A STRATEGIC FRAMEWORK FOR SOCIAL IMPACT ASSESSMENT: AN APPLICATION TO GREENHOUSE GAS MITIGATION STRATEGIES IN CANADIAN PRAIRIE AGRICULTURE

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ABSTRACT

Social Impact Assessment (SIA) is the process of assessing the social consequences that are likely to follow specific policy actions or project development. SIA has not been widely adopted and is said to be the 'orphan' of the assessment process. Using Environmental Assessment (EA) however, there are two primary limitations to EA: first, EA is inherently biased toward the biophysical environment, and social impacts, when considered, are only considered in an indirect or secondary manner; second, EA is targeted at the project level, where many alternatives that may have met the larger goals have been rejected. These limitations are reflected in Canada's agricultural sector where SIAs are rarely, if ever, undertaken. Agriculture is responsible for approximately ten percent of total greenhouse gas (GHG) emissions in Canada, and several better management practices (BMP) have been suggested for managing these emissions in Canadian agriculture. However, there has not been a strategic assessment of the on-farm socioeconomic effects of such programs, nor the geographic implications of a 'one-size-fits-all' policy solution.

This paper presents a 'higher level' strategic assessment of alternative policy options for managing greenhouse gas emissions in Canadian agriculture. Data are collected using a stakeholder survey assessment, and the process is guided by a seven-phase strategic environmental assessment framework. Using this strategic framework, the on-farm social impacts of alternative greenhouse gas mitigation programs are assessed. Data are aggregated using multi-criteria weighting techniques. Stakeholder preference structures for the alternatives set are identified as well, the results of the SIA identified adoption of zero till practices as the most socially acceptable alternative. The

research results suggest that a 'one-size-fits-all' GHG mitigation policy would not be acceptable from a social perspective. The implications of include such issues as: the applicability of regional policies based on soil zone, alternatives to governmental 'top down' hierarchical' policies, and the necessity for collaboration and meaningful dialogue between on-farm individuals and policy makers. Adoption of a GHG mitigation policy in Canada will require education and collaboration between all affected stakeholders and decision makers. The application of a strategic framework illustrates how the SIA process is enhanced when an assessment is completed at the plan, policy, and program level – it enables proactive consideration of the social effects on par with the biophysical effects, and it facilitates consideration of a broad range of alternatives, in support of sustainable development principles.

ACKNOWLEDGEMENTS

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A: Alternative
ACT: Canadian Environmental Assessment Act
APAS: Agricultural Producers Association of Saskatchewan
BMP: Best Management Practices
BPEO: Best Practicable Environmental Option
CEAA: Canadian Environmental Assessment Agency
CH_4: Methane
CO_2: Carbon Dioxide
CWF: Canadian Wildlife Federation
D: Direction
EA: Environmental Assessment
EARP: Environmental Assessment and Review Process
EDA: Exploratory Data Analysis
EIA: Environmental Impact Assessment
ENGO: Environmental Non-Governmental Organization
GHG: Greenhouse Gas
LTM: Long Term Memory
MCE: Multicriteria Evaluation
M: Magnitude
MP: Management Potential
NEPA: National Environmental Policy Act
NGO: Non Governmental Organization
NO_2: Nitrogen Oxide
P: Probability
PPP: Plans, Policies and Programs
SEA: Strategic Environmental Assessment
SIA: Social Impact Assessment
STM: Short Term Memory
T: Temporal Duration
VEC: Valued Environmental Component

1.0 INTRODUCTION

Environmental assessment (EA) is broadly defined as a process to predict the
environmental effects of proposed development activities, and to assist in the approvals
and decision making process (Gibson, 2002). Since its inception under the United
States National Environmental Policy Act (NEPA) of 1969, the mandate of EA has
evolved considerably from a reactive control process towards the proactive integration
of sustainability principles in policy, planning, and project decision making (Gibson,
2002). In Canada, for example, under the *Canadian Environmental Assessment Act* (the
Act), one of the stated purposes of EA is to provide an effective means of integrating
environmental factors into planning and decision making processes in a manner that
promotes sustainable development (the *Act*, 1992 c.37). However, arguably, under
current EA systems and practices there are two fundamental limitations to achieving this
sustainability mandate: EA is biased towards the biophysical aspects and the focus is at
the project level.

First, EA is inherently biased toward the biophysical environment. Social impacts,
when considered in EA, are only considered in an indirect or secondary manner
(Momtaz, 2003; Ziller and Phibbs, 2003). Section 2.1(a) of the *Act* defines
environmental effect as "any change that a project may cause in the (physical)
environment… including any effect of any such change on health and socio-economic
conditions". Thus, while social effects are included in the definition of an
environmental effect, their inclusion in assessment is indirect; social impacts are

interpreted only when they are the result of biophysical change induced by project actions (Burdge, 2003a). For example:

> "If a socio-economic effect (such as job loss) is caused by a change in the environment (such as loss of fish habitat), which is in turn caused by the project, then the socio-economic effect *is* an environmental effect within the meaning of the Act and must be considered when determining significance and the related matters. If the socio-economic effect is not caused by a change in the environment, however, but by something else related to the project (for example, reallocation of funding as a result of the project), then the socio-economic effect is not an environmental effect within the meaning of the Act and cannot be considered in the determination of significance and the related matters." (Canada 1994).

This appears to be inconsistent with the stated view that EA provides an effective means of integrating environmental factors into planning and decision-making processes "in a manner that promotes sustainable development" (*Act*, 1992: preamble), if one accepts that sustainable development is based on the notion that human and ecological well-being are effectively interdependent (Storey and Noble, 2004). EA has considerable potential to give social criteria their rightful place alongside economic and environmental criteria in decision making (Taylor *et al*., 2004), but the limited scope of EA is reflected in the international academic literature (e.g. Momtaz, 2003; Edelstein, 2003; Sandham *et al*., 2005; Vanclay, 2006), and Burdge (2002) has labeled social assessment as the "orphan" of the assessment process. There is a misconception that consideration of social effects is only necessary if these result from environmental impacts (du Pisani and Sandham, 2006). In practice, explains Samya (2003), social assessment is likely to be a relatively autonomous, even disconnected, component of EA, and, while recognized as an important part of EA, has not received equal status in development planning. According to Dani (2003): "SIA [Social Impact Assessment] has been hamstrung by its attempt to emulate or ride on the coat-tails of

environment…for SIA to realize its full potential it needs to go beyond the environmental paradigm" (as cited by du Pisani and Sandham, 2006: 709). Despite this limitation, the suggestion has been made that environmental assessment could contribute to sustainability by extending its scope to include social and economic considerations along with environmental ones (Devuyst, 1999; Sadler, 1999).

Second, EA, particularly in Canada, is targeted at the project level. Project-based assessment is inherently a reactive process, responding to a particular problem and forecasting, or predicting, the most likely outcomes of a project or endeavor (Benson, 2003; Momtaz, 2005; Vanclay, 2006). The project assessment process typically begins with a proposed undertaking; the assessment focuses on evaluating only a limited range of alternative means or functionally similar ways of completing the proposed project (Steinemann, 2001). Impacts are predicted and an alternative is chosen, usually the proposed undertaking, and management emphasis is placed on mitigating potentially adverse impacts (Noble, 2000). While social impacts are often considered in project-based EA, even if indirectly, for undertakings such as dams, pipelines, mines, and tourism resorts (e.g. Bronfam, 1980; Berger, 1994; Barendse and Visser, 1995; Ramanathan and Geetha, 1998; Morimoto and Hope, 2003), project level assessment occurs too late in the planning process to ensure adequate consideration of a full range of alternatives, or functionally different ways of achieving desired ends (Bond and Brooks, 1997; Shrimpton and Storey, 2000). Alternatives are options, choices, or different courses of action; they are a multitude of means to accomplish a single end (Steinemann, 2001), and are an essential characteristic of SIA (Burdge and Robertson, 1990). At the project-level, many decisions and alternatives that are potentially more

sustainable than the proposed initiative are already foreclosed (Walker *et al*., 2000; Steinemann, 2001; Vanclay, 2006). Sadler *et al*. (2000: 8) state that project level EA is "limited in its capability to examine alternatives and options by the relatively late stage of decision making to which it is applied".

The application of social assessment at the early stages of decision making, and to broad policy and planning initiatives, is limited (Baines *et al*., 2003). It is at this pre-project stage, arguably, where a full complement of 'alternatives to' a proposed undertaking may be considered (Bond and Brooks, 1997; Steinemann, 2001; Benson, 2003). If EA is to contribute to improved decision making in support of sustainable development, then a more proactive approach is required where the social implications of decisions and actions are considered at the earliest stages of decision making – that is, at the strategic level of policies, plans and programs (PPP), on par with biophysical impact considerations (Francis and Jacobs, 1999; Eggenberger and Partidário, 2000; du Pisani and Sandham, 2006). This requires the adoption of new assessment frameworks capable of integrating social impacts early in the decision making process, and adopting methods that are consistent with EA practices at the strategic level. The problem is that strategic assessment methodologies for EA remain relatively underdeveloped (Walker *et al*., 2000; Eggenberger and Partidário, 2000), and social impacts have largely been considered second-order to biophysical impacts (Sandham *et al.*, 2005)   The application of a strategic assessment paradigm facilitates decision making at a higher level and contributes to early consideration of alternatives, well in advance of project level EA (Sadler *et al*., 2000).

1.1 Research Purpose and Thesis Structure

The purpose of this research is to demonstrate the use of a methodological framework for the consideration of social impacts at the strategic level of PPP assessment. A case study of greenhouse gas (GHG) mitigation in Canadian prairie agriculture serves as an example to illustrate this framework. The emphasis is placed on the process of demonstrating SIA at the PPP level, and illustrating how practice can be improved by taking the proactive, strategic approach to decision making.

In the sections that follow, the nature of environmental and social impact assessment is introduced, and context provided for the case assessment of GHG mitigation. The research methods and assessment framework are then presented, followed by the assessment results. The paper concludes with a discussion of the implications of the assessment outcome for GHG mitigation policy, and opportunities for advancing SIA at the strategic level

2.0 RESEARCH CONTEXT: NATURE OF ENVIRONEMTNAL ASSESSMENT

Over the past fifty years, environmental awareness has developed and evolved from a basic understanding that humans and their environments are connected to an attempt at socially and environmentally responsible development practices (Buchholz, 1994; Kilcullen and Kooistra, 1999; Mazur, 2001; Anderson and Bieniaszewska 2005). In response to the media and information revolution of the 1950s, and the activities of the environmental movement in the 1960s, the US government was forced to recognize the need for EA legislation and, subsequently, created the US NEPA of 1969; now recognized as the pioneer of contemporary impact assessment (Mitchell, 1995; Burdge, 2002). Designed to be short, simple and comprehensive, NEPA was in direct contrast to the detailed, comprehensive and complex environmental legislation of the 1960s, to that which would follow in the 1970s and 1980s. NEPA is considered a watershed in environmental legislation because of the manner in which it dealt with cross-sectoral issues, and because of its contribution to launching EA into worldwide use (Modak *et al*, 1999).

In 1970, Canada followed the legislative initiatives of the US by establishing a task force to study impact assessment policy and procedure; guidelines were created for impact assessment within federal jurisdiction (Mitchell, 1995). The Canadian Cabinet Committee on Science, Culture, and Information agreed on the need for a formal

assessment process in December, 1973, and two days later established the

Environmental Assessment and Review Process (EARP) and the Federal Environmental

Assessment Review Office (FEARO) (Mitchell, 1995). The EARP was intended to

differ from the NEPA process in several ways, including having no legislated basis so

that it could not be enforceable by the courts. However, there were accountability

concerns that EARP would be carried out inconsistently or would not be adequately

implemented (Mitchell, 1995).

Federal departments considered the EARP order to be an internal policy without any

legal force, but the Federal Court judgment in the case of the Canadian Wildlife

Federation (CWF) changed this perception (Corriveau, 1995). In *Canadian Wildlife

Federation v. Canada*, CWF contested the validity of the permits by *certiorari* because

the Environment Minister had not proceeded to an environmental assessment as

prescribed by the EARP Order. They requested, and received, an injunction from the

court. The court noted that "the EARP Guidelines Order is not a mere description of a

policy or program; it may create rights which may be enforceable by way of *mandamus*"

(*CWF v. Canada*, 1989).

The legal conflicts continued when the Friends of the Oldman River Society

attempted to get the Federal Court, by means of *certiorari* and *mandamus*, to force the

Minister of Transport and the Minister of Fisheries and Oceans to proceed with the

environmental assessment of the Alberta government's project to build a dam on the

Oldman River (Corriveau, 1995). The case went before the Supreme Court, where

judges concluded that the Order was constitutionally valid and its application

mandatory. According to Hunt (1992), these cases created a revolution in three ways:

first, engendering other cases across Canada; second, forcing the federal ministers to take the EARP Order seriously; and third, pushing the Canadian government to adopt new legislation in the form of the *Act*.

In 1992, as part of EA reform in Canada, the Canadian Environmental Assessment Agency (CEAA) replaced EARP. During the creation of the *Act*, CEAA amended many of the limitations present in the EARP Order, and stated four new objectives: 1) ensure that environmental affairs receive careful consideration before action is taken; 2) promote sustainable development and thereby achieve or maintain a healthy environment and a healthy economy; 3) ensure that projects that are to be carried out in Canada or on federal lands do not cause significant adverse environmental effects outside the jurisdictions in which the projects are carried out; and 4) ensure that there be an opportunity for public participation in the environmental assessment process (CEAA, 1992). The *Act* was subsequently introduced, received royal assent in 1995, and amended in 2003.

The Act encourages responsible authorities to take actions that promote sustainable development and thereby achieve or maintain a healthy environment and a healthy economy (CEAA, 1992). Environmental impact assessments have aided in the quest for a healthy environment and economy; however, assessments of social impacts are conspicuously missing from the purpose of *the Act*.

2.1 Social Impact Assessment

Environmental assessment has traditionally been divided into two distinct fields: environmental impact assessment (EIA) and social impact assessment (SIA) (Burdge,

2002, 1999); perhaps a reflection of the academic division between the natural and the social sciences (Barrow, 1997). Subsequently, EIA and SIA have had different evolutions, especially in respect to legislative support and methodological development (Barrow, 2000). SIA, developed as a derivative of EIA (Barrow, 2000), is broadly defined as a systematic analysis of the likely impacts a proposed action (or actions) will have on the day-to-day life of individuals and communities (Burdge, 1999). The field of SIA grew out of a desire to apply sociology and other social sciences to EA in an attempt to predict the social impacts of the environmental effects of development projects subject to NEPA or EARP processes (Burdge and Vanclay, 1995). SIA arose in the late 1970s and early 1980s as the focus of EA shifted from reactive pollution control measures to more proactive impact identification (Gibson, 2002), and multidimensional EAs became common, incorporating SIA, risk analysis, public participation, and putting increased emphasis on issues of alternatives (Sadler, 1999). As SIA became more sophisticated, it expanded through different jurisdictions throughout the world and became a more common analysis tool.

The inquiry by Chief Justice Thomas Berger into the proposed Mackenzie Valley pipeline, from the Beaufort Sea in the Yukon Territory to Edmonton (Alberta), was the first case where social impacts were considered in project decision making (Berger 1977, 1983; Gamble 1978; Gray and Gray, 1977). Berger launched a tour across Northern communities intended to document the existing social environment and expected impacts from the proposed pipeline based on the perspective of the affected people. The inquiry was important because social impacts on indigenous populations were considered in depth and native populations were provided with funding to present

their views and hearings were conducted in native villages and in local dialects (Burdge and Vanclay, 1995). The implications of this inquiry were wide ranging and the focus of SIA took on a political orientation, where the assessment of impacts was focused on the goals of the individual communities. Unfortunately, the Berger Inquiry and the resulting social impact analysis was a fairly isolated incident, and did not incite social impact assessment as the norm.

SIA has typically been neglected, with biophysical assessment taking precedence. This is partly a historical problem, as EA was developed in an era dominated by a technocratic approach to problem-solving with a particular emphasis on biophysical impacts and solutions (Shrimpton and Storey, 2000).

2.2 SIA Frameworks

The administrative framework for EA emerged from political necessity, not from a scientific background, and practice commenced prior to the development of adequate scientific capacity (Cashmore, 2004). As a result, EA has been described as an uneven mixture of planning theory, traditional scientific theory and discipline-specific social, economic and biological theories, with the conceptual whole amounting to less than the sum of all parts (Lawrence, 1997).

Cashmore (2004) identifies five theoretical models of EA, from applied to civic science, representing a range of scientific philosophies. Two of the models, "analytical science" and the "environmental design", are based on the conventional philosophical traditions that view science as an entirely rational process of objective inquiry (Cashmore, 2004). The environmental design model is based on a critique of the

effectiveness of the procedural forms of EA practiced in most jurisdictions. It is a 'passive' model of EA that divorces it from environmental design and management activities, limiting it to reactive analysis and end-of-pipe mitigation (Cashmore, 2004). While there are drawbacks to the environmental design model, the rational process on which it was built, supported by scientific theory, presents a rational model on which to base research, if the reactive analysis can be transformed into a proactive analysis.

The three other models, "information provision", "participation" and "environmental governance", are classified as civic science and distinguished by the belief that EA is a tool for influencing decisions through the application of a pragmatic, inclusive, science as well as stakeholder involvement and value judgments (Cashmore, 2004). The civic models were developed in response to the perceived differences between EIA and science. EA is generally a short-term decision tool, driven by time and resource constraints, and frequently conducted in an atmosphere of political and public controversy (Caldwell, 1991).

EA was created at a time when rational-comprehensive models of policy making were dominant, and early models and definitions of EA reflect this approach to decision making, particularly in terms of the determination to provide a systematic and comprehensive assessment of potential impacts, analysis of alternatives, and in its assumptions of a rational decision maker (Weston, 2000; Lawrence, 2000). In practice, though, real world decision making rarely conforms to the rational model (Cashmore, 2004), and the assumptions of the rational-comprehensive model remain dominant in EA practice (Nitz and Brown, 2001).

Both civic and rational models of SIA are represented in the EA literature, illustrating that the model should be chosen to meet the end goals of the assessment. Buchan (2003), for example, argues that SIA is not only about identifying social impacts, but sharing information and building community awareness. Such civic models are appropriate where researchers aspire to create community participation, community awareness, and a sense of empowerment (Youngkin, 2003; Baines *et al*., 2003; Buchan, 2003), but this is not always the desired goal of SIA. A rational approach may be desired to attain and assess empirical data for impact assessment, such as worker profiles (Leistritz and Murdoch, 1981), population counts, crime rates or input-output analysis (Burdge, 2003b). In other cases a combined approach may be desirable, where empirical and participatory analyses are combined to meet the goals of the project. In fact, according to Burdge (2003b), the line between 'technocratic' or rational SIA and 'participative' or civic SIA may actually be a continuum; background or baseline data is often quantitative and forms the beginning of the research, and qualitative data is gathered in order to build upon the baseline data. There are strengths and challenges to any EA paradigm, and the design of the assessment, either based on a rational or civic process of inquiry, should reflect the goals and objectives of the research as well as the affected environments, both social and environmental.

2.3. SIA – An 'Add On Process'

The United Nations' Rio Summit on the environment (UN, 1992) addressed the need for adopting strategic frameworks that allow for the integration of both developmental and environmental goals (UN, 1992, chapter 10.6b). In addition, the *Agenda* stated that

economic, social and environmental factors need to be fully integrated if decision making and planning are to be successful (UN, 1992, chapter 8.2). In this way, social impacts, and their relationship to environmental and economic issues, have become increasingly important. However, satisfactory interdisciplinary or multidisciplinary approaches to SIA can be difficult to achieve (Rickson *et al.*, 1990).

There are two ways in which SIA can be adopted: as an integral part of planning, decision-making, and monitoring; or as an 'add-on', or separate, process. The trend has been towards the latter (Leistritz and Ekstrom, 1988), in that most SIAs are conducted at the project level with relatively little attention to the strategic levels of decision making (Barrow, 2000). SIAs can be applied after a project has commenced, and would then measure the effects of the project and identify the consequences of the development. In this respect, SIA would serve future projects by providing ex post information and a review of the major effects. It is possible that there would be situations were an anticipatory SIA is not feasible or practical, and an ex post SIA would provide an adequate evaluation; however, if the SIA is undertaken before an action or policy is formulated, it can be used as a proactive tool to benefit decision makers. According to Barrow (2000), practitioners should seek to ensure that SIA is integrated into the planning process as early as possible so that it can be used to choose between alternatives.

Most of the EA literature focuses on the development, or project, phase and the field has generally ignored the impacts that occur before a project has started, that is, during the planning or policy development stage (Walker *et al*., 2000); in the human environment, observable and measurable impacts often take place as soon as there are

changes in social conditions (Freudenburg and Gramling, 1992; Walker *et al*., 2000).

Gramling and Freudenburg (1992) stated:

> "Impacts occur not just when social groups are faced with threats [from a planned development] over which they have little effectual control, but also when there are conflicts over the extent to which a proposed development represents threats and/or opportunities".

