H. French, J. Jacobson, M. Lowe, S. Postel, M. Renner, L. Starke and J. Young (1990). State of the World 1990, (New York: W.W. Norton & Co., 1990), pp.1-16.

________________ and Young, E.Y. (1990). "Feeding the World in the Nineties," in Lester R. Brown, A. Durning, C. Slavin, H. French, J. Jacobson, M. Lowe, S. Postel, M. Renner, L. Starke and J. Young (1990). State of the World 1990 (New York: W.W. Norton & Co., 1990), pp.59-78.

Burt, O.R. (1981). "Farm Level Economics of Soil Conservation in the Palouse Area of the Northwest," American Journal of Agricultural Economics, 63, pp. 83-92.

Careless, R. (1990). Incorporating Environmental Performance Indicators into National Income Accounts, Ethos Consulting Paper for B.C. Round Table on the Environment and the Economy.

Carroll, C.R., J.H. Vandermeer and P.M. Rossel (ed.) (1990). Agroecology, (New York: McGraw-Hill, Inc.).

Craddock, W.J. (1970). Interregional Competition in Canadian Cereal Production, prepared for the Economic Council of Canada, (Ottawa: Queen's Printer).

Daly, H.E. (1968). "On Economics as a Life Science," Journal of Political Economy, 76, pp.392-405.

________________ and J.B. Cobb, Jr. (1989). Measures of Sustainable Economic Welfare.

Department of the Environment (1990). Canada's Green Plan, (Hull: Minister of Supply and Services).

Department of Industrial Development, Trade and Commerce (1966). The Peace River-Liard Region: An Economic Survey, Bureau of Economics and Statistics, Victoria, B.C.

Department of Lands and Forests (1952). Peace River -- South: Land Utilization Survey, 1948-51, Division of Land Utilization Research and Survey, Victoria, B.C.

Dorfman, R., Samualson, P.A. and Solow, R.M. (1958). Linear Programming and Economic Analysis, (New York: McGraw - Hill Book Co., Inc.).

Economic Council of Canada (1988). Handling the Risks: A Report on the Prairie Economy, (Ottawa: Minister of Supply and Services).

Environment Canada (1982). Canadian Climate Normals 1951-1980, various volumes.

Fisher, A.C., J.V. Krutilla and C.J. Cicchetti (1972). "The Economics of Environmental Preservation: A Theoretical and Empirical Analysis," American Economic Review, 62, pp.605-19.

_______________ and Peterson, F.M. (1976). "The Environment in Economics: A Survey," Journal of Economic Literature, 14, pp.1-33.

Graham, J.D. and Lopez, R. (1976). Farm Planning Under Uncertainty: An Application of MOTAD Programming to the Peace River Block of British Columbia, Discussion Paper, Dept of Agricultural Economics, University of British Columbia.

_______________ and Anderson, W. (1982). Agricultural Development Planning in the Peace River Region of British Columbia: A Linear Programming Analysis, Discussion Paper, Dept. of Agricultural Economics, University of British Columbia.

Guide to Farm Practice in Saskatchewan, Revised 1987, (Saskatoon: University of Saskatchewan Division of Extension and Community Relations).

Hazell, P.B.R. and Norton, R.D. (1986). Mathematical Programming for Economic Analysis in Agriculture, (New York: Macmillan Publishing Co.)

Heady, E.O. and W. Chandler (1958). Linear Programming Methods, (Ames: Iowa State University Press)

Hileman, B. (1990). "Alternative Agriculture," Chemical and Engineering News, 68, 26-40.

Hill, S. (1978). "Biological Approaches to Pest Control," in Martha M. Pratt (ed.) Proceedings of the P.E.I. Conference on Ecological Agriculture,(Charlottetown: Institute of Man and Resources/Ark Project).

Hodges, R.D. and Scofield, A.M. (1983). "Effect of Agricultural Practices on the Health of Plants and Animals Produced," in William Lockeretz (ed). Environmentally Sound Agriculture, (New York: Preager Publishers, 1983), pp.3-34.

Holtby, R.G. (1972). Resource Allocation for the Median Peace River Farm in British Columbia, M.Sc Thesis, Dept. of Agricultural Economics, University of British Columbia.

Intriligator, M.D. (1971). Mathematical Optimization and Economic Theory, (Englewood Cliffs: Prentice Hall Inc.)

Johansson, P.O. (1990). "Valuing Environmental Damage," Oxford Review of Economic Policy, 6(1)

Krutilla, J.V. (1967). "Conservation Reconsidered," American Economic Review, 57, pp.777-86.

Lee, S.M., L.J. Moore and B.W. Taylor 111 (1985). Management Science, (Boston: Allyn and Bacon, Inc.).

Lockeretz, W. (ed.) (1983). Environmentally Sound Agriculture, (New York: Preager Publishers).

Mcguire, D.O.C. (1985). Crop Selection Under Conditions of Risk in the Peace Region of British Columbia, B.Sc Thesis, Dept of Agricultural Economics, University of British Columbia.

Meister, A.D., C.C. Chen and E.O. Heady (1978). Quadratic Programming Models Applied to Agricultural Policies, (Ames: Iowa State University Press).

Nisbet, T.G. (1962). A Study of Resource Use on a Selected Farm in the Peace River Area of British Columbia Using the Simplex Method of Linear Programming, Unpublished Graduating Essay, U.B.C., Vancouver.

Norgaard, R.B. (1984). "Coevolutionary Development Potential," Land Economics, 60, 160-73.

Odlum, R.M. (1929). The Peace River Country, B.S.A. Thesis, University of British Columbia.

Postel, S. (1988). "Halting Land Degradation," in Lester R. Brown et al. State of the World 1988, (New York: W.W. Norton & Co., 1988), pp. 21-40

Potter, N. and F.T. Christy, Jr. (1962). Trends in Natural Resource Commodities: Statistics of Prices, Output, Consumption, Foreign Trade, and Employment in the United States, 1870-1957, (Baltimore: The Johns Hopkins Press).

