Impact of Climate Change on Agricultural Production and Food Security of Newfoundland and Labrador, Canada

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Abstract

Newfoundland and Labrador (NL) has a food security issue due to lack of suitable agricultural land, short growing seasons, and unsustainable agricultural policies promoting conventional industrial farming practices, with a limited range of agricultural produce (milk, eggs and poultry) and no facilities for secondary processing of these. The food security issue has been exacerbated in the last decades by climate change events (extreme temperatures, heavy rains and more frequent droughts) which have negatively impacted the province's agricultural industry. The conventional industrial agricultural practices and the profit focus of maximization agricultural policies have contributed to and have intensified several environmental, social and economic problems. They have as well provided an inadequate guarantee for food security, as the NL agriculture industry does not secure enough healthy, fresh, nutritious, and affordable food alternatives for people to live and be healthy. This research is based on quantitative and qualitative data, collected through surveying both crop and dairy farmers located in western, central and eastern regions of the Newfoundland and Labrador province, and through a literature review of peer-reviewed articles, published government reports and documents and news articles. The research results show that any attempt to solve the multi-faceted problems of the NL agriculture impacted by climate change increases the significance of pursuing an agro-ecological approach to farming in the province. Integrated and small, highly diversified farms are one sustainable alternative to modern industrial farming, as they can make the current agricultural practices more resilient to global climate change (GCC), can enhance food security in the province, as well as reduce the impact of agricultural practices on GCC. This study has found that 100 percent of the crop and dairy farms production has been affected by two or more natural hazards, such as long winters/short growing seasons, late spring frost and heavy rains/rain storms, which are the results of climate change. More interestingly, 56 percent of the farm owners in the study area

believe that industrial or conventional farm practices have little or no impact on environmental degradation or climate change, since they follow the agriculture rules and guiding principles imposed by the provincial and the federal government of Canada and apply efficient farm management strategies. In some cases, the soils, chemical fertilizers and fossil fuels are poorly managed by the farmers surveyed in the study area, but a good percentage of the farmers are trying to reduce dependency on chemical fertilizers and pesticides and fossil fuels and at the same time, are trying to increase the use of organic fertilizers, pesticides and renewable energy. Moreover, the current research has shown that there are incipient agro-ecological practices in the province, and that farmers are aware about climate change and the need to adopt more environment friendly farming practices. New policy frameworks and work plans are needed to speed up the transition from the current unsustainable farming practices to small-scale, organic, energy efficient and high yielding agro-ecological practices. Provincial as well as federal government support, and collaboration among educational and research institutions, agricultural farms, non-government organizations and the general public will promote agricultural diversification and integration and more environmentally-friendly farm practices within the province. These will ameliorate province's food security issue, by increasing the supply of local fresh and healthy food, will provide additional financial benefits to the farm holders, as well as protect the local and the global environment.

Impact of Climate Change on Agricultural Production and Food Security of Newfoundland and Labrador, Canada

Chapter I

Introduction

1.1 General overview

Modern, industrial-scale agriculture in the way it is practiced today (intensification, concentration, and monoculture) impacts both the environment and the social welfare of farmers. According to environmental economists, it is mostly interested in producing "commodities" instead of producing nourishing food and exclusively aims to maximize yield and profits; it so impacts food security through monoculture, producing junk foods, reducing soil health or damaging farmlands and harming neighboring and downstream economies (Gliessman, 2015; Hidden Costs, n.d.). During the latter half of the twentieth century, scientific advances and technological innovations, including the development of new plant varieties, the use of chemical fertilizers and pesticides, and the growth of extensive infrastructures for irrigation, have contributed to boost food production in what is referred to as industrial agriculture (Gliessman, 2015).

After industrial agriculture had been introduced in the 1960s in Europe and North America, the immediate effect was a spectacular improvement in agricultural production, and the new era was hailed as the "Green Revolution", a period when productivity of global agriculture increased drastically as a result of new technologically-backed advances, like high-yield crops and multiple cropping (Cunningham, 2017). During the "green revolution", yields per hectare of staple crops such as wheat and rice increased, food prices declined, the rate of increase in food production generally exceeded the rate of population growth, and chronic hunger diminished (Gliessman, 2015). Industrial agriculture was based on the assumption that the soil fertility could be maintained and increased through the use of chemical fertilizers and very little attention was paid to the significance of organic matter in the soil. But a few decades later, the dark side of chemical agriculture became painfully evident when the world food system faces threats due to emergence of new agricultural diseases, rising costs for all the physical factors of production (land, water, energy, inputs), biodiversity loss and climate change. A large number of scientific reports point out that cultivated soils have lost from 30 to 75 percent of their organic matter during the 20th century, and these losses have provoked a serious deterioration of soil fertility and productivity, as well as contributing to worsening droughts and floods (GRAIN, 2011). Food production and consumption are not only key drivers of climate change but also the food industry has a wider impact on the environment as a whole by “destroying forests and savannahs to produce animal feed and generating climate-damaging waste through excess packaging, processing, refrigeration and the transport of food over long distance, despite leaving millions of people hungry” (Grain, 2011, p.1). In fact, it is time to recognize that industrial agriculture’s productivity comes at a steep price and that the bill is eventually going to come due. Due to the industrial system of food production, agriculture is losing the basic biological foundations such as soil fertility, available moisture, nutrient cycling, amenable climate, genetic diversity, and the ecosystem services of natural systems (Gliessman, 2015). Recently, researchers have been raising red flags about the ability of agriculture worldwide to adapt to an earth on which droughts, floods, heat waves, heavy snow and extreme weather events become commonplace and the entire biosphere goes through major shifts with potentially severe consequences for the growing of food (Gliessman, 2015). A large number of experts – policy analysts, politicians, scientists, economists, environmental specialists, researchers, and even some business leaders believe that the industrial methods that dominate the world food system today will not be able to sustain food abundance over the long-run and are also causing great harm to people and to the earth's life-support systems which cannot be sustained (IAASTD, 2009; IFAD, 2013).

Moreover, since the "Green Revolution", human activities like energy intensive farming and using chemical fertilizers have contributed to climate change by generating excessive greenhouse gas (GHG) emissions and damaged soils (Mole, 2014). Nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) are the major greenhouse gasses (GHGs) emitted from agricultural activities. While N_2O emissions originate from field-applied organic and inorganic fertilizers, crop residual decomposition, and manure storage, methane is emitted through enteric fermentation and anaerobic decomposition of stored manure, and CO_2 is emitted during fossil fuel combustion by farm machinery and during the manufacture of agricultural fertilizers and machinery (Agriculture and Agri-Food Canada, 2016). Agriculture plays a dual role in climate change, because it is both a source of GHG emissions, like CO_2 which contribute to climate warming, and a sink for GHG emissions, as healthy agricultural soils and forested areas on the farms have the capacity to sequester, or store, carbon, offsetting the sector's overall contribution to climate change (Agriculture and Agri-Food Canada, 2016). Lately, agriculture has become more a source than a sink for GHG emissions (Agriculture and Agri-Food Canada, 2016; EPA, 2019, January 19). Thus, excessive amounts of heat have been trapped by the greenhouse effect resulting in the global warming of the earth's atmosphere beyond safe levels (Gliessman, 2015; Capra, 2015). The global average land-sea surface air temperature increased by 0.50^0C in the 20^{th} century and is projected to further increase by 1.5 to 4.5^0C in this century (Intergovernmental Panel on Climate Change, 1995). The Ontario Ministry of the Environment (2011) mentioned that the mean annual temperature in Ontario, has increased by 1.4^0C over the last 60 years, and models suggest that by 2050, the mean annual temperature could increase by an additional 2.5^0C to 3.7^0C (from a baseline average during 1961-1990). Warmer air means that there is more energy and more moisture in the atmosphere, which can lead to longer growing seasons in northern countries, but can also produce a wide variety of consequences - floods, tornados, and hurricanes; but also, droughts, heat waves, and wildfires (Capra, 2015). The researchers have found that the rate of rising sea level has been larger than the average rate during the previous two millennia, up to the mid-19th century and it is expected that in the year 2050, the global sea level will rise between 0.17 – 0.41 m (Brown, Lincke, Nicholls and Hinkel, 2015; Kemp, Horton, Donnelly, Mann, Vermeer and Rahmstorf, 2011). Climate change factors such as increase in temperature, change in rainfall patterns, increase of CO_2 concentration in the atmosphere, frequency and intensity of extreme weather events may have significant negative effects on agriculture in the world. It is expected that because of global warming, the agricultural productivity in developing countries will decline by 9-21 percent (IPCC, 2001; Cline, 2007). According to some researchers, the relations between industrial agriculture and climate change are twofold. On one hand, industrially produced food systems are energy-intensive and fossil-fuels based, and thus contribute significantly to climate change (Capra, 2015). On the other hand, the crops grown in the genetically homogeneous monocultures that are representative of industrial farming are not resilient to the climate extremes that are becoming more frequent and more violent (Capra, 2015). All of these consequences are threats to agricultural activity and global food security. Moreover, food processing, packaging, refrigeration and transportation over long distances are also key drivers of human-generated greenhouse gas emissions and climate change (GRAIN, 2011).

The current global food system, propelled by a mostly meat-based diet in the Western countries, an increasingly powerful transnational food industry, and is intensive international food trade is unsustainable. It is responsible for around half of all human produced greenhouse gas emissions: anywhere between a low of 44% to a high of 57% (GRAIN, 2011). It is also responsible for producing tons of food waste (1/3 of all food produced globally is lost or goes to waste, FAO, 2019, June 29). Therefore, industrial agriculture is involved in a vicious cycle: it produces greenhouse gas emissions, and, in the same way, the climate and environmental changes also impact negatively on food production, changing the cropping patterns and endangering the future food security (FCRN, n.d.). The future world requires a transition from industrial agriculture to an agro-ecological farming system that would focus on the use of alternative techniques such as diversified cropping systems, better integration between crop and animal production, increased incorporation of trees and wild vegetation, and so on (GRAIN, 2011). The increase in crop diversity would, in turn, increase the production potential and food security, and the incorporation of organic matter would progressively improve soil fertility, and preserve environmental quality by creating virtuous cycles of higher productivity and higher availability of organic matter (Gliessman, 2015).

1.2 The Canadian context

Canada is a significant player in global agriculture. It is the 5th largest exporter of basic agriculture and agri-food products (durum wheat, pulses and oats) after EU, USA, Brazil and China, as well as the world's sixth-largest importer of agriculture products and agri-foods (Agriculture and Agri-Food Canada, 2016; Issac et al. 2018). As the national database show, the agriculture and agri-food sector employs 2.3 million people (Issac et al. 2018) representing 12.5 percent of Canadian employment in 2016 (Agriculture and Agri-Food Canada, 2017). The contribution of agriculture and agri-food system to the gross domestic product (GDP) was 6.7 percent of Canada's total GDP in 2016 which accounted for $111.9 billion (Agriculture and Agri-Food Canada, 2017). Over the past 30 years (1981-2011), Canadian agriculture has changed significantly, as the total number of farms has decreased but the average farm size, crop area and number of head of livestock per farm have all increased, indicating an intensification and concentration of production (Clearwater, Martin, Mackay and Lefebvre, 2016). In 2001, the total farm area was 67.5 million ha and the average farm size was 273 ha, whereas in 2011, the total farm area has reduced to 64.8 million ha but the average farm size has increased to 315 ha (Agriculture and Agri-Food Canada, 2016). The changing pattern of Canadian agriculture showed that there were 205,730 farms in 2011, whereas the number of farms has reduced by 5.9 percent to 193,492 in 2016 (Statistics Canada, 2011; 2017). Based on Statistics Canada data, Canadian land use for industrial agriculture has intensified, as the area (ha) under field crops, as well as the total crop land under commercial fertilizer, insecticides and conventional tillage has increased 6 percent, 13 percent, 39 percent and 5 percent respectively from 2011 to 2016 (Ching, 2018).

Canada has a long history of governmental support for an export-oriented agriculture that is based on economies of scale, mechanization and standardization, which run counter to policies aimed at significantly expanding agro-ecological production (Bouchard, 2002; Qualman, 2011). Canada is also one of the major emitters of GHGs in the world, with total emissions of 716 Mt CO_2 equiv. in 2017 (Environment and Climate Change Canada, 2019) and the amount of GHG per capita of 20.1 tones CO_2 equiv. in 2015 (Sabau, 2017). Emissions from agriculture represent 10% of Canada’s total emissions, through agricultural activities like industrial agricultural production, transportation, food processing and even food waste (Statistics Canada, 2017), while globally approximately 20 percent of the anthropogenic greenhouse gas emissions occurred from agricultural facilities (IPCC, 1996). However, high global temperatures, prolonged summers, unhealthy soil, and polluted air and water actually make Canada’s food production system more insecure (Food Secure Canada, 2017) while also attempting to fight climate change. According to the Canadian Community Health Survey (2011-2012), 8.4 percent of households were food insecure in Canada in 2012 (Statistics Canada, 2013). Therefore, this is not only a challenge for Canada to feed her people but also a challenge for the world to feed 7.6 billion people (Population Reference Bureau, 2017).

1.3 The Newfoundland and Labrador context

Due to its insular character, Newfoundland is specifically challenged in its efforts to properly feed its population. In addition, the declining number and the ageing farmer population in Newfoundland and Labrador are the more recent problems which affect the agriculture sector of the province (Abdulai, 2018). The Canadian Community Health Survey (2011-2012) has shown that 7.8 percent of the households were food insecure in Newfoundland and Labrador (NL) province (Statistics Canada, 2013). The people of NL suffer from a deficit of both agricultural food production and food provision locally (Evans, 2017), with some estimates of upwards to 90% of all food and other consumable products being shipped into the province from out of province sources (Food First NL, 2016).

The province of Newfoundland and Labrador continues to face major health, environmental, economic, and social challenges including high rates of chronic disease, a changing climate and an unstable economy, and continuing high rates of poverty and food insecurity (Food First NL, 2016). The Indigenous people (especially the communities of Nunatsiavut in Labrador) face unique challenges, including social, environmental, and economic factors impacting access to traditional, wild foods, as well as high costs, limited availability, and poor quality of store-bought food (Food First NL, 2016).

Newfoundland and Labrador has the smaller number of farms among all the Canadian provinces in 2016, accounting for less than 1 percent of all farms in Canada (Statistics Canada, 2017). According to the most recent report, there were 407 farms counted in 2016, down 20.2 percent from the previous census in 2011.Similar to the number of farms, the number of farm operators in NL declined by 25.2 percent from 668 in 2011 to 500 in 2016 and exceeding the decline in the number of farms (-20.2%). In NL, the total farm area was recorded at 77,319 acres in 2011 with average farm size 152 acres but in 2016, the total farm area was reduced (8,5%) to 70,747 acres, while the average farm size was increased to 174 acres. More importantly, the crop and vegetables land area were decreased by 4.8 percent and 8.2 percent respectively from 2011 to 2016. It is also reported that the number of dairy cows in NL has decreased by 13.9 percent from 2011 to 5,299 head in 2016 (farms reporting dairy cows declined 10.5%), while the number of beef cattle declined 28.5 percent from 2011 to 528 head in 2016 (farms reporting beef cattle declined 23.8%), (Statistics Canada, 2017). It is alarming that the NL agriculture is declining under almost all aspects.

The NL province relies heavily on outside food sources and due to poor harvests in other provinces, people of NL would pay higher food prices, and due to the natural disasters, like winter storms which disrupt land and water transportation, people face shortages of fresh foods at the grocery stores and buy highly processed items with a long shelf life (Everybody Eats, 2015). According to a recent discussion paper of Food First NL, many households are struggling to afford enough healthy food and are depending on food banks or family and friends where emergency food programming is absent. The province has the lowest rate of consumption of vegetables and fruits in Canada, as well as the highest rate of diabetes and obesity (Everybody Eats, 2015). These factors highlight some of the current food security challenges faced in Newfoundland and Labrador.

Climate change forecasts may bring good news for agriculture here in NL in the coming decades, with an extended growing season and fewer frost days, but the ongoing climate change also provides conditions ripe for new challenges such as shifts in disease, expanded range of some pests, heavy rain storms and soil erosion (Fitzpatrick, 2017). For instance, recent floods from rain storms and hurricanes have washed away the crop fields and the access roads have remained impassable for a couple of days (Fitzpatrick, 2017)). If any factor like temperature, rainfall fertility and frost is not right, “it can cut into the yield and to cover and trying to cover the loss occurred due to disasters will increase food prices” (Fitzpatrick, 2017). In terms of contributions to greenhouse gas emissions from the agriculture sector, carbon dioxide is released from cultivation of the soil and use of farming equipment powered by fossil fuels, methane comes from cattle and livestock manure, and nitrous oxides come from use of chemical fertilizers.

NL emissions from agriculture, show that even though they are lower than in other provinces (Manitoba, for instance), they are outstripped by emissions from solid waste disposal. In 2015, Newfoundland emitted 91 kilotons of carbon dioxide equivalent from agriculture, compared to 776 kilotons from waste (Fitzpatrick, 2017). Farmers have been exploring the possibilities of an extended growing season by experimenting with new plants and crops and irrigation patterns.

1.4 Objectives of the research

This research attempts to investigate the negative consequences of climate change on food production and food security in NL. It also aims to identify the measures taken by the farmers to reduce the GHG emissions and to justify whether agro-ecological approaches could be feasible for a sustainable agricultural system in NL. This study will attempt to answer the following research questions:

- How is agricultural food production in NL affected by global climate change (GCC) and how is it impacting climate change?
- What are the measures taken by the farmers to reduce the GHG emissions and keep the environment intact?

- Do agro-ecological approaches make current agricultural practices in the province more resilient to global climate change (GCC) as well as reduce the impact of agriculture on GCC?

The current provincial food system and farming face and are caught up in numerous challenges and unsustainable conditions, including biophysical dimensions such as climate change (Beddington et al. 2011), environmental pollution, escalating losses of biodiversity, and deteriorating ecosystem services (Millennium Ecosystem Assessment, 2005; Nellemann et al. 2009; Steffen et al. 2004;2015). The provincial agriculture and food insecurity are a concern not only for the people of the province but also for decision makers. Recently, the President of the Newfoundland and Labrador Federation of Agriculture, the provincial Fisheries and Land Resources Minister and the Federal Agriculture Minister discussed the politics of climate change and its many impacts on the provincial agriculture and decided to undertake a new risk-assessment project for this province's farmers (Fitzpatrick, 2017). As for the provincial farmers, they decided to work against the backdrop of climate change and are expected to reduce greenhouse gas emissions (Fitzpatrick, 2017). This would involve significant changes in the current farming practices, aiming to introduce more agro-ecological principles in the provincial agriculture and food system.

Large number of studies and reports indicate significant potential gains from transitioning toward an agro-ecological approach in agriculture as a way of feeding current populations sustainably while allowing future generations to support their livelihoods (AFSA, 2016; Burley, Becheya, Hallows and Bebb 2016; Ching 2016; Cook, Hamerschlag and Klein 2016, FAO 2015a; 2015b). One of the core characteristics of transitioning to agro-ecology farming systems is the regenerative trend of increased "outputs" per unit of "inputs", for a more resourceful agriculture, and using and conserving biodiversity on a long-term basis. In agro-ecology agriculture systems, the use and combination of different techniques and diversification strategies, as well as small-scale integration of various farming activities (crops, animal husbandry, apiculture, etc.) make food producing systems more resilient and restore and nourish the soil and enhance the local environment, instead of continuously degrading it (Vaarst et al. 2011). Imbruce (2015) refers that these production systems allow for lower costs and more diverse cereal crop, fruit and vegetables supply.

From a general point of view, it is evident that a system of industrial agriculture that is highly centralized, energy-intensive, excessively dependents on chemical fertilizers, water and fossil fuels overuse, can create serious harm for the environment, and produce health hazards for farm workers and consumers. Moreover, it is unable to provide food security or to cope with increasing climate disasters; it cannot be sustained in the long run (Capra, 2015). Therefore, incorporating agro-ecological practices in the current agricultural system which is dominated by industrial farming practices is one of the viable and sustainable alternative ways to fight both climate change and ensure food security. This study's working hypothesis is that the industrial agricultural production systems have significant impacts on GHG emissions and on global climate change, as well as on agricultural food production. This study aims to explore the state of NL agriculture impacted by climate change to raise awareness on the contribution of an agro-ecological approach to fighting climate change and solving the problem of food security in the NL province, and to assess the possibility of transitioning from industrial agriculture by incorporating agro-ecological practices in the agriculture of the province.