The fact that these social impacts occur before formal EA processes are triggered (pre-project) may assist in helping to explain the persistent difficulties experienced with SIA studies carried out as part of the impact assessment process (Walker *et al*., 2000). SIAs are typically less well funded than environmental and economic assessments, and they are often initiated too late in the assessment process to make a significant contribution to the results (Ziller and Phibbs, 2003).

The EA process should seek to inform decision makers of the likely impacts of a proposed action, but the assessment should not be the complete decision making process (Benson, 2003). The traditional approach to EA has been oriented toward environmental impacts at the project level and tends to neglect socio-economic impacts (Glasson and Heaney, 1993), resulting in a reactive process that does not significantly contribute to sustainable development initiatives (Bond and Brooks, 1997; Momtaz, 2005). These difficulties contribute to the reactionary nature of current SIA practice and a more proactive application of the assessment process at the strategic level would improve social impact consideration in decision making. The SIA process needs to facilitate intended positive consequences, or goals, of development, and prevent unintended negative consequences. Therefore, SIA needs to be goal oriented and proactive, not just reactive (Vanclay, 2003). Francis and Jacobs (1999) maintain that social impacts should be assessed throughout and beyond the scope of the project, and

du Pisani and Sandham (2006) add that SIA must adopt a strategy that can both anticipate and react to change.

2.4 Toward a More Proactive Approach

In the EA literature, the recognition that a project-focused approach in EA is too limited to address the range of policy alternatives in a development process has led to the identification of the need for assessment at the more strategic levels (Eggenberger and Partidário, 2000). In other words, there is a growing recognition of the need for EA of the implications of policy, plan, and program (PPP) alternatives at an early stage in the decision-making process (Noble, 2000; Noble, 2002a, 2002b; Renton and Bailey, 2000), and that strategic environmental assessment (SEA) can play a significant role in enhancing the integration of sustainability concerns in policy and planning processes (Eggenberger and Partidário, 2000).

Strategic environmental assessment broadly refers to the higher-order EA of proposed or existing PPPs and their alternatives (Noble, 2002a), and is inherently a decision support tool, capable of integrating environmental and social issues into PPP decision making processes (Vicente and Partidário, 2006). A strategic approach is one in which the determination of the basic long-term objectives and the adoption of courses of action and allocation of resources necessary to achieve these goals is developed (Noble, 2000). It reflects a proactive approach by acting in anticipation of future problems or needs to create and examine alternatives leading to the preferred option (Noble, 2000). SEA is a concise analysis from which further investigation can be tiered,

with the subsequent analysis focusing on the strategy the SEA yields (Clark, 2000; Noble, 2002a).

SIA, in its current form, is characteristically a reactive process, responding to a particular problem and forecasting, or predicting, the most likely outcomes of a project or endeavor. A typical SIA process, for example, begins when a proponent identifies a project and determines the need for a social assessment. This assessment evaluates available options and considers a limited range of pre-determined alternatives (Steinemann, 2001). The alternatives assessed are limited to functionally similar ways of completing the project (alternative means, or alternative approaches); 'alternatives to' the project, or functionally different ways to meet the overall objectives (alternative designs), are not typically considered (Steinemann, 2001). This means that by the time the assessment process commences it is already too late to reconsider the decision that foreclosed more strategic alternate designs, or 'alternatives to'.   The focus of SIA is thus simply to determine the 'least negative method' of reaching the completion of the project (Noble, 2000).

Project level SIA is an excellent tool and should not be dismissed as ineffective. However, there is a need for a higher order social impact assessment process that takes 'alternatives to' into consideration and is established at the strategic level (Bond and Brooks, 1997; Benson, 2003; Vanclay, 2006). Identification of the best alternatives from a range of several at the strategic level is not intended to replace project level based assessment – rather, it is intended to improve the effectiveness and efficiency of the assessment process while providing for better integration of social impacts and concerns (Bond and Brooks, 1997). However, in order for social impacts to be properly

considered in the context of broader visions, goals, and objectives, at the strategic levels

of assessment, methodological development is required. This is particularly the case in

Canada's agricultural sector where EA, if applied has been limited to project level

analysis of biophysical impacts, with little to no consideration of social impacts at the

strategic level.

2.5 SIA in Context: Toward a Proactive Approach in Canadian Agriculture

Agriculture, along with forestry and fisheries, has not benefited from systematic

environmental analysis and management (Duffy, 2004), and EA is seldom applied to

farm practices despite the EA model being well suited for evaluating plans and

operations in this sector. This is not to say that EA applications do not occur, but full

scale EA processes, from screening to post monitoring, are relatively rare compared to

other Canadian resource sectors.   Moreover, EA policies and legislation have excluded

agriculture in many jurisdictions worldwide, including those of the Canadian federal and

provincial governments (Duffy, 2004). If Canadian agriculture is to move in the

direction of sustainability, then the biophysical, social and economic implications of

proposed actions should be considered, in agricultural PPP assessment and decision

making (Gibson, 2002; Pope *et al*., 2004).

In 2001, a biophysical analysis of several competing on-farm practices was

conducted in the Canadian agricultural sector to evaluate the potential impacts and

benefits for non-renewable energy use and GHG emissions reduction (Agriculture and

Agri-Food Canada, 2001). A biophysically preferred option was identified (increased

use of forage) from this assessment to form the basis of an ongoing energy use and

emissions reduction policy and proactive program. However, such an option, while

biophysically optimal, may not necessarily be socially acceptable to those who must

implement such a policy at the on-farm level. The social impacts of energy and

emissions reduction were not assessed in conjunction with the biophysical assessment,

reinforcing the "add on" and reactionary nature of SIA. An application of SIA at the

strategic level, in combination with biophysical impact considerations, is necessary to

ensure policy development that is both biophysically effective and socially acceptable.

Utilizing SIA in this manner enables the full consideration of alternatives, and promotes

a more sustainable decision making process.

2.5.1 Greenhouse Gas Mitigation in Canadian Agriculture

The increase in GHG emissions and the necessity to reduce them has been

recognized as an international problem. The Kyoto Protocol, adopted on December 11,

1997 at the third session of the Conference to the Parties (COP-3) in Kyoto, Japan, is

intended to serve as a policy instrument to mitigate climate change through reductions in

GHG emissions. Under the terms of the Kyoto Protocol, Canada agreed to reduce its

greenhouse gas emissions by 6% below its 1990 levels by the years 2008-2012

(Environment Canada, 2002). If Canada is to meet its Kyoto commitment, GHG

emissions must be reduced and mitigation measures taken.

Figure 2.1 depicts Canada's GHG emissions from 1990 to 2004, and projects GHG

emissions to 2010. Total emissions of all GHGs in 2004 were 26% above the 1990

level of 608 Mt. Between 2000 and 2001, emissions declined by 1.3%, representing the

first decline in emissions since 1991. This decline in emissions appears to be mainly the

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result of a warmer than average winter, reduced energy use in some industrial sectors, and declines in fuel consumption for several modes of transportation (Olsen *et al*., 2003). In 2001, Canada's emissions decreased by 9.5 Mt from the 2000 level of 730 Mt. The energy sector was responsible for most of the decrease, with emissions declining over 8.7 Mt (Olsen *et al*, 2003). As indicated below, emissions in 2004 increased to 758 Mt, up 4 Mt (0.6%) from 754 Mt in 2003. Between 2003 and 2004, there were increases in some sectors (including agriculture), but the overall growth was minor, owing mainly to significantly reduced emissions from electricity production (less coal and more nuclear generation) and, to a lesser extent, a reduced demand for heating fuel because of a warmer winter (Environment Canada, 2006).
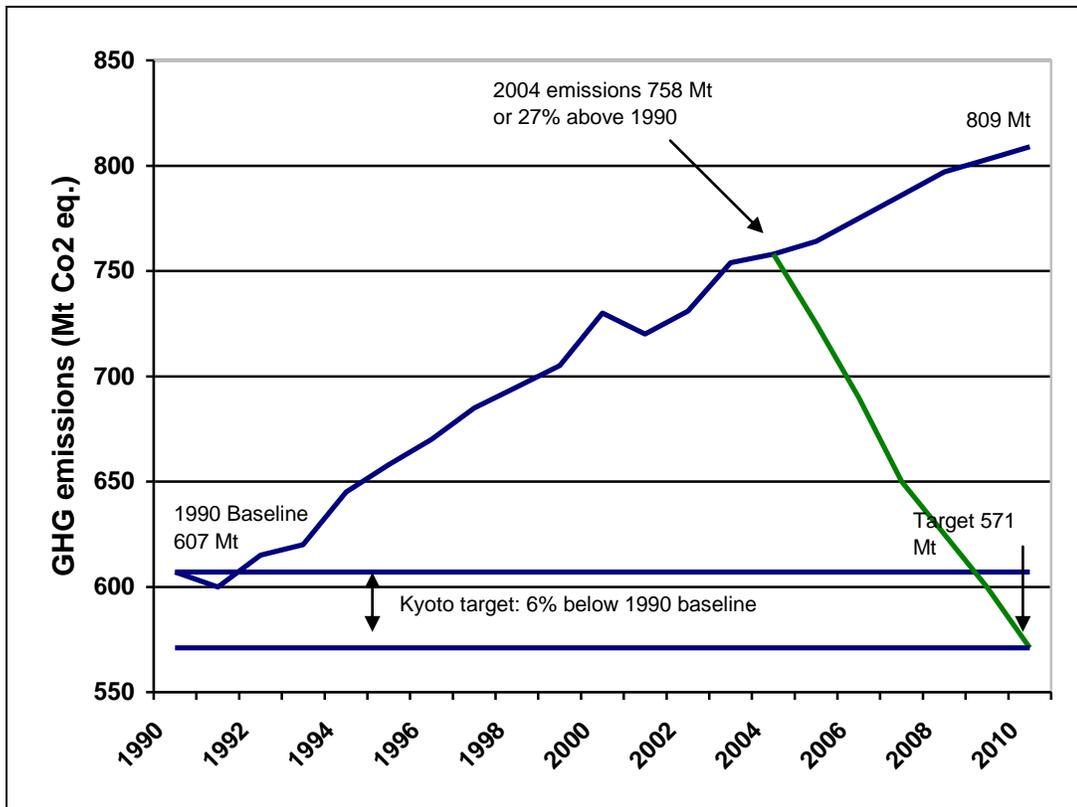
Figure 2.1 Canadian emission trend and forecast, 1990 - 2010
Source: Olsen *et al*., 2003; Environment Canada, 2006

The atmospheric concentrations of nitrogen oxide (NO_2), carbon dioxide (CO_2), and methane (CH_4), are increasing at rates ranging from 0.3% to 0.9% per year, largely because of anthropogenic effects on the carbon and nitrogen cycle (Desjardins *et al.*, 2001). The agriculture and agri-food industries have been identified as significant producers of NO_2, and CH_4 emissions (Desjardins *et al.*, 2001; Alberta Sustainable Agriculture Council, 2002), and the agricultural sector is responsible for approximately 10% of the GHG emissions in Canada (Desjardings and Riznek, 2000; Neitzert *et al.*, 1999).

Unlike other sectors, however, CO_2 emissions from fossil fuel use account for only a small portion of agricultural GHG emissions (AAFCCT, 2000). Emissions from agriculture are primarily nitrous oxides associated with fertilizer, and methane associated with livestock manure. Estimates indicate the N_2O emissions from agricultural soils represent the largest source of GHGs from the sector, and N_2O emissions from agricultural nitrogen sources (mainly fertilizer and animal manure) represent 61% of GHG emissions from the agriculture sector; CH_4 from ruminants and other sources represents 38%, while net CO_2 emissions account for less than 1% of GHG emissions (Desjardings and Riznek, 2000). The rate of carbon loss from agricultural soils has even slowed in recent years due in large part to soil conservation practices (Smith *et al.*, 2004). Because primary GHG emissions in agriculture are nitrous oxides and methane, strategies that work in other industries, such as reducing fuel consumption and using more efficient light bulbs, will not necessarily produce effective results in the agricultural industry (Environment Canada, 2003). Therefore, the industry requires

creative GHG mitigation solutions and studies that specifically address the unique

agricultural situation.

In order to ensure that policies governing agricultural GHG mitigation are made in

an informed manner, both the social and biophysical aspects must be considered in

assessment and decision making. In the case of GHG mitigation initiatives in Canada, a

biophysical assessment has already occurred (Agriculture and Agri-Food Canada, 2001),

identifying increased use of forage as the preferred GHG mitigation measure. However,

there has not been an assessment of mitigation alternatives from a social perspective.

The problem is that the biophysically preferred option may not necessarily be socially

acceptable to individuals at the on-farm level, and a one size fits all mitigation strategy

may not be appropriate across all Prairie regions. Based on the application of a strategic

framework for SIA, the following sections will evaluate GHG mitigation alternatives in

an attempt to identify the most socially preferred mitigation option and policy

implications.

3.0 RESEARCH METHODS

The overall research and assessment process was based on a stakeholder survey and assessment exercise, guided by a seven-phase generic strategic environmental assessment (SEA) framework proposed by Noble and Storey (2001) (Figure 3.1). The SEA framework is based on a multicriteria approach to the planning process at different tiers of decision making, which makes it ideal for this particular research problem.
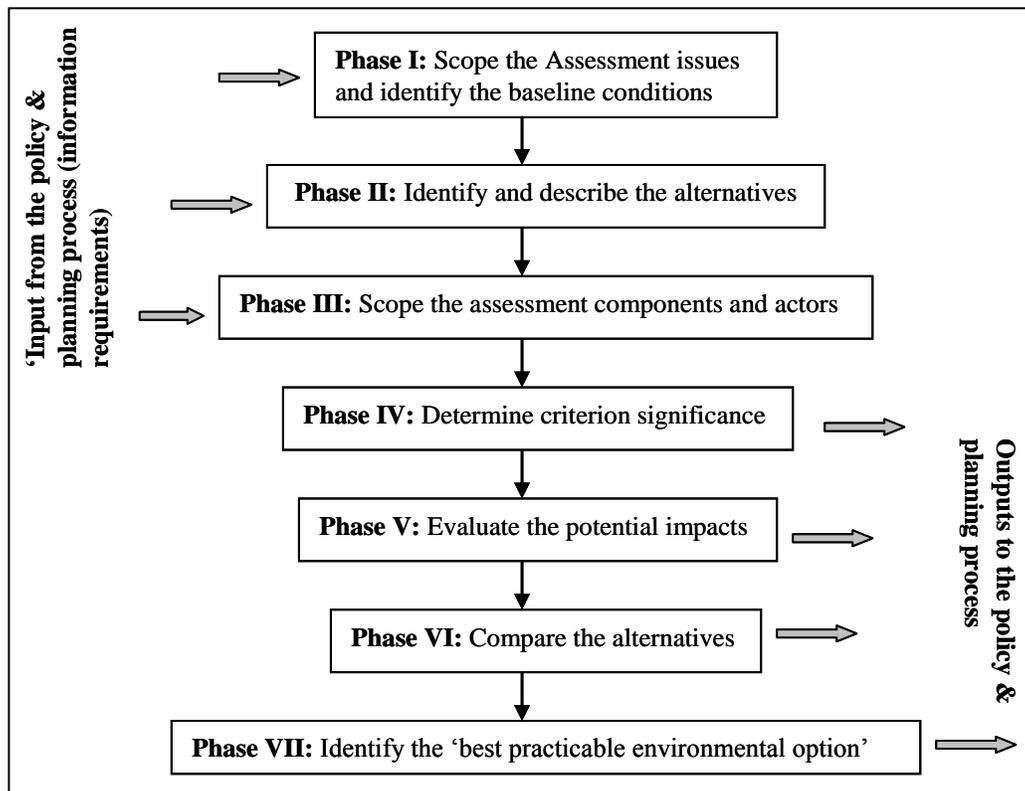
Figure 3.1 Generic seven-phase SEA assessment framework
Source: Noble and Storey, 2001

Many SIA issues involve the resolution of problems involving multiple alternatives and multiple criteria on which to evaluate those alternatives. Because of these conflicting elements, it is difficult to reach clear and uncomplicated solutions to problems that will satisfy all interests. Major developments or policies have a wide range of impacts – both biophysical and social – and the trade-offs between such impacts are often crucial in decision-making (Glasson, 1995). Decision analysis techniques such as cost-benefit analysis, public choice theory, and multi-attribute utility theory are beneficial when addressing only single objective problems, but problematic when addressing multiple criteria or competing objectives within a single problem set (Voogd, 1983; Nijkamp *et al*., 1990). A multicriteria approach, as facilitated by Noble and Storey's (2001) assessment framework, provides a process to analyze the trade-offs between alternatives based on their different socioeconomic and environmental impacts (Carver, 1991). The following sections describe the research methodology and assessment methods based on the seven-phase framework.

3.1 Phase I: Scoping the issue(s)

Identifying alternative solutions, and a preferred strategy, for GHG mitigation involves the simultaneous evaluation of competing alternatives against a range of objectives and constraints. In essence, finding a satisficing solution to GHG mitigation from a social perspective is a multi-criteria problem and requires investigating the relative merits of a set of decision alternatives based on a set of competing objectives (Voogd, 1983). Methods to address multicriteria problems have been used successfully throughout both environmental management and assessment literature (see Howard,

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1991; Munda *et al*., 1994; Huylenbroeck and Coppens, 1995; Noble 2002b).

Multicriteria evaluation (MCE) facilitates inventorying, classifying, analyzing and

arranging the available information concerning choice-possibilities (Voogd, 1983). The

method consists of a set of evaluative criteria, a set of weights indicating the importance

of those criteria, a set of alternatives and a set of performance measures indicating the

performance of each alternative with respect to each criterion (Hajkowicz, 2000).

MCE problems are often structured using organizational matrices that display the

given set of alternatives and the criteria for which each alternative is evaluated (Voogd,

1983). Given the set of *A* (alternatives) and *G* (evaluation criteria), and assuming the

existence of *n* alternatives and *m* criteria, it is possible to build an *n* x *m* matrix *P,* the

evaluation or impact matrix, whose typical element P_{ij} ($i = 1, 2…., m; j = 1, 2, …, n$)

represents the evaluation of the jth alternative by means of the ith criterion (Munda *et al*.,

1994). Therivel and Morris (1995) use this technique, for example, where all relevant

projects are listed on one axis of a matrix, environmental components, or criteria, on the

other, and the impacts on a particular component summarized in the relevant cell. In

this particular assessment, a multicriteria approach is used as it provides quantified data

and a systematic approach, which allow for data aggregation and a structured and

accountable analysis of impacts, alternatives, criteria and competing interests.

3.2 Phase II: Alternatives Selection

The consideration of alternatives should be an essential part of the assessment

process and has been described as "the heart" of the environmental assessment process

(Council on Environmental Quality, 1987). One of the first steps in any assessment

process is the creation, identification, or selection of alternatives that will be considered in the analyses (Steinemann, 2001). According to Steinemann (2001), alternatives are options, choices, or choices in action; they are a means to accomplish ends. Alternatives can be developed through the use of computer models, literature reviews, consultation with experts, or through comparison with other similar situations (Bell *et al.*, 1977; Tonn, 2000).

There are two different types of alternatives typically addressed in impact assessment processes: the 'alternative means' of executing a particular plan or project (alternative designs); and various 'alternatives to' (alternative approaches) that will meet specified goals and objectives. In this research, 'alternatives to' are the focus of assessment, and represent functionally different ways of meeting the objective of GHG mitigation. Each GHG mitigation alternative is relatively broad or conceptual, as compared to alternatives that might be proposed at the project level, due to the strategic nature of this research. The alternatives were adopted from Agriculture and Agri-Food Canada (2001) and Kulshreshtha *et al.*'s (2002) *Canadian Economic and Emissions Model for Agriculture*, and are summarized as follows:

A1: Enhanced nitrogen use efficiency, where there is elimination of the fall application of nitrogen fertilizer. This option would be accomplished by either a reduction in fertilizer use or improved nitrogen efficiency through proper timing, placement, lower application levels, and precise control of fertilizers to match crop requirements. Fertilizer efficiency increases as soil organic matter increases, which reduces nutrient losses. Long-term gains in fertilizer efficiency are associated with cropping systems such as minimum tillage and direct seeding, which tend to increase soil organic matter over time.

A2: Adoption of zero-till practices where there is a 50% increase in zero-tillage over current levels and direct seeding practices occur. The increase in zero tillage area reduces the area for conventional and minimum tillage by about one third. The shift of land from conventional

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tillage to zero tillage changes the mix of cropping inputs. One trade off is that zero tillage relies on the use of herbicides rather than tillage for weed control. As the area under zero tillage increases relative to conventional tillage, the use of herbicides increases, but machinery and fossil fuel use decline.

A3: Decreased summerfallow area, or a 50% reduction in current summerfallow area. Summerfallow practice has been decreasing in most areas of the Canadian Prairies in recent years. Use of this option may reduce the amount of canola that is grown in all soil zones, as well as wheat and durum in the Brown soil zones, but increase the amount of crop produced on stubble. This alternative would potentially necessitate higher rates of fertilizer use.

A4. Increased use of forage in crop rotations; shifting 10% of the cropland to forage production. This option assumes an increase in the area of land devoted to forage production, and due to the expansion of the livestock industry, a market will be created for an increase in forage production with annual crop rotations. Legume forage that converts atmospheric nitrogen into forms available for plant uptake reduces the amount of fertilizer nitrogen required by subsequent cereal and oilseed crops. This option has the lowest herbicide and fertilizer energy use.