Rennie, D.A. (1986). Agricultural Soil Issues in Canada, Report prepared for the Science Council of Canada, Mimeo.

Report of the Joint UNEP/World Bank Expert Meeting on Environmental Accounting and the System of National Accounts, (Paris, November 1988).

Ruttan, V.M. (1971). "Technology and the Environment," American Journal of Agricultural Economics, Presidential Address, pp.707-17.

Saskatchewan Agriculture and Food (1989). Cost of Producing Grain Crops in Saskatchewan 1989, Economics Branch.

Schrage, L. (1986). Linear, Integer and Quadratic Programming with LINDO, (Palo Alto, CA, The Scientific Press).

Science Council of Canada (1986). A Growing Concern: Soil Degradation in Canada, (Ottawa: Minister of Supply and Services).

Scitovsky, T. (1954). "Two Concepts of External Economies," Journal of Political Economy, 62, pp.143-51.

Senate of Canada (1984). Soil at Risk: Canada's Eroding Future, A Report on Soil Conservation by the Standing Committee on Agriculture, Fisheries and Forestry, Hon. H.O. Sparrow (Chairman), (Ottawa: Minister of Supply and Services).

Smith, V.L. (1968). "Economics of Production from Natural Resources," American Economic Review, 58, pp.409-31.

Soule, J., D. Carre and W. Jackson (1990). "Ecological Impact of Modern Agriculture,"in C.R. Carroll, J.H. Vandermeer and P.M. Rossel (ed.) (1990). Agroecology, (New York: McGraw-Hill Publishing Co.), pp.165-88.

Turner, R.K. (1988). "Pluralism in Environmental Economics: A Survey of the Sustainable Economic Development Debate," Journal of Agricultural Economics, 39, pp.352-59

Tivy, J. (1990). Agricultural Ecology, (Essex: Longman Group UK Ltd.).

van Kooten, G.C. (1987), "A Socioeconomic Model of Agriculture: A Proposal for Dealing with Environmental Problems in Rural Economy," The Prairie Forum, 12, pp. 157-68.

_______________ and Furtan, W.H. (1987). "A Review of Issues Pertaining to Soil Deterioration in Canada," Canadian Journal of Agricultural Economics, 35, pp.33-54.

_______________ (1990). "Bioeconomic Evaluation of Private Wetlands," Paper prepared for the American Agricultural Economics Association Annual Meeting, Vancouver, August 4-8, 1990.

_______________ and Kennedy, G. (1990), "An Economic Perspective on Sustainable Agriculture in Western Canada," Canadian Journal of Agricultural Economics, 38, pp. 741-56.

_______________, W.P. Weisensel and D. Chinthammit (1990). "Valuing Trade-Offs between Net Returns and Stewardship Practices: The Case of Soil Conservation in Saskatchewan," American Journal of Agricultural Economics, (February), pp.102-13.

van Vliet, L.J.P., A.M.F. Henning and M.D. Novak (1986) "Soil Erosion Loss Monitoring and Prediction Under Semi-Arid Agriculture in the Peace River Prairie Region of NW Canada," in Publication 40, International Institute for Land Reclamation and Improvement, Netherlands.

_______________ and Hall, J.W (1991). "Effects of Two Crop Rotations on Seasonal Runoff and Soil Loss in the Peace River Region," Canadian Journal of Soil Science, 71, pp.1-12.

Weisensel, W.P., K.A. Rosaasen and R.A. Schoney (1991). A Review of the Preliminary 1987 Saskatchewan Assessment Manual: Possible Implications for Natural Habitat, Final Report.

Wilson, C.F. (1979). Canadian Grain Marketing, (Winnipeg: Canadian International Grains Institute).

Winpenny, J.T. (1991). Values for the Environment: A Guide to Economic Appraisal, (London:HMSO).

World Commission on Environment and Development. Our Common Future, (Oxford: Oxford University Press, 1987).

World Conservation Union (1989). From Strategy to Action: IUCN's Response to the Report of the World Commission on Environment and Development, (Gland, Switzerland, IUCN).

APPENDICES

APPENDIX A

ACTS ADMINISTERED BY THE FEDERAL MINISTER OF AGRICULTURE (BY PROGRAMME)

Agri-Food Programme

Scientific Research and Development
Experimental Farm Station Act
Forestry Development and Research Act

Inspection and Regulation
Animal Disease and Protection Act
Canada Agricultural Products Act
Canada Dairy Commission Act
Canada Meat Import Act
Feeds Act
Fertilizer Act
Hay and Straw Inspection Act
Livestock and Pedigree Act
Meat Inspection Act
Pest Control Products Act
Pesticide Residue Compensation Act
Plant Quarantine Act

Farm Financial Programme
Agricultural Products Board Act
Agricultural Stabilization Board Act
Crop Insurance Act
Prairie Farm Loans Interest Rebate Act
Prairie Farm Rehabilitation Act

Agriculture Development
Advance Payments for Crops Act
Agricultural Products Co-operative Marketing Act
Agricultural Products Marketing Act
Farm Improvement and Marketing Cooperatives Loans Act
Farm Products Marketing Agencies Act

Industry Acts
Fruit, Vegetables and Honey Act
Livestock and Livestock Products Act
Seeds Acts

Grains and Oil seeds Programme
Canada Grain Act
Canadian Wheat Board Act
Prairie Grain Advance Payments Act
Western Grain Stabilization Act
Grain Futures Act

Canadian Dairy Commission
Canadian Dairy Commission Act
Agriculture Stabilization Act