1.5 Significance of the study

Climate change, greenhouse gas emissions, global warming, industrial agricultural production systems, food security and sustainable development are burning issues at the present time. In Canada, the federal government, the provincial governments, as well as municipal governments, national and international food and environmental organizations are becoming aware of the causes and consequence of climate change and its impact on food security. The provincial government of NL, policy makers, research institutions and people of the province are concerned about the food security and climate change impacts on the agriculture of this province and are interested in research aiming to identify and mitigate the problems. The research findings of this thesis will provide ideas for policy formulations. When published, this research will fill up some literature gaps in the fields of agro-ecology, consequences of industrial agriculture and global climate change contexts. Current and future researchers will get an academic source of information for carrying further research. Finally, the completed thesis will be stored in the MUN library system, where future students will get an opportunity to review this research and build on it.

1.6 Organization of the thesis

The first chapter (introduction) contains the general overview of proposed topic, a presentation of current agricultural practices in NL as well as in Canada, the research objectives and questions, as well as statements on the significance and limitations of the study. A literature review related to effects of industrial agriculture practices, climate change impacts on agriculture, and the theoretical framework on feasibility and sustainability of agro-ecological farm practices in small scale or large scale commercial farms all over the world, including Canada are presented in the second chapter. The third chapter focuses on research methods, theoretical concepts, sampling and data collection and data analysis. Chapter four discusses the current agro-ecological practices in NL from different aspects, in the two types of farms that have been researched, dairy farms and crop farms. In the results sections, chapter five explains the general characteristics of crop farm, impacts of climate change on crop production and respondents' opinions about government supports. Chapter six includes results from the dairy farms analysis. It provides important information about the features of dairy farms, and farmers' opinions on different issues. Synthesizing the information provided by crop and dairy farmers, chapter seven attempts to answer the research objectives and research questions. Finally, chapter eight offers some policy recommendations and concludes the discussion.

1.7 Limitations of the study

This study has some limitations due to the difficulties to collect data which have created some challenges in preparing the report. The first barrier is the location of the farms where one farm is far from another and the researcher's impossibility to visit all the farms due to long distances. The data collection started at the end of December 2019, which is the middle of winter season, when most of the crop farms were closed and farmers were away from the farm house. Therefore, visiting the farms and conducting face to face surveys was very difficult for the researcher. The second difficulty is that there are very few farms addresses in NL Farm Guide 2016, so that the researcher can approach through mail the farmers for conducting the surveys. The researcher has had no direct communication with farmers except for the farmers surveyed at the Gander meeting of the farmers arranged by NL Federation of Agriculture and the farmers visited physically. Lack of financial support or research funding is another challenge, since to complete the field surveys a big amount of money is needed, which was not an option for the researcher. Due to all of these reasons, the research sample is very small and it is rather difficult to represent a whole population with a small sample size.

Chapter II

Literature Review

2.1 Introduction

This chapter presents the results of the literature search carried out by the researcher during fall 2018. The literatures reviewed by the researcher include peer-reviewed articles, relevant book chapters, government and NGOs official reports and policy statements, official publication of foreign government and international bodies (United Nations, World Bank, etc.) and gray literature (newspaper and news articles, etc.). The literature is related to assessing the impact of climate change on agricultural productivity, food security and sustainable agricultural practices. Also, the literatures on the impact of modern industrial and commercial farming on the environment producing environmental hazards like greenhouse gas (GHG) emissions, global warming, floods, droughts, etc. have been covered in this section. This study also has reviewed research articles on agro-ecology (the theoretical framework of the thesis), examining the feasibility and sustainability of agro-ecological farm practices in small scale or large scale commercial farms all over the world, including Canada.

2.2 Impact of industrial agriculture on the environment

Industrialized agricultural systems are taking a huge toll on surrounding environments by polluting air and waterways, creating dead zones in the oceans, destroying biodiverse habitats in forests, releasing toxins into food chains, endangering public health via disease outbreaks and pesticide exposures, and contributing to GHG emissions (Horrigan, Lowrence and Walker, 2002; Tilman, Cassman, Matson, Naylor, and Polasky, 2002; Diaz and Rosenberg 2008). To explain the impact of industrial agriculture on the environment, Aydinalp and Cresser (2008) have reported:

> "Agricultural facilities contribute approximately 20 percent of the annual increase in anthropogenic greenhouse gas emissions (IPCC, 1996) and they also contribute to global warming through carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) gas emissions. CH_4 has the highest global warming potential, which is about 300 times the potential of CO_2 and about 20 times that of N_2O. The main GHGs sources are nitrogen fertilizers, flooded rice fields, soil management, land conservation, biomass burning and livestock production and associated manure management".

According to the GRAIN (2011) report, the modern agricultural production system contributes 11-15 percent to global GHG emissions. Approximately, 15-18 percent of GHGs originate from land-use change and deforestation, 15-20 percent from food processing, transportation, packaging and retail, and 25-40 percent of the current excess of CO_2 in the atmosphere comes from the destruction of soils. During the journey of food from farms to traders, to food processing, to stores and supermarkets, up to 50 percent of all the food produced by the industrial food system is no longer useful, which would be sufficient to feed the world's hungry six times over (Stuart, 2009; GRAIN, 2011). A significant amount of this waste decomposes away on garbage dumps and landfills, producing substantial amounts of greenhouse gases; and that accounts for between 3 to 4 percent of the global GHG emissions (Bogner et al. 2008).

Gliessman (2015) explained that industrial agriculture is also causing human suffering and irreparable damage to the ecological systems on which people rely. The study discussed that industrial agriculture puts future agricultural productivity at risk by overdrawing and degrading agricultural resources (soil, water, and genetic diversity), altering global ecological processes on which agriculture ultimately depends, and by weakening and dismantling social conditions conducive to resource conservation and improving human health (Gliessman, 2015). In economic terms, these adverse impacts are called externalized costs which have serious consequences both for the future and the present and these can potentially one day cause the industrial agriculture system to collapse.

Surveys conducted by Ching (2018) and IPES-Food (2009) found that aspects of 'industrial agriculture' such as - the input-intensive crop monocultures and industrial-scale animal feedlots have successfully increased the volume of food production at the expense of the environment, human health and animal welfare, where very less attention was given to address the root causes of poverty and hunger. The scholars identified numerous negative impacts that are produced by industrial agriculture, such as environmental degradation and pollution that threaten the agriculture, high greenhouse gas emissions that contribute to climate change, loss of agricultural biodiversity, inequalities in access to food which result persistent undernourishment and malnutrition in some regions, and obesity and overweight in others, and the marginalization of smallholder farmers, their practices, rights and knowledge systems (IAASTD, 2009; FAO, 2010; Smith et al., 2014; IFAD, 2013).

Another study highlights some visible and invisible flows between 'agriculture and food systems', 'human (economic and social) systems' and 'biodiversity and ecosystems' (TEEB, 2015). The visible positive flows show food and raw materials that are provided by agriculture and the food systems, contributing to human well-being. There are invisible positive flows (positive externalities) such as pollination, genetic diversity, soil formation and nutrient cycling and invisible negative flows (negative externalities) which include soil erosion, air, water and soil pollution, greenhouse gas emissions, loss of ecosystem complexity and number of species reduction. Therefore, the report has suggested that it is necessary to assess the wide range of hidden costs and benefits of the industrial agricultural production systems which will provide context-specific examples and recommendations for a sustainable food system that can feed the world (TEEB, 2015).

Other research found that the development in science and technological activities at farm level produced troublesome results in nature. The environment has started processes of deterioration and pollution rapidly because of increasing damages to the environment by human activity in every aspect that is exceeding the renewability capacity of the environment. The study referred to the causes of environmental pollution which include unintended usage of agricultural lands, wrong agricultural practices, erroneous use of pesticides and chemical fertilizers, irrigation, tillage and plant hormone applications. Irregular and rapid industrialization, urbanization, organic and inorganic wastes that were left in the environment, burning stubble, absence of crop rotation and inappropriate management of animal wastes also had negative effects on the environment (Onder, Ceyhan and Kahraman, 2011).

In their analysis, Seguin et al. (2010) mentioned that livestock benefit from nature but at the same time, they affect the environment in many ways. Currently, high-intensity animal production has become the biggest consumer of fossil energy in modern/industrial agriculture which releases huge amounts of CO_2 to the atmosphere (IPCC, 1996). The production of breathable/respiratory dust (feed components, hair and skin cells, insect parts, viruses, bacteria, soil particles etc.), the quality of hay and the fungal diversity were the most sensitive parameters to agricultural practices and climate change factors. The scholars documented that the livestock produce 15 percent of the global methane emissions since animal digests cellulose and releases methane gas into the air. Another study shows that the livestock industry is responsible for approximately 5 to 10 percent of the overall contribution to global warming (Aydinalp and Cresser, 2008; IPCC, 1996).

Destruction of forests in order to obtain agricultural land produces greenhouse gases. This represents the second major negative impact after the negative effects of greenhouse gases created by the usage of fossil fuels in intensive agriculture. Forested land collects 20 or 40 times more carbon than agricultural lands and a maximum amount of carbon is released into atmosphere when forest has been destroyed in order to create agricultural land. Agricultural practices, like worldwide paddy cultivation in low-oxygen environment are responsible for 40% of global methane emissions (Onder and Kahranman, 2010). Aydinalp and Cresser (2008) state that irrigated rice fields have been found to produce more CH_4, than deepwater rice. The same study shows that better management of rice paddies, appropriate water management and direct seeding instead of transplanting can contribute to decreasing of CH_4 emissions. To kill insects and other pests as well as disease-causing organisms and neutralize soil acidity, farmers in many countries burn crop residues, such as cereal straw, sugarcane stubble and rice straw which releases CO2. The major sources of agriculture-based N_2O emissions are using nitrogen fertilizer, legume cropping, animal waste, biomass burning and during the breaking of new land (Aydinalp and Cresser, 2008).

Capper, Cady and Bauman (2007) compared the environmental impact of pasture-based, low-input systems with correspondingly low milk production systems characteristic of the 1940s with modern-day ratio high-input/high-output (2007) in US dairy production. This study found that modern dairy intensive practices require considerably fewer resources, like animals, land, feed stuffs, water etc., and produce less waste outputs, like manure, CH_4 and N_2O, than dairying in 1994 for producing one billion kilograms (kg) of milk. In the case of the carbon footprint, the scholars identified an increased footprint per (2007) cow compared with its 1994 counterpart. This proves the point debate that modern-day intensive productive practices are less environmentally sustainable than their 1994 equivalent but when expressed on an outcome basis (per kg of milk) then the carbon footprint per kg of milk in 2007 is only 37% of that in 1994 (Capper, Cady and Bauman, 2007). The experts suggest that to achieve an economically and environmentally sustainable milk supply, agriculturalists need to identify efficient management systems and practices that make the best use of available resources and minimize the potential environmental impact (Capper, Castaneda-Gutierrez, Cady, and Bauman, 2008). According to a recent report of the Food and Agriculture Organization (FAO, 2006), livestock are responsible for global anthropogenic greenhouse gas emissions as well as for deforestation for pasture as a major contributor to global carbon dioxide emissions. This has been exacerbated by the use of formerly food-producing agricultural land to grow bio-fuel crops (Sawyer, 2008; Steinfeld, Gerber, Wassennaar, Castel, Rosales and de Haan, 2006).

Sequi (1999) discussed that leaching of agrochemicals and erosion of contaminated soil particles pollutes ground and surface waters, which are the major impacts of agricultural practices on the environment. These happened either by "water infiltration in soil, with the consequent possibility of nutrient and pesticides leaching, or, if water undergoes surface runoff by erosion processes, that can lead sometimes to transport of relevant amounts of soil particles to water streams" (Sequi, 1999). In recent years, the organic matter content in soils has generally decreased, sometimes to worrying levels, but famers can handle the organic matter balance of their soils by reducing the intensity of tillage, proper crop rotations and selecting different organic fertilizers. The use of organic amendments is important in modern sustainable agriculture but use of chemical fertilizers is more convenient for a farmer due to the easier handling, storage, and other characteristics of feasibility. Dudal and Roy (1995) recommended an integrated plant nutrition system (combination of mineral fertilizers with locally available organic sources of plant nutrients) which ensures that plant nutrition be environmentally, socially and economically viable.

2.3 Effects of climate change on agriculture

The impact of climate change on agricultural productivity and crop yields will vary considerably across many regions and is likely to be small to moderate, which will probably result in a slight overall decrease of world cereal productivity (Aydinalp and Cresser, 2008). As an example, the most negative effects of climate change are predicted in resource poor countries, in dry land areas at lower latitudes and in arid and semi-arid areas, especially in South, Southeast Asia and Africa, where low-income populations dependent on isolated agricultural systems are particularly vulnerable to hunger and severe hardship and barely food-sufficiency (Matthews, Kropff and Bachelet, 1994; Matthews, Kropff, Bachelet and van Lar, 1994). It has been reported that new combinations of plant diseases, weeds, insects and pests may emerge due to changes in temperature, rainfall patterns and the increase in CO_2 levels which increase the risk of losses of crop output (Aydinalp and Cresser, 2008).

Since 2003 and up to 2013, natural hazards and disasters, namely drought, floods, storms, earthquakes, tsunamis, affected 1.9 billion people and damaged US$ 494 billion crops in developing countries (FAO, 2015). The natural hazards destroy critical agricultural assets and infrastructures which can change agricultural trade flows and slow economic growth in developing countries where the sector is important to the economy. The low levels of rainfall and high temperatures could reduce the soil moisture in some tropical and mid-continental regions, whereas in some climatic zones, loss of soil organic matter, leaching of soil nutrients, salinization and erosion are a likely consequence of climate change (Aydinalp and Cresser, 2008). Agriculture in low-lying coastal areas or adjacent to river deltas may be affected by a rise in sea level, as well as agriculture in some flood-prone regions of Asia such as China and further to the south in Eastern Asia, may also be affected by strong monsoons (World Resources Institute, 1998).

Another important agricultural sector, livestock production, may be affected by changes in climate, cropping patterns as well as ranges of disease vectors. The higher temperatures would likely result in a decline in dairy production, reducing animal weight gain and reproduction and lower feed-conversion efficiency in warm regions but in cooler regions, more feed may be required, survival of young animals may be reduced, while energy costs for heating of animal quarters may increase. Cattle, like goats, horses and sheep, are also vulnerable to an extensive range of nematode worm infections and other diseases, most of which have their development stages influenced by climatic conditions (Aydinalp and Cresser, 2008)

Tibesigwa and Visser (2016) have shown that ongoing changes in climate and household food insecurity are likely to be more widespread in most small-holder and subsistence farm households in sub-Saharan Africa. The research found that male-headed households are more food secure compared to female-headed households, and the household food security gap between male - and female-headed households is wider in rural areas than in urban areas, where rural male and female-headed households are more likely to report chronic food insecurity.

Amiraslany (2010) examined the economic impact of climate change on agriculture in Canadian prairies and the viability of production systems, along with the impact of market price effects by predicting the economic impact of climate change. The study found that climate change is beneficial for most regions of the Canadian prairies except for some southern regions of Alberta. The findings show that the direct impact of climate change and price change increased the land value on an average by 31%, whereas the indirect impacts from different sectors increased the land value up to 51%. Canada's crops and food supplies are affected by climate change effects which range from increased intensity and frequency of climate extreme events such as flooding and drought, to complex mixes of longer-term warmer, wetter and drier conditions (O'Riordan, Karlsen, Sandford and Newman, 2013). These climate change conditions facilitate the introduction of new varieties of crops and increase production of some food crops and diminish losses in others. The initiatives, policies, programs and practices of climate change adaptation make clear that Canada is well prepared to anticipate and prepare for climate change and to reduce the risks of or to respond to extreme climate events that exceed coping ranges (O'Riordan, Karlsen, Sandford and Newman, 2013).

However, the Newfoundland and Labrador Climate Change Action Plan does not contain specific adaptation measures for the agricultural sector and perceives adaptation as a challenge compared to mitigation, whereas the western Canadian provinces have been increasingly active in their efforts to help the agricultural sector adapt to climate change (Government of Canada, 2010). In February 2010, the Government of British Columbia adopted a three-part climate change adaptation strategy which includes: "research and education; integration of adaptation into government activities; and risk assessment and implementation of priority actions" (Government of Canada, 2010, p. 6). The stakeholders in government and the agricultural industry in Ontario, Quebec and the Atlantic provinces generally seem less concerned about the impacts of climate change and they have structured their mitigation strategy and are generally shifting resources towards adaptation (Government of Canada, 2010; 2016).

A FAO's study sets targets that aim to better understanding of disaster impact on the agriculture sector and help inform appropriate sector-specific disaster risk reduction policies and financial investments that build resilience in agriculture and farmers' livelihoods. Considering the important role of resilience in agriculture for food security and nutrition, some countries (such as Pakistan and United Republic of Tanzania) have started to adopt clear policies that include protecting, restoring and improving food and agricultural systems in a timely, efficient and sustainable manner (FAO, 2015).

A number of authors have analyzed the impacts of climate change on water availability, crop yield, crop water productivity and food security based on a climate, water and crop yield model (Kang, Khan and MA, 2009). Crop yields affected by climate change are projected to be different in various areas, in some areas crop yields will increase, and for other areas they will decrease, depending on the latitude of the area and system of irrigation application. Climate change is one of the greatest pressures on the hydrological cycle along with population growth, pollution, land use changes and other factors which reduce water availability, increase precipitation fluctuations and decrease crop production. If the irrigated areas are expanded and water resources are expected to be replenished by snow accumulation and the snowmelt process, the water system, food and environmental quality will be more vulnerable to climate changes (Aerts, Droogers, 2004; Dracup and Vicuna, 2005).

2.4 Food security and sustainable agriculture in NL and Canada

Lack of infrastructure to promote and support labour force and skills development, insufficient supportive agricultural policies, decreasing farmer population, few job opportunities in rural areas are the main barriers to maintaining a consistent and reliable food supply in Newfoundland and Labrador. The Newfoundland and Labrador province depends on imported foods due to lack of local production. The imports rely on ferry service, which is sensitive to disruption, and thereby contributes to the province's overall low level of food security (Quinlan, 2012). The Quinlan (2012) considers that by increasing agricultural capacity though training, supportive government policies and infrastructure development, the province will be able to create employment, sustain rural economies, and increase local food production – all of which will help create a more food secure Newfoundland and Labrador. Randell (2018) mentioned that the provincial farmers can't utilize the market since there's no federal inspection plant for red meat livestock where the federal inspection is a requirement of chain grocery stores like Sobeys or Dominion. The author also highlighted that in the case of dairy produce, there are no secondary processing factories to produce ice cream, cheese or yogurt in the NL province except some of the small artisanal or boutique cheese factories and some creamers. Due to this reason, the industrial milk basically is shipped to the mainland to sell it (Quinlan, 2012).

According to the report Environmental Sustainability of Canadian Agriculture (ESCA) in 2016, the crop and livestock sectors are closely connected because the feed and manure management requirements of on-farm livestock determine the cropping systems of many farms (Agriculture and Agri-Food Canada, 2016). In the same way, the development of specific livestock production systems is encouraged by the efficient local production of some crops. The relationship between land use and livestock production has significant implications for assessing and mitigating greenhouse gas emissions, soil erosion, surface water and ground water contamination, soil carbon depletion and air quality degradation (Agriculture and Agri-Food Canada, 2016).

An increase in confined livestock numbers could result in an increase in methane emissions and a higher risk of water contamination, but if the increase in animal numbers is accompanied by improvements in air quality control and in manure storage and handling, the overall effect may be an improvement in environmental sustainability. Correspondingly, an increase in potato production may leave larger areas of soil unprotected over the winter but if winter cover crops are added to the potato rotation, the net effect may be an improvement in soil protection (Agriculture and Agri-Food Canada, 2010; Agriculture and Agri-Food Canada, 2016).

In Canada, the agriculture sector is one of the largest consumers of water accounting for approximately 9 percent of water withdrawals. Additionally, 74 percent of withdrawal water is consumed for irrigation (not returned for downstream use) (Agriculture and Agri-Food Canada, 2010). Increasing demand for supplies of fresh water and the possible implications of reduced supply due to climate change increases the need for efficient water use on agricultural land and as a solution, it is suggested that producers move away from flood irrigation methods to highly efficient drip nozzle center pivot systems (Agriculture and Agri-Food Canada, 2010).