A5. A ten percent improvement in the fuel efficiency of farm equipment, or a 10% increase in fuel efficiency. Energy use for fuel and machinery was about 34% of the total energy use for prairie agriculture in 1996. Since most of the direct fossil fuel use in crop production occurs through the use of farm machinery, fuel efficiency gains would significantly reduce energy use. This alternative suggests a 10% increase in fuel efficiency of farm machinery through the use of more efficient/less use of fuel intensive equipment. A 10% improvement in fuel efficiency will result in savings in energy input costs, without any expected change to the cropping mix.

These alternatives were evaluated in Agriculture and Agri-Food Canada's biophysical assessment, and thus, the same alternatives were used for the social assessment. These alternatives are not necessarily mutually exclusive and there may be relationship or correlations between them; however, for the purposes of the assessment, it is assumed that the participants are able to distinguish between the alternatives and consider each based on its merits and associated issues. The use of five different choice

options is ideal, as the literature on memory suggests that there are a limited number of categories that a person can retain and compare. According to the traditional model of human memory (Waugh and Norman, 1968), temporary short-term memory (STM) holds items for immediate recall, and long-term memory (LTM) is useful for retrieving stored items using cues. STM is assumed to have a limited capacity of around seven "chunks", where a chunk corresponds to a familiar pattern already stored in LTM (Miller, 1956). Miller (1956) also showed that an individual cannot reliably compare more than seven categories, or alternatives (plus or minus two, depending on the stimulus or individual). More recently, there has been discussion in psychology literature regarding the number of limits (see Henderson, 1972; Luck and Vogel, 1997; Halford *et al.*, 1998), and many researchers believe the number of chunks that can be cognitively recalled is actually four plus or minus two (Cowan, 2000). Therefore, limiting the number of alternatives to five reduces the level of uncertainty associated with STM capacity and thus improves ability of participants to compare competing mitigation alternatives across criteria.

3.3 Phase III: Assessment Actors and Components

This phase of the methodology involves the identification of the individuals involved in the assessment process as well as specifying the survey process and criteria which will be used to evaluate the environmental implications of the alternatives (Noble and Storey, 2001). The number and nature of the assessment criteria vary depending on the issue to be addressed, the level of abstraction of the action, the scale of impacts, the level of detail required, and the available time and budget (Noble and Storey, 2001).

3.3.1 Assessment actors

For this research, a quantitatively based assessment was desired to allow data aggregation and a consistent, systematic analysis of potential impacts, so that the most preferred option(s) could be identified. To that end, a technique was required that was capable of collecting data from experts over a geographically diverse area, where potential regional variations in assessment data and outcomes could be isolated.

Participant selection

Purposive sampling was used to select assessment participants. In this case the procedure involved asking initially a number of 'experts' to identify the types of members that should comprise the sample. Kerlinger (1986) explained purposive sampling as a type of non-probability sampling, which is characterized by the use of judgment and a deliberate effort to obtain representative samples by including typical areas or groups in the sample. Essentially, the researcher attempts to obtain a sample using his/her own judgment and reasoning as fit for the study purpose. Since each member of the population does not have an equal chance of being selected, the sample is, by definition, non-random. The purpose of the research governs the selection of the sample, excluding members of the population who do not contribute to that purpose.

Potential participants were selected in the primary stages of the project. Key informant contacts and web-based searches were used to locate experts with experience in agriculture or agricultural GHG mitigation. Since the purpose of this research is to find the most socially acceptable GHG mitigation option at the on-farm level, individuals with extensive farming backgrounds, and practical experience, were ideal

participants. These participants aided in the process by identifying other key individuals. The people that identify and assess the impacts should be the individuals most affected by the potential change (Harris *et al*., 2003). Therefore, farming professionals and industry representatives and decision makers from across the Prairies were identified. There were two types of decision makers included in this research: individuals at the on-farm level that would be affected by new farm policies, and individuals that influence policy making (government, academia, industry, and others). The University of Saskatchewan ethics board requires that written materials preserve the anonymity of the study participants. Thus, organizations of key informant contacts are listed in Appendix A, but individual names are withheld in accordance with ethics policy.

Affiliation

Individuals were identified through organizations such as the National Farmers Union, the Prairie Farm Rehabilitation Administration, Keystone Agricultural Producers, the Saskatchewan Wheat Pool, the Seed Growers Association, Action Committee on the Rural Economy, and Regional Economic Development Authorities. Provincial government employees such as agricultural business agrologists, farm management specialists, and climate change specialists were also participants. Environmental organizations such as the Saskatchewan Soil Conservation Association, the Southern Alberta Conservation Association, the Parkland Conservation Farm Association, and the Nature Conservancy of Saskatchewan were identified for their conservation and ecological knowledge.

Many of the Saskatchewan participants were identified through the Agricultural

Producers Association of Saskatchewan (APAS)[1]. Since the members identify

themselves as experienced farmers, have extensive applied agricultural or environmental

science backgrounds, and are interested in influencing policy, they were targeted as

potential participants. Similarly, members of the Association of Alberta Agricultural

Fieldmen were included because they are self-designated "agricultural and

environmental generalists" and they have broad perspectives on agricultural issues

(AAA Fieldmen, 2005). The study drew participants from across the three Prairie

Provinces: Manitoba, Saskatchewan, and Alberta. In total, 353 individuals were

contacted representing farmers and producers, government, farmer's unions, economic

development authorities, and academics.

Survey Process

The participants were sent an assessment package which included a letter of

introduction with a request for participation, a description of the five alternative

cropping practices, and the assessment document. The assessment was comprised of

thirteen assessment matrices and the participants were asked to assess the five GHG

mitigation options based on thirteen socio-economic and sustainability criteria (see

3.3.2). An adaptation of Salant and Dillman's (1994) four phase questionnaire

administration process was utilized to administer the assessment exercise (see Table

3.1). The research was time sensitive, since the data had to be collected during the

farming off-season (October 2004 – March 2005). The surveys were mailed to the

[1] APAS members are located in many towns across Saskatchewan, representing a broad geographical area. APAS identifies one of the goals of the members is to provide input toward policy development initiatives (APAS, 2005).

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potential participants in November, 2004 and during December, 2004 and January,

2005, a follow-up email, or phone call, was made to each of the potential respondents.

Table 3.1 Survey process according to Salant and Dillman (1994)

Phase One	A short advance-notice letter to all members of the sample
Phase Two	Mail Survey (1 week after letter)
Phase Three	Postcard follow-up (up to one week after survey)
Phase Four	Personalized cover letter with a self-addressed return envelope. This is sent to all non-respondents three weeks after the second mail-out.

A second phone call occurred in late January or early February to the respondents

who had not been reached, or who had indicated they would like to participate but

whose survey had not been received.

The surveys were numbered for tracking and coding purposes; as the surveys were

returned the researcher transferred the data into a database and used the tracking number

to identify the province, and soil zone, in which the respondent lived. Participants were

asked demographic questions to identify their occupation, and where farming was

indicated as their primary or secondary occupation an additional question was asked

about whether it was their full-time or part-time occupation. This facilitated

disaggregate grouping of participants by occupation and by soil zone.

3.3.2 Assessment criteria

Criteria represent the participants' points of view through the manner in which they

establish comparisons between alternatives. According to Voogd (1983), 'criterion' is

used in a flexible way, and defined as a measurable aspect of judgment by which the

various alternatives under consideration can be characterized. There are three types of

criteria in MCE: attainability criteria, veto criteria, and desirability criteria (Voogd,

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1983). Attainability criteria are governed by boundaries and constraints, such as

financial constraints, availability of government policies, or availability of grants. Veto

criteria are based on minimum requirements, and they usually have a defined threshold,

and desirability criteria relate to the degree which a particular alternative is desirable

from a certain point of view, such as accessibility to facilities, social equity, or

efficiency. The socioeconomic and sustainability criteria used in this assessment are

characterized as both desirability and attainability criteria, as they are meant to

determine the attractiveness of certain alternatives and they are governed by boundaries;

it is assumed at this point that they are all attainable options.

There are two main ways to determine the set of criteria. The top-down, or

deductive, approach is where the criteria are built in a hierarchical structure leading

from primary goals to main objectives, which in turn are broken down to specific

criteria; the bottom-up, or inductive, approach is where the criteria are identified through

a systemic elicitation process, and then subsequently grouped in broad categories

(Keeney and Raiffa, 1976). Regardless, criteria should include a number of properties

including: value relevance, or criteria linked to goals of the stakeholders enabling them

to specify preferences; understandability, so the concept behind the criterion is clear;

measurability, so the performance of alternatives can be expressed on a scale;

completeness, where the set of criteria strives to cover all important aspects of the

problem while being concise; non-redundancy, meaning no criteria reflect the same

concept as another, avoiding double-counting and over-attributing importance of a

single aspect (Diakoulaki and Grafakos, 2004). One of the difficulties in choosing the

number of criteria involved in a survey is the inherent trade off between too few and too

many. A researcher may wish to build a model as close as possible to a real-world problem, increasing the number of criteria to a level that its applicability becomes almost impossible (Munda *et al*., 1994). Similarly, if a small number of criteria is used so that the study stays simple and quick to complete, the model may suffer from oversimplification (Munda *et al*., 1994).

The assessment criteria used in this research are aspects that characterize the larger issues, or valued environmental components (VECs). The VECs are the categories that were deemed important when identified through a review of the social impact assessment literature in the summer of 2004, and refined through discussions with key informants (see Table 3.2). Initially, a literature search identified papers discussing factors affecting on-farm adoption of agricultural practices, and from these potential VECs were identified, along with their associated criteria. Literature discussing barriers to the adoption of new technologies was critical to this task. For example, Vanclay and Lawrence (1992) analyzed such barriers and categorized them as: conflicting information; risk; implementation costs and capital outlay; intellectual outlay; loss of flexibility; complexity; and incompatibility with other aspects of farm management and personal objectives. In order to ensure the VEC list was complete, discussions were held with key informants who had knowledge of agriculture, technology, and current practices.

These discussions are supported by Keeney (1992), who emphasizes the importance of generating options based on the values of people concerned. Individuals were sent the list of potential VECs, along with a project description, before the discussions took place and asked to consider what they would add, delete, or change. Discussions with

ten key informants then took place in August 2004, on the phone, or in person if the

person resided locally. The discussions were in the form of semi-structured interviews,

where the interviewer had a specific goal in mind, namely to develop a complete list of

VECs and criteria, but to allow the respondent to identify whatever key points they felt

would increase the effectiveness of the VEC list. Respondents were asked what VECs

were important and represented concerns associated with running a farming operation,

and which VECs were unnecessary or redundant. The researcher used the opinions of

the respondents to modify the VEC list.

For example, VEC_{12} and VEC_{13}, "impact on soil resources" and "impact on water

resources", were initially composites labeled "environmental impact". However, one

person suggested that the use of the term "environment" might create a negative

association with the VEC amongst farmers, and that both soil and water are important,

and distinct, considerations from a farming perspective. Similarly, instead of one

"economic" category, it was deemed important to separate economic risk, economic

costs, and economic benefits to adequately encompass the economic perspective.

Table 3.2 Assessment VECs and associated assessment criteria.

VECs	Criterion
1. Crop/commodity production volume	▪ Impact of cropping practice on production volume
2. Crop/commodity production quality	▪ Impact of cropping practice on quality of crop produced
3. Economic risk	▪ Cropping practice exposure to economic risks, including consumer costs
4. Economic benefits	▪ Cropping practice potential to generate positive economic benefits
5. Economic costs	▪ Costs of cropping practice in terms of input costs, energy costs, investment and equipment
6. Flexibility of farm operations	▪ Impacts on-farm flexibility, scheduling of farm activities, business, and current management practices
7. Complexity of cropping practice	▪ Cropping practice is feasible and practical to implement with current farm technology and infrastructure
8. Institutional support	▪ Requirements for government and industrial financial and administrative support
9. Community support	▪ Requirements for peer support amongst farmers and the agribusiness for managing greenhouse gases
10. Time commitment	▪ Cropping practice requirements for additional time commitment, affecting family time or time currently dedicated to other on- or off-farm activities
11. Labour requirements	▪ Cropping practice demand for or effect on labour requirements
12. Impacts on soil resources	▪ Impact of cropping practice on soil fertility, erosion, or other soil resources
13. Impacts on water resources	▪ Impact of cropping practice on water quality, quantity or other water resources

3.4 Phase IV: Impact Evaluation

The choice of evaluation and assessment methods and techniques depends on the nature of the data and the desired outcome, and the methods can vary from simple checklists to complicated matrices (Noble and Storey, 2001). In this assessment, participants were asked to evaluate the impacts of each alternative on the basis of each VEC. Each of the 13 VECs had a matrix associated with it, and for each matrix the respondent was asked to rate the potential impact on the basis of a number of impact evaluation criteria (see Figure 3.2) following the model proposed by Bonnell (1997). These impact evaluation criteria were used to derive an assessment score for each VEC/alternative combination.

It was necessary to construct a matrix through which the decision-makers could assign numerical values representing the relative significance of the impact of each alternative based on the criteria (Bonnell, 1997). A score could be calculated for each alternative, thus providing a standard means of comparison.   One method of presenting such information was developed by Leopold *et al*. (1971), where a matrix summarizes and displays interactions between specific actions and environmental characteristics. Many adaptations have since been made to this original matrix formation, including descriptive, symbolized, characterized, numeric, and combinative forms (Chase, 1976). The last method, combinative, uses each matrix cell to assess potential impacts in terms of importance, probability, time of occurrence, duration, benefit, effect of remedial measures, and risk (Shopley and Fuggle, 1982).

	Magnitude Impact of cropping practice on total crop production volume	Direction Expected nature of the impact	Probability Likelihood of an effect on crop production volume	Duration Length of time cropping practice would affect crop production volume	Management Impacts can be mitigated/realized with current investment, resources and technology
Alternative cropping practices	Major / Moderate / Minor / Negligible	Unknown / Negative / Neutral / Positive	Unknown / >80% chance / 61 to 80% chance / 41 to 60% chance / 20 to 40% chance / <20% chance	Uncertain / Permanent / >10 years / 6 – 10 years / 2-5 years / 0-1 years	Strongly disagree / Slightly disagree / Slightly agree / Strongly agree
a. Enhanced nitrogen use efficiency	○ ○ ○ ○ ○ ○	○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○
b. Adoption of zero till practices	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○
c. Decreased summerfallow area	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○
d. Increased use of forage in crop rotations	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○
e. 10% increase in farm equipment fuel efficiency	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○

1. Crop / commodity production volume
 • Impact of cropping practice on crop production volume

Figure 3.2 Sample assessment matrix for alternatives A_1 to A_5 for VEC_1, crop commodity / production volume

For this assessment, respondents were asked to rate the potential impact of each GHG mitigation alternative based on each individual impact evaluation criterion. For example, participants were asked to evaluate each GHG mitigation alternative against each VEC_1 (crop production volume) based on five impact assessment characterization components (Bonnell, 1997; Glasson *et al.*, 1999), namely:

- magnitude of the potential impact (major, moderate, minor, negligible etc)

- direction of the expected impact (unknown, negative, neutral, positive);

- probability that the VEC would be affected by the proposed alternative (unknown, <20%, 20-40%, 41 to 60%, 61 to 80%, >80%);

- temporal duration of the potential impact (uncertain, 0-1 years, 2-5 years, 6-10 years, >10 years, permanent);

- management potential (ability of the impact of the GHG strategy on VEC_i to be managed given current levels of government support and technology)

The impact of GHG mitigation option 'I_a' on 'VEC_i' is thus a function of magnitude (m), direction (d), probability (p) temporal duration (t), and management potential (mp), where $IaVEC_i$ = d [m x p x t] x mp. The total 'I_a' across all $VECs_{i \to n}$ is indexed as Σ (d [m x p x t] x mp). Where d is positive (+), the objective is to identify the *maximizing* condition, enhancing the positive impacts. Conversely, when d is negative (-), the object is to *minimize* the negative condition. Assessment scores were calculated to give both a pre- and post- management potential impact score, so the potential to manage the impacts of implementing each GHG mitigation strategy could be tested on the data.

3.5 Phase V: Impact Significance

Once the potential impacts of each alternative are identified, it is important to determine impact significance (Noble and Storey, 2001). Significance is an expressed value judgment by society on the importance of the effects (Duinker and Beanlands, 1986). Significance requires reference to the affected environment in terms the intensity of impacts and the importance communities place upon them (Sippe, 1999). There are many methods that can be used to judge significance (see, for example, Voogd, 1983; Therivel and Morris, 1995), and in this assessment impact significance was determined by asking the participants to assign weights to each of the VECs. Weights, or criterion priorities, allow the participant to specify the perceived importance of individual factors relative to the others included in the evaluation, thereby allowing for an interpretation of relative significance (Carver, 1991).

Criterion Weighting

Evaluating the significance of predicted environmental effects is one of the most important steps in any environmental assessment (Bonnell and Storey, 2000). An assessment matrix cannot be evaluated purely on the basis of standardized criteria scores, because different criteria usually have different levels of importance (Carver, 1991). In order to derive a ranking of the alternative scenarios on the basis of the individual criterion information, the relative importance of the criteria for the decision set has to be determined (Huylenbroeck and Coppens, 1995). When individual assessment scores are combined to derive a single aggregate impact score, each assessment criterion contributes equally to the overall impact assessment (Noble, 2002b). According to Hajkowicz *et al*. (2000), the primary purpose of weighting the criteria is to develop a set of *m* cardinal or ordinal values which indicate the relative importance of each criterion. Therefore, if *n* is the alternative ($a_{i=1}$, $a_{i=2}$, $a_{i=3}$, …, $a_{1=n}$), then *m* criteria ($c_{j=1}$, $c_{j=2}$, $c_{j=3}$, …, $c_{j=m}$) has a corresponding weight vector *W* ($w_{j=1}$, $w_{j=2}$, $w_{j=3}$, …, $w_{j=m}$) (Hajkowicz *et al*., 2000). These weighted criteria will then be used to determine the relative value of each alternative. As Noble (2002b) explains, since the assessment criteria are formulated based on the 'min-max' solution (selecting the alternative that minimizes potential negative impacts or maximizes potential positive impacts), the higher the assessment score (weight), the more preferred alternative *i* is over *j* on criterion c. In this way, an understanding can be gained in terms of which alternative is preferred based on each individual VEC.

In most studies the decision maker will specify the weight applied to each alternative (Hajkowicz *et al*., 2000). In this assessment the participants were asked to rate the

importance of each VEC from '1' (unimportant) to '7' (extremely important). With this technique, it is possible to alter the importance of one criterion without adjusting the weight of another (Hajkowicz *et al.*, 2000). This weighting allows the researcher to understand the significance of each criterion independent of the others. An understanding of the way participants view the VECs facilitates an assessment of the alternatives with respect to the perceived importance's of each criterion.

3.6 Phase VI – VII: Comparing the Alternatives and Identifying the Best Practicable Environmental Option

The final phases of Noble and Storey's (2001) framework involve comparing the assessment scores derived for each alternative, and identifying the 'best practicable environmental option' (BPEO). In order to compare the alternatives there is a need to rank each alternative with respect to each criterion weight and to derive composite priorities (Voogd, 1983). One approach to comparing the alternatives is the use of a multicriteria evaluation technique such as a concordance analysis, which establishes a preference structure based on the outranking relationships between alternatives (Bruen, 2002). The concordance analysis is most useful when a large number of competing schemes need to be short-listed to a smaller number of 'preferred ones' (Bruen, 2002). Uncertainties may exist in formulating alternatives, in determining impact significance, or in the selection and application of assessment measures; thus, before a preferred option is identified with any degree of confidence, an 'uncertainty assessment' should take place, including a sensitivity analysis (Noble and Storey, 2001)

Sensitivity analysis can be used to identify the important uncertainties for the purpose of prioritizing additional research (Frey and Patil, 2001), and to provide insight

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into the robustness of model results when making decisions (Manheim, 1998; Huylenbroeck and Coppens, 1995). Statistical methods involve running simulations in which inputs are assigned probability distributions and assessing the effect of variance in inputs on the output distribution (Frey and Patil, 2001). Statistical methods allow the researcher to identify the effect of interactions among multiple inputs (Frey and Patil, 2001). There are at least two sensitivity issues to address in EA-related decision making, including sensitivity of EA output with respect to: disagreements within the assessment group; uncertainties in the assignment of criteria weights (Noble, 2002b). Uncertainty in criterion weighting is a significant issue that needs exploration because criterion weights are subjective numbers about which individuals often disagree (Noble, 2002b). In this research, the values of the criterion weights were altered so the sensitivity to ranking threshold could be evaluated.

The meaning of the term BPEO was discussed in the Eleventh Report by the Royal Commission on Environmental Pollution (Cm. 310) (Tromans, 1993):

> "A BPEO is the outcome of a systematic consultative and decision-making procedure which emphasizes the protection and conservation of the environment across land, air, and water. The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term".