Canadian Livestock Feed Board
Livestock Feed Assistance Act

Farm Credit Corporation
Farm Act
Farm Debt Review Act
Farm Syndicates Credit Act

Miscellaneous Acts

Source: Agriculture Canada 1988, pp.51-52

APPENDIX B

ACTS ADMINISTERED BY THE BRITISH COLUMBIA MINISTRY OF AGRICULTURE AND FISHERIES (BY PROGRAMME)

Extension and Education
Agrologists Act
Farmers and Women's Institutes Act
Livestock Act
Pharmacists Act
Veterinarians Act
Veterinary Laboratory Act
Regulatory Services
Agricultural Produce Grading Act
Livestock Brand Act
Livestock Public Sales Act
Meat Inspection Act
Natural Products Marketing Act
Financial Assistance
Agricultural Credit Act
Agricultural Land Commission Act
Agricultural and Rural Development Act
Cattle Horn Act
Farm Distress Assistance Act
Farm Income Assistance Act
Insurance for Crops Act
Livestock Lien Act
Direct Services
Grasshopper Control Act
Livestock Disease Control Act
Livestock Protection Act
Plant Protection Act
Soil Conservation Act
Weed Control Act
Industry Acts
Bee Act
Farm Products Industry Act
Fur Farm Act
Livestock Industry Act
Margarine Act
Milk Industry Act
Seed Grower Act
Seed Potato Act
Other Acts

Source: Agriculture Canada 1988, p.48

APPENDIX C

B.C. LAND INVENTORY SOIL CAPABILITY CLASS DESCRIPTION FOR AGRICULTURE

Class 1	Land is capable of producing the widest range of vegetables, cereal, grains,forages berry fruits and numerous crops. Soil and climate conditions are optimum.
Class 2	Land is capable of producing the same crops as above with some restrictions in the range of varieties due to minor soil or climate limitations
Class 3	Land is capable of producing a narrower range of crops with good management. Soils and/or management limitations are restrictive.
Class 4	Land is capable of a more restricted range of the crops found in a region than might be possible on class 3 land. hardy cereal grains, hardy vegetables, and forages can be grown. The soil and climate limitations can only be ameliorated with special management.
Class 5	Land is capable of producing perennial forage crops only.
Class 6	Land is natural rangeland. Soil and/or climate limitations preclude cultivation, but grazing may be possible from its natural state.
Class 7	Land has no capability for agricultural use at all.

Source: Agriculture Canada 1983, p.33

APPENDIX D

RESULTS OF DUALITY AND SENSITIVITY ANALYSES, BY MODEL

THE BASE CASE

OBJECTIVE FUNCTION VALUE 74155.1200

VARIABLE	REDUCED COST
W1	11.829300
W2	11.059300
W3	.000000
W4	.000000
W5	.000000
A1	7.179297
A2	6.589301
A3	.000000
A4	2.849994
A5	4.670002
B1	.309999
B2	.000000
B3	.050695
B4	7.130697
B5	11.650710
C1	.000000
C2	.000000
C3	7.330698
C4	19.060700
C5	26.550700
F1	12.259300
F2	11.469300
F3	.000000
F4	5.844997
F5	9.575001
U1	45.744300
U2	44.174300
U3	13.965000
U4	7.859997
U5	.000000
SF1	31.779300
SF2	30.209300
SF3	.000000
SF4	.000000
SF5	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	201.166000	.000000
3)	822.480800	.000000
4)	331.520000	.000000
5)	334.880000	.000000
6)	166.600000	.000000
7)	.000000	-6.105000
8)	.000000	-9.994995
9)	.000000	71.994300
10)	.000000	70.424300
11)	.000000	40.215000
12)	.000000	34.110000
13)	.000000	30.220000
14)	.000000	-66.035000
15)	114.537500	.000000
16)	.000000	-31.850700
17)	.000000	-20.110000
18)	.000000	-39.710700
19)	.000000	-7.950548

RANGES IN WHICH THE BASIS IS UNCHANGED:

	OBJ COEFFICIENT RANGES		
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	53.640000	11.829300	INFINITY
W2	52.840000	11.059300	INFINITY
W3	33.690000	2.849994	.081224
W4	21.480000	12.210000	2.849994
W5	13.700000	.049958	4.670003
A1	66.150000	7.179297	INFINITY
A2	65.170000	6.589301	INFINITY
A3	41.550000	.294954	2.849994
A4	26.490000	2.849994	INFINITY
A5	16.890000	4.670002	INFINITY
B1	84.760000	.309999	INFINITY
B2	83.500000	16.178090	.092700
B3	53.240000	.050695	INFINITY
B4	33.950000	7.130697	INFINITY
B5	21.650000	11.650710	INFINITY
C1	105.180000	INFINITY	.309999
C2	103.610000	.092700	12.049010
C3	66.070000	7.330698	INFINITY
C4	42.130000	19.060700	INFINITY
C5	26.860000	26.550700	INFINITY
F1	52.500000	12.259300	INFINITY
F2	51.720000	11.469300	INFINITY
F3	32.980000	.328055	5.844997
F4	21.030000	5.844997	INFINITY

F5	13.410000	9.575001	INFINITY
U1	26.250000	45.744300	INFINITY
U2	26.250000	44.174300	INFINITY
U3	26.250000	13.965000	INFINITY
U4	26.250000	7.859997	INFINITY
U5	30.220000	3.246708	.024979
SF1	-25.820000	31.779300	INFINITY
SF2	-25.820000	30.209300	INFINITY
SF3	-25.820000	9.382908	.072188
SF4	-25.820000	INFINITY	11.689990
SF5	-25.820000	.049958	6.493415

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	201.166000	INFINITY
3	530.000000	822.480800	INFINITY
4	.000000	331.520000	INFINITY
5	.000000	334.880000	INFINITY
6	.000000	166.600000	INFINITY
7	.000000	156.264200	52.139230
8	.000000	26.400790	26.400790
9	331.520000	46.292060	25.643460
10	334.880000	46.292060	25.643460
11	321.720000	26.400790	47.659210
12	337.960000	26.400790	47.659210
13	74.060000	335.276700	47.659210
14	.000000	47.659210	26.400790
15	.000000	114.537500	INFINITY
16	.000000	23.482840	13.008300
17	.000000	32.917500	301.962500
18	.000000	23.482850	13.008310
19	.000000	43.369880	24.024720