According to the 2018-19 guidelines of the provincial agrifoods assistance program, the government of Newfoundland and Labrador released The Way Forward – Agriculture Sector Work Plan on October 23, 2017 to pursue opportunities, create employment and remove barriers to support agricultural growth. The research project completed by Quinlan (2012) under The Strategic Partnership of the Harris Centre Student Research Fund has identified that lack of labor and skills development opportunity is one of the barriers to achieving community food security in the province. To overcome the labor shortage in agriculture and increase the labor force skills, policy experts suggest that Newfoundland and Labrador has a chance to attract a niche of immigrants and refugees who may not want to settle in larger centers and then train them by opening an agricultural college at Memorial University or at the College of the North Atlantic (Bird, 2018; Quinlan, 2012). To achieve the agricultural growth targets, The Agriculture Sector Work Plan has set specific action items such as: increase Newfoundland and Labrador's food self-sufficiency to at least 20 percent by 2022 (from approximately 10 percent at present); increase secondary processing of food products, particularly industrial milk, industrial eggs, cranberries, fruit and vegetables and meat; and generate an additional 500 person years of employment, upon attainment of the food self-sufficiency target (Provincial Agrifoods Assistance Program, 2018; Agriview, 2018).

> To increase food self-sufficiency and increasing employment opportunities, The Agriculture Sector Work Plan identified key challenges and opportunities related to agriculture development; agriculture production; agriculture business development and risk management; human resources and labour; research, innovation and diversification; market access and development; and processing and value-added agriculture (The Way Forward, 2019; Fisheries and Land Resources, 2018, May 10).

The Environmental Farm Planning (EFP) is a national program implemented provincially which gives farming enterprise an opportunity to rate concerns in areas of use, pesticide and fertilizer handling, energy efficiency, manure storage and distribution along with multiple aspects of crop cultivation and production (Government of Newfoundland and Labrador, 2018). The EFP helps producers to identify environmental risks and develop plans to minimize the negative impacts on the environment while promoting practices of sustainable farming.

The Canadian Agricultural Partnership is a $3 billion, five year (April 01, 2018 to March 31, 2023) Federal-Provincial-Territorial (FPT) Framework Agreement that will provide $37 million to Newfoundland and Labrador for the agriculture, agri-foods, and agri-products sector to support employment creation, new entrants, secondary processing, economic growth, and food self sufficiency (Government of Newfoundland and Labrador, 2018). It is considered that climate change impacts on the Newfoundland and Labrador agriculture may result in higher temperatures, increased precipitations and more variable and extreme weather patterns. The Government of Newfoundland and Labrador will provide financial support to promote environmentally sustainable practices and climate change mitigation and adaptation strategies to enable the agriculture and agri-processing sector to enhance productivity, manage risks, reduce greenhouse gas emissions, introduce beneficial management practices, build public confidence and contribute to clean growth opportunities.

2.5 Agro-ecology and sustainability

A number of publications reviewed underline the need for agriculture to move away from practices that destroy organic matter and the environment to practices that build-up the organic matter in the soil and keep the environment sustainable. The new scenario would require a fundamental change in approach from the current industrial system of agriculture to diversified cropping system, better integration between crop and animal production, increased incorporation of trees and wild vegetation, and so on (GRAIN, 2011). Some studies assess the contributions of diversified farming systems (DFS) to food security, food sovereignty and the global food supply and also investigate to what extent industrialized forms of agriculture are being replaced by diversified farming systems in the world (Kremen, Iles and Bacon, 2012). The authors define Diversified Farming Systems (DFS) as “farming practices and landscapes that include functional biodiversity at multiple spatial and/or temporal scales in order to maintain ecosystems services that provide critical inputs to agriculture, such as soil fertility, pest and disease control, water efficiency, and pollination” (Kremen, Iles and Bacan, 2012, p.3). DFS are related to agro-ecology as it includes polyculture, noncrop plantings such as insectary stripes on field borders, integration of livestock or aquaculture with crops (mixed cropping systems), and/or rotation of crops or livestock, including cover cropping and rotational grazing. The experts also claimed that including natural or semi-natural communities of plants and animals within the cropped landscape, such as fallow fields, riparian buffers, pastures, woodlots, meadows, ponds, marshes, streams, rivers and lakes or combinations thereof (Kremen and Miles, 2012), support both desired components of biodiversity and "associated biodiversity"; together these two elements make up agro-biodiversity (Perfecto et al, 2005). Crop diversification, one of the practices of DFS and incorporation of organic matter in the soil would progressively increase the capacity of soil to hold water which would mean that excessive rainfall would lead to fewer, less intense floods and droughts and reduce soil erosion, soil acidity and alkalinity (GRAIN, 2011).

A key principle of agro-ecology is the diversification of farming systems (DFS), as diversified farming systems maintain genetic and species diversity in fields. Also agro-ecology practices help spreading the risks and reducing the vulnerabilities in uncertain climate conditions (Ching, 2018). Mixtures of crop varieties are grown through intercropping (growing two or more crops in proximity), agro-forestry (combining trees and shrubs with crops), and other techniques (Capra, 2015). Livestock is integrated into farms to support the ecosystems above the ground and in the soil. Diversified farming systems are able to adapt to and resist the effects of severe droughts, exhibiting greater yield stability and smaller decline of productivity than monocultures.

According to FAO (2003), "agro-ecology is defined as the study of the interactions between plants, animals, humans and the environment within agricultural systems". Agro-ecology as a discipline, therefore covers integrative studies of agronomy, ecology, sociology and economics and also integrates these with traditional knowledge and local farmers' knowledge for sustainable agro-ecosystems management (FAO, 2003; TWN and SOCLA, 2015). The term agro-ecology has been used by scientists and researchers to refer the application of ecological principles to agriculture. It is an old practice of building up soil which started as bio-dynamics in the 1920s in Europe (FAO, 2019).

Contemporary interest in agro-ecology has emerged in response to evidence of wide-ranging social and ecological problems related to the industrial model of agricultural production which has long been promoted in most developed economies, including Canada, starting under settler colonialism (Isaac et al. 2018; Tomich, 2011; Mendez, Bacon, and Cohen, 2013; Martin and Isaac, 2015). Recent evidence suggests that agro-ecological practices help to address a number of global social and environmental problems, including soil degradation, the depletion and contamination of water, the detrimental effects of pesticides on human health, emissions of greenhouse gases, and the loss of genetic resources (Tilman, Cassman, Matson, Naylor and Polasky, 2002; Mostafalou and Abdollahi, 2017).

One of the most important aspects of agro-ecology is that its practices improve the adaptive capacity of agro-ecosystems and reduce their vulnerability to natural disasters, climate change impacts, and new and emerging environmental and economic system stresses and shocks (IAASTD, 2009). As evidence, the small-scale farmers in Central America using agro-ecological methods were significantly more able to withstand the adverse effects of Hurricane Mitch than plots farmed conventionally. A similar result was found by participatory action research for agro-ecologically managed plots in Guatemala, Honduras and Nicaragua which retained more topsoil, field moisture and vegetation and experienced less erosion and lower economic losses than plots on conventionally managed resource-extractive farms (IAASTD, 2009).

It is known that a diversified farming system is a component of agro-ecological systems that depend on specific combinations of traditional and contemporary knowledge, local cultures, practices and government policies (Kremen, Iles and Bacon, 2012). Temporal and spatial designs of diversified farming systems include crop rotations, polycultures, agroforestry systems, cover crops and mulching, green manures and crop-livestock mixtures which have a wide-range of agro-ecological effects (Ching, 2018). The previous study claimed that agro-ecology is said to be a knowledge intensive approach as opposed to input-intensive agricultural practices. At farm level, this means the re-skilling of farmers, who not only combine modern science and local knowledge, but regenerate new situated knowledge like participatory breeding, participatory varietal selection, peer-based quality checks, and environment specific knowledge (Coolsaet, 2016).

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) refers to agro-ecology as a scientific approach which ensures agricultural sustainability since it combines scientific inquiry with indigenous and community-based experimentation, emphasizing technology and innovations that are knowledge-intensive, low cost and readily adaptable by small and medium-scale producers (IAASTD, 2009). Agro-ecological farming also encourages the cultivation of resilience and maintenance of healthy ecosystem functions instead of over reliance on external inputs such as fossil fuels, fertilizers and synthetic chemical pesticides that can have high energy, environmental and health costs. Conservation of natural resources, increasing ecological resilience, improving health and nutrition, economic stability, climate change mitigation and increasing social resilience and institutional capacity are the broad range of equitable and sustainable development goals set by agro-ecological approaches (IAASTD, 2009).

The general assumptions that agro-ecological methods are necessarily less productive than the high-input conventional systems are incorrect. An Essex University study of 286 resource-conserving projects in 57 countries has found that agro-ecological farming achieved on average a production increase of 79 percent per hectare, with all projects achieving increased water efficiency, and 77 percent showing significant reductions in pesticides use (IAASTD, 2009). Another comprehensive examination of nearly 300 studies worldwide by University of Michigan has found that organic agriculture could produce enough food, on a per capita basis, to provide 2,640 to 4,380 kilocalories per day per person (more than the suggested intake for healthy adults) (IAASTD, 2009).

In the last two decades, peasant agriculture, food sovereignty and agro-ecologically based production systems have gained much attention in the developing world due to climate change and the economic and energy crises (Altieri, Funnes-Monzote and Petersen, 2012). La Via Compesina is an international movement founded in 1993, which presently comprises 182 local and national organizations in 81 countries from Africa, Asia, Europe and the Americas, bringing together millions of peasants, small and medium size farmer, landless people, rural women and youth, indigenous people, migrants and agricultural workers from around the world (La Via Compesina, 2019, June 30). It has been built to defend peasant agriculture for food sovereignty as a way to promote social justice and dignity and strongly opposes corporate drivers, profit taking and industrial agriculture that destroy sustainable peasant and family farm, social relations and nature (La Via Compesina, 2019, June 30; Rosset and Martina-Torres, 2012). In Cuba, Brazil, Philippines and Africa, it was found that the agro-ecological development model is the only viable option to meet present and future food needs depending on small farms which emphasize diversity, synergy, recycling and integration as well as social processes that value community participation and empowerment

(Altieri, Funnes-Monzote and Petersen, 2012). Given the present and predicted near future climate change, energy and economic scenarios, agro-ecology has emerged as one of the most robust pathways towards designing biodiverse, productive, and resilient agro-ecosystems today (Altieri, Funnes-Monzote and Petersen, 2012).

Agro-ecology consists of principles, concepts, and strategies that must form the foundation of any system of food production that can make a legitimate claim to being a more sustainable successor to industrial agriculture (Gliessman, 2015). The scientific principles agro-ecology applies to design and management of agro-ecosystems (Gliessman, 2015) include practices which "increase biodiversity, nurture soil health and soil biodiversity, technologies, innovations and practices which diversify farms and farming landscapes, close cycle and enhance recycling, promote ecosystem services and stimulate interaction between different species, such that the farm can provide its own organic matter, pest regulation and weed control, without resort to external inputs" (TWN and SOCLA,2015, p. 8). The sustainable food system of the future will be made up, in large part, of innumerable small to medium scale agro-ecosystems, each relatively self-contained, adapted to local conditions, and focused primarily on satisfying the food needs of a local population (Gliessman, 2015). Agro-ecology consists of a variety of agricultural techniques, often based on traditional practices and with these techniques, healthy organic food is grown in decentralized, community-oriented, energy-efficient, and sustainable ways (Capra, 2015).

When farmers grow crops organically, they use technologies based on ecological knowledge rather than chemistry or genetic engineering to increase yields, control pests, and build soil fertility. Farmers plant a variety of crops, rotating them so that insects that are attracted to one crop will disappear with the next. Instead of chemical fertilizers, the farmers enrich their fields with manure and tilled-in crop residue, thus returning organic matter to the soil to restart the biological cycle (Capra, 2015). Solar energy is the natural fuel that drives these ecological cycles, and living organisms of all sizes are necessary to sustain the whole system and keep it in balance.

When soil is farmed organically, moreover, its carbon content increases, and thus organic farming contributes to reducing the CO_2 content of the atmosphere (Capra, 2015; UNEP, 2011). It is estimated that “a widespread conversion to organic farming could mitigate 40 percent of the world’s agriculture greenhouse gas emissions in a minimum implementation scenario, and up to 65 percent in a maximum carbon sequestration scenario” (Niggli, Fließbach, Hepperlyand Scialabba, 2009; Ching, 2018, p.7). In other words, agro-ecology not only is more resilient to global warming than industrial agriculture; it also helps stabilize the climate, whereas industrial agriculture aggravates climate change.

Sustainable agriculture is a new environmentally friendly agricultural technique which is promoted by developed countries (Onder, Ceyhan and Kahraman, 2011). The authors recommended that good agricultural practices (GAP), organic agriculture and precision agriculture (efficient or good management) are the three general applications of environmentally friendly agriculture. For instance, crop rotation and sowing of legumes are good practices that enable nitrogen fixation and fallowing reduce the negative effect of agriculture on climate change. More recently attention has focused on the technique of adaptation, such as changes in crops and crop varieties, improved water management and irrigation systems, changes in using fossil fuels and changes in planting schedules and tillage practices. All these will be important in limiting the negative effects and taking advantage of the beneficial effects of changes in climate (Aydinalp and Cresser, 2008).

During the last decade, attention on the impact of natural disasters and the effects of agricultural protection has been growing. Different studies discussed five theories for agricultural protection, namely rural bias, vulnerability, development paradox, theory of collective actions and shocks (Hoogezand, 2013). According to Olson (1965), the theory of collective action is that small groups with specific interests could easier organize and are therefore more effective in lobbying and secure their government support. Agricultural producers are vulnerable to market fluctuations since agricultural producers have an inelastic supply. Income from farming is volatile to random factors like natural disasters that affect production and prices (Meuwissen, et al. 2003). Due to this vulnerability and despite the small decrease in output due to natural disasters, the agricultural producers lobby effectively influences politicians to secure protection. The rural bias theory suggests that when agricultural protection is established, it is difficult to expel it, which is called "rural bias of electoral institutions" (Rae, 1971). If the farmers' group represents the majority of the population, then the composition of government spending is larger towards farmers (Olper and Raimondi, 2009). Anderson and Hayami (1986) show that certain types of shocks (like financial shock in the 1980s that opened the Uruguay negotiations and therefore led to a worldwide decrease in agricultural protection) could drive changes in producer support by governments. In developed countries the relatively small group of agricultural producers receives relatively high level of financial support and subsidies, while in developing countries the relatively large group of farmers did not receive any support at all and could be taxed which is called the development paradox (Beghin and Kherallah, 1994). Hoogezand (2013) has given a sixth theory related to agricultural support which shows a link between natural disasters and agricultural protection that is the lack of private agricultural insurance market. Studies show that high-income countries (in the European Union) and countries in Africa have been increasing government policy support after natural disasters and for agricultural export products. The author has suggested that private agricultural insurance might be more effective than government support and also that government intervention on the agricultural insurance markets crowds out private initiatives and produces market inefficiencies (Hoogezand, 2013).

The Food and Agriculture Organization of the United Nations (FAO, 2011) has anticipated that 20-30 percent of the farm's yields would increase if women had the same access to productive resources as men. The FAO report has also indicated that if there is no gender gap or imbalance then 2.5 percent to 4 percent of the farm's yields would increase in developing countries, and with these foods it is possible to reduce the number of undernourished people globally by 12-17 percent. Agro-ecology can help rural women to become more autonomous and empowered through knowledge, resource independence, and access to innovations and participation at various levels (Lopes and Jomalinis, 2011).

Rapid decline in traditional agro-ecological knowledge within peasant and indigenous communities throughout the world, lack of adequate extension services and technical assistance currently limits the spread of agro-ecology. In addition, other barriers like lack of investment, resources and policy support directed to agro-ecology, prevalence of vicious incentives and subsidies and concentration of power in a limited number of large multinational corporations promote unsustainable and high-emissions agriculture (Ching, 2018; IPES-Food, 2016). The research has found that agro-ecology could therefore directly and indirectly contribute to achieving the UN sustainable development goals (SDGs) in an integrated, comprehensive and holistic manner, especially SDG 2 which aims to "end hunger, achieve food security and improve nutrition and promote sustainable agriculture" (Ching, 2018).

The researcher used agro-ecology as a theoretical framework since agro-ecology is the science behind sustainable agriculture. Depending on the natural and social sciences, agro-ecology provides a framework for assessing four key systemic properties of agriculture, namely productivity, resilience, equity and sustainability. An agro-ecological approach recognizes the multi-functional dimensions of agriculture and measures sustainability in terms of social, environmental and economic impacts (IAASTD, 2009). The design of agro-ecological practices is based on scientific ecological principles that include soil conservation, water conservation and quality, wildlife and biodiversity conservation, forests and forest management, and species and genetic diversification (Forests Ontario, 2019; Ching, 2018; IAASTD, 2009). Recent studies have shown that applying agro-ecological principles in small-scale settings can produce up to two times more food in the next 10 years (USC Canada 2017; Fraser, 2012). Agro-ecological principles present a sustainable approach which can help to ensure farms continue to produce the high levels of diversity, integration, efficiency, resilience and productivity needed to adapt and feed the world all while protecting and preserving ecosystem stability (Forests Ontario, 2019). Therefore, introducing agro-ecology principles in NL agriculture has the potential to double food production by 2022, and promote adaptation to climate change, thus protecting the environment.

Chapter III

Research Methods

This research has used a mixed methods approach for collecting data during the Fall and Winter semesters in 2018-2019. The beginnings of this research were directly related to the course Sustainability Monitoring and Assessment (ENVP 6522) which was taught by Dr. Gabriela Sabau in the Winter 2018 semester and her interest in sustainable agricultural production and food security within NL. The duration of data collection and analysis was from September 2018 to June 2019. Within this timeframe, the schedule consisted of design of the research proposal, development of research tools (survey, cover letter, informed consent, etc.) getting approval of the research tools from the Grenfell Ethics Board, literature review, conducting of surveys/interviews and data analysis and writing of the thesis. Two sampling methods, namely simple random and snow balling techniques, were used to collect data and conduct the surveys/interviews utilized in this research. These are further described in the latter part of this chapter.

3.1 Theoretical framework

As stated by Gliessman (2015), industrial agriculture should be replaced by more sustainable food systems based on agro-ecology, which can distribute food more equitably, reduce food overconsumption and waste, and insure that the land is used to feed people rather than automobiles and livestock. Agro-ecology is the means of securing both sustainable food systems and agricultural development. In this project, the theoretical framework that will be used is the economics of strong sustainability (Pelenc, Ballet and Dedeurwaerdere, 2015). The neo-classical conception of sustainability implies prudent conduct aiming to keep non-diminishing the income (Hicks, 1946) that secures a non-diminishing level of consumption in the future. The main condition for sustainability then becomes keeping a nation's productive capacity intact by maintaining its capital portfolio, which includes various forms of capital (man-made, human, natural, social and technological) non-diminishing (Ayres, van den Bergh, and Gowdy, 2001).

The fundamental debate regarding sustainability is whether we choose to adopt a "strong" or a "weak" conception of sustainability (Pelenc, Ballet and Dedeurwaerdere, 2015). Weak sustainability assumes that natural capital and manufactured capital are essentially substitutable (Solow, 1974) and considers that there are no essential differences between the kinds of well-being they generate (Ekins, Simon, Deutsch, Folke and De Groot, 2003; Neumayer, 2003). The only thing that matters is the total value of the aggregate stock of capital, which should be at least maintained or ideally increased for the sake of future generations (Solow, 1993). In addition, from a weak sustainability perspective, technological progress is assumed to continually generate technical solutions to the environmental problems caused by the increased production of goods and services (Ekins, Simon, Deutsch, Folke and De Groot, 2003).

Authors writing on strong sustainability demonstrate that natural capital cannot be viewed as a mere stock of resources. Rather, natural capital is a set of complex systems consisting of evolving biotic and abiotic elements that interact in ways that determine the ecosystem's capacity to provide humans society directly and/or indirectly with a wide array of functions and services (Noeland O'Connor, 1998; Ekins, Simon, Deutsch, Folke and De Groot, 2003, 2003; Brand, 2009). Daly and Farley (2014) demonstrate that natural capital is complementary to man-made capital and constitutes the limiting condition in the total capital frame. The concept of critical natural capital highlights the need to maintain the ecological functioning of natural systems above certain thresholds of degradation in order to conserve the capacity of natural capital to provide the services which are critical for human existence and well-being (Noël and O'Connor, 1998; Ekins, Simon, Deutsch, Folke and De Groot, 2003; Brand, 2009).