The BPEO is therefore not necessarily the "best" decision, but one that is identified through the decision making process, and can assist with policy planning by identifying the "most preferred" alternative. The decision- or policy- maker can then decide how best to use the BPEO, either through its implementation, or weighing it against other courses of action. Ideally, in pursuit of sustainable development, the BPEO would consider economic, social, and environmental factors.

4.0 RESULTS AND ANALYSIS

Assessment data were compiled and evaluated using multi-criteria and exploratory analytical techniques. A total of 64 respondents returned the assessment documents for analysis; hence, an 18% response rate was achieved through the survey process. The number of surveys received by soil zone are as follows: three respondents from the brown chernozemic soil zone, five respondents from the dark brown chernozemic soil zone, twenty one respondents from the black chernozemic soil zone, six respondents from the dark gray chernozemic soil zone, three respondents from the gray luvisolic soil zone, and twenty six respondents with an unknown soil zone. Twenty nine respondents identified their primary occupation as a "farmer" and thirty five respondents identified their primary occupation as "non-farmer".[2] Demographic information available from the survey indicates: 74% of the participants were 46 years old or greater, the average farm size was 2,844 acres, and the main crops produced by the farmers are 1) cereals (wheat/barley) and 2) oilseeds and/or cattle raising.

Exploratory data analysis (EDA) is an approach or attitude regarding how data analysis should be completed, including data description and the measurement of association (Sibley, 1988). The underlying assumption of EDA is that the more the researcher knows about the data, the more effectively the data can be used to develop, test, and refine theories (Hartwig and Dearing, 1979). EDA employs a variety of graphical techniques to maximize insight into a data set; uncover underlying structure;

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[2] See Section 4.6 for a discussion of "farmer" and "non-farmer" self-identification.

extract important variables; detect outliers and anomalies; test underlying assumptions; and develop models (Tukey, 1977; Agresti and Finlay, 1997). The goal of EDA is not to examine theoretically specified relationships, but to uncover structure and assist with the hypothesis creation (Agresti and Finley, 1997; Sibley, 1988). Thus, a positive aspect of EDA is that the researcher is not drawn into making decisions about the significance of a relationship (Sibley, 1988); rather, the data unfolds and the researcher uncovers relationships with no predisposed beliefs. Another appealing characteristic of EDA is that such methods are resistant to, and summary statistics are not excessively affected by, extreme outliers (Besag, 1981; Sibley, 1988). Drastic shifts in the data will not occur because of one or two values. EDA techniques were employed in this research to investigate patterns in the data and to find areas where further analysis could be pursued. All data were standardized prior to analysis so as to ensure consistency and comparability (see Carver, 1991).

4.1 GHG Mitigation Preferences: Unweighted

The unweighted assessment scores for each alternative-criterion combination were derived using the impact evaluation criteria and $IaVEC_i = d \, [m \, x \, p \, x \, t] \, x \, mp$ (Figure 4.1). For example, crop production quality (VEC_2), economic costs (VEC_5), and institutional support (VEC_8), show that increased use of forage (A_4) is preferred (i.e., relatively lower impact) to the adoption of zero till practices (A_2). In contrast, increased use of forage (A_4) is less preferred than the adoption of zero till practices (A_2) for every other VEC. However, before conclusions can be drawn regarding alternative preference

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structures, VECs need to be weighted to capture relative impact significance (i.e., criterion or VEC importance).
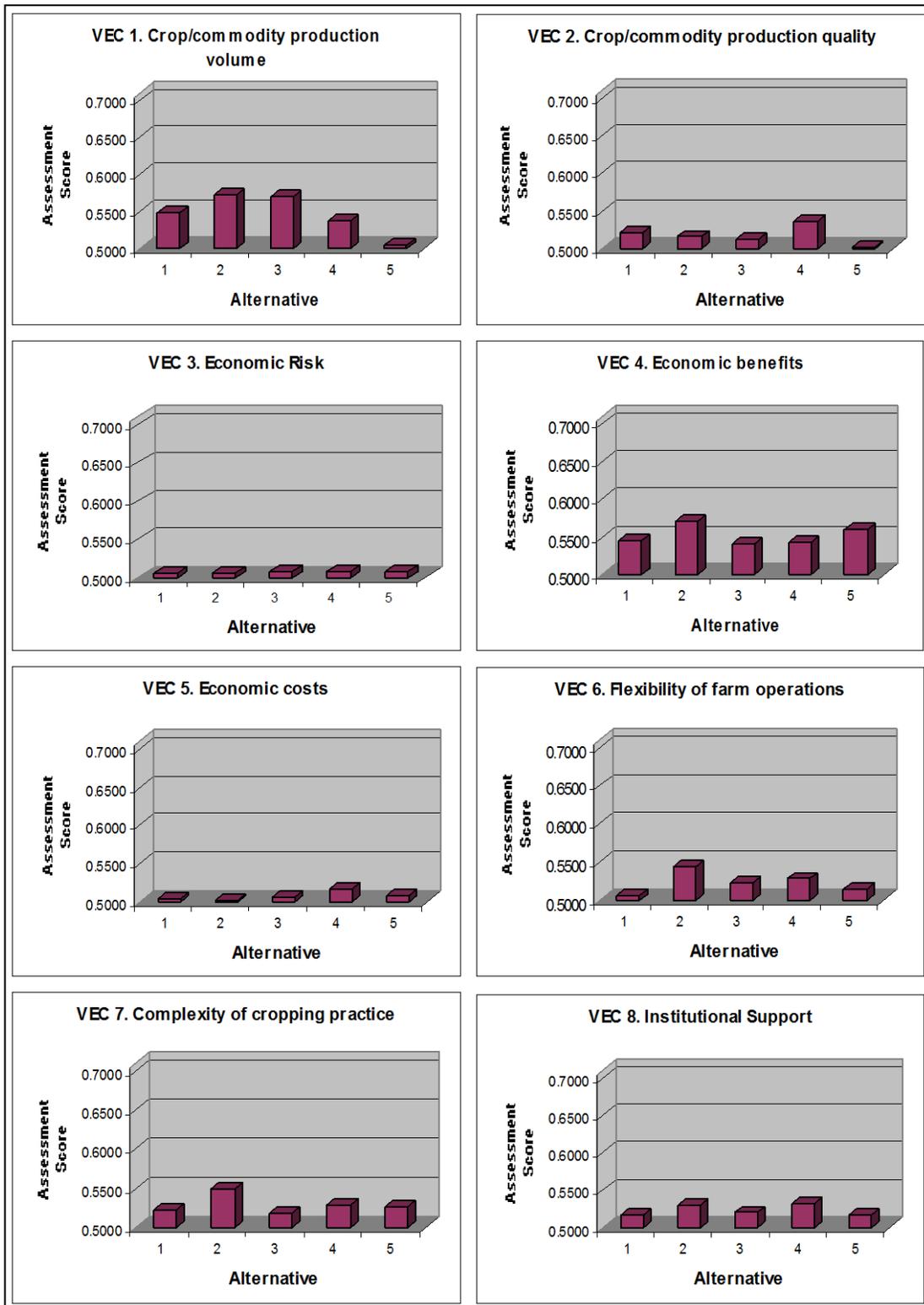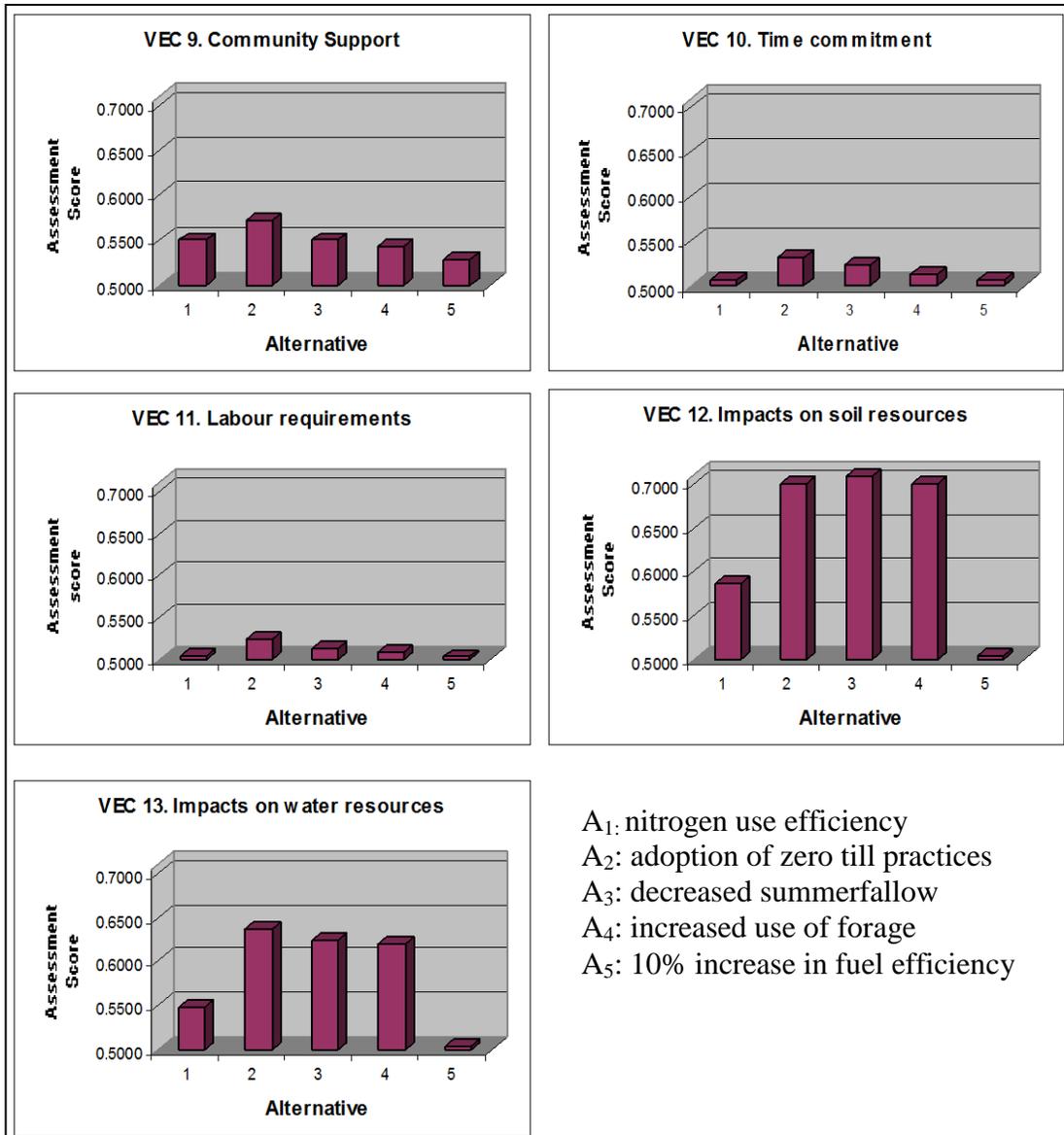
Figure 4.1 Aggregate un-weighted assessment scores by VEC

A$_1$: nitrogen use efficiency
A$_2$: adoption of zero till practices
A$_3$: decreased summerfallow
A$_4$: increased use of forage
A$_5$: 10% increase in fuel efficiency

4.2 Criteria (VEC) weights

A relative impact significance score was determined by assigning weights to the VECs[3]. For each VEC the median of the weight was taken, which represented the middle value of the data set; however, the median does not inform the researcher on the

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[3] Refer to section 3.5 Phase V: Impact Significance for method of assigning weights.

nature of the data spread. One method to identify the median, the data spread, and the

skewness of the data is by a conventional   box-plot[4].

Based on the box-plot data (Figure 4.2) there are apparent VEC groupings. VEC_{1-5}

all relate to economic costs and benefits and have median weights greater than or equal

to six, indicating that economics plays a relatively significant role when evaluating the

alternative cropping practices. Production volume (VEC_1) and production quality

(VEC_2) have long, lower hinges, representing a larger spread (i.e. less consensus) in the

data than for economic risks (VEC_3), economic benefits (VEC_4), and economic costs

(VEC_5). Economic costs and benefits have the highest medians, and relatively small

hinges; while the distribution is negatively skewed, the panelists generally agree that

economic costs and benefits are of importance, with economic risks only slightly less

important.

The three outliers for economic risks, economic benefits, and economic costs

($VECs_{3-5}$) that are located in the 4th weight category, are all attributed to the results of

only one participant's response; the same situation occurs with the three extreme outliers

(located at the 3rd weight level, at $VECs_{3-5}$), but attributable to a different participant.

Approximately 60% of the outliers can be credited to only two participant surveys,

suggesting a relative consensus amongst participants with regard to the VEC weightings.

There may be local climate or topographical conditions that contributed to the weighting

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[4] The boxplot is one type of graphical display used in EDA, and is beneficial for providing a
diagrammatic summary of statistical information. Box plots convey median and variation information, as
well as detecting and illustrating similarities and differences is distributions between groups of data
(Chambers *et al*., 1993; Sibley, 1988). Box plots display the factor of interest on the x-axis, and the
response variable on the y-axis. The median and quartiles are displayed, spread is indicated by the length
of the box, defined by the position of the quartiles (or hinges), the position of the median line indicates the
skewness of the distribution, and outliers show data extremes.   Because the median and hinges are
resistant to the impacts of a few outliers, the boxplot is also resistant to gross influence by these values
(Hoaglin *et al*., 1983).

of the VECs in the outlier surveys. For example, the participant who was responsible

for the extreme outliers is a farmer located in the dark gray chernozemic soil zone.

There may be some conditions that contribute to this respondent evaluating $VECs_{3-5}$

(economic risks, economic benefits, economic costs) much lower than the majority of

the respondents; the participant may have particular circumstances, such as wealth,

which allow him/her to be less concerned with economic factors. These outlying

respondents suggest less importance of the "economic criteria" than do the aggregate

group.

Flexibility of operations and complexity of cropping practices (VEC_6 and VEC_7)

have the same medians (median = 5), though VEC_6 is normally distributed and VEC_7 is

negatively skewed. Institutional and community support (VEC_8 and VEC_9) show a large

range across the entire set of possible weights. The median weight for both VECs is 4,

the lowest of the boxplots, but there is also considerable variation in the group's

response. Time commitment (VEC_{10}) and labour requirements (VEC_{11}) are similar with

median weights of 5, and a large data spread.

The environmental VECs, impacts on soil (VEC_{12}) and water (VEC_{13}) resources indicate

that while the median weights are 6, or very important, there is considerable variation of

opinion, as demonstrated by the data spread. These medians suggest that environmental

indicators are very important, but the spread suggest more variation than in weights than

the economic VECs exhibit. These differences may be due, in part, to variation across

soil zones, an issue returned to later in this paper.
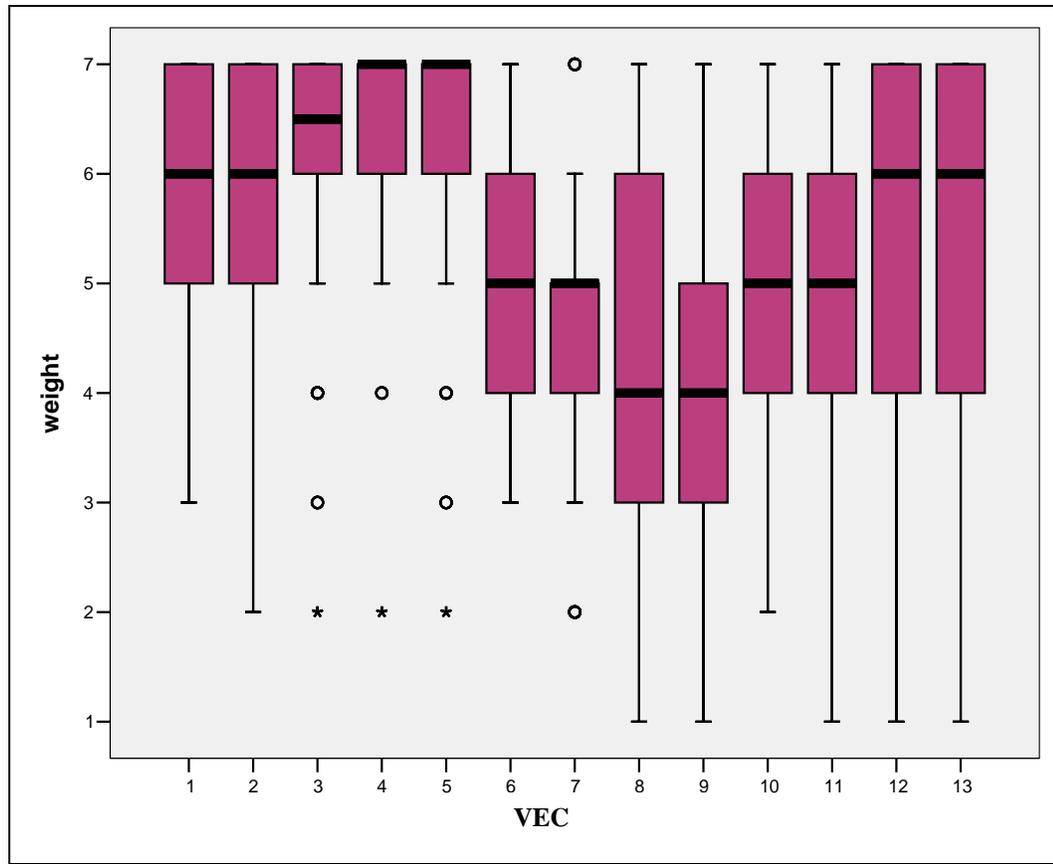
Figure 4.2 Box plot of VECs and associated weights.*
* Note: The black lines represent the medians, the box represents the middle 50% of the data, the upper hinge indicates the 75th percentile, and the lower hinge indicates the 25th percentile. The circles are data outliers and the stars are extreme outliers.

Tukey's hinges and the median criteria weights (Table 4.1) are used to explore the dataset for significant differences, using a 95% confidence interval (CI) for the median. Median weights are used to obtain the weighted assessment scores because the data were not normalized, and thus, using means is not feasible. Based on Tukey's hinges, if the data spreads overlap at this level, it cannot be said that a significance difference exists. The cells in table 4.2 indicate cases where criterion *i* (column) is significantly different than criterion *j* (row) as designated by:

> = criterion *i* significantly greater than *j*
< = criterion *i* significantly less than *j*
/ = cannot be said that criterion *i* and *j* are different

Table 4.1 Median criteria weight and 95% CI, n=63

VEC	95% Confidence Interval		
	Lower	Median	Upper
1. Crop/commodity production volume	5.600	6.000	6.398
2. Crop/commodity production quality	5.600	6.000	6.398
3. Economic risk	5.800	6.000	6.200
4. Economic benefits	6.800	7.000	7.200
5. Economic costs	6.800	7.000	7.200
6. Flexibility of farm operations	4.600	5.000	5.398
7. Complexity of cropping practice	4.800	5.000	5.200
8. Institutional support	3.400	4.000	4.600
9. Community support	3.600	4.000	4.400
10. Time commitment	4.600	5.000	5.398
11. Labour requirements	4.600	5.000	5.398
12. Impacts on soil resources	5.400	6.000	6.597
13. Impacts on water resources	5.400	6.000	6.597

Table 4.2 Paired differences, Tukey's hinges test for significance between VECs

	1	2	3	4	5	6	7	8	9	10	11	12	13
1		/	/	<	<	>	>	>	>	>	>	/	/
2			/	<	<	>	>	>	>	>	>	/	/
3				<	<	>	>	>	>	>	>	/	/
4					/	>	>	>	>	>	>	>	>
5						>	>	>	>	>	>	>	>
6							/	/	>	/	/	<	<
7								>	>	/	/	<	<
8									/	/	/	<	<
9										<	<	<	<
10											/	<	<
11												<	<
12													/
13													

When impact assessment scores are multiplied by the median weights to obtain a weighted assessment score, the perceived importance of the alternatives based on each VEC changes only slightly from the unweighted scores (Figure 4.3). For example, a comparison of crop production quality (VEC_2) and institutional support (VEC_8) still

show that increased use of forage (A_4) is preferred to adoption of zero till practices (A_2), but the two alternatives have similar assessment scores, with A_4 only slightly preferred. The graphs in Figure 4.3 closely resemble those of Figure 4.1; the comparison of alternatives across the VECs only becomes meaningful when the criteria weights have been factored into the assessment scores. The insignificant differences between weighted and unweighted assessment scores in this case are due to the only minor differences across median VEC weights, a factor attributed in part to the spread in the observations.

4.3 Aggregate Impact Assessment Results

4.3.1 Pre-Management

Based on $IaVEC_i = d\,[m \times p \times t]$, an assessment score is calculated for each VEC-alternative combination. Using the Statistical Package for the Social Sciences (SPSS), median impact scores were identified for each alternative (A_1-A_5) based on each VEC (VEC_{1-13}). These medians were tabulated (Table 4.3) and used to derive the initial alternative preference structure. The "pre-management" data shown in Table 4 are aggregate, and calculated in absence of management potential (mp); this allowed for an evaluation of the significance of management in influencing the preference structure across each affected VEC.