(1) No Government Subsidy (NG)

OBJECTIVE FUNCTION VALUE

53876.5100

VARIABLE	REDUCED COST
W1	5.240005
W2	4.470005
W3	.000000
W4	.000000
W5	7.779999
A1	.590003
A2	.000000
A3	.000000
A4	2.849996
A5	12.450000
B1	.309992
B2	.000000
B3	6.639997
B4	13.719990
B5	26.019990
C1	.000000
C2	.000000
C3	13.920000
C4	25.650000
C5	40.920000
F1	5.670004
F2	4.880007
F3	.000000
F4	5.845000
F5	13.465000
U1	31.295000
U2	29.725000
U3	6.105001
U4	.000000
U5	.000000
SF1	25.190000
SF2	23.620000
SF3	.000000
SF4	.000000
SF5	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	.000000	-6.154738
3)	561.186000	.000000
4)	331.520000	.000000
5)	334.880000	.000000
6)	5.667171	.000000
7)	.000000	-6.105003
8)	.000000	-6.105003
9)	.000000	53.852160
10)	.000000	52.282160
11)	.000000	28.662160
12)	.000000	22.557160
13)	.000000	22.557160
14)	.000000	-78.525000
15)	.000000	-6.763737
16)	336.033600	.000000
17)	84.008380	.000000
18)	.000000	20.110010
19)	.000000	-18.330000
20)	.000000	-26.190000

RANGES IN WHICH THE BASIS IS UNCHANGED:

	OBJ COEFFICIENT RANGES	
VARIABLE	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	5.240005	INFINITY
W2	4.470005	INFINITY
W3	2.849996	4.470005
W4	9.476839	2.849996
W5	7.779999	INFINITY
A1	.590003	INFINITY
A2	6.639998	.590004
A3	4.470005	2.849996
A4	2.849996	INFINITY
A5	2.450000	INFINITY
B1	.309992	INFINITY
B2	20.110010	.309992
B3	6.639997	INFINITY
B4	13.719990	INFINITY
B5	26.019990	INFINITY
C1	INFINITY	.309992
C2	.309992	13.920000
C3	13.920000	INFINITY
C4	25.650000	INFINITY
C5	40.920000	INFINITY
F1	5.670004	INFINITY
F2	4.880007	INFINITY
F3	6.155001	4.880007

F4	5.845000	INFINITY
F5	13.465000	INFINITY
U1	31.295000	INFINITY
U2	29.725000	INFINITY
U3	6.105001	INFINITY
U4	3.890000	4.738420
U5	6.105003	3.889999
SF1	25.190000	INFINITY
SF2	23.620000	INFINITY
SF3	11.690000	12.210000
SF4	9.476839	7.779999
SF5	7.779999	6.105003

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	111.916100	7.083963
3	530.000000	561.186000	INFINITY
4	.000000	331.520000	INFINITY
5	.000000	334.880000	INFINITY
6	.000000	5.667171	INFINITY
7	.000000	5.667171	103.066000
8	.000000	.000000	74.060000
9	331.520000	10.898400	135.071100
10	334.880000	10.898400	135.071100
11	321.720000	186.526800	11.806610
12	337.960000	186.526800	11.806610
13	74.060000	186.526800	11.806610
14	.000000	5.667171	103.066000
15	.000000	212.000500	75.607560
16	.000000	336.033600	INFINITY
17	.000000	84.008380	INFINITY
18	.000000	84.008390	88.521970
19	.000000	84.008390	78.341250
20	.000000	5.667174	78.341250

(2) SOME GOVERNMENT SUBSIDY (SG)

OBJECTIVE FUNCTION VALUE

65244.7700

VARIABLE	REDUCED COST
W1	11.880000
W2	11.110000
W3	.000000
W4	.000000
W5	.000000
A1	7.229997
A2	6.640001
A3	.000000
A4	2.850006
A5	4.670003
B1	.309998
B2	.000000
B3	.000000
B4	7.080006
B5	11.600000
C1	.000000
C2	.000000
C3	7.280003
C4	19.010010
C5	26.500000
F1	12.310000
F2	11.520000
F3	.000000
F4	5.845005
F5	12.128070
U1	39.271930
U2	37.701930
U3	7.441929
U4	1.336933
U5	.000000
SF1	31.829990
SF2	30.260000
SF3	.000000
SF4	.000000
SF5	5.106140

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	180.840500	.000000
3)	796.080000	.000000
4)	331.520000	.000000
5)	334.880000	.000000
6)	150.339600	.000000
7)	.000000	-6.105000
8)	.000000	-12.548070
9)	.000000	65.521930
10)	.000000	63.951930
11)	.000000	33.691930
12)	.000000	27.586930
13)	.000000	26.250000
14)	.000000	-69.691930
15)	.000000	-4.507615
16)	408.369800	.000000
17)	102.092400	.000000
18)	.000000	20.110000
19)	.000000	-11.690000
20)	.000000	-19.550000

RANGES IN WHICH THE BASIS IS UNCHANGED:

		OBJ COEFFICIENT RANGES	
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	43.460000	11.880000	INFINITY
W2	42.660000	11.110000	INFINITY
W3	23.510000	2.850006	7.378310
W4	11.300000	12.210000	2.673866
W5	3.520000	5.106140	4.670003
A1	55.970000	7.229997	INFINITY
A2	54.990000	6.640001	INFINITY
A3	31.370000	11.690000	2.850005
A4	16.310000	2.850006	INFINITY
A5	6.710000	4.670003	INFINITY
B1	74.580000	.309998	INFINITY
B2	73.320000	3.473087	.309998
B3	43.060000	4.737408	2.480777
B4	23.770000	7.080006	INFINITY
B5	11.470000	11.600000	INFINITY
C1	95.000000	INFINITY	.309998
C2	93.430000	.309998	3.473087
C3	55.890000	7.280003	INFINITY
C4	31.950000	19.010010	INFINITY
C5	16.680000	26.500000	INFINITY
F1	49.110000	12.310000	INFINITY
F2	48.330000	11.520000	INFINITY
F3	29.590000	4.440001	5.845005

F4	17.640000	5.845005	INFINITY
F5	10.020000	12.128070	INFINITY
U1	26.250000	39.271930	INFINITY
U2	26.250000	37.701930	INFINITY
U3	26.250000	7.441929	INFINITY
U4	26.250000	1.336933	INFINITY
U5	26.250000	INFINITY	2.553070
SF1	-36.000000	31.829990	INFINITY
SF2	-36.000000	30.260000	INFINITY
SF3	-36.000000	3.863704	7.378310
SF4	-36.000000	INFINITY	2.673866
SF5	-36.000000	5.106140	INFINITY

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	180.840500	INFINITY
3	530.000000	796.080000	INFINITY
4	.000000	331.520000	INFINITY
5	.000000	334.880000	INFINITY
6	.000000	150.339600	INFINITY
7	.000000	70.409820	70.409820
8	.000000	41.612210	.000000
9	331.520000	104.638800	228.638500
10	334.880000	104.638800	228.638500
11	321.720000	405.095400	89.526150
12	337.960000	101.741300	89.526150
13	74.060000	301.400900	74.060000
14	.000000	89.526150	41.612210
15	.000000	81.468800	99.456010
16	.000000	408.369800	INFINITY
17	.000000	102.092400	INFINITY
18	.000000	102.092400	178.942300
19	.000000	48.247170	102.092500
20	.000000	48.247170	35.204910

(3) NO SUMMERFALLOW ON LAND CLASSES 4 - 5 (NOSF)

OBJECTIVE FUNCTION VALUE

66611.2300

VARIABLE	REDUCED COST
W1	11.570000
W2	11.109990
W3	.000000
W4	.000000
W5	.000000
A1	6.920075
A2	6.640069
A3	.000000
A4	2.850077
A5	4.670081
B1	.000000
B2	.000000
B3	.000000
B4	7.079995
B5	11.600000
C1	.000000
C2	.309991
C3	7.590004
C4	19.320000
C5	26.810010
F1	12.260000
F2	12.409990
F3	.260002
F4	.000000
F5	11.590000
U1	43.730000
U2	43.099990
U3	12.210000
U4	.000000
U5	.000000
SF1	.000000
SF2	.000000
SF3	12.210000
SF4	.000000
SF5	15.719990

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	.000000	-3.922657
3)	561.186000	.000000
4)	330.366400	.000000
5)	.000000	-.630005
6)	321.720000	.000000
7)	19.980800	.000000
8)	.000000	-11.750000
9)	.000000	67.626400
10)	.000000	66.996400
11)	.000000	36.106410
12)	.000000	23.896410
13)	.000000	27.866410
14)	.000000	-95.800000
15)	92.409230	.000000
16)	.000000	-32.109920
17)	.000000	-20.420010
18)	.000000	-39.970010
19)	.000000	-5.736263
20)	.000000	43.730000

RANGES IN WHICH THE BASIS IS UNCHANGED:

		OBJ COEFFICIENT RANGES	
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	53.640000	11.570000	INFINITY
W2	52.840000	11.109990	INFINITY
W3	33.690000	2.850078	.260002
W4	21.480000	.260002	2.850078
W5	13.700000	11.750000	4.670081
A1	66.150000	6.920075	INFINITY
A2	65.170000	6.640069	INFINITY
A3	41.550000	32.109920	2.850077
A4	26.490000	2.850077	INFINITY
A5	16.890000	4.670081	INFINITY
B1	84.760000	.309991	1.260010
B2	83.500000	1.260010	.309991
B3	53.240000	4.669831	7.079997
B4	33.950000	7.079995	INFINITY
B5	21.650000	11.600000	INFINITY
C1	105.180000	11.207600	.309991
C2	103.610000	.309991	INFINITY
C3	66.070000	7.590004	INFINITY
C4	42.130000	19.320000	INFINITY
C5	26.860000	26.810010	INFINITY
F1	52.500000	12.260000	INFINITY
F2	51.720000	12.409990	INFINITY
F3	32.980000	.260002	INFINITY

F4	21.030000	5.219999	.260002
F5	13.410000	11.590000	INFINITY
U1	26.250000	43.730000	INFINITY
U2	26.250000	43.099990	INFINITY
U3	26.250000	12.210000	INFINITY
U4	26.250000	7.859997	3.019982
U5	30.220000	INFINITY	7.859997
SF1	-25.820000	1.260010	INFINITY
SF2	-25.820000	INFINITY	1.260010
SF3	-25.820000	12.210000	INFINITY
SF4	-25.820000	INFINITY	12.210000
SF5	-25.820000	15.719990	INFINITY

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	67.115960	2.883985
3	530.000000	561.186000	INFINITY
4	.000000	330.366400	INFINITY
5	.000000	73.827550	1.153594
6	.000000	321.720000	INFINITY
7	.000000	19.980800	INFINITY
8	.000000	19.980800	.000000
9	331.520000	71.360020	4.806643
10	334.880000	1.517887	217.139900
11	321.720000	71.360010	4.806642
12	337.960000	111.859900	4.806642
13	74.060000	111.859900	4.806642
14	.000000	36.913780	.576797
15	.000000	92.409230	INFINITY
16	.000000	39.270600	36.913780
17	.000000	92.409230	36.913770
18	.000000	39.270590	36.913770
19	.000000	213.753500	75.607570
20	.000000	.576797	.000000