From an ecosystem's perspective, a minimum necessary condition of "strong sustainability" is that the total stock of natural capital remains constant over time but this does not state that all ecosystem services everywhere have to be sustained exactly as they are provided that their capacity to renew themselves is conserved (Pelenc, Ballet and Dedeurwaerdere, 2015). This can also be referred to as a concept of "environmental quality" and is represented as a function of the stocks of biological resources, ecosystem space, nutrients available, and other environmental assets that are essential for the integrity of the ecosystem, and provide use and non-use values to society (Hediger, 1998). As maintenance of natural capital is essential for practicing sustainable agriculture, this project will be based on the strong sustainability theoretical concept.

3.2 Sampling and data collection

This study used both primary and secondary data to answer the research questions and fulfill the objectives of the research and to develop some policy recommendations which might facilitate the introduction of agro-ecological approaches/practices within the current industrial agriculture of the province. The Newfoundland and Labrador province was selected as a study area to assess the contribution of the agricultural sector to greenhouse gas emissions and how food production and food security systems were affected by environmental degradation and climate change.

In order to identify the natural hazards that affect agricultural production in the NL province, the farm practices that have contributed to climate change and the actual barriers to adopt agro-ecology principles within the province, self-administered surveys were developed and utilized to gauge the opinion of NL farm operators. Self-administered surveys were determined an appropriate data collection technique due to the ease of execution as well as the ability to collect appropriate information from the respondents spread out over a large geographic area (Bourque, 2003), such as the farmers in NL. For this research, the crop and dairy producer's surveys (see Appendices C and D) were sent by Canada Post letter service, across the province. Farms were selected and the surveys were sent to the farm postage addresses with the help of Young Farmers' Forum, Saint John's Office. The self-administered survey contained 71 questions in the case of crop farms survey and 81 questions in the case of dairy farms survey. The questions referred to the farm size, operations, land preparation, impact of natural hazards, agricultural activities creating greenhouse gas emissions, sustainable farm practices, farmers' interest about organic, agro-ecology and integrated farm practices and supports received from the government.

The surveys, the informed consent forms, the letter of invitations and a return envelope with pre-paid postage were mailed to randomly selected farms (60 farms) through the Young Farmers' Forum on February 10th 2019. The response rate as of May 9th, 2019 was 18.33 percent indicating that the researcher received 11 completed surveys out of 60. The researcher physically attended the Annual General Meeting arranged by the Newfoundland and Labrador Federation of Agriculture held on January 29-31, 2019 in Gander. On this occasion, using the snow ball sampling method, the researcher interviewed 9 farmers with the help of farm owners and an officer of the Young Farmers' Forum. Moreover, the researcher also visited physically 12 farms in Stephenville, Pasadena, Deer Lake, Humber Valley and Cormack and interviewed 5 farmers, as some farms were closed and some farmers were not available at the farms during the time of the visit to assist the researcher to increase response rates as well as to gain practical knowledge about farm management. At the time of visiting the farms, this study has given priority to those areas where intensive farm activities are taking place. Due to logistic, time and cost constraints, as well as the lack of mailing addresses of farmers, it was not possible to survey all of the farms in the province and the sample size 81 (60+9+12) of the 407 farms or 19.9% of all farms in NL was low. The response rate within this group was also relatively low 30.86% (received 25 completed surveys out of 81) presumably due to poor timing of the survey delivery (winter, January to end of April) as most of the crop farms were closed in the winter season in NL. A suitable pre-tested and ethically approved questionnaire has been used to collect necessary information from respondents. The telephone directory of NL, the Newfoundland and Labrador Farm Guide 2016, the online member directory of Newfoundland and Labrador Federation of Agriculture and the GPRS (General Packet Radio Services) were used for getting the addresses and contact information of the farmers.

The secondary data has been collected from relevant literature related to agriculture and the environment, including published journal articles, reports of government departments and international organizations, periodicals, newspapers and conference papers. The key variables that have provided guidelines for collecting secondary data included: industrial food production systems, food security level in NL, global temperature and greenhouse gas emissions, impacts of agricultural activities on greenhouse gas emissions in NL, and the effects of climate change on agricultural production and food security in this province.

3.3 Data analysis

Content analysis is a method that may be used with either qualitative or quantitative data and in an inductive or deductive way (Elo and Kyngas, 2008). Both inductive and deductive analysis processes are represented as three main phases: preparation, organizing and reporting, where the preparation phase is similar in both approaches. Inductive analysis extracts the concepts from data, where there are no previous studies dealing with the phenomenon, whereas the aim of a deductive approach is to test a previous theory in a different situation or to compare categories at different time periods (Elo and Kyngas, 2008).

In this study, a deductive method has been used to analyze secondary data, but an inductive approach has been used to analyze both qualitative and quantitative primary data in order to identify responses to the research questions which could lead to new policies for food security and environmental sustainability.

Statistical data which had been collected through surveys and interviews with farm owners has been entered into an electronic data file for analysis, using the IBM Statistical Package for the Social Sciences (SPSS) Edition 23 to calculate frequencies of responses, demographics, as well as other inferential statistics analysis on categorized data (Evans, 2017). The Microsoft Office Excel spreadsheet has been used to calculate the average, maximum and minimum value, and to draw figures, charts and tables, etc.

Chapter four discusses the present state of agro-ecological practices in NL based on agro-ecological principles and goals. Based on secondary articles, government and non-government officials' reports, and book chapters, the researcher explains the soil health and land preparation method, progress of organic farming, use of traditional knowledge in farming, supply of renewable energy, water management, agroforestry and diversified farming practices in NL.

Chapter IV

Agro-ecological Practices in Newfoundland and Labrador, Canada

4.1 Agro-ecology as a means of sustainable development

The world is facing multiple inter-related crises, economic, social, financial, energy, food-related and ecological. These crises do not evolve randomly but as a result of the current dominant economic system that promotes unlimited economic growth at the expense of people's health, natural resources and the planet (TWN and SOCLA, 2015). In modern industrial agriculture, this dominant economic system has produced increased yields by applying fossil fuel energy, mechanization, and advanced crop breeding methods. There are serious challenges to modern industrial agriculture, such as food insecurity and climate change, and the very base of agriculture could be destroyed by the conventional agricultural practices which are unsustainable. Agro-ecology is a scientific discipline that applies ecological concepts, theories and principles to study, design, manage and evaluate sustainable agricultural systems that are not only productive and resource conserving but also have the greater potential for fighting hunger, particularly during economically and climatically uncertain times (TWN and SOCLA, 2015; Agroecology in Action, 2019; Altiery, 2012; Altiery and Nicholas, 2012).

Recent studies show that agro-ecology is a new technological and development approach which can secure the agricultural needs of present and future generations without depleting the natural resource base and disempowering communities (TWN and SOCLA, 2015; Agroecology in Action, 2019). The agro-ecological approach has a deeper understanding of the complex long-term interaction between natural resources, people and the environment and also has broad performance criteria, which include properties of ecological sustainability, food security, economic viability, resource conservation and social equity, as well as increased food production (Agroecology in Action, 2019). In investigating agro-ecology, family farming is an important topic, since most of the cases of family farming involve the use of local knowledge and biology based farming regulations and practices which can result in diversified production and mixed cropping systems instead of monoculture and chemical solutions (Lafontaine and Jannoyer, 2014). Agro-ecological research includes all the important biophysical, technical, social and economic components of farming systems and regards these systems as the fundamental units of study, where mineral cycles, energy transformation, biological processes, human and socioeconomic relationships are analyzed as a whole in an interdisciplinary fashion (Agroecology in Action, 2019). Agro-ecology is gaining ground in countries as diverse as the United States, Brazil, Germany, France and Malawi. In Cuba, about 46-72 percent of peasant farms are using agro-ecological practices and generating over 70 percent of the domestic food production (Schutter, 2011).

4.2 Agro-ecological practices in Newfoundland and Labrador and the rest of Canada

There is an argument about the development and constraints of agro-ecology in Newfoundland and Labrador (NL) and the entire Canada due to two different perspectives. In Canada, the development of agro-ecology can be considered as a response to the environmental degradation caused by the industrial productive form of agriculture, whereas in many other countries agro-ecology has developed as the revitalization of place-based farming knowledge (Altieri, 2004; Saylor and Alsharif and Torres, 2017; Desmarais and Wittman, 2014). Although the prevalence and prominence of agro-ecology is growing in Canada, but its presence is still small and the support for its development is limited. The present rigorous assessment of the current state of agro-ecological practices, the related social movements, and the achievements of agro-ecological science essentially elucidate that agro-ecology in Canada is a ‘responsive’ agricultural approach (a response to the various social and ecological problems associated with the prevailing industrial model of agricultural production that has been promoted in the country under settler colonialism), rather than a consolidated history of yield maximization models (Isaac et al. 2018). Considering climate change and its geographic location, and its food security condition, Newfoundland and Labrador is more vulnerable compared to other provinces in Canada. Anagro-ecological approach is an alternative way to reduce the food insecurity problem and to deal with the lack of adequate soil in the province.

4.2.1 Traditional and Indigenous knowledge

To develop an alternative agriculture and food system in Canada, it is necessary to investigate the linkage between Indigenous cultivation techniques and agro-ecology principles (ISOFAR, 2019). The scholars have focused on terrestrial agriculture because fisheries, foraging and other forms of food provisioning practiced by Indigenous people are very much aligned with agro-ecological principles and complementary notions of agricultural bioregionalism (Knezevic, Blay-Palmer, Levkoe, Mount and Nelson, 2017). Morrison (2011) argued that Indigenous food provisioning practices are tremendously important to food sovereignty struggles in Canada and at the same time, advancement of agro-ecology in Canada is necessary to address the realities of ongoing settler colonialism and Indigenous dispossession. The historical trajectories of settlers' agriculture compromising Indigenous sovereignty, as well as the current and former development projects, such as increasing number of urban centers, residential schools, industrial pollution, treaty violations and generations of relocation through government policies are the threats to indigenous food ways and their living territories (Coulthard, 2014; Pasternak, 2013; Sharifi, Petoukhow, McAuley and Hull, 2018).

A recent report shows that around 4.9 percent of the total Canadian population are Indigenous and more than 3.5 million hectares of reserve lands are managed by them (Sharifi, Petoukhow, McAuley and Hull, 2018). Locally or regionally collected traditional foods are central to the cultural, spiritual, and physical health of Indigenous peoples and communities. It is identified that "changes in land use designations, habitat loss, limited access to suitable land, local extirpations, the arrival of invasive pest and disease species, cross-pollination with commercial crops, the loss of traditional knowledge, cultural displacements and the transition to Western diet are the different aspects of colonization which hindered access to traditional food" (Sharifi, Petoukhow, McAuley and Hull, 2018). Due to change in lifestyle and lack of access to traditional food, the Indigenous people have suffered more from high levels of chronic respiratory disease, diabetes, obesity and cardiovascular disease than among the general Canadian population.

Many Indigenous peoples and communities are trying to find out ways to revitalize traditional lifestyle practices. These efforts are also worthy for Canadian people since the Indigenous peoples' traditional knowledge of stewardship and cultivation of plants and animals may help today's society deal with some of the negative consequences of contemporary industrial agriculture and climate change. It is suggested that supporting Indigenous communities in managing their lands, applying traditional knowledge and promoting traditional foods production on their lands can greatly improve the health, biodiversity, food security and sovereignty, employment opportunities and the economy of these communities and of Canada (Sharifi, Petoukhow, McAuley and Hull, 2018). The authors show that around 550 different species of plants have been utilized in the traditional diets of Indigenous peoples in Canada, which has generated a wealth of ecological traditional knowledge among them. Indigenous cultivation practices are intimately tied to agro-ecology and organic farming, as:

> "Indigenous Peoples in Canada have a long history of effectively managing food plant production and plant habitats using practices such as succession, regeneration, selective harvesting, pruning/coppicing berry bushes, controlled burn, habitat creation, and distributed use and harvest across landscapes and over time (seasonal rounds). Their social management strategies such as proprietorship, socially determined conservation, distributed seasonal access to resource areas, trade and exchange, feasting and sharing, and knowledge transmission enabled them to create and manage an efficient ecological food system" (Sharifi, Petoukhow, McAuley and Hull, 2018).

NL has a long history of family farming as well as community gardening, where people use their traditional knowledge for cultivating crops and rearing livestock. Newfoundland and Labrador has the largest Indigenous population (including First Nations, Metis or Inuit) of all the Atlantic provinces, at 45,725 people in 2016, making up 8.9 percent of the provincial population (Statistics Canada, 2016).

Many Indigenous communities (e.g. Inuit communities) collect or harvest wild food from land and sea (caribou, seal, porpoise, fish, birds, berries and plants) which is an essential part of their diet. Currently, the communities of Nunatsiavut face unique food security challenges due to changing weather, losing sea ice, and wildlife migration patterns, as well as increasing costs of getting out on the land to hunt, and high cost and poor quality of store-bought food (Food First NL, 2015). In the coming year (2020), when the Muskrat Falls hydro dam on Labrador's lower Churchill River floods an area double the size of the Victoria city, it is expected that microbes will convert inorganic mercury found in flooded soils and vegetation. The researchers state that most human exposure to methyl mercury comes from eating fish, although marine mammals like seals and other traditional foods can also carry high levels of mercury which may cause serious damage of hearing, speech and vision and in many cases, permanent symptoms of kidney, lung and skin ailments (Cox, 2019). According to the study, country foods are at the heart of the Inuit health, well-being and culture, but due to Muskrat Falls, the wildlife locally caught and consumed by Inuit, living around Lake Melville, constitute 70 percent of their future exposure to mercury (Cox, 2019).

Applying the traditional knowledge and farm practices of Indigenous peoples and local communities in NL is one of the best ways for ecosystem management, adapting agriculture and sustainable use of natural resources that are gaining credence as a key weapon in the fight against climate change. The modern or industrial agriculture (using hybrid seeds) is more vulnerable to climate change due to increase reliance on external resources whereas, applying traditional and crop varieties can enable the industrial agriculture to cope with extreme weather and environmental change over the long term and needs less external resources (IIED, 2011).

4.2.2Practice of organic farming

Though it is thought that certified organic production is the closest proxy of agro-ecology, but actually organic production fails to capture all the multiples dimensions of agro-ecological practices and motivations (Isaac et al. 2018). According to Statistics Canada, between 2001 and 2016, the number of organic farms increased 65 percent which shows a trend toward increased ecological farming across the country and possibly a transition to the adoption of more ambitious agro-ecological practices. Most of the organic farms in Canada are concentrated in Saskatchewan (773 farms), Ontario (405 farms), Quebec (372 farms), and British Columbia (319 farms) (Statistics Canada, 2001a). The figures might be outdated as currently the agricultural census no longer asks farmers to specify which of their products are certified organic (Statistics Canada, 2016a). Though the volume of organic farming increased in Canada, certified organic products account for no more than 1.9% of the total production (Isaac et al, 2018).

The 2006 census of agriculture has shown that 11,937 farms produced uncertified organic products, which indicates that numerous farms in Canada are following organic, ecological and agro-ecological practices that remain otherwise unreported (Statistics Canada, 2006; Isaac et al, 2018). It is a good sign that consumer demand and the supply of organic products continue to increase both domestically and globally, and that Canada has achieved significant gains in market share acreage under organic management (COG, 2017). In 2015, Canada had the 5th largest organic market in the world valued at $4.7 billion, with the majority of Canadians regularly purchasing organic products (International Federation of Organic Agriculture Movements, 2017; Canada Organic Trade Association, 2016). Other studies show that in spite of the 16 percent annual growth rate in demand for organic products in Canada, the number of organic producers in Canada grew by a mere 2 percent between 2004 and 2014, compared to the US, where a 65 percent increase occurred in the same time (COG, 2017).

The organic and ecological agricultural sector in Newfoundland and Labrador represents a cross-commodity industry with broad agricultural products ranging from vegetables, hay, fruits and berries, poultry, wild crafting, greenhouse production, value added products and non-timber forestry products (ACORN, 2013). The number of certified organic farms has been decreasing in the province, but still both consumers and producers place a high importance on the value of organic production due to health benefits, wellbeing, resource conservation and food security (CBC, 2016; ACORN, 2013). According to Schwabe (2016), many farmers in Newfoundland and Labrador had already used organic production methods starting in 1996 with the support of the Organic Crop Improvement Association (OCIA) of

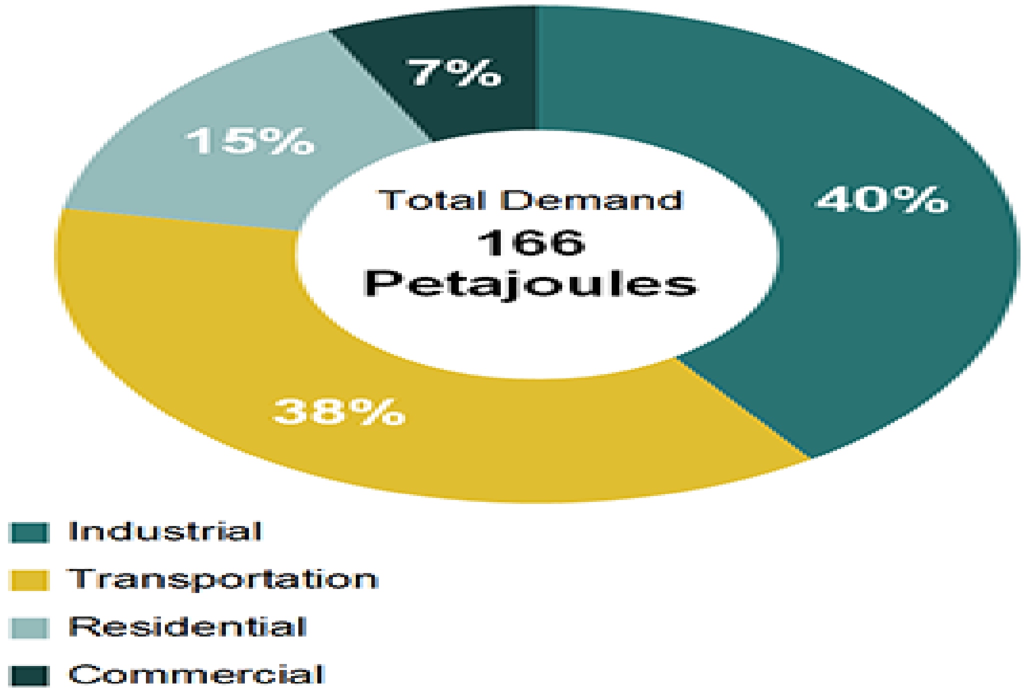
PEI (Prince Edward Island) (Department of Natural Resources, 2013), but presently there are only two farms certified as organic and more farmers are interested in starting the certification process. Development of the certified organic production began in 1996 in NL and since then producers have met unique challenges like high certification costs, perceived difficulties with the certification process, and lack of consistent consumer demand (ACORN, 2013). Growth of the sector requires a robust strategic plan which focuses on government support for certification, professional training, consumer understanding of the term “organic”, new entrants, infrastructure, and marketing, which will greatly assist the sector to take advantages of niche marketing opportunities, expansion efforts, and increased sales and profitability (ACORN, 2013).

4.2.3 Renewable energy

Energy availability is the golden thread that connects health, food production, education, economic growth and the environment and increases social equity. Development is not possible without energy and sustainable development is not possible without sustainable energy, where renewable energy (offshore and onshore wind, solar, geothermal power and tidal power) is considered as a source of clean, secure and sustainable energy (Gaiaeducation, 2019). Though Newfoundland and Labrador is rich in non-renewable energy sources (crude oil and natural gas), geographically it is also a suitable place for producing electricity from renewable energy sources.

As seen in Figure-4.1, the end-use demand of energy in Newfoundland and Labrador was 166 petajoules (PJ) in 2016, which is the 8^{th} largest demand in Canada, and the 4^{th} largest on a per capita basis. This 166 PJ end-use energy came from different sources, such as 102 PJ (62%) came from refined petroleum products, 37 PJ (22%) from electricity, 20 PJ (12%) from natural gas and 7 PJ (7%) from biofuels (National Energy Board, 2018). The industrial sector was the largest consumer of end-use energy and it demanded 40 percent of the total demand, followed by transportation at 38 percent, residential at 15 percent and commercial at 7 percent. It is difficult to find out end-use energy demand for the agriculture sector in Newfoundland and Labrador separately, but the agri-industry, agri-food and agri-product transportation and farm activities need significant amounts of fuel and electricity (National Energy Board, 2018).