Since the criteria were formulated on a 'min-max' scale, the higher the assessment score the more preferred is Alternative *i* over *j* for that particular VEC. For example, Figure 7 shows that A_3 (decreased summerfallow area) is the preferred cropping

practice for minimizing impacts on water resources (VEC_{12}), but is least preferred based on the complexity of the cropping practice (VEC_7) and economic costs (VEC_5).
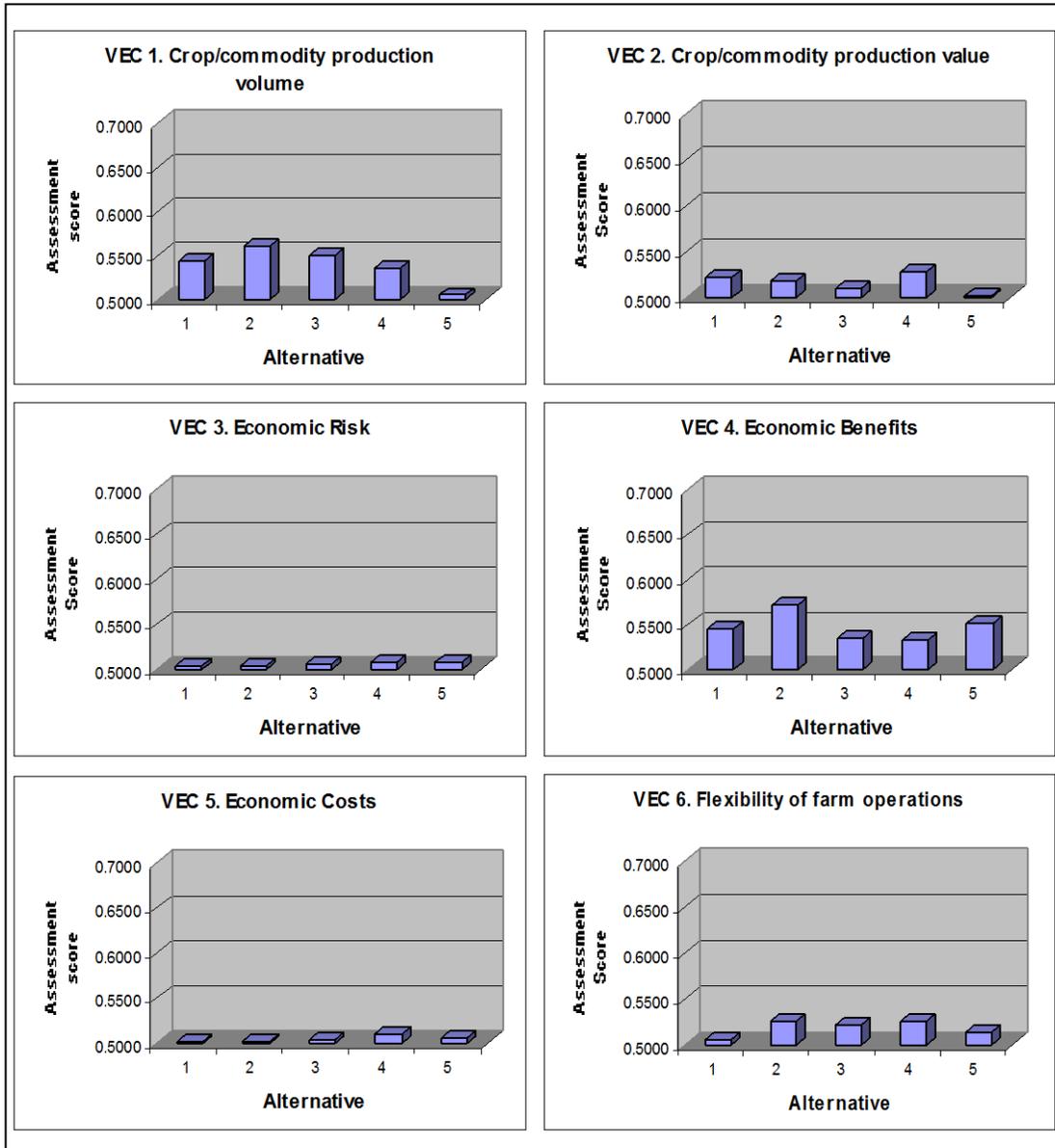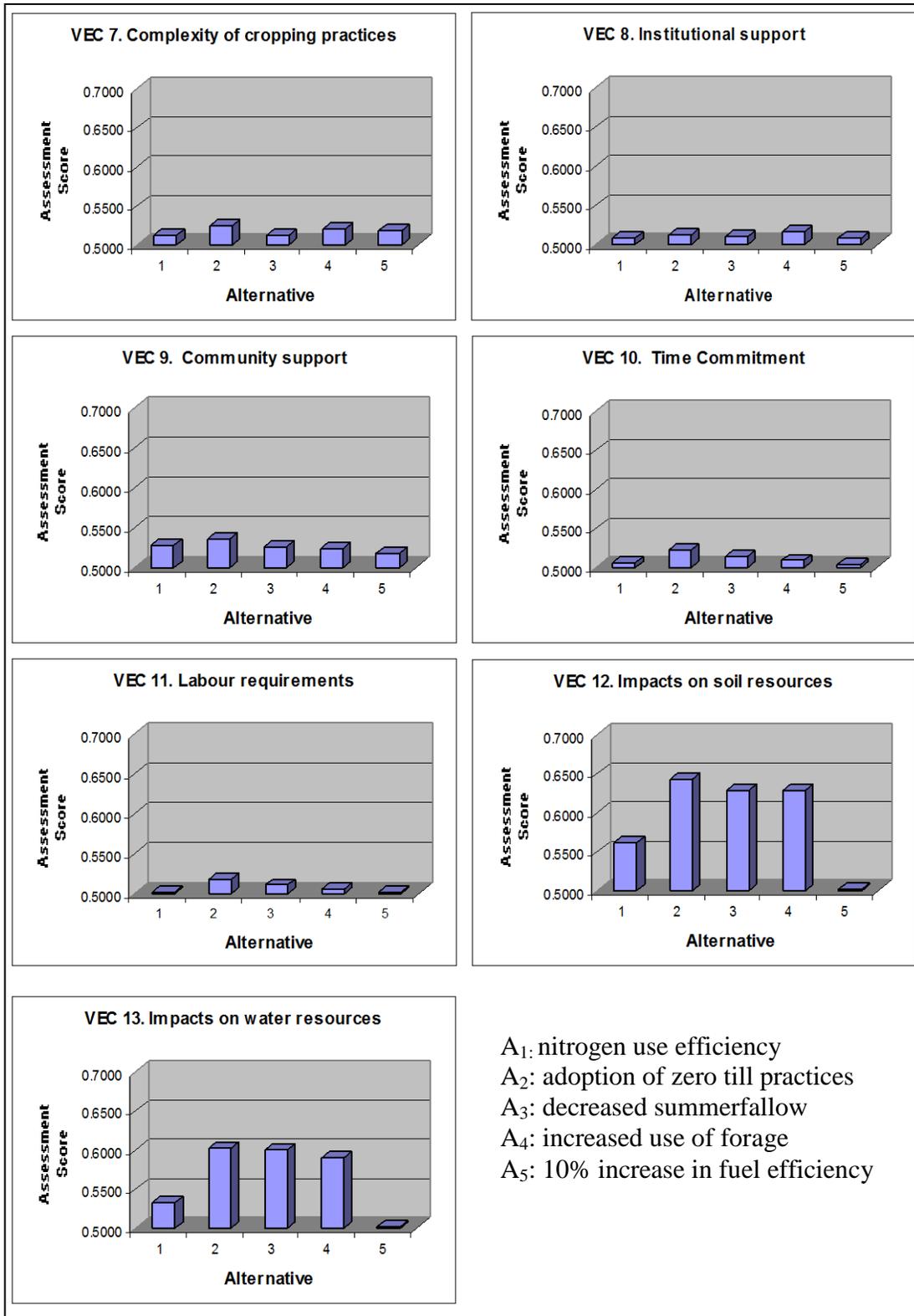
Figure 4.3 Weighted assessment scores for each VEC.

Table 4.3 Aggregate standardized assessment scores, pre-management potential

VEC	Nitrogen use efficiency (A_1)	Adoption of zero till (A_2)	Decreased summerfallow (A_3)	Increased use of forage (A_{4+})	10% increase in fuel efficiency (A_5)
1	0.5765	0.6020	0.6105	0.5612	0.5069
2	0.5459	0.5255	0.5238	0.5459	0.5034
3	0.5085	0.5082	0.5115	0.5136	0.5139
4	0.6020	0.6509	0.6020	0.5893	0.6131
5	0.5068	0.5038	0.5111	0.5234	0.5238
6	0.5136	0.5680	0.5255	0.5510	0.5255
7	0.5289	0.5510	0.5242	0.5425	0.5340
8	0.5208	0.5306	0.5204	0.5476	0.5204
9	0.5510	0.5964	0.5567	0.5527	0.5340
10	0.5085	0.5510	0.5340	0.5204	0.5068
11	0.5048	0.5493	0.5217	0.5111	0.5034
12	0.6224	0.7857	0.7976	0.7551	0.5028
13	0.5791	0.7381	0.7143	0.7041	0.5045
$\sum$	7.0688	7.6605	7.4533	7.4179	6.7925

This suggests that decreased summerfallow area is considered environmentally friendly, complex and not economically viable. The VECs that were identified as important by the pre-management analysis include: production volume (VEC_1), economic benefits (VEC_4), impacts on soil resources (VEC_{12}) and impacts on water resources (VEC_{13}) (Figure 4.4).

Based on the pre-management impact data, a preliminary order of preferences can be derived using the cumulative assessment score (Figure 4.5), identifying the adoption of zero till practices (A_2) as the most preferred alternative, and a 10% increase in fuel efficiency (A_5) as the least preferred option.
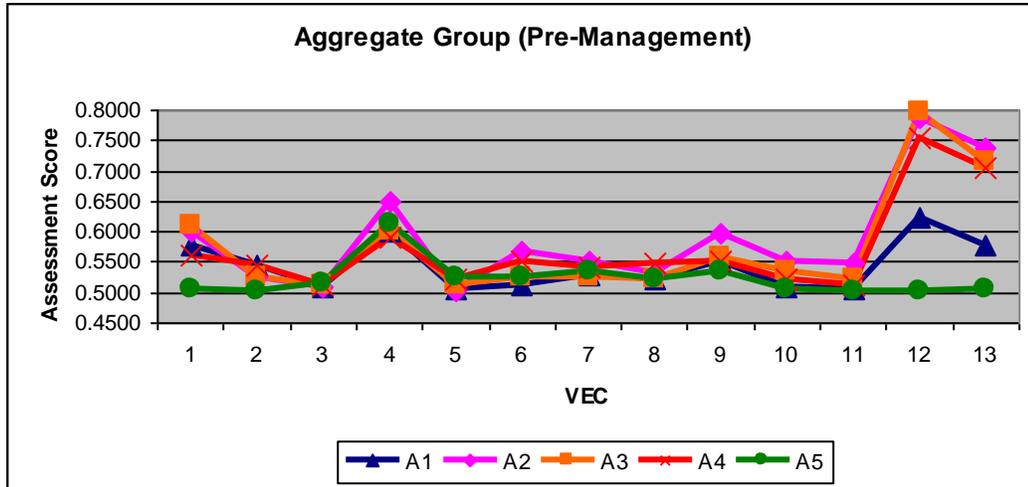
Figure 4.4 Aggregate group data, standardized pre-management, by VEC

Increased use of forage (A_4) and decreased summerfallow (A_3) are rated similarly in the preference structure. The Mann-Whitney test is applied as an absolute measure to test whether the differences between the individual alternatives, on a pairwise basis, are statistically significant (Table 4.4). In this case, decreased summerfallow area (A_3) and increased use of forage in crop rotations (A_4) are not statistically different.
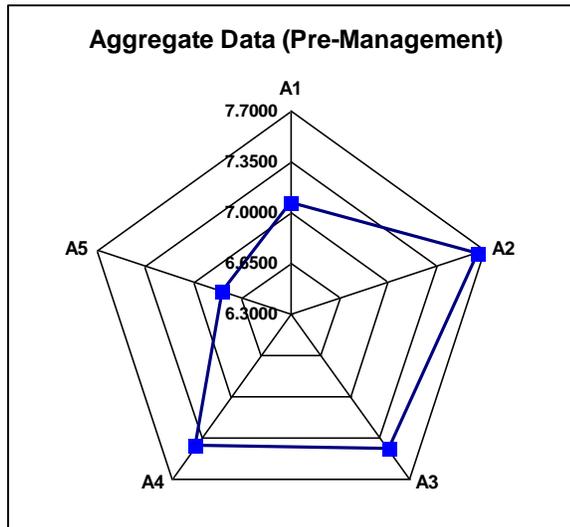
Figure 4.5 Radial diagram of preference structure for aggregate data, pre-management

Table 4.4 Mann-Whitney U test for significant difference (prob-values)

		Alternative				
		1	2	3	4	5
Alternative	1		0.000	0.000	0.000	0.000
	2			0.001	0.000	0.000
	3				0.932	0.000
	4					0.000
	5					

4.3.2 Post-Management Results

The formula $IaVEC_i = d \, [m \times p \times t] \times mp$ was used to derive median values for the post-management potential data (Table 4.5). The pre-management assessment scores were multiplied by the management potential (mp) score and the results compared to assess the perceived influence of management practices.

Table 4.5 Aggregate standardized, post-management assessment scores

VEC	Nitrogen use efficiency (A_1)	Adoption of zero till (A_2)	Decreased summerfallow (A_3)	Increased use of forage (A_{4+})	10% increase in fuel efficiency (A_5)
1	0.5438	0.5595	0.5500	0.5357	0.5044
2	0.5214	0.5184	0.5111	0.5287	0.5020
3	0.5047	0.5051	0.5066	0.5077	0.5079
4	0.5446	0.5714	0.5345	0.5333	0.5510
5	0.5021	0.5011	0.5048	0.5095	0.5071
6	0.5043	0.5255	0.5204	0.5245	0.5128
7	0.5128	0.5255	0.5122	0.5208	0.5177
8	0.5092	0.5121	0.5102	0.5170	0.5089
9	0.5279	0.5357	0.5264	0.5245	0.5186
10	0.5062	0.5230	0.5145	0.5094	0.5043
11	0.5015	0.5170	0.5102	0.5057	0.5017
12	0.5616	0.6429	0.6286	0.6276	0.5014
13	0.5323	0.6020	0.6000	0.5893	0.5024
∑	6.7724	7.0392	6.9295	6.9337	6.6402

Figure 4.6 shows the assessment scores of the five alternatives measured across the assessment criteria. The post-management data exhibit similarities to the pre-management data for many of the assessment criteria, and economic benefits (VEC_4) and impact on soil resources (VEC_{12}) are rated highly; this suggests that they are very important considerations in the decision set. All alternatives, except A_5 (10% increase in fuel efficiency), have large assessment scores based on VEC_{12} (impact on soil resources), which implies that A_{1-4} have perceived positive benefits for soil resources. VEC_{13}, impact on water resources, was also rated highly compared to VECs in the "operations/support" group ($VECs_{6-11}$). Again, a 10% increase in fuel efficiency (A_5) has the lowest score, and is perceived to be of little benefit to conserving soil or water resources ($VECs_{12\&13}$).
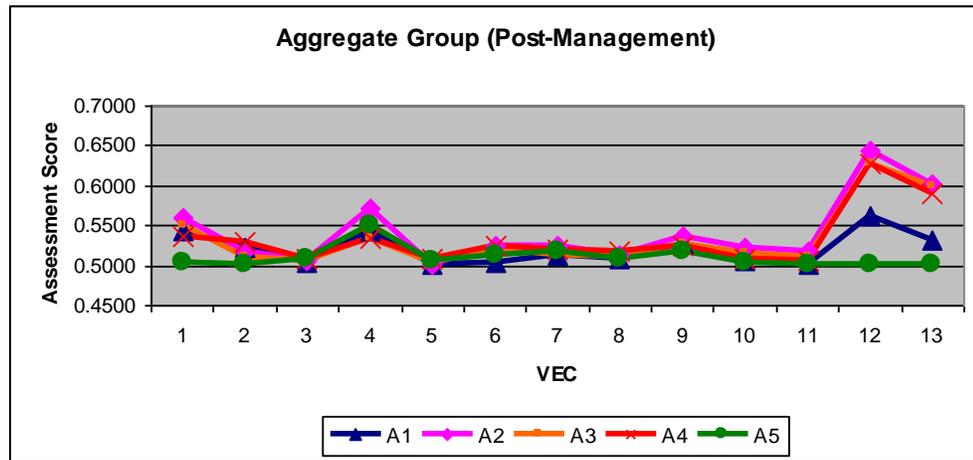
Figure 4.6 Aggregate group data, standardized post-management, by VEC

The post-management potential preference structure (Figure 4.7) is based on the cumulative impact scores across all criteria using post-management assessment data. It shows that adoption of zero till practices (A_2) continues to be the most preferred alternative, and a 10% increase in fuel efficiency (A_5) the least preferred. Similar to the

pre-management results, alternative 3 and alternative 4 are not statistically different

(Table 4.6).
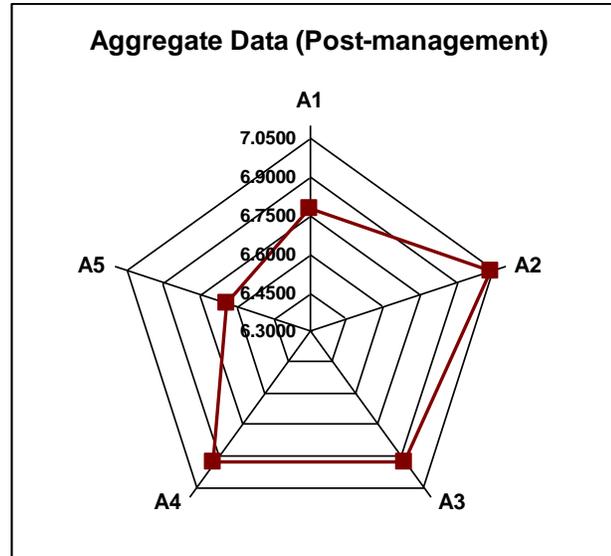
Figure 4.7 Weighted preference structure for the
aggregate group post-management

Table 4.6 Mann-Whitney U test for significant difference,
post-management (prob-values)

		Alternative				
		1	2	3	4	5
Alternative	1		0.000	0.000	0.001	0.000
	2			0.011	0.006	0.000
	3				0.909	0.000
	4					0.000
	5					

4.3.3 Influence of Impact Management Potential Measures

The results for the pre- and post- management scores (Figures 8 and 10) are similar,

suggesting that the preference structure does not change, regardless of current

management activities to support adoption, or to offset the perceived impacts associated

with implementing the GHG mitigation measures. That is to say, the preference

structure for the pre- and post-impact management assessment scores changes little.

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Based on the comparison of the VECs, for example, both aggregate sets of data evaluate economic benefits (VEC_4) and impacts on soil resources (VEC_{12}) highly, suggesting environmental and economic criteria are important. Alternative 2 (adoption of zero tillage practices) was the most preferred option in both the pre-management and post-management aggregate group structures. In short, the addition of the management score to offset the impacts of adopting the GHG mitigation alternatives does not affect either the choice structure or the importance of the VECs. The remainder of the analysis will use post-management data.

4.4 Aggregate Impact Assessment Preference Structure

An outranking of alternatives was derived using a concordance analysis and standardized scaling parameter. In light of the multiple alternatives and multiple criteria involved in this problem, analysis is needed where the relative preference structure is derived based on an outranking relationship of all alternatives considered simultaneously. The concordance analysis is a tool that allows such an outranking, examining the differences between choice-possibilities within the context of all competing alternatives simultaneously, after which a final appraisal score can be calculated for the choice set (Voogd, 1983). The degree to which choice alternatives and VEC weightings confirm or contradict the 'outranking' relationship between alternatives can be measured (Carver, 1991). Each alternative acquires a dominance score and the total dominance index can be derived and the alternatives ranked. According to Aubert (1986), the outranking relationship for two alternatives *i* and *j* can be defined as: (1) *i* scores equal or better than *j* on a sufficient number of criteria

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(concordance index); and (2) the differences in the factor scores where j is better than i are not too high (discordance index). Voogd (1983) and Noble (2002b) describe the information in such a concordance analysis as follows:

- the concordance set C(ij), where alternative i is preferred to alternative j

- the discordance set D(ij), where alternative j is preferred to alternative i

- the tie set T(ij), where alternative i is equally preferred to alternative j

and,

$$c_{ii} = (\sum_{j\varepsilon C(ii')} W_j + \tfrac{1}{2} \sum_{j\varepsilon T(ii')} Wj)/(\sum_{j=1}^{n} W_j)$$

where W equals the weighted impact score. The concordance analysis was used to determine the weighted ranking of each alternative and to derive a relative measure of preference of one alternative over the others (Table 4.7).