(4) No GRAINS ON LAND CLASSES 4 - 5 (NOG)

OBJECTIVE FUNCTION VALUE

77001.4500

VARIABLE	REDUCED COST
W1	4.930005
W2	4.470002
W3	.000000
W4	.000000
W5	.000000
A1	.280000
A2	.000000
A3	.000000
A4	2.849994
A5	4.669998
B1	.000000
B2	.000000
B3	6.639997
B4	13.720000
B5	18.240000
C1	.000000
C2	.310017
C3	14.230010
C4	25.960010
C5	33.450010
F1	17.491770
F2	17.011770
F3	12.131770
F4	.000000
F5	11.590000
U1	48.961770
U2	47.701770
U3	24.081760
U4	.000000
U5	.000000
SF1	24.880000
SF2	23.620000
SF3	.000000
SF4	.000000
SF5	15.720000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	58.206920	.000000
3)	546.962000	.000000
4)	331.520000	.000000
5)	334.880000	.000000
6)	142.061900	.000000
7)	.000000	-24.081760
8)	.000000	-35.831760
9)	.000000	75.211770
10)	.000000	73.951770
11)	.000000	50.331760
12)	.000000	26.250000
13)	.000000	30.220000
14)	98.812000	.000000
15)	.000000	-38.750020
16)	.000000	-20.420020
17)	.000000	-46.610020
18)	.000000	-5.736263
19)	.000000	35.953530
20)	.000000	-76.151760

RANGES IN WHICH THE BASIS IS UNCHANGED:

	OBJ COEFFICIENT RANGES		
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	53.640000	4.930005	INFINITY
W2	52.840000	4.470002	INFINITY
W3	33.690000	2.849994	4.470002
W4	21.480000	INFINITY	2.849994
W5	13.700000	15.720000	4.669998
A1	66.150000	.280000	INFINITY
A2	65.170000	6.639997	.280000
A3	41.550000	4.470003	2.849994
A4	26.490000	2.849994	INFINITY
A5	16.890000	4.669998	INFINITY
B1	84.760000	.310017	.279999
B2	83.500000	.280000	.310017
B3	53.240000	6.639997	INFINITY
B4	33.950000	13.720000	INFINITY
B5	21.650000	18.240000	INFINITY
C1	105.180000	INFINITY	.310017
C2	103.610000	.310017	INFINITY
C3	66.070000	14.230010	INFINITY
C4	42.130000	25.960010	INFINITY
C5	26.860000	33.450010	INFINITY
F1	52.500000	17.491770	INFINITY
F2	51.720000	17.011770	INFINITY

F3	32.980000	12.131770	INFINITY
F4	21.030000	5.219999	11.130980
F5	13.410000	11.590000	INFINITY
U1	26.250000	48.961770	INFINITY
U2	26.250000	47.701770	INFINITY
U3	26.250000	24.081760	INFINITY
U4	26.250000	7.860000	5.219999
U5	30.220000	INFINITY	7.860001
SF1	-25.820000	24.880000	INFINITY
SF2	-25.820000	23.620000	INFINITY
SF3	-25.820000	26.489940	23.620000
SF4	-25.820000	INFINITY	15.720000
SF5	-25.820000	15.720000	INFINITY

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	58.206920	INFINITY
3	530.000000	546.962000	INFINITY
4	.000000	331.520000	INFINITY
5	.000000	334.880000	INFINITY
6	.000000	142.061900	INFINITY
7	.000000	.000000	53.799960
8	.000000	.000000	.000000
9	331.520000	23.000050	25.106650
10	334.880000	23.000050	188.316500
11	321.720000	53.799960	10.733360
12	337.960000	97.011530	249.118000
13	74.060000	97.011530	74.060000
14	.000000	98.812000	INFINITY
15	.000000	98.812000	17.118170
16	.000000	98.812000	17.118170
17	.000000	7.318198	17.118170
18	.000000	226.697400	80.846190
19	.000000	26.899980	.000000
20	.000000	10.733360	53.799960

(5) CONTINUOUS CROPPING (CC)

OBJECTIVE FUNCTION VALUE

57168.5500

VARIABLE	REDUCED COST
W1	3.200001
W2	2.910003
W3	.000000
W4	.579563
W5	6.459563
A1	.170001
A2	.000000
A3	.000000
A4	2.439563
A5	9.509562
B1	.090003
B2	.000000
B3	1.700003
B4	5.219565
B5	12.979570
C1	.000000
C2	.000000
C3	4.080001
C4	9.119563
C5	17.849560
F1	.110001
F2	.000000
F3	1.360001
F4	4.669561
F5	12.289560
U1	26.910440
U2	26.020440
U3	8.640438
U4	.000000
U5	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	458.120000	.000000
3)	.000000	53.160440
4)	.000000	52.270440
5)	.000000	34.890440
6)	.000000	26.250000
7)	.000000	26.250000
8)	.000000	-6.614437
9)	.000000	-16.434440

10)	149.243000	.000000
11)	.000000	-.604877
12)	.000000	-11.304440
13)	92.684880	.000000

RANGES IN WHICH THE BASIS IS UNCHANGED:

	OBJ COEFFICIENT RANGES		
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	40.520000	3.200001	INFINITY
W2	39.920000	2.910003	INFINITY
W3	25.450000	10.337310	.758586
W4	16.230000	.579563	INFINITY
W5	10.350000	6.459563	INFINITY
A1	48.680000	.170001	INFINITY
A2	47.960000	1.360000	.170001
A3	30.580000	.758586	1.360001
A4	19.500000	2.439563	INFINITY
A5	12.430000	9.509562	INFINITY
B1	53.450000	.090003	INFINITY
B2	52.650000	2.558144	.090003
B3	33.570000	1.700003	INFINITY
B4	21.410000	5.219565	INFINITY
B5	13.650000	12.979570	INFINITY
C1	60.100000	INFINITY	.090003
C2	59.210000	.090003	1.457753
C3	37.750000	4.080001	INFINITY
C4	24.070000	9.119563	INFINITY
C5	15.340000	17.849560	INFINITY
F1	52.500000	.110001	INFINITY
F2	51.720000	.583101	.110001
F3	32.980000	1.360001	INFINITY
F4	21.030000	4.669561	INFINITY
F5	13.410000	12.289560	INFINITY
U1	26.250000	26.910440	INFINITY
U2	26.250000	26.020440	INFINITY
U3	26.250000	8.640438	INFINITY
U4	26.250000	INFINITY	.579563
U5	26.250000	INFINITY	6.459563

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	530.000000	458.120000	INFINITY
3	331.520000	66.817340	41.422550
4	334.880000	375.124400	41.422550
5	321.720000	21.323110	110.138500
6	337.960000	154.474800	337.960000
7	74.060000	154.474800	74.060000
8	.000000	40.090400	228.995600
9	.000000	40.090400	14.566370
10	.000000	149.243000	INFINITY
11	.000000	37.694520	53.358480
12	.000000	40.090400	14.566370
13	.000000	92.684880	INFINITY

(6) CONTINUOUS CROPPING WITH NO GOVERNMENT SUBSIDY (CCNG)

OBJECTIVE FUNCTION VALUE

38989.8400

VARIABLE	REDUCED COST
W1	4.510002
W2	4.220003
W3	.000000
W4	14.226120
W5	15.100000
A1	1.480000
A2	1.310000
A3	.000000
A4	11.080000
A5	18.150000
B1	.090000
B2	.000000
B3	.389999
B4	12.550000
B5	20.310000
C1	.000000
C2	.000000
C3	2.770000
C4	16.450000
C5	25.180000
F1	.109998
F2	.000000
F3	.049999
F4	12.000000
F5	19.620000
U1	19.580000
U2	18.690000
U3	.000000
U4	.000000
U5	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	438.830300	.000000
3)	.000000	38.320820
4)	.000000	37.430820
5)	.000000	18.740820
6)	.000000	18.740820
7)	.000000	18.740820
8)	.000000	-6.560001
9)	.000000	-15.070000

10)	134.413400	.000000
11)	71.794500	.000000
12)	.000000	-9.940001
13)	.000000	-12.515300

RANGES IN WHICH THE BASIS IS UNCHANGED:

		OBJ COEFFICIENT RANGES	
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	20.170000	4.510002	INFINITY
W2	19.570000	4.220003	INFINITY
W3	5.100000	15.070000	4.220003
W4	-4.120000	14.226120	INFINITY
W5	-10.000000	15.100000	INFINITY
A1	28.330000	1.480000	INFINITY
A2	27.610000	1.310000	INFINITY
A3	10.230000	9.940001	1.310000
A4	-.850000	11.080000	INFINITY
A5	-7.920000	18.150000	INFINITY
B1	33.100000	.090000	INFINITY
B2	32.300000	6.560001	.090000
B3	13.220000	.389999	INFINITY
B4	1.060000	12.550000	INFINITY
B5	-6.700000	20.310000	INFINITY
C1	39.750000	INFINITY	.090000
C2	38.860000	.090000	2.770000
C3	17.400000	2.770000	INFINITY
C4	3.720000	16.450000	INFINITY
C5	-5.010000	25.180000	INFINITY
F1	45.720000	.109998	INFINITY
F2	44.940000	.389999	.109998
F3	26.200000	.049999	INFINITY
F4	14.250000	12.000000	INFINITY
F5	6.630000	19.620000	INFINITY
U1	26.250000	19.580000	INFINITY
U2	26.250000	18.690000	INFINITY
U3	26.250000	1.309999	.049999
U4	26.250000	INFINITY	11.080000
U5	26.250000	INFINITY	15.100000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	530.000000	438.830300	INFINITY
3	331.520000	5.938981	135.933200
4	334.880000	89.304350	18.806770
5	321.720000	188.022400	18.806770
6	337.960000	89.304350	18.806770
7	74.060000	89.304350	18.806770
8	.000000	4.513626	201.620200
9	.000000	4.513626	87.554280
10	.000000	134.413400	INFINITY
11	.000000	71.794500	INFINITY
12	.000000	4.513626	87.554270
13	.000000	53.582610	11.284060

(7) CONTINUOUS CROPPING WITH SOME GOVERNMENT SUBSIDY (CCSG)

OBJECTIVE FUNCTION VALUE

48042.7700

VARIABLE	REDUCED COST
W1	4.559995
W2	4.269996
W3	.000000
W4	8.162914
W5	11.769990
A1	1.529997
A2	1.359995
A3	.000000
A4	7.739995
A5	14.819990
B1	.090006
B2	.000000
B3	.340004
B4	9.160004
B5	16.920000
C1	.000000
C2	.000000
C3	2.719999
C4	13.060000
C5	21.790000
F1	.110000
F2	.000000
F3	.000000
F4	8.610000
F5	16.230000
U1	22.970000
U2	22.080000
U3	3.339999
U4	.000000
U5	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	458.120000	.000000
3)	.000000	45.795620
4)	.000000	44.905620
5)	.000000	26.165620
6)	.000000	22.825620
7)	.000000	22.825620
8)	.000000	-6.559996
9)	.000000	-15.020000
10)	134.413400	.000000

11)	89.348190	.000000
12)	.000000	-9.890005
13)	.000000	-5.707301

RANGES IN WHICH THE BASIS IS UNCHANGED:

	OBJ COEFFICIENT RANGES		
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	30.350000	4.559995	INFINITY
W2	29.750000	4.269996	INFINITY
W3	15.280000	15.020000	4.269996
W4	6.060000	8.162914	INFINITY
W5	.170000	11.769990	INFINITY
A1	38.510000	1.529997	INFINITY
A2	37.790000	1.359995	INFINITY
A3	20.410000	9.890005	1.359995
A4	9.330000	7.739995	INFINITY
A5	2.250000	14.819990	INFINITY
B1	43.280000	.090006	INFINITY
B2	42.480000	6.559996	.090006
B3	23.400000	.340004	INFINITY
B4	11.240000	9.160004	INFINITY
B5	3.480000	16.920000	INFINITY
C1	49.930000	INFINITY	.090006
C2	49.040000	.090006	2.719999
C3	27.580000	2.719999	INFINITY
C4	13.900000	13.060000	INFINITY
C5	5.170000	21.790000	INFINITY
F1	49.110000	.110000	INFINITY
F2	48.330000	.340004	.110000
F3	29.590000	1.359995	.340004
F4	17.640000	8.610000	INFINITY
F5	10.020000	16.230000	INFINITY
U1	26.250000	22.970000	INFINITY
U2	26.250000	22.080000	INFINITY
U3	26.250000	3.339999	INFINITY
U4	26.250000	INFINITY	7.739995
U5	26.250000	INFINITY	11.769990

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	530.000000	458.120000	INFINITY
3	331.520000	5.938963	209.003600
4	334.880000	89.304510	18.806720
5	321.720000	335.276700	18.806720
6	337.960000	89.304510	18.806720
7	74.060000	89.304510	18.806720
8	.000000	4.513611	201.620100
9	.000000	4.513612	128.746200
10	.000000	134.413400	INFINITY
11	.000000	89.348190	INFINITY
12	.000000	4.513612	92.409240
13	.000000	53.582710	11.284030

(8) EROSION (ER)

LP OPTIMUM FOUND AT STEP 39

OBJECTIVE FUNCTION VALUE

73322.8400

VARIABLE	REDUCED COST
W1	5.240001
W2	4.469993
W3	.000000
W4	.000000
W5	15.720000
A1	.589996
A2	.000000
A3	.000000
A4	2.849998
A5	20.390000
B1	.310001
B2	.000000
B3	6.639997
B4	13.720000
B5	33.960010
C1	.000000
C2	.000000
C3	13.920000
C4	25.650000
C5	48.860000
F1	5.670002
F2	4.879993
F3	.000000
F4	5.844999
F5	17.435000
U1	31.295000
U2	29.724990
U3	6.105000
U4	.000000
U5	.000000
SF1	25.190010
SF2	23.620000
SF3	.000000
SF4	.000000
SF5	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	129.091100	.000000
3)	728.862500	.000000
4)	331.520000	.000000
5)	334.880000	.000000
6)	108.940000	.000000
7)	.000000	-6.104996
8)	.000000	-2.134995
9)	.000000	57.545000
10)	.000000	55.974990
11)	.000000	32.355000
12)	.000000	26.250000
13)	.000000	30.220000
14)	.000000	-74.820010
15)	106.609300	.000000
16)	.000000	-38.440000
17)	.000000	-21.441600
18)	.000000	-46.300000
19)	.000000	-7.361328
20)	1553.966000	.000000
21)	349.414200	.000000
22)	.000000	3.329004

NO. ITERATIONS= 39

RANGES IN WHICH THE BASIS IS UNCHANGED:

	OBJ COEFFICIENT RANGES		
VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
W1	53.640000	5.240001	INFINITY
W2	52.840000	4.469993	INFINITY
W3	33.690000	2.849998	4.269990
W4	21.480000	4.269990	2.849998
W5	13.700000	15.720000	INFINITY
A1	66.150000	.589996	INFINITY
A2	65.170000	6.639997	.589996
A3	41.550000	4.469994	2.849998
A4	26.490000	2.849998	INFINITY
A5	16.890000	20.390000	INFINITY
B1	84.760000	.310001	INFINITY
B2	83.500000	22.031330	.310001
B3	53.240000	6.639997	INFINITY
B4	33.950000	13.720000	INFINITY
B5	21.650000	33.960010	INFINITY
C1	105.180000	INFINITY	.310001
C2	103.610000	.310001	13.920000
C3	66.070000	13.920000	INFINITY
C4	42.130000	25.650000	INFINITY
C5	26.860000	48.860000	INFINITY

F1	52.500000	5.670002	INFINITY
F2	51.720000	4.879993	INFINITY
F3	32.980000	7.052926	4.879993
F4	21.030000	5.844999	INFINITY
F5	13.410000	17.435000	INFINITY
U1	26.250000	31.295000	INFINITY
U2	26.250000	29.724990	INFINITY
U3	26.250000	6.105000	INFINITY
U4	26.250000	7.860002	2.134995
U5	30.220000	2.134995	7.860002
SF1	-25.820000	25.190010	INFINITY
SF2	-25.820000	23.620000	INFINITY
SF3	-25.820000	4.269989	12.210000
SF4	-25.820000	4.269990	11.690000
SF5	-25.820000	15.720000	2.134995

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	.000000	129.091100	INFINITY
3	530.000000	728.862500	INFINITY
4	.000000	331.520000	INFINITY
5	.000000	334.880000	INFINITY
6	.000000	108.940000	INFINITY
7	.000000	108.940000	116.927500
8	.000000	.000000	74.060000
9	331.520000	7.691276	46.127960
10	334.880000	60.481300	46.127970
11	321.720000	215.151800	67.217450
12	337.960000	215.151800	67.217450
13	74.060000	215.151800	74.060000
14	.000000	19.046160	57.398030
15	.000000	106.609300	INFINITY
16	.000000	7.691276	46.127960
17	.000000	7.450579	288.791000
18	.000000	7.691276	46.127960
19	.000000	39.390920	91.836740
20	2800.000000	INFINITY	1553.966000
21	5600.000000	INFINITY	349.414200
22	4200.000000	224.260600	95.230800