Figure-4.1: End-Use Demand by Sector (2016)



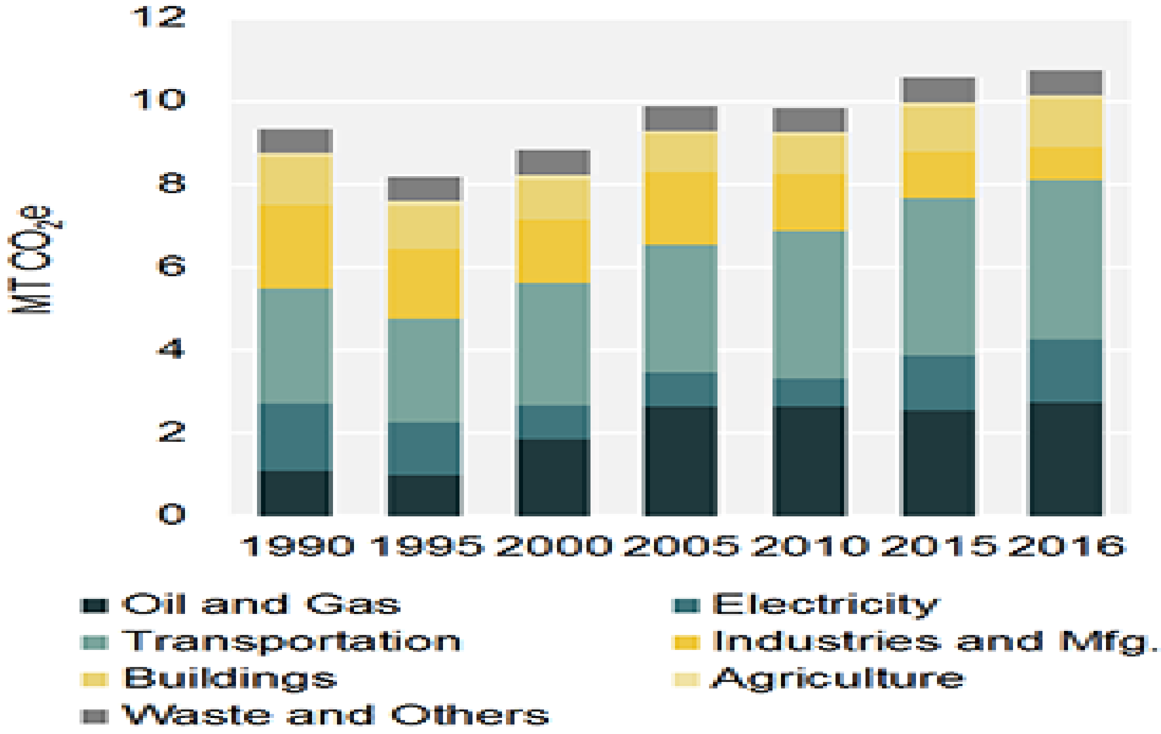
Source: NEB – Canada's Energy Future 2018

In 2016, Newfoundland and Labrador's greenhouse gas emissions were 10.8 megatonnes (MT) of carbon dioxide equivalent (CO_2e) and 20.3 tonnes per capita which is 4.6 percent above the Canadian average of 19.4 tonnes per capita. The major emitting sectors in Newfoundland and Labrador are (Figure 4.2): transportation at 36 percent of emissions, oil and gas production at 25 percent and electricity generation at 14 percent (National Energy

Board, 2018). Crops, vegetables, livestock farms and even greenhouses need petroleum, gasoline and electricity for running their farming activities which also produce greenhouse gases. In 2017, the provincial government has set an emissions reduction target of 10 percent below 1990 levels by 2020, but as of 2016, the province actually emitted 16 percent more over 1990 levels (Mercer, 2019).

The provincial government is in the process of implementing the Muskrat Falls hydro energy development project and aims to close the Holyrood generating station (running on diesel oil) but still the government is not on track to meet its 2020 target. In 2019, the provincial government adopted new emissions reduction targets, aiming to reduce greenhouse gas emissions by 30 percent below its 2005 greenhouse gas emissions level by 2030. The new target is criticised due to failure to achieve the previous target and the non-legislated emissions-reduction targets. More trouble has occurred in 2018, a year prior to publishing a new provincial climate action plan, when the NL provincial government released its "Advance 2030: A plan for growth in the Newfoundland and Labrador oil and gas industry", aiming to double offshore oil production by the end of the next decade (Mercer, 2019). The same report mentioned that the production of 77 million barrels of offshore crude oil was responsible for 1.6 MT of GHS emissions in 2016. If the province would start increasing offshore oil production to 237 million barrels annually, then greenhouse gas emissions from the sector will account for a staggering 4.9 MT annually by 2030, which is 71 percent of the province's new annual emissions target of 6.9 MT in 2030 (Mercer, 2019). The isolated communities in Newfoundland and Labrador which obtain electricity by burning diesel oil use approximately 18 million litres of fuel per year which produces 50,000 tonnes of CO_2 emissions, as well as health challenges, the risks of fuel spills and leaks, and other detrimental impacts (Mercer, 2019).

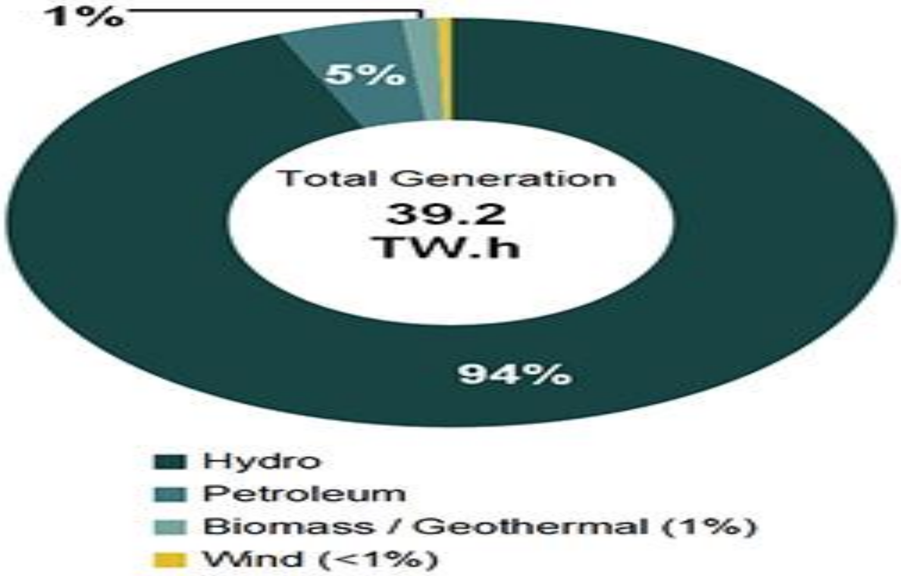
Figure-4.2: Greenhouse gas emissions by sector



Source: Environment and Climate Change Canada – National Inventory Report, 2017

Newfoundland and Labrador is the 5th largest producer of electricity in Canada with 7,717 megawatts (MW) generating capacity. In 2017, 39.2 terawatt hours (TWh) of electricity has been generated by this province, which is approximately 7 percent of total Canadian generation (National Energy Board, 2018). The Figure-4.3 shows that in 2017, Newfoundland and Labrador has generated 94 percent of its electricity from hydro sources, 5 percent from petroleum, 1 percent from geothermal and less than 1 percent from wind.

Figure-4.3: Electricity Generation by Fuel Type (2017)



Source: Statistics Canada (Tables 25-10-0020-01 and 25-10-0019-01), NEB Estimates, 2017

The Upper Churchill Falls hydro generating station is one of the largest power plants in Canada, located in Labrador with 5,428 MW generating capacity. The produced electricity belongs to Hydro-Quebec under a long term contact that will expire in 2041 (National Energy Board, 2018). The Lower Churchill Falls project consists of Muskrat Falls station (824 MW generating capacity) which is projected to run with full capacity by autumn 2020, and Gull Island station (2,250 MW generating capacity), which is expected to be completed three years after the completion of Muskrat Falls (National Energy Board, 2018). Though there are some debates about the massive cost and social and environmental impacts of Muskrat Falls, the provincial government often states that when the Muskrat Falls mega-hydroelectric dam goes online, 98 percent of the province's electricity needs will be provided by renewable energy (Seward, 2018). Newfoundland and Labrador is a significant interprovincial and international net exporter of electricity, as it has exported 28.4 TWh (72%) of produced electricity in 2017. The remaining 10.8 TWh (28%) was consumed by the provincial residential, industrial and commercial sectors.

To mitigate the GHG emissions, the 2018 provincial climate action plan includes eight focus areas with a total of 33 action items. The major shortcoming of this action plan is considered to be the lack of monitoring policy to measure the progress on those action items in order to ensure the initiatives are meeting their goals (Mercer 2019). The provincial government expected that the carbon pricing program introduced in January 2019 will reduce cumulatively GHG emissions by over 0.65 MT between 2019 and 2030 and 1MT from shutting the Holyrood generating station. But considering the current emissions of 10.8 MT, an addition of 3.3 MT from the expanded offshore oil production is expected to raise Newfoundland and Labrador's emissions to 13 MT of GHG emissions, or nearly double the target of 6.9 MT (Mercer, 2019). If the provincial government decides to produce 113 megawatts of wind energy, which would be theoretically capable of displacing the 0.63 MT of GHG emissions produced annually at Holyrood and, at the same time if the Muskrat Falls project will displace 1 MT of provincial emissions annually, the provincial climate action plan has chances to succeed.

Even if the climate action plan seeks opportunities to develop renewable and low-carbon energy (e.g. hydro, wind, tidal, hydrogen and smart grid technology) for local and export markets experts consider that renewable energy development by private sector proponents, community groups, municipalities, education institutions, indigenous governments is prohibitively and deliberately difficult in Newfoundland and Labrador (Mercer, 2019). It is argued that "Newfoundland and Labrador Hydro is the only company permitted to own, supply, distribute, transmit, think about, dream about, or do anything related to renewable energy development in the province" (Mercer, 2019). This study considers that there are untapped into opportunities into the agriculture sector for reducing the GHG emissions in the province, both by keeping the trees standing (through carbon sequestration) and by transitioning from industrial agriculture practices to agro-ecological practices in the farming sector. This study will try to assess the potential of NL farms to contribute to lowering the province's GHG emissions by introducing renewable energy in their operations (use solar/wind energy to run electric tractors, water pumps and for heating cow sheds) and by supplying their farm products locally.

4.2.4 Soil health

To build up a healthy farm ecosystem, soil health is the most significant consideration as agricultural productivity is directly linked to the availability and health of productive soil. Most of the common farming practices employed in industrial agriculture, such as application of synthetic fertilizers and pesticides, monocropping, mechanical tillage, and application of factory farm waste, can degrade soil health over time. Declining soil quality ultimately increases the necessity of man-made inputs, which in turn contribute to climate change (FoodPrint, 2019). The components of soil, like air, water, minerals and organic material, are also vulnerable and damaged due to pollution and industrial farm practices. Monocropping is the practice of growing the same crop on the same plot of land, year after year, which depletes the soil nutrients, reduces organic matter in soil and can cause significant erosion (Dominion Bureau of Statistics, 1945). Soil scientists have demonstrated that monocropping alters the microbial landscape of soil, decreasing the amount of beneficial microbes and causing poor plant growth over time (Forestry and Agri-foods, 2016).

All plants need micronutrients like nitrogen (N), phosphorous (P), and potassium (K) for healthy growth and productivity. In order to fulfil the soil's deficiency in these nutrients, synthetic fertilizer must be applied to boost plant productivity in industrial crop production. Excessive fertilizer use can cause soil acidification, build-up of salts in the soil, heavy metal contamination and accumulation of nitrate, and also can contribute to climate change and to water pollution through the release of N_2O (Adams, 2014; Department of Fisheries and Aquaculture, 2001).

Some pesticides are toxic to human health and can escape into the environment after application and some kill nearly all soil organisms – not just the harmful ones – including beneficial bacteria, fungi and other organisms that help maintain healthy soils (Newfoundland and Labrador Statistics Agency, 2017; MMSB, n.d.). Mechanical tillage and the use of heavy farm equipment can cause both soil compaction and soil erosion where compaction leads to poor water absorption and poor aeration which further leads to stunted root growth in plants and smaller yields. Additionally, topsoil erosion leads to loss of natural nutrients and organic materials which further leads to increased susceptibility to drought and flood (Steiner, 1924; Demeter, 2016).

Local, small-scale farms owned and operated by rural families were perceived as backward and superseded for the future of farming and food provision in the Newfoundland and Labrador, and were actively discouraged (Cadigan, 1998). This type of decentralized and family owned farming was actively discouraged by successive governments in the past, in an attempt to centralize production and assist in government regulation of industrial agricultural activities (Cadigan, 1998). Though the centralization of agriculture and the practice of industrialized farming methods were considered more efficient for bringing economies of scale, in fact industrial agriculture is not well suited to NL conditions due to soil acidity, stony soil, rocky topography, lack of soil availability, lack of readily available inputs , as well as climate variability (Forestry and Agri-foods, 2017). It is challenging to collect and use natural and appropriate farming inputs in an unforgiving landscape, with short growing seasons and a punishing climate (Evans, 2017). The issue is also complicated by the food insecurity in the province. Studies show that if no food is being imported into the NL province due to disruption of marine ferry service or in air transportation, the food security ranges only few days (Quinlan, 2012). Newfoundland and Labrador government is trying to focus on finding additional productive soils, improving their productive capacity and therefore increase crop yield. This can be done, according to experts by producing and enhancing soil in the most effective and non-harmful way for the sake of both human health and of the surrounding environment. A study done in NL has found that integrated and traditional alternative approaches to soil development and food production may not achieve the economies of scale or surplus crop productivity (Evans, 2017, p.9, pa. 2) but these means have been linked to increased sustainability and overall resilience of food production systems around the world (Gliessman, 2015).

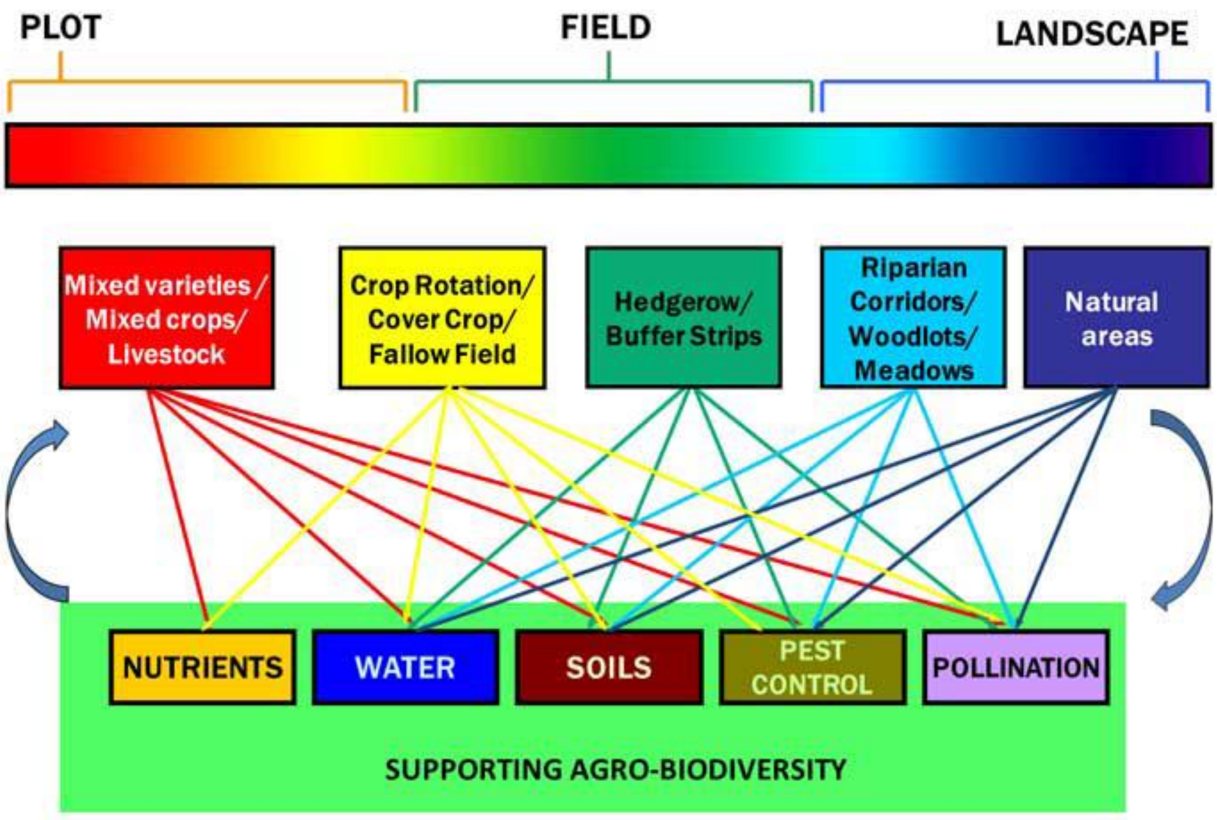
Traditionally, fishery discards, seaweed, and peat were added to the soils in NL for supplementary farming (garden plots and integrated animal husbandry operated by families) that helped to increase the productivity of the soils found in many outport communities (Hynes, 2009). Seaweed is readily found throughout coastal NL and is a cheap and effective source of essential nutrients for use in compostable soil improvement and to neutralize soil acidity (Adams, 2014; Food First NL, 2012). Though seaweed can be used as a natural fertilizer, the dried seaweed placed directly on top of soils around the ornamental plants or crops, would act as an effective natural deterrent for garden pests such as slugs, ants, or other nuisance insects (Adams, 2014). Traditionally, shellfish, fishery discards, including undesirable portions of fish, such as cod heads and other offal, as well as fish spines and backbones provided an important set of nutrients, calcium, as well as biologic activity for the organic breakdown within soils to make nutrients more available to plants (Evans, 2017). This practice should be continued in NL farming activity, though the Environmental Protection Act (2002) and most compost and garden management guidebooks suggest avoiding composting of fish and fish bones due to concerns over odours, flies, and attracting animals such as bears, vermin, and other nuisance animals. Recently, the waste management strategy has been reviewing after 16 years and now, it does not provide any regulations for composting in the province (Government of Newfoundland and Labrador, 2019). This study considers that NL is rich in peat moss and peat bog land that has the suitable properties for decomposition of fish waste, in its natural ability to absorb odours associated with decomposition, as well as the absorption of ammonia odours when mixed with manure (Johnson, 2018). Traditional supplementary family farms, were producing chickens, cows, cattle, horses, sheep, goats and pigs that were not only sources of protein but also important sources of fertilizer, in the manure that they generated. Obviously, not everyone in NL has convenient access to the ocean or peat land resources for gathering natural inputs and conventional farming and soil properties in this province require using synthetic fertilizers. However, still there are ample opportunities to use organic/natural fertilizers in small, medium as well as large farms in this province.

4.2.5 Diversified farming systems

Developing a Diversified Farming System (DFS) is one of the agro-ecology principles which can contribute to creating a more sustainable, socially just, and secure global food system (Kremen and Miles, 2012; Claire, Iles and Bacon, 2012). DFS are defined as farming practices and landscapes that deliberately include certain combinations of traditional and contemporary knowledge, functional biodiversity, cultures, practices, and governance structures at multiple spatial and/or temporal scales. By maintaining ecosystem services, DFS provide critical inputs to agriculture, such as soil fertility, nitrogen fixation, nutrient cycling, pest and disease control, water use efficiency, and pollination, thereby achieving a more sustainable form of agriculture that relies primarily upon inputs generated and regenerated within the agro-ecosystem, rather than on external or often non-renewable inputs (Pearson, 2007; Shennan, 2008; Claire, Iles and Bacon, 2012; Zhang et al. 2007).

At the plot and field scales, the DFS may include polycultures, non-crop plantings on field borders such as living fences and hedgerows, integration of livestock or fish with crops, and/or rotation of crops or livestock over time, including cover cropping and rotational grazing. At the landscape scale, DFS may incorporate natural or semi natural communities of plants and animals within the cropped landscape/region, such as fallow fields, pastures, riparian buffers, meadows, woodlots, peatbogs, ponds, streams, rivers, and lakes or combinations thereof and these heterogeneous landscapes support beneficial components of agrobiodiversity (Perfecto et al. 2005).