Table 4.7 Concordance matrix for the aggregate group

	A_1	A_2	A_3	A_4	A_5	Σ	Standardized Score	Rank
A_1		0.18	0.30	0.23	0.51	1.22	0.01	4
A_2	0.82		0.81	0.68	0.81	3.12	1.00	1
A_3	0.70	0.19		0.53	0.60	2.06	0.45	3
A_4	0.77	0.32	0.46		0.81	2.36	0.60	2
A_5	0.49	0.19	0.40	0.19		1.21	0.00	5

The results of the concordance analysis were scaled to obtain a standardized score using the following equation (after Voogd, 1983; Carver, 1991):

Standardized score =   Raw score – minimum raw score

Maximum raw score – minimum raw score

Use of this standardization method means that the least preferred alternative will always

be zero, the preferred alternative will be one, and other alternatives scored in between.

The equation is only applicable to 'benefit' criteria, or those where a higher score

implies a better score (Carver, 1991), as is the case in this assessment. These

standardized scores were used to derive the preference structure of the aggregate group,

based on all outranking relationships considered simultaneously. This indicates the

position of each alternative based on the extent to which they are outranked by all other

alternatives. The result is a relative outranking relationship indicating an aggregate

preference set (Figure 4.8).
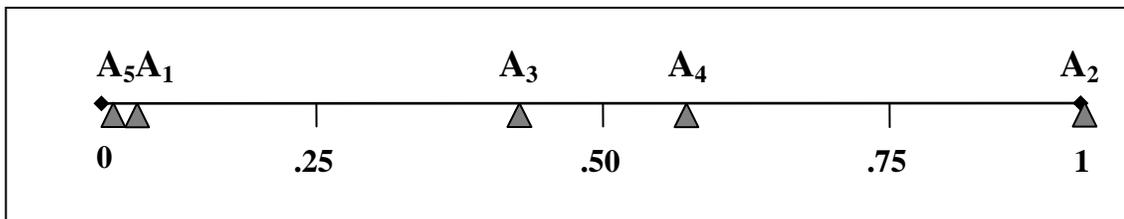
Figure 4.8 Scaled post-management preference structure

To examine the extent to which the ordering of alternatives derived from the

concordance matrix agrees with the information contained within the matrix itself, an

index of similarity can be calculated (Middleton, 2000). This index, identified as

Jaccard's coefficient, is represented as $S_j = n11 / n11 + n01 + n10$, where:

S = similarity

n = number of variables

$n11$ = number of pairs coded the same in both sets

$n01$ = number of pairs coded 0 in first sample but 1 in second

$n10$ = number of pairs coded 1 in first sample but 0 in second

In the concordance matrix C_{ii} when $i > i'$ from the ranked order of alternatives, then if $C_{ii} > 0.5$, a value of 1.0 is assigned to the pair in both sets, and if $C_{ii} < 0.5$, a value of 0 is assigned to the pair in set 1, and 1 to the corresponding pair in set 2 (Massam, 1985). When $S = 1.0$, perfect similarity exists and the ranked order perfectly represents the information in the concordance analysis. For the aggregate group, $A_2 > A_4 > A_3 > A_1 > A_5$, and using the Jaccard's coefficient, $S_j = 90\%$, or 0.90, indicating similarity between the overall concordance ranking and the individual scores contained in the assessment matrix.

4.5 Disaggregate Impact Assessment Preference Structure: by Soil Zone

An advantage of adopting a structured approach to SIA at the strategic level is that it allows for the disaggregation of the assessment outcome to see, in this case, whether a one size fits all policy approach is suitable across different soil zones. The brown chernozemic soil zone (Figure 4.9) shows variation among economic benefits and economic costs ($VECs_{4\&5}$). A 10% increase in fuel efficiency (A_5) and increased use of forage (A_4) are most preferred in terms of economic benefits (VEC_4), while adoption of zero tillage practices (A_2) and decreased summerfallow (A_3) are least preferred with regard to economic costs (VEC_5). Increased use of forage (A_4) is the most preferred across all soil zones in terms of minimizing impacts on soil (VEC_{12}) and water resources (VEC_{13}), with the exception of the dark brown chernozemic soil zone.

The dark brown chernozemic soil zone (Figure 4.9) has a similar perceived effect on the economic criteria ($VECs_{1-5}$) as the brown chernozemic soil zone. In this soil zone,

the preference structure resembles the brown chernozemic zone, but adoption of zero till practices (A_2), nitrogen use efficiency (A_1), and increased use of forage (A_4) would have a perceived effect on the labour requirements (VEC_{11}).

Both the black (Figure 4.9) and dark gray (Figure 4.9) soil zones depict a relatively similar structure, with the adoption of zero till practices (A_2), decreased summerfallow (A_3), and increased use of forage (A_4) preferred in terms of perceived impacts on soil resources (VEC_{12}). The five alternatives show little variation across the other remaining VECs.

Adoption of zero till practices (A_2), nitrogen use efficiency (A_1), and a 10% increase in fuel efficiency (A_5) are preferred in terms of economic benefits (VEC_4) and economic costs (VEC_5) in the gray luvisolic soil zone (Figure 4.9). Increased use of forage (A_4) is the least preferred GHG mitigation option in terms of minimizing economic costs (VEC_5). Decreased summerfallow (A_3) and increased forage (A_4) are preferred in terms on minimizing impacts on soil resources (VEC_{12}); this is similar to the black and dark gray chernozemic soil zones.

The VECs that display the most variation across soil zones are maximizing economic benefits (VEC_4), minimizing economic costs (VEC_5), and minimizing the impacts on soil (VEC_{12}) and water resources (VEC_{13}). These were also the VECs identified as the most important by the assessment participants. Regardless of the alternative chosen, the economic costs and benefits will be an important consideration, and are influenced by the ease of implementation of the alternative on that particular type of soil. Similarly, the environmental benefits and challenges for the adoption of the alternatives hinges on soil type and local climates, including the moisture regime.

Brown Chernozemic

Dark Brown Chernozemic

Black Chernozemic

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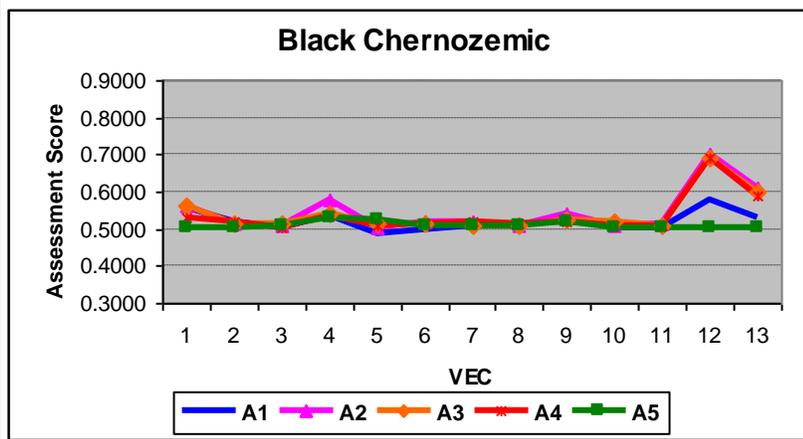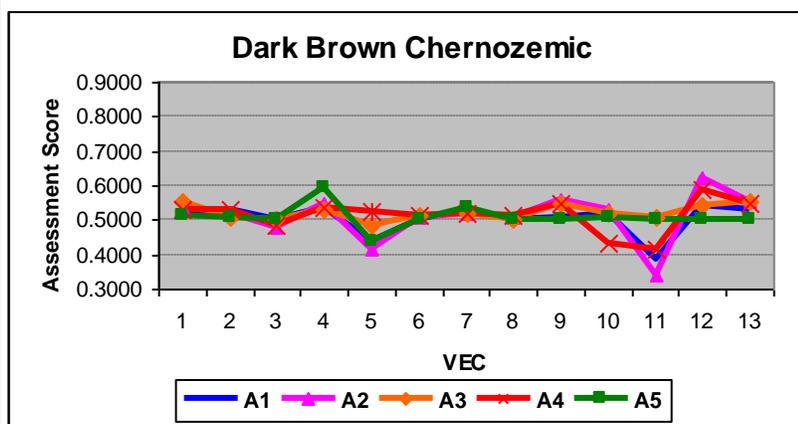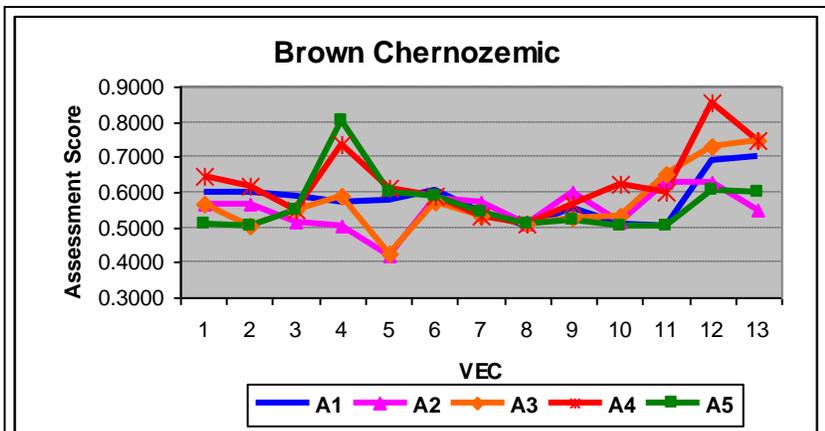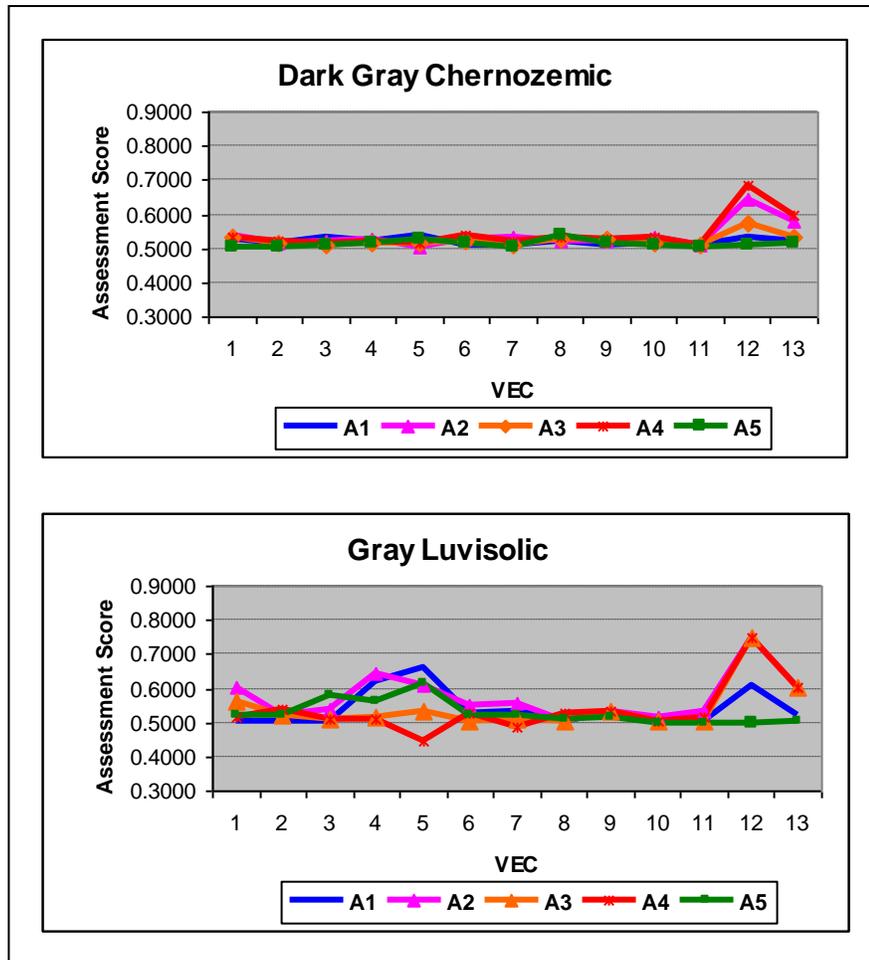
Figure 4.9 Soil zone standardized assessment scores, by VEC

Similar to above, a concordance analysis was performed for each soil zone (Table 4.10a-e) to determine the outranking relationships (Table 4.12). The resulting scaled output is depicted in Figure 4.10.

Table 4.10a Concordance analysis for Brown Chernozemic soil zone

	A_1	A_2	A_3	A_4	A_5	Σ	Standardized Score	Rank
A_1		0.69	0.51	0.22	0.76	2.18	0.51	2
A_2	0.31		0.32	0.21	0.57	1.41	0.06	4
A_3	0.49	0.68		0.26	0.64	2.07	0.44	3
A_4	0.78	0.81	0.74		0.73	3.06	1.00	1
A_5	0.24	0.35	0.38	0.29		1.26	0.00	5

Table 4.10b Concordance analysis for Dark Brown Chernozemic soil zone

	A_1	A_2	A_3	A_4	A_5	Σ	Standardized Score	Rank
A_1		0.4	0.47	0.41	0.58	1.86	0.45	4
A_2	0.6		0.52	0.45	0.57	2.14	0.81	3
A_3	0.53	0.48		0.52	0.76	2.29	1.00	1
A_4	0.59	0.55	0.48		0.58	2.2	0.88	2
A_5	0.42	0.43	0.24	0.42		1.51	0.00	5

Table 4.10c Concordance analysis for Black Chernozemic soil zone

	A_1	A_2	A_3	A_4	A_5	Σ	Standardized Score	Rank
A_1		0.15	0.21	0.22	0.54	1.12	0.07	4
A_2	0.85		0.57	0.72	0.82	2.96	1.00	1
A_3	0.79	0.43		0.56	0.84	2.62	0.83	2
A_4	0.78	0.28	0.44		0.82	2.32	0.68	3
A_5	0.46	0.18	0.16	0.18		0.98	0.00	5

Table 4.10d Concordance analysis for Dark Gray Chernozemic soil zone

	A_1	A_2	A_3	A_4	A_5	Σ	Standardized Score	Rank
A_1		0.31	0.46	0.24	0.8	1.81	0.22	4
A_2	0.69		0.57	0.39	0.83	2.48	0.65	2
A_3	0.54	0.43		0.17	0.7	1.84	0.24	3
A_4	0.76	0.61	0.83		0.83	3.03	1.00	1
A_5	0.2	0.17	0.93	0.17		1.47	0.00	5

Table 4.10e Concordance analysis for Gray Luvisolic soil zone

	A_1	A_2	A_3	A_4	A_5	Σ	Standardized Score	Rank
A_1		0.9	0.32	0.29	0.66	2.17	0.73	2
A_2	0.1		0.85	0.74	0.65	2.34	1.00	1
A_3	0.68	0.15		0.51	0.43	1.77	0.10	4
A_4	0.71	0.26	0.49		0.55	2.01	0.48	3
A_5	0.34	0.35	0.57	0.45		1.71	0.00	5

Table 4.11 Mann-Whitney test for significant difference, soil zones 1-5

		Soil Zone				
		1	2	3	4	5
Soil Zone	1		0.000	0.000	0.000	0.000
	2			0.019	0.006	0.001
	3				0.327	0.061
	4					0.239
	5					

Table 4.12 Rankings based the concordance analysis for each soil zone

Brown chernozemic	4 > 1 > 3 > 2 > 5
Dark Brown chernozemic	3 > 4 > 2 > 1 > 5
Black chernozemic	2 > 3 > 4 > 5 > 1
Dark gray chernozemic	4 > 2 > 3 > 1 > 5
Grey luvisolic	2 > 1 > 4 > 3 > 5

* where > establishes that the alternative outranks the following alternatives

The preferred alternative varies by soil zone (Figure 4.10), suggesting that the aggregate preference structure is not representative of soil zone variations. The aggregate data shows adoption of zero till practices (A_2) as the most preferred option, which is also reflected in the black chernozemic and gray luvisolic soil zones. However, participants from the brown chernozemic and dark gray chernozemic soil zones identify increased use of forage (A_4) as the most preferred option, which corresponds to the biophysical assessment findings of Agriculture and Agri-Food Canada (2001). Results of the dark brown chernozemic soil zone agree neither with the aggregate data, nor with the biophysical report; the most preferred option in this soil zone is a decreased summerfallow (A_3).

Each preference structure is different; however, four of the five soil zones (all but the black chernozemic) show a 10% increase in fuel efficiency (A_5) as the least preferred option. The least preferred alternative in the black chernozemic soil zone is nitrogen use efficiency (A_1), but a 10% increase in fuel efficiency (A_5) is only slightly more preferred. Overall the preferred alternative, based on preference structures derived from impact assessment scores, varies across soil zone suggesting that the aggregate assessment data and resulting preference structure are not representative of the geographic variation. This suggests that the alternatives are valued differently

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across soil zones, and there are different perceptions of social impacts associated with their implementation, and that a blanket "one size fits all" alternative would be difficult to achieve.
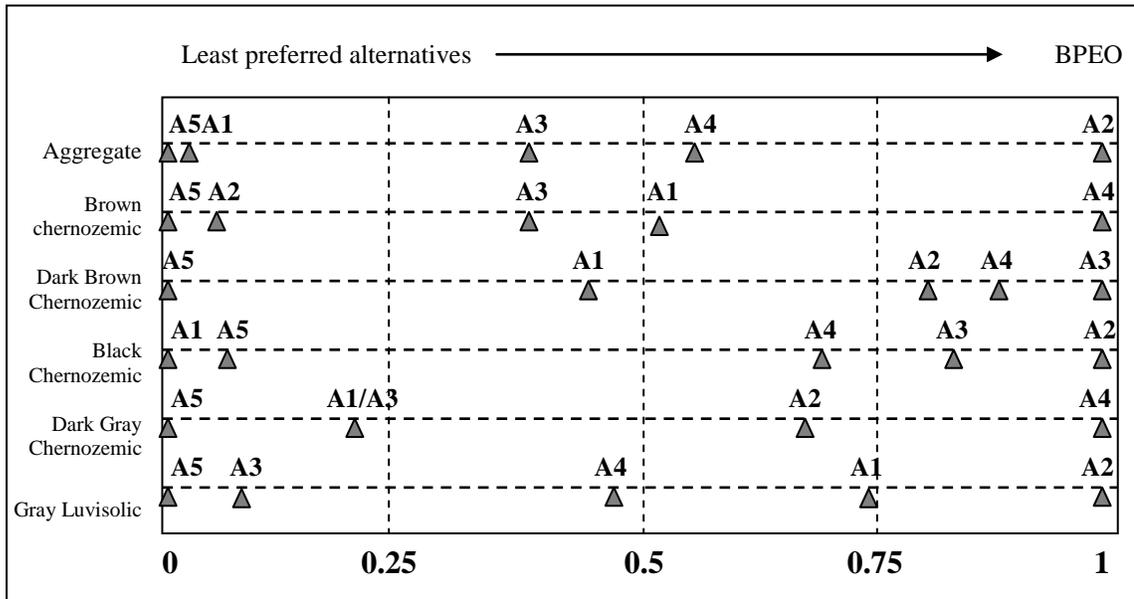
Figure 4.10 Scaled aggregate and disaggregate choice structures.

4.6 Disaggregate Impact Assessment Preference Structure: by Occupation

In addition to soil zones, the disaggregate data were analyzed for occupation based on two participant groups: farmer and non-farmer. Occupation was asked in the demographic section of the assessment document, and farmers self-identified. Non-farmer participants identified themselves as employees of government, academic, environmental non-governmental organization (ENGO), or other organizations, and did not consider themselves farmers. The rationale for analyzing the groups in this manner is to ascertain whether there are differences in alternative preference based on occupational groups and interests.

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The farmers (Figure 4.11) show variation among economic benefits and economic costs (VEC_4 and VEC_5). Adoption of zero till practices (A_2) is the most preferred in terms of economic benefits (VEC_4), and least preferred with regard to economic costs (VEC_5). Zero till practices may generate economic benefits, but farmers estimate that there will be the most input costs, energy costs or equipment costs, associated with this option. Increased use of forage (A_4), and decreased summerfallow (A_3) are most preferred for minimizing impacts on soil resources (VEC_{12}), but adoption of zero till practices is slightly more preferred for minimizing impacts on water resources (VEC_{13}).