Figure 4.4 Conceptual model of a Diversified Farming System



Source: Claire, Iles and Bacon, 2012

Figure 4.4 shows DFS practices across different agro-ecological scales. The plot scale (red) includes multiple genetic varieties within a single crop or livestock species, or multiple species intercropped, including agroforestry, and/or integration of livestock. The field scale (yellow) incorporates crop rotations, cover cropping/green manuring, or fallowing. The field perimeter scale (green) practices planting of hedgerows or grassy buffer strips around crops. The landscape scale (light and dark blue) includes woodlots, meadows, pastures, riparian corridors and other natural and semi-natural habitants in the cropped area. These heterogeneous farming practices promote critical ecosystem services, such as nutrient and water cycling, soil formation, pest and disease control and pollination (Claire, Iles and Bacon, 2012).

Canadian farms provide a diverse range of crops and livestock for domestic and international markets. There are literally hundreds of crops being grown in open fields and greenhouses across the country – from more traditional crops like wheat, corn and soybean to pulses, fruits and vegetables, flowers and specialty crops. Thousands of farmers in Canada produce a wide variety of animals on their farms such as chickens, turkeys, laying hens, beef cattle, dairy cows, sheep, goats, horses, pigs etc. (Schaer, 2014). The NL agricultural industry, which is narrowly specialized in producing milk, eggs and poultry, faces challenges in striving to grow and diversify due to climate change uncertainties, short growing seasons, soil quality, bio-security risks, and consolidation of the food industry. But a diversified farming industry is of vital importance to this province for its food security, income and employment generation and environmental sustainability. Farmers in this province can adopt the model of DFS, as they can have access to areas of farming land at affordable price for producing crops, vegetables, livestock, fruits, milk and growing trees surrounding the field. Open water sources like rivers, lakes or streams are also available, where farmers can farm fish to meet the family food demand and can sell the surplus fish in local markets.

In conclusion, to solve the problems of food insecurity and climate change and to reduce the environmental impacts of industrial agriculture, agro-ecological practices are one of the most effective ways. Applying Indigenous knowledge in farming practice, using renewable energy in farm production, applying organic fertilizers to the soil instead of lime and chemical fertilizers and adopting a diversified farming system can help to grow the NL food industry in a sustainable manner.

Chapter V

General Characteristics and Practices of Crop Farms Surveyed

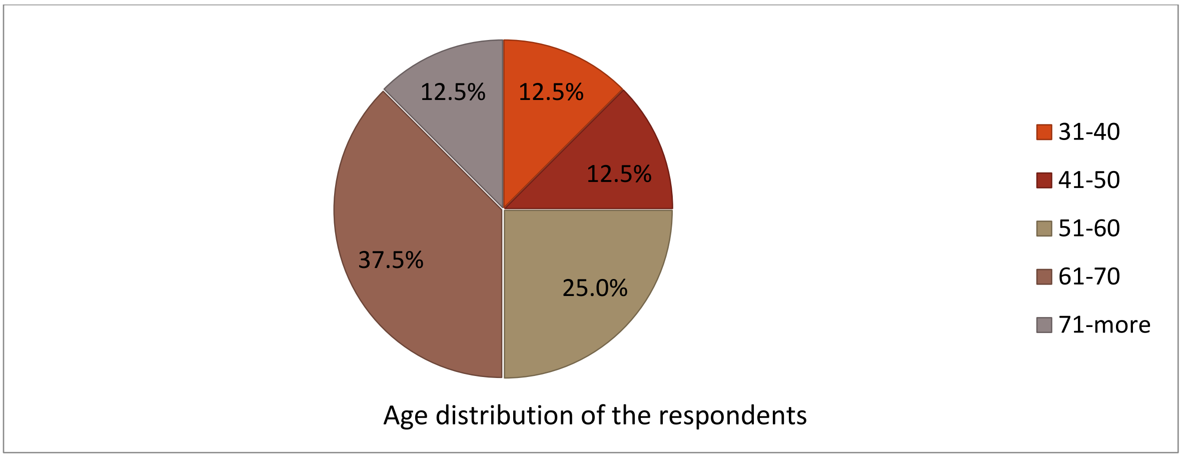
The number of farms is decreasing in Newfoundland and Labrador province due to climate change impacts, shortage of labor force and the ageing of the farmer population (Quinlan, 2012; Abdulai, 2018). The evidence of climate change can be seen all over the world but because of its geographic location, the climate change impact is more acute in this province. Due to poor soil quality, short growing seasons, and diminishing number of farms in operation, only 10 percent of the provincial food is supplied by the local farmers (Fitzpatrick, 2017). The small amount of local food production and the uncertainty of imported food supply due to inclement weather or unreliable ferry service have made this province suffer from food insecurity and unsustainable development. This chapter discusses the impact of climate change (natural hazards) on crop production, and the effects of agricultural activities on climate, as revealed by the primary data collection during this study.

5.1 General features of the respondents and farms

5.1.1 Age distribution of the respondents

Figure 5.1 has shown that 12.5 percent of the respondents' age is less than 40 years, whereas the same percentage of respondents' age is more than 71 years. At the same time, 37.5 percent of the respondents' age is between 61 to 70 years. This indicates that most of the respondents are going to retire very soon. Existing published data have shown that in 2016, 58.2 percent of farm operators' age is 55 years or more and 36.9 percent of farm operators' age is between 35 to 54 years in NL (Statistics Canada, 2017).

Figure 5.1: Age distribution of the respondents as surveyed

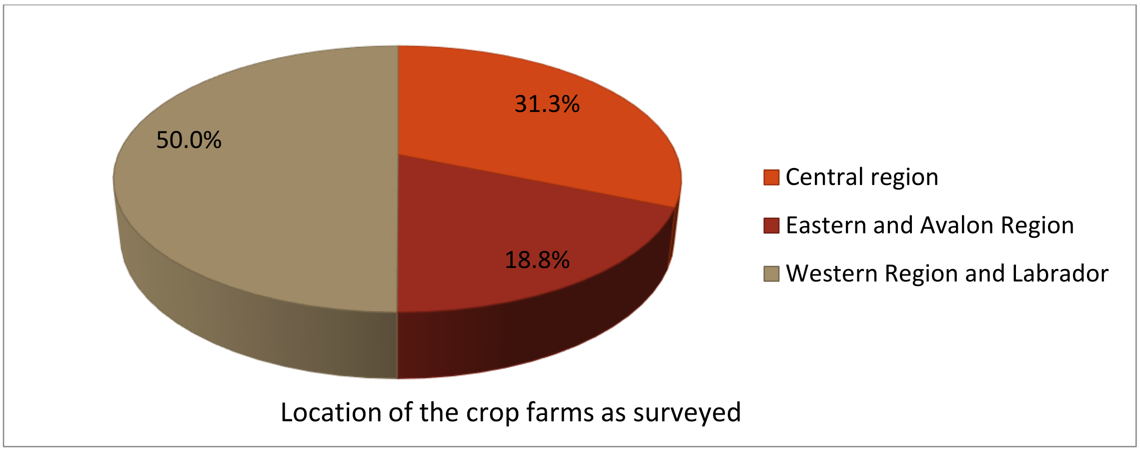


The percentage of mid-age respondents is very small as 25 percent between 51 to 60 years old and 12.5 percent are between 41-50 years old. A published report has shown that the average age of the farmers in this province is 55, and it is a great challenge for this province to increase food production from 10 percent to 20 percent working with so many senior people who have plans to quit farming (Bird, 2018).

5.1.2 Location of the farms surveyed

According to the Newfoundland and Labrador Farm Guide 2016, the province is divided into three regions, namely Eastern and Avalon region, Central region and Western region and Labrador, depending on the intensity of farming. This study has followed the simple random and snow balling sampling methods and it has found that 50 percent of the surveyed respondents from the Western region and Labrador, an area which is renowned for agriculture farming (Figure 5.2). The Eastern and Avalon region is also famous for farming, but only 18.8 percent of the respondents come from this region while 31.3 percent of the respondents are from the Central region (Gander, Grand-Falls-Windsor, Campbelton etc.).

Figure 5.2: Location of the crop farms surveyed



5.1.3 Age of the farm as identified by respondents surveyed

In Newfoundland and Labrador most of the farms are family farms operated by family members, generation after generation. The survey data has shown that 50 percent of the farm age is less than 20 years. This means that the farms are very young and have a chance to increase the size of operation. There are few farms (6.25%) which have been operating for more than a half century, whereas 18.75 percent of the farm's age is between 31 to 40 years (Table 5.1)

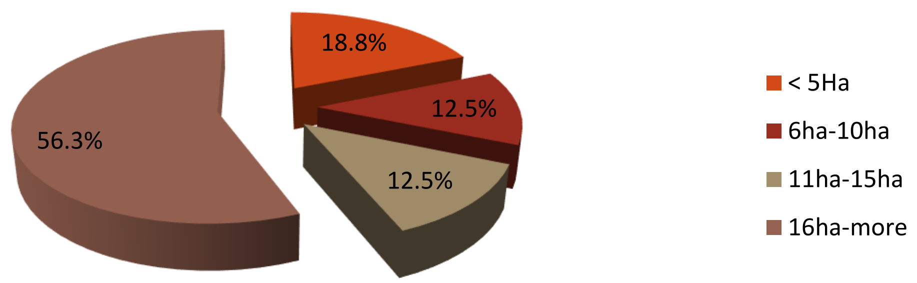
Table 5.1 Year of farming as identified by respondents

Range of years of farming	Percentage of respondents
1-10	25.00%
11-20	25.00%
21-30	12.50%
31-40	18.75%
41-50	12.50%
51-more	6.25%
Average years of farming	26.19

5.1.4 Size of surveyed farm

Though the number of farms is decreasing, the average size of farms is increasing in the province (Statistics Canada, 2017). The survey has shown that 56.3 percent of the farms have more than 16 ha of crop land (they are relatively large) whereas 18.8 percent of the farms have less than 5 ha (they are relatively small). There are only 12.5 percent of the farms with an area between 6ha to 10 ha and the same percentage for the farms with an area between 11ha to 15 ha (Figure 5.3).

Figure 5.3: Farm size as identified by respondents



Farm size as identified by respondents

5.1.5 Greenhouse, livestock, size of production and small scale farming

Greenhouses are very important for germination before starting the planting season and for producing vegetables all the year round, especially for Newfoundland and Labrador due to long winters, heavy snow and high winds. Greenhouses also give producers the chance to create their own growing environment to protect crops from a host of pests and diseases, extreme weather conditions and outdoor pollution such as pesticides drift (Industries Harnois, n.d.). According to Agriculture and Agri-Food Canada (2017), Newfoundland and Labrador province had 5,900 square meters of greenhouse space in 2017, but the area is very small compared to Ontario, Quebec and British Columbia provinces. The survey found that 50 percent of the respondents in the study area have greenhouses with an average size is 347.11

square meters (Table 5.2). Greenhouses are the best solution for organic farming, as they are giving the producers complete control over climate, organic fertilizers and equipment management (Industries Harnois, n.d.). As a part of integrated farming (DFS), the crop farm respondents have been asked about livestock farming and 43.75 percent of the crop farmers have mentioned that they have also livestock for tourism as well as commercial purposes. To understand the future food production and supply form of the local crop farms, the researcher asked two questions about the action farmers had taken in the last five years and the action they will take in the near future. To response on these questions, 62.5 percent of the crop farmers increased the size of production in the last 5 years and 50 percent of the crop farmers have plan to increase farm operation in near future. More importantly, 75% of respondents think that there are advantages in small-scale farming since they can manage them more efficiently and effectively.

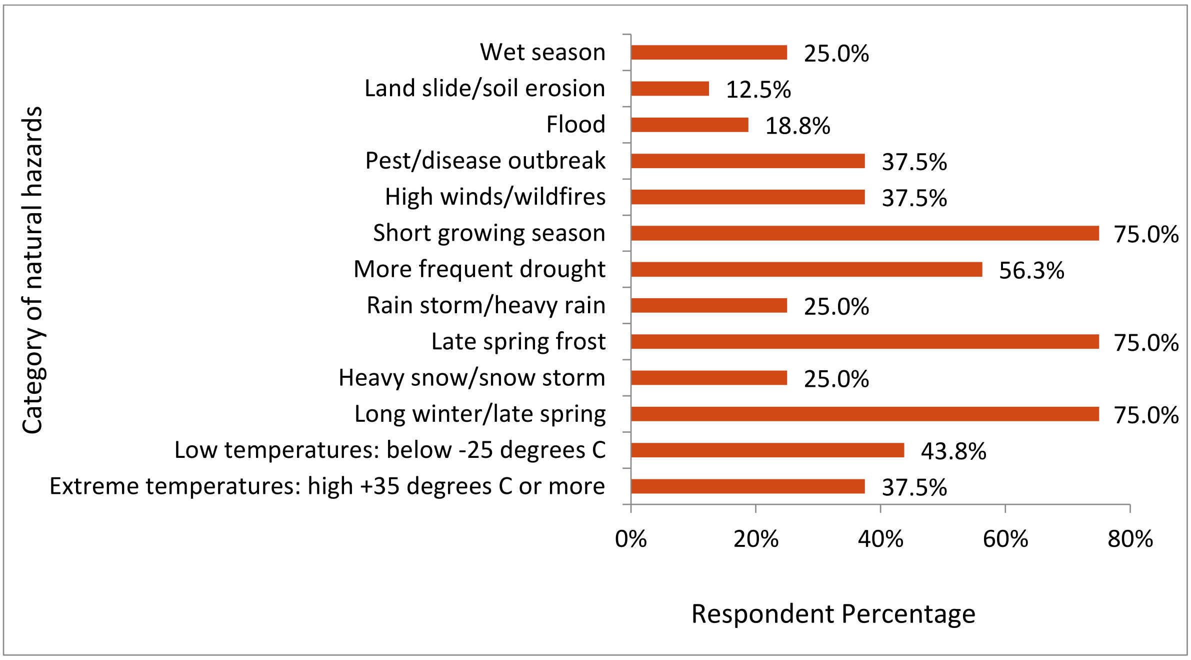
Table 5.2: Greenhouse, livestock, size of production and small scale farming

Additional farm practices and plans	Percentage
Do you have greenhouse on your farm?	50%
Average area of greenhouse (square meters)	347.11
Do you raise livestock on your farm?	43.75%
Did your farm increase the size of production in the last 5 years?	62.50%
Do you have plans to increase the size of production in near the future?	50%
Do you think that there are advantages in small scale farming?	75%

5.2 Impacts of climate change on crop farming in Newfoundland and Labrador

Newfoundland is an island where snow fall exists around 5 to 6 months (from early November to end of April) with frequent snow storms or heavy snow. Figure 5.4 has shown that 75 percent of the farmers indicated that short growing seasons or long winters and late spring frost are the major natural calamities that affect the crop production and farm activities. Because of increasing global temperatures, 37.5 percent of respondents have shown that they are facing high temperatures (like +35 degree Celsius or more) and 56.3 percent of respondents complained about more frequent drought. Some farmers have installed new water pumps, whereas other farmers have used more water for irrigation which increased their production cost.

Figure 5.4: Natural hazards affecting crop production as identified by farmers surveyed



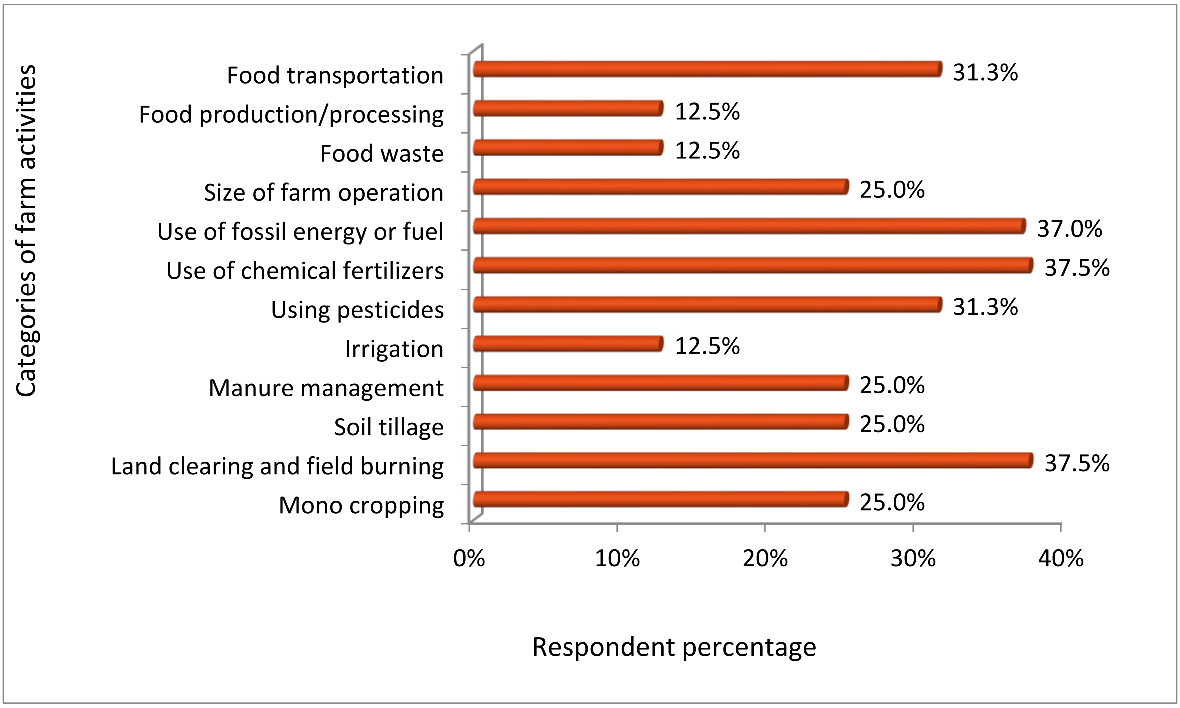
The field survey has shown that 43.8 percent of the farmers identified that low temperatures (like below -25 degree Celsius) have had a bad impact on agricultural activities, especially in greenhouse production in the winter season as they need more energy for heating. More frequent rain or rain storms are related to the wet seasons and both of these natural hazards destroy vegetables and crop fields as mentioned by 25 percent of the farmers. New types of pests or diseases outbreaks have been indicated by 37.5 percent of the farmers and they have explained that high temperatures are the cause of spreading new pests and diseases.

5.3 Agricultural activities contributing to climate change in Newfoundland and Labrador

Agricultural production systems or farm activities (both small scale and large scale) have a contribution to greenhouse gas emissions and climate change. From the beginning of land preparation to the food processing and transportation, greenhouse gases are emitted in the environment in different ways. The survey results show that 43.8 percent of respondents believe that large scale or industrial farming practices are contributing to environmental degradation and climate change (Appendix A, Table A-2). Generally, using fossil fuels, chemical fertilizers and land clearing and field burning activities are producing CO_2 and N_2O emissions and for each case 37.5 percent of the farmers responded in the affirmation on these issues. Figure 5.5 has shown that 31.3 percent farmers have indicated that using chemical pesticides is harmful for water, air and soil, which are the major and basic elements of the environment. It is a good sign that 50 percent of the respondents (Appendix A, Table A-4) mentioned that they are trying to apply alternative methods (instead of using chemical pesticides), such as intensive farming, organic pesticides, bio-control, sterile insect techniques, spreading sawdust and "no insect no spray" strategy (Appendix A, Table A-5). Land tilling and food transportation systems are the largest contributors to greenhouse gas emissions, and 31.3 percent of the respondents indicated that using fossil fuels by farm machineries and food transportation vehicles enhances carbon emissions and climate change. Large farm size and mono cropping are related to industrial farming systems which are the major contributors to climate change as mentioned by experts and previous reports (Gliessman, 2015). Only 25 percent of the respondents (Figure 5.5) of the study area identified these two practices as causes of climate change. The reason of this poor response is that 56.3 percent of the respondents of the survey area thought that industrial agricultural production systems do not produce too much greenhouse gases, if they also follow the best management practices on their farms. Soil tilling and manure management were indicated by

25 percent of the respondents as the sources of climate change. According to the survey report, food processing, irrigation systems and food waste have been identified by few respondents (12.5% for each) as a source of greenhouse gas emissions and climate change.

Figure 5.5: Agricultural activities contributing to climate change as identified by respondents

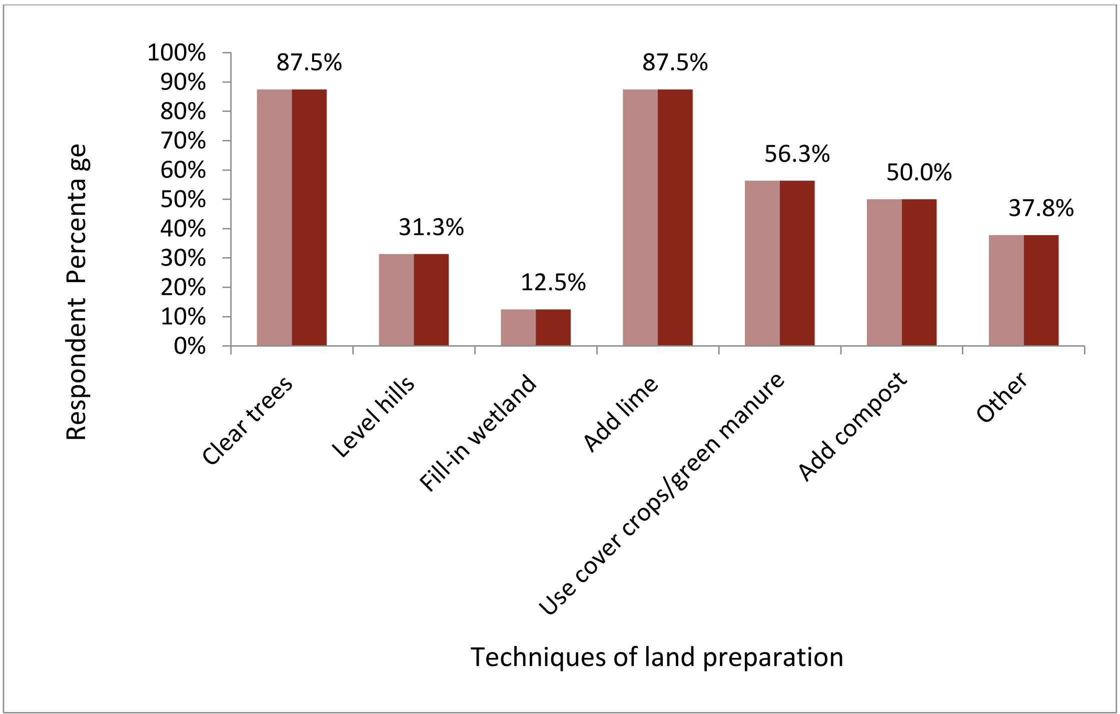


5.4 Agro-ecological principles followed by the NL farmers surveyed

5.4.1 Land preparation

A soil survey report describes Newfoundland's landscape as a mixture of bogs, hills, barrens, outcrops, rock, water bodies and mineral soil. The Newfoundland soils are mostly acidic, stony and have firm to compact sub-soils, except for the natural vegetation, elevated ridges, river terraces and coastal lowlands where the soils are suitable for agricultural use (Forestry and Agrifoods, 2017). Most of the interior barrens are surrounded by boreal forest which is characterized by dominantly coniferous species and broad leave deciduous trees. To prepare land for cultivation, 87.5 percent of the respondents clear trees, while 31.3 percent level hills and 12.5 percent fill-in wetlands (Figure 5.6). Therefore, agriculture is responsible for losing trees or even forest area in this province. Loss of forests and trees is a major contributor to greenhouse gas emissions and increases the speed of climate change. Forests are the best carbon sequesters but when people cut trees, they release into the atmosphere all the carbon they have been storing which is dangerous for the environment. Leveling hills has a bad impact on the ecosystem since it increases the soil erosion, landslides and it decreases soil fertility. Deficiency of nutrients and minerals and imbalance of pH are the general limitations of the soils of NL and due to this reason farmers need to apply external inputs. The survey found that 87.5 percent of the respondents apply agricultural lime to neutralize the soil's pH in order to enable the plant growth, whereas 56.3 percent and 50 percent use green manure and compost respectively to improve soil health. Though 68.8 percent of the respondents (Appendix A, Table A-1) have expressed their opinion that over application of lime is not good for soil health or for the environment, not a single respondent uses the traditional fertilization techniques like applying fisheries discards, seaweed and peat moss to improve and maintain the soil health.

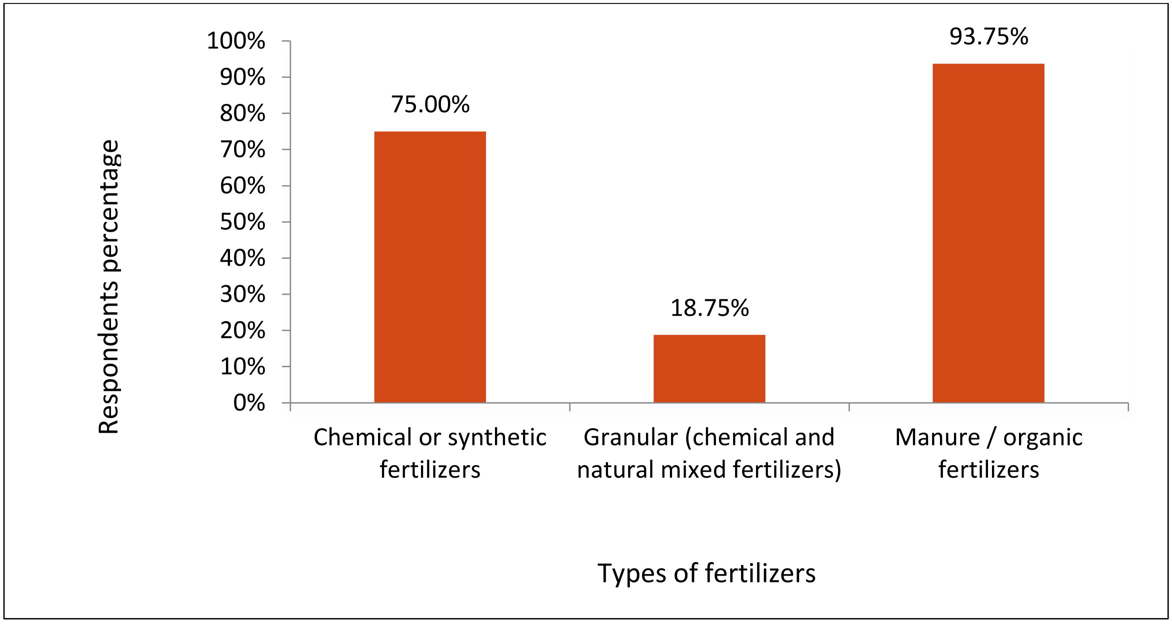
Figure 5.6: Land preparation techniques as indicated by respondents surveyed



5.4.2 Use of chemical, organic and mixed fertilizers

In order to maintain the appropriate composition of Nitrogen (N), Phosphorous (P) and Potassium (K) in the soils, 75 percent of the respondents use chemical or synthetic fertilizers such as urea, phosphate and potash. Most of the respondents use prescribed N-P-K ratios, like 14-13-13, 20-20-20 or 30-10-10, depending on early plant nutritional needs, soil test results, as well as natural nutrient sources of N-P-K, as it is a fundamental component to minimizing harmful environmental effects and getting desirable growing results. Considering the harmful effects of chemical/synthetic fertilizers, 43.8 percent of the respondents are trying to use less chemical fertilizers and more granular and organic fertilizers (Appendix A, Table A-3). The survey has found that 18.75 percent of the respondents use granular (chemical and natural mixed fertilizers) for getting better growing results and reducing the environmental impacts. It is a good sign that 93.7 percent of the respondents (Figure 5.7) are applying manure or organic fertilizers to inject essential nutrients back into their depleted soils stock. The respondents didn’t mention any proper method of applying manure in their fields, as it is known that over application (more than 10,000 gallons/acre liquid swine effluent) or too frequent applications have serious environmental effects and also reduce the crop yield (Government of Saskatchewan, 2019). The surface run-off manures, and the impending danger to pollute water bodies with poisonous pathogens such as E.coli, or nutrient overfilling of the water column in general, can pose serious risks to the natural and the human environment (Gliessman, 2015; Evans, 2017).

Figure 5.7: Response of farmers surveyed concerning use of chemical, organic and mixed fertilizers



The application of chemical and organic fertilizers depends on anticipated crop nutrient requirements, soil test results (nutrient already available in the soil) and variability of nutrient content and form of the fertilizers. Over and improper application of chemical fertilizers and manure may increase the risks of nutrient losses to the environment, lead to deterioration of environmental quality and sometimes reduce the crop yield (Government of Saskatchewan, 2019). Therefore, it is difficult to compare the recommended doses with doses applied by respondents because of difference in soil quality and nutrient requirements. Table 5.3 shows that small size farms (<5ha) use less chemical as well as manure compared to the recommended doses, but as the farm size increases (6ha-10ha) respondents use more chemical fertilizers (on average 7,762kg/year) compared to the recommended range (1,859.22kg/6ha/year to 3,098.70kg/10ha/year). The results were similar where farm size is 11ha -15ha and 16ha and more. All farmers use less manure compared to the recommended doses, as the use of manure depends on availability of manure from their livestock farms.

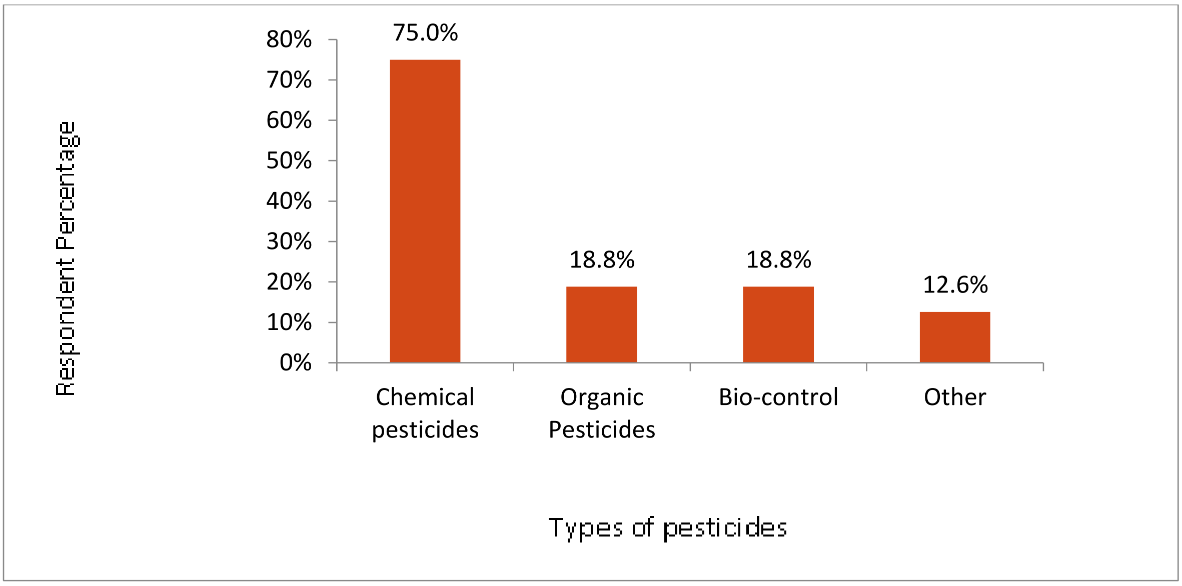
Table 5.3: Average amount of fertilizer as applied by respondents

Farm Size	Use of average chemical fertilizer (kg/year)	Recommended dose (kg/ha)	Use of average manure (kg/year)	Recommended dose (kg/ha)
<5ha	540.00	1,549.35kg/5ha	16,666.67	189,500kg/5ha
6ha-10ha	7,762.00	1,859.22kg/6ha - 3,098.70kg/10ha	50,000.00	227,400kg/6ha-379,000kg/10ha
11ha-15ha	9,750.00	3,408.57kg/11ha - 4,648.05kg/15ha	16,000.00	416,900kg/11ha-568,500kg/15ha
16ha and more	16,722.22	4,957.92kg/ha-	140,000.00	606,400kg/16ha-
Correlation value	0.948	-	0.821	

5.4.3 Use of different pesticides to control pests or diseases

Most of the respondents (75%) of the survey area use chemical or synthetic pesticides to control pests or diseases. Normally, the NL farmers need to use fewer pesticides because of the cooler climate of this province, and as evidence, a report showed that NL has one of the disease free bees populations in the world (The Way Forward on Agriculture 2018). Very few respondents (18.8% of each) use organic pesticides and bio-control methods to protect crops and vegetables from pests attack. Figure 5.8 shows that 12.6 percent of the respondents use safer soap or sawdust to control pests. It is good news that very few respondents noticed new types of pests (12.5%) and diseases (6.25%) on their farms in the last couple of years (Appendix A, Table A-6 and A-7). To minimize the harmful effects of pesticides use on the environment, 50 percent of the respondents are trying to use alternative ways to control pest attacks like the integrated pest management (IPM) system, intensive farming, the sterile insect technique (SIT), best management practices and the “no insect no spray” technique (Appendix A, Table A-4 and A-5).

Figure 5.8: Response of the farmers surveyed concerning use of pesticides



5.4.4 Fuel and electricity consumption and use of alternative sources of energy

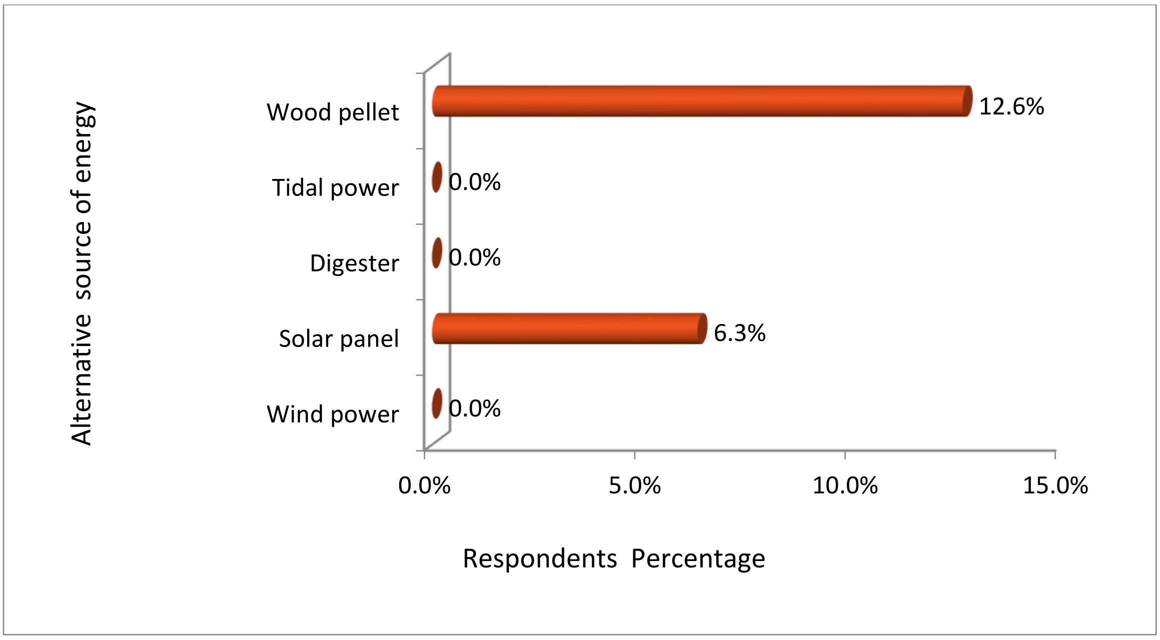
Fossil fuels and electricity are important inputs to run the agricultural production, processing and transportation. Newfoundland and Labrador' agriculture is heavily mechanized due to shortage of skilled and experienced labor force and large farm operation (Canadian Agricultural Human Resource Council, 2014). Table 5.4 shows that small size farms (area <5ha) use 4,166.67 gallons of fossil fuels and pay CAD $3,633.33 as electricity bills per year for farm operation. As the farm size increases (16ha and more), use of fossil fuels (18,655.55 gallons) and electricity cost (CAD $6,277.78) also increases. To find out the correlation between farm size and fuel consumption and electricity cost, this study uses the upper limit of farm size. The correlation coefficient of fuel consumption and farm size is 0.766, which indicates a positive strong but insignificant relation between the two variables. There is a positive strong and significant relation between the farm size and electric cost, as the correlation coefficient value is 0.926 (Table 5.4). Therefore, the use of fuel as well as the electricity cost will increase with increase of the farm size.

Table 5.4: Yearly use of fuel and cost of electricity as identified by respondents

Farm Size	Yearly average use of fuel (gallon)	Yearly average electricity bill ($)
<5ha	4,166.67	3,633.33
6ha-10ha	1,550.00	4,200.00
11ha-15ha	4,000.00	4,500.00
16ha and more	18,655.55	6,277.78
Correlation value	0.766	0.926

It is expected that around 95 percent of electricity will be produced from hydro power in NL province once the Muskrat Falls hydro project is operational, which is less harmful for the environment. Though respondents know that burning fossil fuels produces greenhouse gas emissions, but they have no alternatives to fossil fuels. Wood pellets are used by 12.6 percent of the respondents, but their burning also produces black carbon which is a major contributor to global warming (Drouin, 2015). Very few (6.3%) percent of the respondents use solar panels for a renewable source of energy, but no one uses digesters and tidal or wind power. But the geographic features of this province indicate that there is a great opportunity to use tidal and wind power for producing renewable energy (Mercer, 2019).

Figure 5.9: Alternative sources of energy as identified by respondents



5.4.5 Water use for irrigation and alternative sources of water

To incrase agricultural productivity levels and achieve food security, efficient and efeective water management is essential (IFPRI, n.d.), as it can reduce the negative effects of irrigation on the hydrologic cycle,goundwater level and the environment. Due to high temparature and frequent drought, the farmers of NL use more water than before. Some respondents have installed new water pumps, whereas others have a plan to develop irrigation infrastructure. The survey indicates that the medium size farms (6ha-10ha) use much more water (20,473,200 liter/per year) than larger size farms(11ha to 15ha) (525,000 liter/per year). The explanation for the high amount of water used might be that there is a cranberry farm in the study area which needs huge amounts of water (Table 5.5). There is a positive but insignificant relation between farm size and water use as the correlation coefficient value is very low at 0.162.

Table 5.5: Yearly use of water as identified by respondents

Farm Size	Yearly average use of water (liter)
<5ha	291,666.67
6ha-10ha	20,473,200.00
11ha-15ha	525,000.00
16ha and more	4,972,222.22
Correlation coefficient value	0.162

Considering the negative effects of using ground water for irrigation, experts suggest to use surface water which is more environmentally friendly (Lamm, 2002). The respondents indicated that 56.3 percent have access to natural surface water sources like streams, rivers, and lakes (Figure 5.10). The survey also indicated that 37.5 percent of the respondents collect rain water to use for irrigation purposes. Very few respondents (6.3%) recycle their household water for reusingit on thefarm.