The non-farmers share a similar VEC preference structure, as illustrated by Figure 4.12. The most noticeable difference is that non-farmers do not identify a specific cropping practice as having more economic costs than the others, and all alternatives are preferred equally with regard to economic costs (VEC_5).
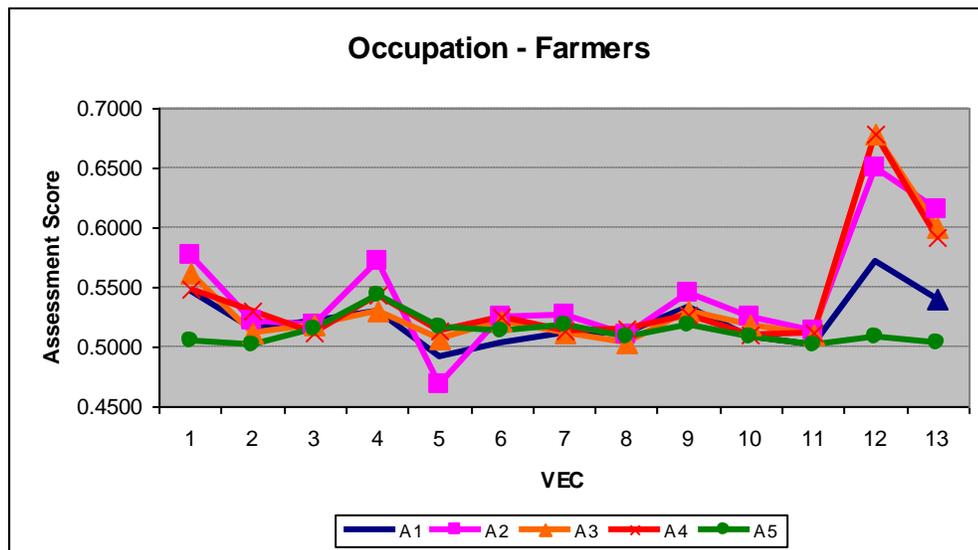
Figure 4.11 Assessment scores for farmers, by VEC
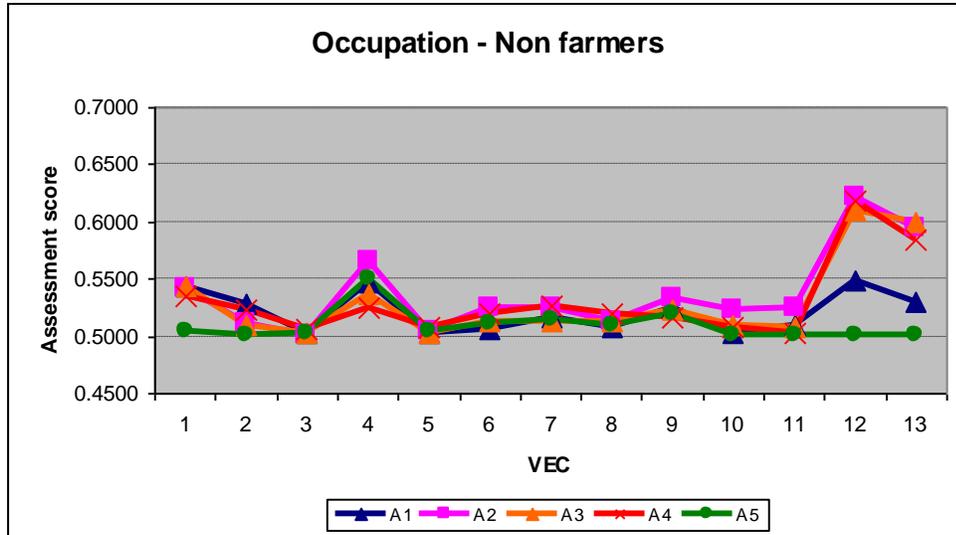
Figure 4.12 Assessment scores for non farmers, by VEC

The choice structure for the occupation groups shows a high level of homogeneity (Figure 4.13), with farmers (n = 29) and non-farmers (n = 35) similar across all alternative preferences. The preference structure for both groups, based on their concordance analyses, is: A2 > A4 > A3 > A1 > A5, reflecting that of the aggregate group.
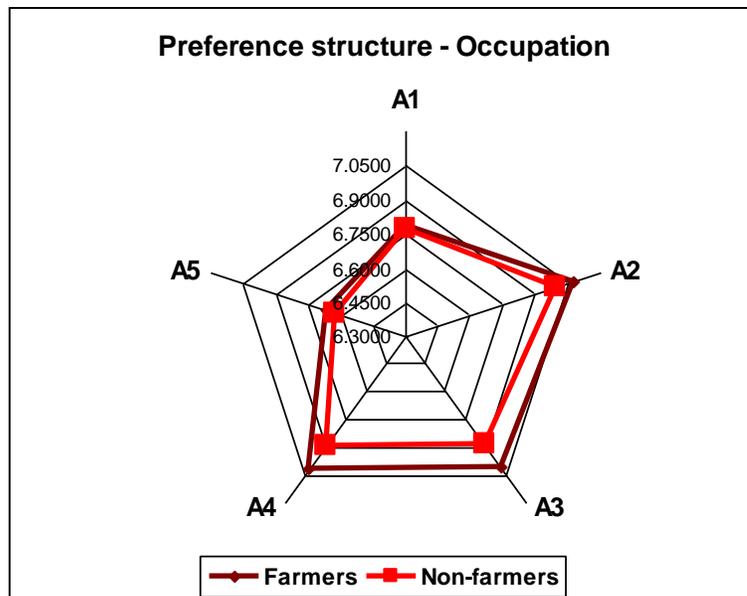
Figure 4.13 Preference structure for the disaggregate group, by occupation

4.7 Identifying the Best Practicable Environmental Option and Sensitivity Analysis

To determine the robustness of the output, a sensitivity analysis of the group's order of GHG preferences was performed. Figure 4.14 summarizes the sensitivity results for six alterations in the aggregate weights. The 13 VECs were divided into groupings based on EDA, and the threshold for changes in the preference order was determined. First, the VECs were grouped based on the box-plot analysis and the inherent similarities between certain VECs/criteria. For example, VECs$_{1-5}$ are all related to economic factors, and were designed to compare how important economic criteria would be when compared to environmental criteria, or flexibility criteria. During the EDA, VECs$_{1-5}$ were grouped with a similar median weight, indicating that the respondents felt that the economic VECs were of similar importance. The other two groups were established in the same manner. The VEC groupings are: 1) production and economic, VECs$_{1-5}$; 2) institutional and operational VECs$_{6-11}$; 3) environmental VECs$_{12-13}$.

There is no standard approach to a sensitivity analysis; however, one common approach is to adjust the weight of criterion/VEC groups and assess the subsequent response in output (Insua, 1999). The weights represent changing conditions, such as a set of different economic conditions (for VECs$_{1-5}$) or an altered institutional policy and support setting (VECs$_{6-11}$). A sensitivity analysis of criterion weights requires investigating the sensitivity of the rankings of alternatives to small changes in the value of those criterion weights (Noble, 2006). Following the approach of Janssen (1996), VEC weights were adjusted first by 50%, and if no significant change occurs in the output, the weight is increased by 75%, 100%, etc. However, if at any point there is a

change in the output preference structure, the weights are lowered and reassessed. During the sensitivity analysis, the weight of a group of VECs (for example, the environmental VECs, or $VECs_{12 \& 13}$) was increased by 50%. If no significant changes in the rank order of the alternatives were observed, the weight was increased to 75% and the order re-evaluated; if there was no change at 75%, the preference structure was deemed insensitive to changes in that specific VEC grouping. However, if there was a difference at the 50% weight adjustment level, then the weighting of the group of VECs was decreased to 15%, then 10% to find the approximate threshold of sensitivity. A preference structure that showed change in the rank order at a 10% increase in weights was deemed sensitive to change.

The 'distance' between A_5 (10% increase in fuel efficiency) and A_1 (nitrogen use efficiency) increases with a 75% increase in the environmental VECs (VEC_{12} and VEC_{13}). Alternative A_2, adoption of zero till practices, remains unchanged when the weight of the environmental VECs increased, but decreased summerfallow (A_3) and increased use of forage (A_4) change order in the preference structure, with A_4 now slightly less preferred and A_3 much more preferred. With a 25% increase in the environmental VECs there is a minimal effect on the overall choice structure, with A_3 increasing slightly but maintaining its order. The sensitivity threshold for the environmental VECs is close to 50%, where there are slight increases in preferences for A_1 (nitrogen use efficiency) and A_3 (decreased summerfallow). For the aggregate group, if the importance of GHG mitigation impacts on soil (VEC_{12}) or water (VEC_{13}) increased, or where the relative importance of those VECs increased in some way, there would not be a noticeable change in the overall preference structure. This may suggest

that despite the emphasis on soil and water conservation on the Canadian Prairies, and the potential for these conservation measures to increase in the future, there would not be an impact on the most preferred aggregate alternative.

When the economic $VECs_{1-5}$ are increased by 75%, the result is that A_5 (10% increase in fuel efficiency) becomes more important, and A_4 (increased use of forage) increases importance, such that A_4 becomes the second most preferred option and almost equally preferred to A_2 (adoption of zero till practices), the BPEO. If the economic VECs are increased by 25% weight, the overall order of GHG policy preferences remains unchanged from the group's unadjusted ranking of alternatives. Increasing the effect of the economic VECs by 75% creates a situation where increased use of forage (A_4) is more preferred, but it does not replace the BPEO. Increasing the importance of the support/flexibility VECs (6-11) does not affect the preference structure, indicating that if their relative importance changed and support/flexibility became more desirable, the most preferred GHG mitigation alternative would not change. Based on the aggregate sensitivity analysis it can be concluded that the preference structure is relatively robust and insensitive to changes in the relative weighting of the VECs.
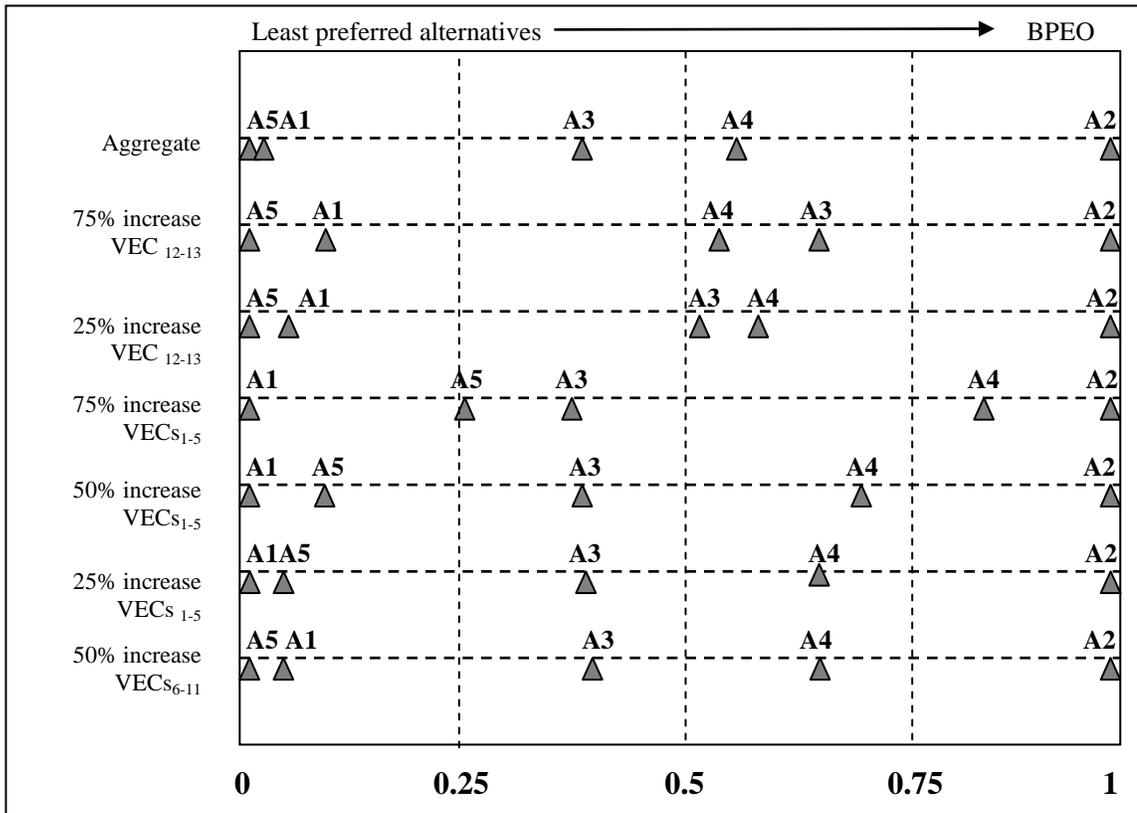
Figure 4.14 One-dimensional scaling results of sensitivity analysis of aggregate group's preferences to uncertainties, derived based on concordance/discordance sets.

4.7.1 Disaggregate Sensitivity Analysis

The disaggregate data show some variation with altered VEC weights; while each soil zone was tested for sensitivity in the three major VEC groupings, only the key findings are summarized in Figure 4.15.   The brown chernozemic soil zone differed from the aggregate results with increased use of forage (A_4) as the most preferred option, followed by nitrogen use efficiency (A_1).   There was little effect when the economic ($VECs_{1-5}$) and support/flexibility ($VECs_{6-11}$) weights were manipulated, and a 50% increase in the environmental VECs ($VEC_{12 \& 13}$) increased the importance of A_3 (decrease in summerfallow), though A_4 remains the BPEO in this soil zone.

In the dark brown chernozemic soil zone, decreased summerfallow (A_3) is identified as the BPEO, but when the environmental VECs are increased by 50%, A_3 becomes less preferred and A_2 (adoption of zero till practices) increases in preference to become the BPEO. This suggests that the results are sensitive to changes in the relative importance of environmental characteristics, including conditions of the soil (VEC_{12}) and water (VEC_{13}) resources.

The preference structure the black chernozemic soil zone was affected by a 50% increase in the importance of the economic VECS ($VECs_{1-5}$). In this soil zone the least preferred alternatives A_1 (nitrogen use efficiency) and A_5 (10% increase in fuel efficiency) changed order, as did A_2 (the BPEO) and A_3. This soil zone is significantly affected by changing the weight of the economic VECs; with a 15% increase in the importance of the economic $VECs_{1-5}$, A_3 and A_2 are equally ranked as the BPEO, suggesting that the BPEO is relatively sensitive to changes in economic conditions. In the dark gray chernozemic soil zone, with a 50% increase in the economic VECs, A_1 (nitrogen use efficiency) becomes 15% more preferred, but the overall choice structure does not change.

In the gray luvisolic soil zone, decreased summerfallow (A_3) and increased use of forage (A_4) both become more preferred when the environmental VEC weights were increased by 50%. These two alternatives are strongly affected by environmental VECs; while the increase does not affect the BPEO, they do become much stronger alternatives when increased weight is placed on environmental factors. This affect is minimal at a 25% increase, indicating a high threshold and a low sensitivity; the significant increase at 50% is noteworthy.

The disaggregate data, and resulting sensitivity analysis, consistently identify A_5 (10% increase in fuel efficiency) as the least preferred option, but the rest of the rankings vary by soil zone. Adoption of zero till practices (A_2) and increased use of forage (A_4) are the most selected BPEOs, with the exception of the dark brown chernozemic soil zone, where decreased summerfallow (A_3) is ranked highest. Any changes in rankings affecting preference structure occurred at a 50%, or greater, change in the VEC weight, indicating a high threshold and thus a robust preference structure. Based on the disaggregate sensitivity analysis, there are minor uncertainties (threshold range of tolerance is approximately 25% for most soil zones) in the estimation of criterion weights, but they are insignificant with regard to the BPEO and the overall preference structure.
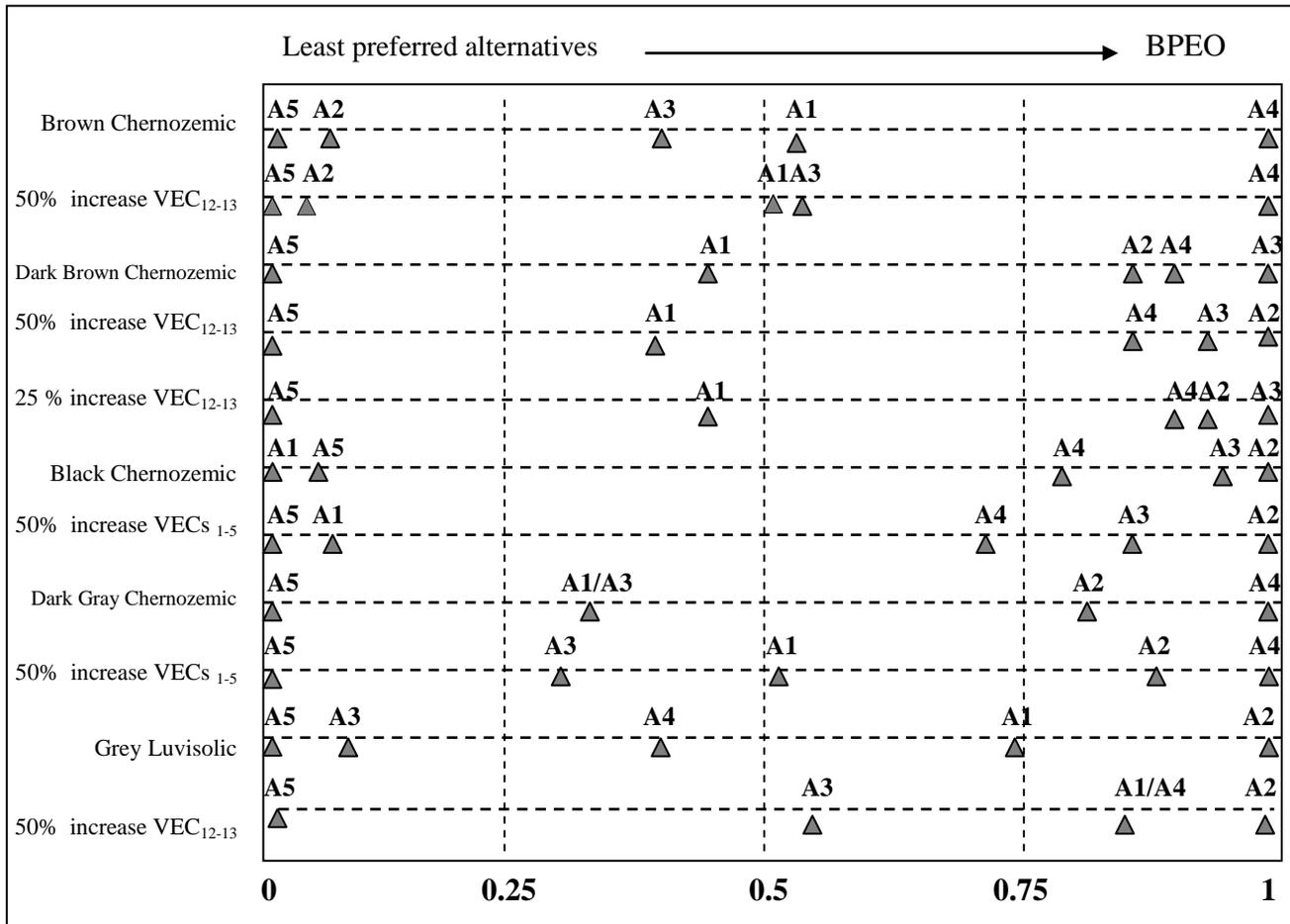
Figure 4.15 One-dimensional scaling results of sensitivity analysis of disaggregate group's preferences to uncertainties, by soil zone

5.0 OBSERVATIONS AND CONCLUSION

Steadily increasing interest over the past 15 years in the idea of sustainable development has brought challenges to the way in which impact assessment has been traditionally conceived (Pope *et al*., 2004). Impact assessment has recently been reassessed in the literature to take into account sustainable development agendas (Gibson, 2002; Verheem, 2002), and many of the definitions for sustainable development identify the 'three-pillar', or 'triple bottom line', approach as ideal, where social, biophysical and economic factors are considered (Pope *et al*, 2004). The Canadian Government identified sustainability as a key purpose in *The Act*, where "the Government of Canada seeks to achieve sustainable development by conserving and enhancing environmental quality and by encouraging and promoting economic development that conserves and enhances environmental quality" (CEAA, 1992), and "environmental assessment provides an effective means of integrating environmental factors into planning and decision-making processes in a manner that promotes sustainable development" (CEAA, 1992). Despite the increased attention on sustainable development, there are challenges to incorporating this sustainability mandate into current EA frameworks.

This paper presents a structured methodological framework for SIA at the strategic level of decision making. This research resulted from the need to address two fundamental limitations in current EA frameworks. First, there is an inherent bias

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towards the biophysical environment and neglect of social impacts in development assessment and decision-making (Momtaz, 2003, 2005). Second, assessments are reactionary in nature and EA is typically targeted at the project-level (Eggenberger and Partidário, 2000; Momtaz, 2005). In the first instance, Du Pisani (2006), for example, emphasizes that SIA is often seen as no more than a subset of EIA, and Glasson and Heaney (1993) argue that socio economic impacts merit a higher profile within the EA process. In the second, project level assessment contributes to SIA as an "add-on process" (Leistritz and Ekstrom, 1988), focused on 'alternative means' rather than the more sustainable 'alternatives to' (Glasson, 1995; Steinemann, 2001). As the primary goal of SIA is to anticipate a course of events following development and to manage them accordingly (Taylor *et al.*, 2004), SIA must adopt a more strategic approach that is able to both anticipate and react to change (du Pisani, 2006). This means that the analysis of social impacts should extend to pre-project higher tiered planning and decision making (Francis and Jacobs, 1999), making a reactive process more proactive in nature (Glasson, 1995).

In light of the limitations to sustainability of project-based assessment, a SEA framework was adopted in the research and demonstrated for a SIA of GHG mitigation options. This research illustrates how SIA, when advanced to the strategic level, provides for a more proactive approach to social impact consideration and decision support, thereby creating an opportunity for a more comprehensive evaluation of alternatives, balancing both biophysical and social concerns.

5.1 Key findings

The concordance analysis was used to determine the weighted ranking of each alternative and to derive a relative measure of preference of one alternative over the others. For the aggregate data A_5 (10% increase in fuel efficiency) is the least preferred alternative, with A_1 (nitrogen use efficiency) also ranked very low in preference. Decreased summerfallow (A_3) and increased use of forage (A_4) are almost equally preferred, as the Mann-Whitney U test for significance found that there was not a significant difference between them. Adoption of zero till practices (A_2) has been identified as the most favored GHG mitigation alternative for the aggregate group.

Several VECs were identified as important in the aggregate group analysis, including economic benefits (VEC_4) and impacts on soil resources (VEC_{12}). This suggests these are important considerations when a policy for GHG mitigation is considered; economic benefits and the impacts on the soil would ideally be important considerations during the alternative selection process. All alternatives have an apparent benefit for VEC_4 (economic benefits), that is to say they were all rated highly, though adoption of zero till practices (A_2) garnered the highest score, and appears to be the most preferred from an economic perspective. The only alternative not perceived to have a positive benefit on soil impacts is a 10% increase in fuel efficiency (A_5), the least preferred alternative in the aggregate group.

The disaggregate soil zone analysis highlighted the importance of maximizing economic benefits while minimizing economic costs ($VECs_{4\&5}$), while also considering which alternatives will have a minimal impact on soil and water resources ($VECs_{12\&13}$). This is not to say that the other VECs are not important; rather, the economic and

environmental VECs displayed the most variation across the soil zones, while the benefits of each alternative were relatively equal across all of the flexibility and support VECs ($VECs_{6-11}$). The exception to this was a perceived effect on labour requirements (VEC_{11}) in the dark brown chernozemic soil zone, where nitrogen use efficiency (A_1), adoption of zero till practices (A_2), and increased use of forage (A_4) have a greater effect on labour requirements than the other alternatives. This, in part, makes these three alternatives (including A_2, the aggregate preferred alternative), less preferred in this soil zone; however, adoption of zero till practices (A_2) is still preferred with regards to impacts on soil resources (VEC_{12}), so there is a possibility that the positive benefits of soil conservation may offset the labour requirements if the aggregate policy were introduced in this soil zone.

The most preferred alternative varies by soil zone, with nitrogen use efficiency (A_4) preferred in the brown and dark gray chernozemic soil zones, decreased summerfallow (A_3) favoured in the dark brown chernozemic soil zone, and adoption of zero till (A_2) given preference in the black chernozemic and gray luvisolic soil zones. Despite the different preference structures for the five different soil zones, they have some similarities. A 10% increase in fuel efficiency (A_5) was the least preferred option in almost all cases, with it being second to nitrogen use efficiency (A_1) in one soil zone. Similarly, nitrogen use efficiency (A_1) is either least preferred, or close to it, in three of the soil zones; it is not the most favorable alternative in any zone.

The preference in brown and dark gray chernozemic soil zones corresponds to the findings of the Agriculture and Agri-Food Canada (2001) biophysical report, where increased use of forage (A_4) was also selected as the GHG mitigation option. Adoption

of zero till practices (A_2) is most preferred in the black chernozemic and gray luvisolic soil zones, as well as in the aggregate data. This suggests that there is a considerable split, where the importance of the alternatives is potentially affected by the characteristics of different soil zones. There may be different perceptions associated with the execution of a GHG mitigation policy, and the local conditions in different regions of the Prairies affect the ease of implementation of the alternatives. The split may also be related to the limited sample size and unequal representation from the five soil zones, issues addressed further in Section 5.4, "Research Limitations and Directions".

The results were also analyzed by occupation, namely whether the survey respondent identified themselves as a farmer or their primary occupation was another field (non-farmer). The most preferred alternative for both farmers and non-farmers is adoption of zero till practices (A_2), reflecting the same choice of the aggregate group. Despite the economic benefits (VEC_4) and positive impacts on soil resources (VEC_{12}) associated with the adoption of zero till practices (A_2), farmers identified economic costs (VEC_5) as a significant barrier to its implementation. If this alternative is to be acceptable for farmers, a subsidy or other incentive program may help offset the input and/or capital costs associated with the execution of such a GHG mitigation policy.

A sensitivity analysis is used to analyze the robustness of the data and determine whether adjusting the importance of the VECs affects the preference structure, including the BPEO. The weights of the VEC groupings were adjusted and the overall changes in structure identified; overall the aggregate preference structure is relatively robust and insensitive to change. There is some variation within the disaggregate data, with

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varying sensitivity thresholds in the different soil zones. Similar to the aggregate data, A_5 (10% increase in fuel efficiency) is consistently ranked the lowest and identified as the least preferred alternative. The black chernozemic and grey luvisolic soil zones consistently identified A_2 (adoption of zero till practices) as the BPEO throughout the sensitivity analysis, while the brown chernozemic and dark gray chernozemic soil zones showed a preference for increased use of forage (A_4). The dark brown chernozemic soil zone was the only one that preferred A_3 (decreased summerfallow), and was relatively insensitive to changes in the weights (a 50% change in $VECs_{12-13}$ caused A_2 to become the BPEO). Since all of the major changes in preference structure, and changes in the BPEO, occurred when the weights were raised by 50% or greater, the disaggregate sensitivity analysis has minor uncertainties; overall they are insignificant with respect to the BPEO.

5.2 GHG Mitigation: Case Study Conclusions

As part of SEA methodology, alternatives are evaluated and a BPEO selected. This does not necessarily mean that the BPEO is the best decision, but rather it gives decision makers a viable option for informed decision making. Bond and Brooks (1997) state that identifying the BPEO is a step towards sustainable development, if the environmental and socio-economic factors are taken into consideration. For this case study, the aggregate data identified A_2 (adoption of zero-till practices) as the most preferred alternative, or the BPEO. This option emphasizes an increase in the zero-tillage area, and decreased use of conventional and minimum tillage. The sensitivity analysis for the aggregate data confirmed that the SIA output is robust with respect to minor uncertainties in the assessment process, as adoption of zero-till practices (A_2) remained

the preferred option even at 75% variation in VEC weights for certain components. This indicates that if economic or environmental situations should change, and their relative importance increase, A_2 would remain the most preferred option based on the aggregate assessment data. However, the disaggregated data did indicate that the preferred option varies by soil zone; adoption of zero till practices (A_2), decreased summerfallow (A_3) or increased use of forage (A_4) were preferred in different soil zones across the Prairies.

5.2.1 Current Agricultural Practices

Canadian land management practices and agricultural practices are changing, and mitigating GHG emissions is a timely question. Zero-till practices are on the rise due in part to their carbon sequestration abilities, reduced soil erosion, reduction of GHG emissions, and enhanced resilience and productivity of the land base, and summerfallow land is declining drastically due to soil erosion and potential loss of soil productivity.

The group preference for zero tillage systems (A_2) is reflected in the current 'state of affairs' in Canadian agriculture. The 2001 Census of Agriculture identifies changing trends in Canadian land management systems, particularly the decrease of summerfallow practices and the increase of conservation or zero till practices. The national census demonstrates the increasing use of more environmentally friendly practices to minimize wind and water erosion and soil compaction. Conservation tillage, for example, minimizes the number of passes farmers make over their fields, which in turn reduces the number of hours spent in each field, thereby decreasing fuel costs and lowering carbon emissions (Statistics Canada, 2003). The use of conservation tillage

and no-till seeding techniques first appeared in significant proportions in 1991, when conventional tillage accounted for 69% of all tillage practiced, with zero tillage practiced on only 7% of tilled land (Statistics Canada, 2003). By 2001, zero tillage or conservation tillage was practiced on 59.5% of the tilled land, reducing conventional tillage significantly (Statistics Canada, 2003).

Summerfallow practice has been declining in Canadian agriculture. For example, Saskatchewan farmers reported 37,994,752 acres of cropland in 2001, up 6.8% from 1996; this accounts for about 42% of all cropland area in the nation (Statistics Canada, 2003). Much of this increase has been at the expense of summerfallow, which declined 29.3% to 7,738,453 acres between 1996 and 2001; the decrease is partly due to increased adoption of a reduced tillage system because of its potential for soil moisture conservation (Statistics Canada, 2003). Similarly, in Alberta, dry conditions have prompted a significant reduction in tillage; according to the self reported census data, the more environmentally-friendly practices of no-till seeding or conservation tillage were used on 63% of the land prepared for seeding in 2001, compared to 43% in 1996 and 27% in 1991 (Statistics Canada, 2003).

Although there is regional variability attributed to any farm management practice, the 2001 Census of Agriculture identifies summerfallow as a decreasing land management practice across Canada, and illustrates the increasing popularity of conservation and zero-tillage practices. These trends are reflected in the SIA results, where adoption of zero-till practices (A_2) is the BPEO for the aggregate group and several of the disaggregated groups. Decreased summerfallow (A_3) would be strongly

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supported in the dark brown chernozemic (2) and black chernozemic soil zones (3), allowing for a further reduction of this management practice.

5.2.2. Comparison of Biophysical and SIA BPEOs and Implications for GHG Mitigation Policy

The SIA results in this research complement Agriculture and Agri-Food Canada's biophysical assessment (2001) by evaluating the GHG mitigation alternatives from a social perspective. The biophysical assessment found that increased use of forage (A_4) would have the greatest impact on reducing energy use on the Canadian Prairies. From an economic perspective, as forage area is increased there is a decrease in energy use due to the lower use of crop production inputs such as fertilizer, fuel, machines, and chemicals. The net results of the report show that energy use varied across the different soil zones. The SIA results differed and identified A_2 (adoption of zero till practices) as the BPEO, but like the biophysical assessment they exhibited varied results within the disaggregated data analyzed by soil zone. This suggests that selection of a single alternative may not necessarily satisfy both the biophysical and social criteria, and what is biophysically preferred is not always socially acceptable across the entire Prairie region. As such, a 'one size fits all', or single, policy solution for GHG mitigation may not be appropriate.

A national agricultural GHG mitigation initiative might be successful if it was sensitive to changes in physical geography, on-farm practices, and thus soil zones across Canada. The disaggregate data suggests that regional policies, established by soil zone characteristics and situated under a national GHG mitigation mandate, would be of greater value. At the regional level, sensitivities to local conditions, on-farm

preferences, and specific soil characteristics could be evaluated. However, in addition to the spatial perspective offered by the soil zone analysis, and the resulting complicating factors for policy analysis, there are other contributing issues that must be considered with regard to a GHG mitigation policy.

This case study illuminates the spatial differences between soil zones, but due to the limited scope, it did not explore issues such as farm size, type of crops produced, debt levels, age of the farmer and their changing values over time, or farmer's education level. These are important factors to consider when establishing any policy: national, regional, provincial, or local. Defining the values and attributes of the 'on the ground' farmer, as well as the farmers' abilities to implement policy changes, are critical if there is to be majority acceptance of a new policy or program. In essence, it must be feasible for the individuals at the on-farm level to implement the policy.

Often the government will establish a policy in a 'top down' hierarchical manner and expect that given time, and perhaps a few incentives, the requirements of that policy will be enacted at the on-farm level. If this structure was used for GHG mitigation, it might be a success, but the costs to the individual and the difficulties associated with implementation may create a feeling of coercion and result in farmer dissatisfaction with the policy and the government that is 'forcing' the changes. Some farmers respond negatively to issues of climate change, and while they may have wide-ranging experiential or situation specific knowledge, they may not have extensive formal education, a tool that provides a greater understanding of the meta-theoretical reasons that illustrate why farm practice changes are necessary. GHG mitigation policies can be

created, but unless the individuals at the on-farm level understand why these policies are necessary, implementation will be hindered.

This research suggests that a 'one size fits all' policy may not work in light of the spatial/location differences identified by the disaggregate soil zone analysis and a multitude of other factors such as the values and abilities of the farmers. A federal government imposed strategy is one approach, but another method is to organize tailored GHG mitigation policies. These plans could be structured to reduce GHG emissions through a variety of factors; for example, farm type and size could be used to organize the plans, putting more emphasis on emissions reductions from large scale producers of specific crop types. Alternatively, soil zone and topography could be used to distinguish the areas that should utilize a certain GHG reduction cropping practice.

The key to a new policy or plan is education and collaboration with the farming community. Involving farmers in discussions of GHG reduction policies, and recognizing the issues that they have with the selected cropping practices, will lead to an understanding of the GHG mitigation cropping practices that have the greatest likelihood of success. The stakeholders need to be involved at all levels of the policy making process; they should be involved at all stages where their input is meaningful and will illuminate areas of discussion or guide a course of action. This type of dialogue would facilitate a relationship between policy makers and farmers; the reasons behind decisions could be explored. For example, in this case study, the policy makers could learn why farmers prefer A_2 (adoption of zero till practices) from a social perspective in some soil zones while A_4 (increased use of forage) is more socially favourable in others. A_4 is the biophysically preferred option, and if it could be made

more attractive from a socioeconomic perspective in the majority of the soil zones (through, for example, financial incentives), a 'one size fits all' spatial policy would become a possibility. Even if a single policy is not practicable, collaborative initiatives will identify the farmers' primary issues, including their values, interests, economic and production needs, as well as providing an assessment of the actions that are feasible. In short, it will pinpoint the type of regional or local plans that would best serve their needs in addition to reducing GHG emissions.

The GHG mitigation plans would not necessarily need to be formalized under a government initiative, but could be designed in a collaborative manner through other organizations. Private industry or non-governmental organizations (NGOs) may have roles to play in this type of initiative. The creation of these plans could fall under the purview of an organization similar to the Agricultural Producers of Saskatchewan. This type of province-wide, grassroots, and producer focused farm association are typically composed of experienced farmers with extensive agricultural backgrounds, and are focused on making improvements to agricultural programs. If subsidies are involved, farmers may prefer to work with a non-biased third party for the distribution. At the farm level, producers may prefer to work with NGOs to achieve GHG emission reductions, as opposed to working directly with the government, as the individual farmer can feel persecuted or victimized by governmental policies and programs.

Regardless of the organization (government or non-government) that implements the GHG mitigation policy, and whether it is created nationally, provincially, or through a series of tailored regional policies, the key to success will be the ongoing collaborative efforts. Contributing factors to the successful implementation of a GHG mitigation

strategy are: education at the grassroots or on-farm level (including community workshops and discussion), and meaningful dialogue between farmers, scientists, environmentalists, and policy makers where issues are recognized and validated by all parties. Careful considerations of these factors will facilitate a GHG mitigation policy where the social, environmental and economic criteria are regarded equally, thus promoting a "three pillar" sustainable approach to policy and decision making. The challenge remains that that in practice social impacts are rarely considered in EA, and even less so at strategic levels of assessment and decision making.

5.3 Advancing SIA

The purpose of this paper is to illustrate a how structured, 'tiered forward', strategic methodology advances the practice of SIA. Curtis (1994) and Dyson (1991) agree that a strategy is the process of defining goals or visions in terms of the desirable principles to be established, proposing alternative possibilities to achieve these principles, and selecting the most desirable approach. SEA, similar to SIA, can be: approached through highly structured and rationalized processes; highly regulated; or result more simply from providing principles and informal procedures and changes in the decision-making process (Partidário, 1999). It can also be accomplished in a number of ways: rational, civic, or somewhere on the continuum. Regardless of the theoretical framework, the accompanying assessment and decision exercise must identify issues, assemble the necessary viewpoints, determine alternative solutions, and select a course of action (Mitchell, 1997). These are the basics of a strategic assessment: acting in anticipation of future problems, needs, or challenges and creating and examining alternatives leading to

a preferred option, thus facilitating a proactive approach PPP decision making (Noble, 2000a).

There is a need for good practice in SIA, and, as demonstrated in this paper, adopting a strategic approach contributes to improved practice and the alternatives selection process. Classic SIA tends to be a reactionary process, the result of a project-level analysis focused on end of the pipe mitigation (Glasson and Heaney, 1993; Noble, 2000; Vanclay, 2006); a chance to select the 'least worst' option from a group of alternatives that are different ways to accomplish the same, predetermined, project (Noble, 2000). In contrast 'emerging' SIA, as in the case demonstrated here, shows that changes in methodology and the adoption of a new framework can create a more proactive process, where an end goal is established, and the alternatives under consideration, functionally different ways to accomplish that goal, are systematically assessed in order to determine a BPEO, a set of options that can then inform decision making and PPP development (Bond and Brooks, 1997; Francis and Jacobs, 1999; Steinemann, 2001; Noble, 2000). An SIA in this manner sets the context for tiered forward planning, and allows for a choice of strategy that reflects the most preferred option. This enables social impacts to be identified and mitigated at the earliest stage of decision making, thus focusing on the identification of the "most preferred" course of action that considers broader sustainability objectives.

The Act makes it clear that one of the main purposes of EA is to "integrate environmental factors into planning and decision-making processes in a manner that promotes sustainable development". If EA is completed before an action is foreclosed, at the strategic level, it can provide decision makers with critical information necessary

for the successful design and implementation of PPPs. An SIA, used in conjunction with other EA tools, at this higher tier, is a valuable step towards achieving sustainable development.

5.4 Research Limitations and Directions

The framework for this research was adopted from SEA literature and is quantitative in nature and reliant on statistical analysis. This approach presents both advantages and challenges. Quantitative assessment builds a level of accountability into the research, allowing the researcher to include to a larger number of potential respondents, and requires few special data acquisition skills. A further advantage of a quantitative approach is that the analyst can adjust the statistical parameters of the assessment results to account for changing circumstances, and follow up on the original assessment as conditions change temporally.

The difficulty with quantitative assessment of social impacts, particularly at the strategic level, is that respondents are asked to translate their opinions and feelings into numeric scores, and in turn, statistical analysis is a blunt tool for translating that data back into the thoughts of the surveyed respondents. In this respect, a qualitative analysis, while subjective and interpretive, creates an opportunity to explore a respondent's motivations and opinions.

One direction for future research would be the qualitative exploration of the motivations behind the respondent's GHG mitigation preferences. This would allow for identification of specific reasons for the alternative selection and allow the researcher to better learn why the disaggregate results vary from region to region and from the

Agriculture and Agri-Food Canada (2001) biophysical analysis results. It would also allow the researcher to discern whether a combination of the different alternative cropping practices might be practicable. Perhaps a single alternative is an unrealistic option, and a combination might be more acceptable. This in-depth questioning is not possible with the quantitative survey document utilized in this case study, but illustrates the benefits of alternative methods in future research.

A future direction for this research would thus be a combined analysis of environmental, social, and economic impacts. When these three pillars are considered simultaneously, the environmental impacts are weighted directly in light of economic and social concerns. A study of this nature would assist with the selection of a single, robust aggregate GHG mitigation option; although the results of both the SIA and biophysical analysis suggest that there would remain regional differences in impact and choices.

The purpose of this paper is to present a structured methodological framework for SIA at the strategic level of decision making. The case study application of GHG mitigation alternatives that was used to demonstrate this strategic framework has some limitations. The sample size was limited, with only sixty four participants; this was partly due to the restrictive nature of an agricultural survey process (i.e. it must be done over the winter, non-harvest season), and partly due to the complex nature of the assessment document. The limited scope of the sample size, and the fact that the soil zones are not equally represented means that the results may not entirely capture the actual variation within the area of study. This is particularly evident in the black soil zone, which contained 21 out of the total 64 participants. This, in part, explains why the

black soil zone is similar to the results of the aggregate soil zone, as it contains one-third of the participants; the black soil zone has a significant influence on the aggregate assessment preference structure. This limits the conclusions of the GHG mitigation case study from a data and spatial context.

The VECs utilized in this case study represent a range of the possible options, as selected through research and interviews with experts. While this research adopted VECs of a social, economic and biophysical nature, if the range of VECs had been narrowed to those strictly social in nature, the results of the alternative preference structure may have been different.

A further limitation of the case study was inherent in the purposive sampling technique. Typically, the respondents were over the age of 50, and those identified as farmers were responsible for relatively large farm holdings (though whether they were owned or leased is not known). Gender and socioeconomic status were not ascertained, but in general, the researcher noticed that men were most often identified as the "farmer" in the contact information provided by organizations such as APAS. Based on this information, it is possible that a bias exists in the data, where the older, more affluent men were more likely to become involved with farming and producer organizations such as those used to identify the participants. Thus, women, minorities, and less wealthy or farming experienced individuals could be underrepresented in this research.

A direction for further research would be the equal representation of all soil zones so they can be compared evenly, and an attempt to identify a representative range of participants, including gender and socioeconomic status. This would ensure a more

representative case study and address some of the issues associated with this type of participant bias. Despite these limitations, the case study provided the possibility to test the strategic framework and assess the effectiveness of applying SIA at a tiered forward PPP level. A preference structure was identified, based on five GHG mitigation alternatives, and the BPEO was identified. As this research was situated at the PPP level, and "forward tiered", the next step for this case study would be a "classic" social impact assessment. In this way, the direct social impacts could be identified at the project level, which is the next tier of the assessment process. As the research context indicated, the goal of this project was not to replace project level assessment, but to enhance the SIA process by providing an assessment of 'alternatives to' at the strategic level. In this manner, the research was successful, and the framework addressed some of the limitations present in current project based SIA.

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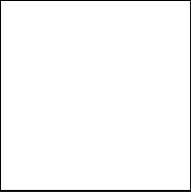
7.0 APPENDIX A

7.1 List of Informant Contacts by Organization Type

Five individuals from the agriculture sector
Two individuals from the provincial government
Three individuals from non-governmental or research organizations (including the University of Saskatchewan)