Figure 5.10: Collection of rain water, use of natural surface water sources and recycling household and farm water, as identified by respondents

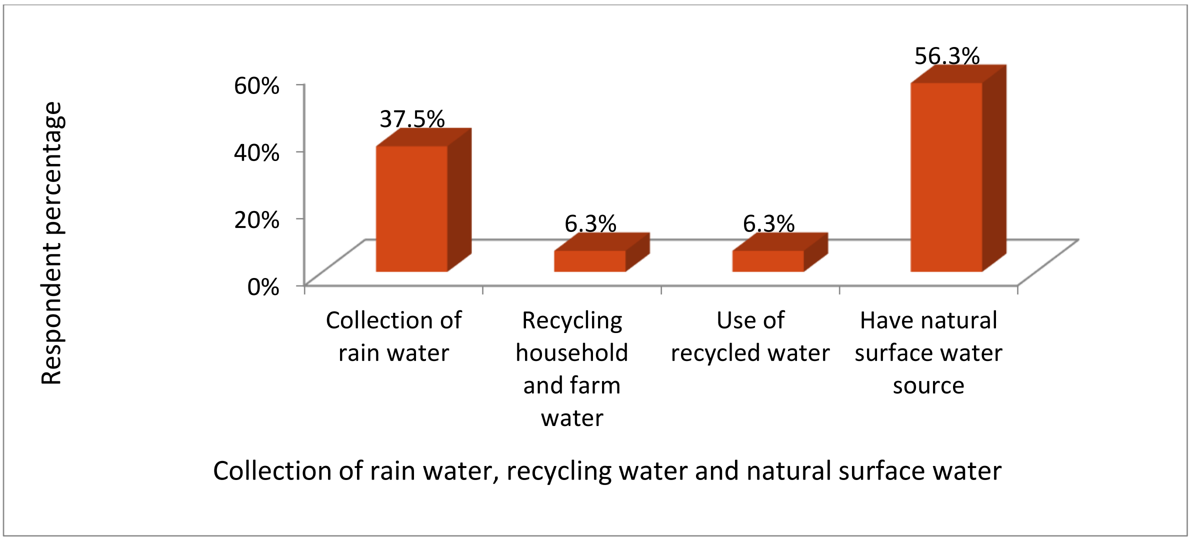
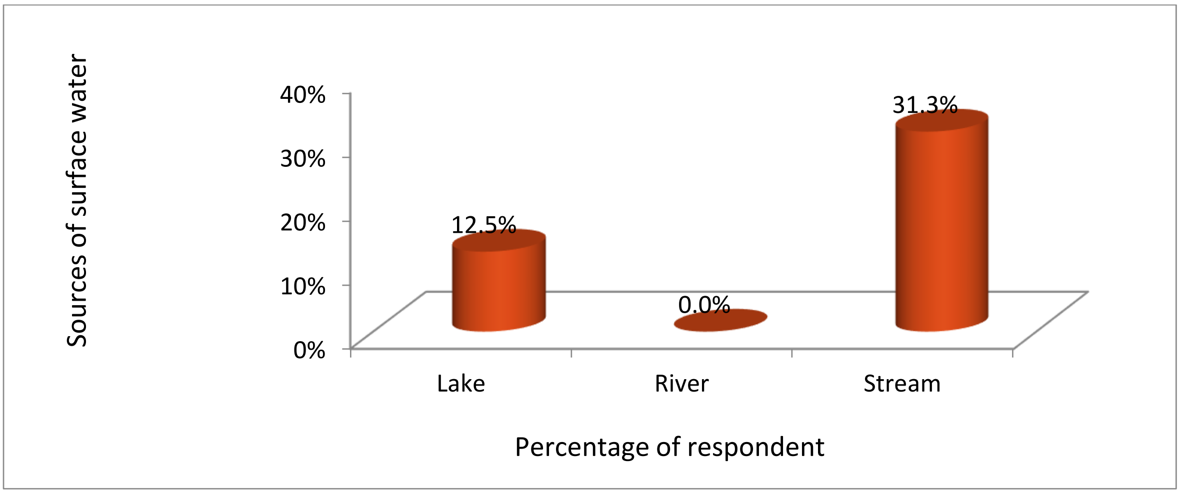


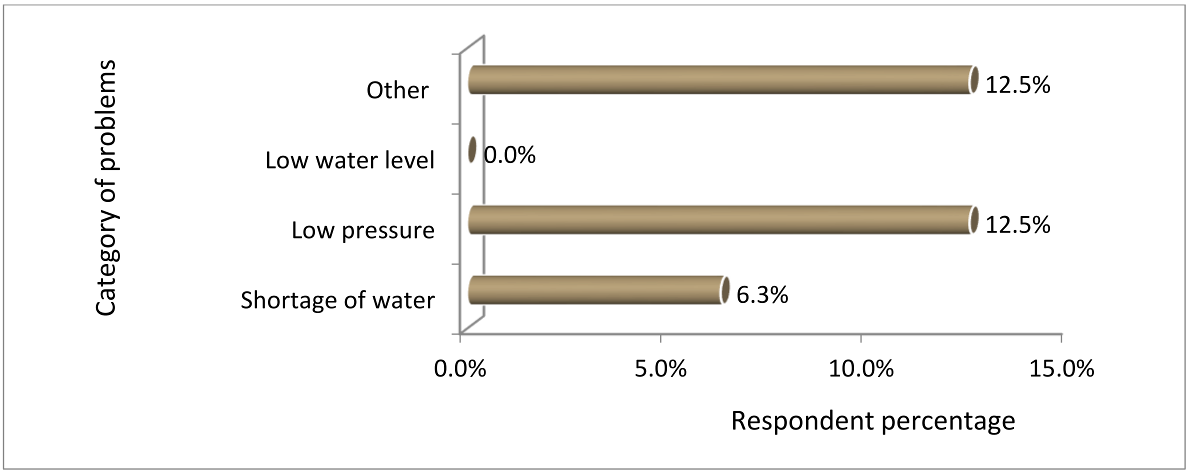
Figure 5.11 shows that 31.3 percent of the respondents have access to streams as a natural surface water source, whereas 12.5 percent use a lake for water supply. Though there are some natural surface water sources, very few respondents use the water for irrigation.

Figure 5.11: Category of natural surface water used by farmers surveyed



The respondents in the study area do not face serious problems with water for irrigation because of sufficient rainfall in the summer season. Moreover, sometimes heavy rains or rain storms destroy the crop fields. The survey indicates that more recently 12.5 percent of the respondents face low water pressure in the pump, whereas another 12.5 percent face other problems, like money shortage for developing/digging wells and no access to open water bodies near the farm (Figure 5.12). Because of the droughts or high temperatures 6.3 percent of the respondents face water shortage during the crop production season.

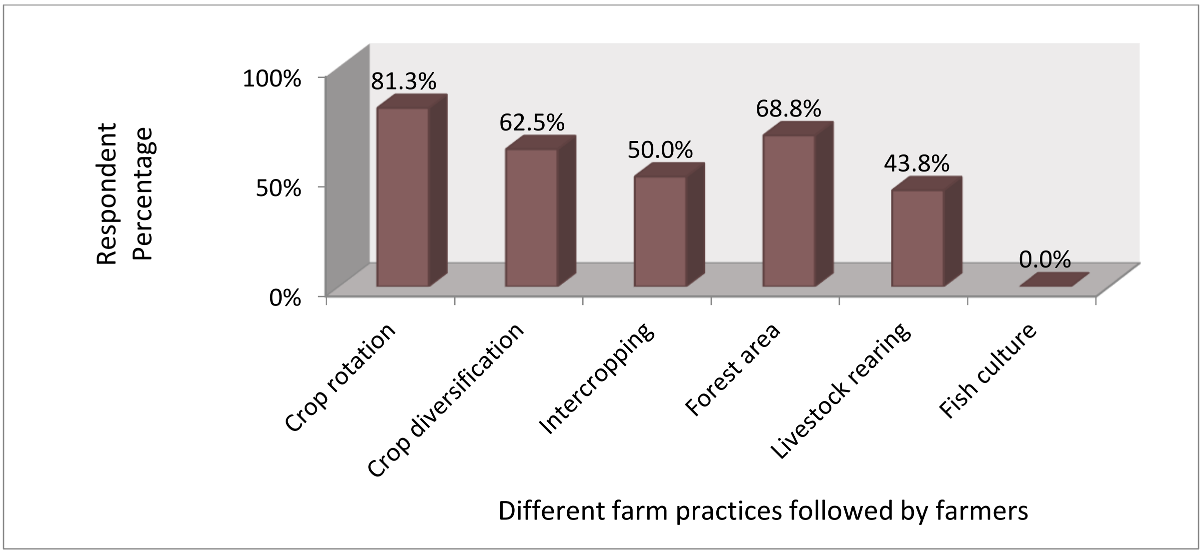
Figure 5.12: Irrigation problems as identified by farmers



5.4.6 Diversified farming practices in the NL province

Diversified farming systems are one of the important principles of agro-ecology farm practices that help to maintain ecosystem services and ensure farmers' income and food security. If the farm has a diversified cropping system, a forest area, livestock and a water body for fish farming then the farm is an integrated farming system which can create a more sustainable, socially just and secure food system. The survey indicates that 81.3 percent of the respondents practice crop rotation and 62.5 percent cultivate multiple crops together (such as berries, vegetables, corn etc.) to maintain soil health and control pests and diseases and reduce risk of crop loss (Kremen, Iles and Bacon, 2012). Inter-crops have the potential to increase the crop yield and farm profits as well as act as an insurance against failure of one crop in abnormal years and also help to uptake nutrients from both layers (organic upper layers and underlying rocky layers) of soil (Kumar, 2018). Though the respondents have no commercial forest area on their farms, but 68.8 percent of the respondents (Figure 5.13) have trees on their farmland and 87.5 percent of the farmers believe that trees contribute to improving environmental conditions (Appendix A, Table A-8). Some crop farm respondents (43.8 percent) have livestock on the farm, like cows, sheep, pigs, horses, hens and so they get milk, egg, meat, and manure. Some farmers also raise animals as a tourist attraction, for tourists who visit their farm in the summer season.

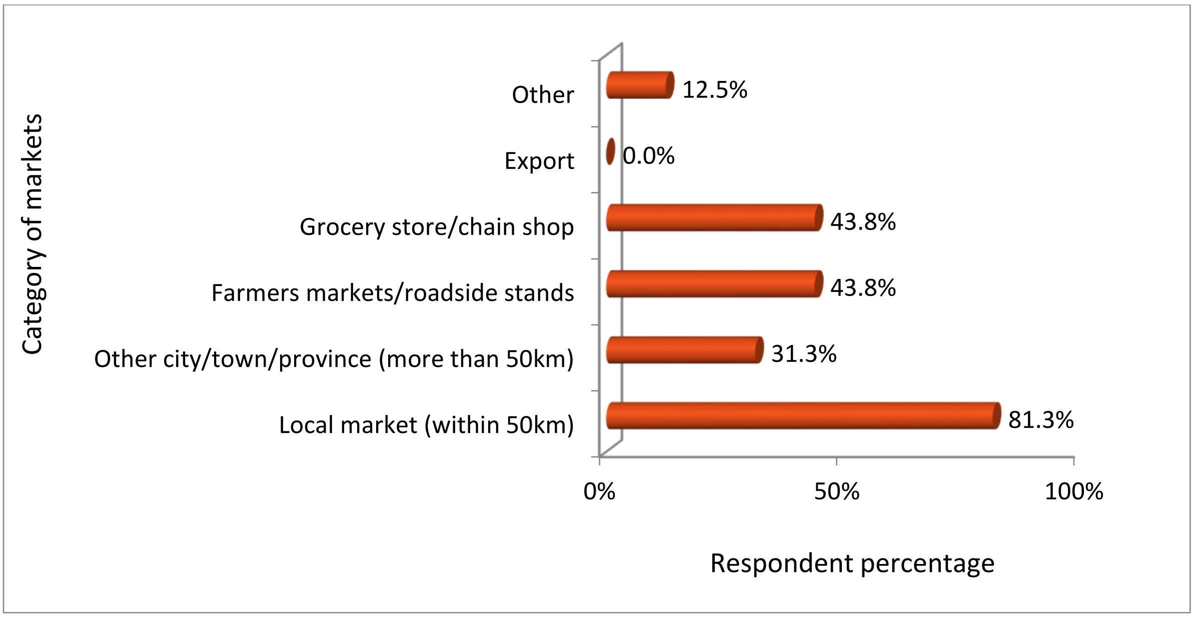
Figure 5.13: Diversified farming practices as indicated by respondents



5.4.7 Location of selling farm products

Selling farm products in the local market or at short distance reduces the transport costs as well as reduces greenhouse gas emissions from the transportation sector. Much pollution occurs from food transportation in NL province since 90 percent of the foods are imported from other provinces. The remaining 10 percent foods are produced locally and nothing (0.0%) goes to export. The positive and strong point is that 81.3 percent of the locally produced food are sold in local markets (within 50 km) as identified by respondents, and 43.8 percent are sold in grocery stores/chain shops and the same percentage are sold in farmers markets/roadside stands (Figure 5.14). The survey results show that 31.3 percent of the respondents sell their produce in other cities/towns or provinces which are at a distance of more than 50 km from the farm location. The literature on sustainable food systems suggests that food should be produced and consumed locally, as it is healthier and more environmentally friendly (APHA, 2007) and the respondents of the survey area follow this practice.

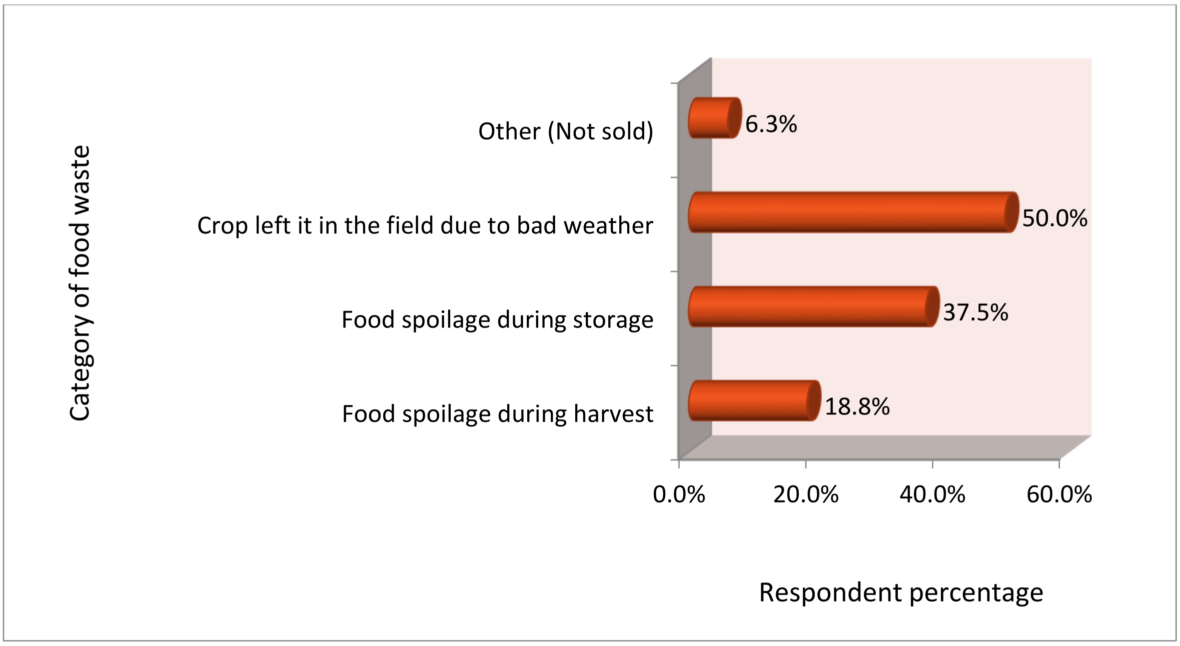
Figure 5.14: Types of market for selling products as identified by respondents



5.4.8 Causes and management of food waste

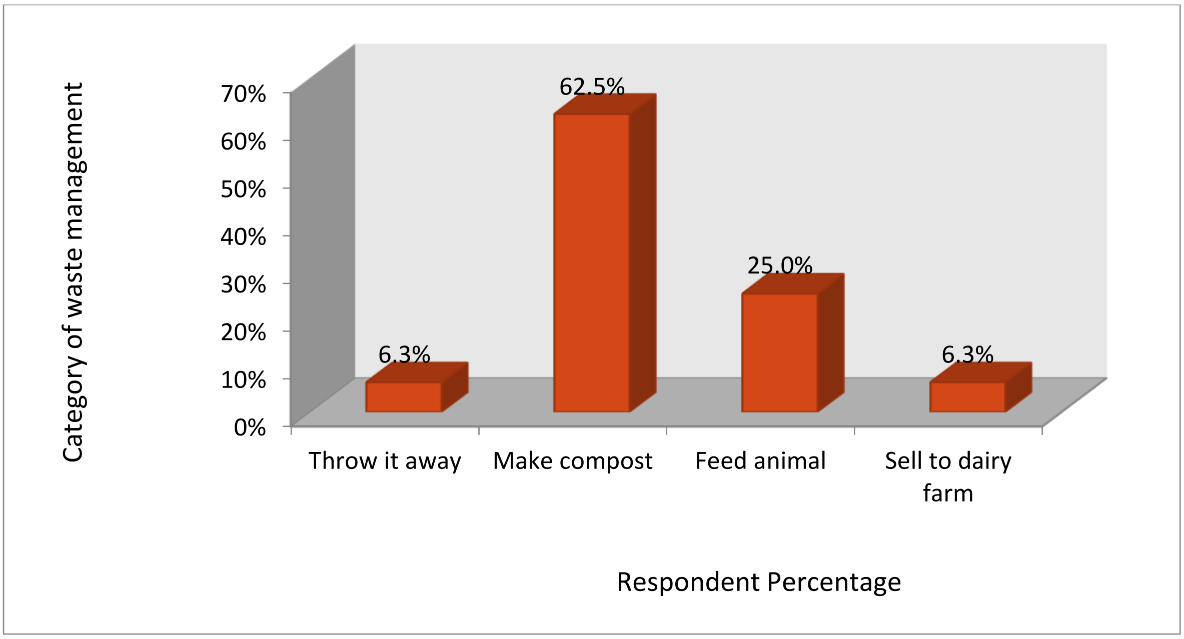
Farmers of Newfoundland and Labrador consider that climate change is an everyday topic at home and in their business. Because of the rain storms or hurricanes, farmers are forced to leave their crops in the field and sometimes storms have washed away access roads which remained impassable for a couple of days (Fitzpatrick, 2017). Figure 5.15 shows that 50 percent of the respondents identified bad weather as a cause of food waste, whereas 37.5 percent mentioned that most of the food is wasted during storage time. During harvest time, farmers also lost crops/foods, which were indicated by 18.8 percent of the respondents. Only 6.3 percent of the respondents indicated that foods were wasted because of not being sold either due to low quality or no customers in farmers markets or roadside markets.

Figure 5.15: Reasons of crop/food waste as identified by respondents



Proper management of food or crop waste can reduce the air, water and soil pollution and can reduce greenhouse gas emissions. Burning crop residues produces black carbon, and manure waste produces methane gas and both greenhouse gases have harmful effects on the environment. If the food waste is not managed properly, then rotted food produces bad odor and pollutes the environment. The respondents indicated that very small amounts of crops or foods are wasted on their farms, as they manage food waste properly. The survey indicates that 62.5 percent of the respondents manage their waste by making compost and use the compost on their land, 25.0 percent feed wastage food to their animals as food supplement and for getting more manure and milk. A small number of respondents (6.3 percent) manage the food waste either by throwing it away or selling it to the dairy farms, respectively (Figure 5.16).

Figure 5.16: Food waste management as indicated by respondents



5.5 Organic farming and barriers to success

The major contribution of organic farming is to a low carbon economy through enhancing soil health and increasing soil carbon sequestration capacity, by ensuring that these lands retain the capacity to produce food for future generations of Canadians (Lynch, 2014; Rodale Institute, 2011). According to the report of the Atlantic Canadian Organic Regional Network (ACORN), as of 2016, the number of organic farms was decreasing within the total number of farms in NL province. In 2006, there were 52 farms that have indicated themselves as 'organic' or being 'environmentally-friendly farms' within NL, but in 2016 only 2 farms in NL have been found that still held the Canadian 'Certified Organic' designation (Stats Canada, 2007). This survey indicated that 37.5 percent of the respondents have planned to introduce organic farming, whereas 62.5 percent of the respondents have no plans about organic farming (Appendix A, Table A-9). The respondents identified some barriers which actually discourage farmers from introducing organic farming. As the total number of farms in NL is decreasing but the average farm size is getting bigger, and the farmers are running their farms for commercial purposes, introducing organic farming is not feasible, as indicated by 6.25 percent of the respondents. Another difficulty is that 6.25 percent of the farmers need to apply lime and chemical fertilizers to prepare the soil and obtain higher yields, which is not acceptable in organic farming. Due to lack of experience in organic farming and unavailability of organic inputs, 6.25 percent of the respondents who are interested to introduce organic farming are not able to do that. Table 5.6 shows that 12.5 percent of the respondents identified that getting organic certification is a big barrier, whereas 6.25 percent of the respondents mentioned that there were no large numbers of consumers of organic foods in the province due to the higher price compared to price of non-organic foods.

Table 5.6: Barriers to organic farming as identified by respondents

Barriers to organic	Respondents Percentage
Not feasible for large scale commercial farming	6.25%
Some crops in NL need chemical fertilizer, lime, chemical pesticides and GMOs to be successful/profitable	6.25%
Respondents are planning to retire (old age)	12.50%
No experience about organic farming	6.25%
Lack of available organic inputs	6.25%
Difficult with certification	12.50%
Manpower shortage	6.25%
No big market	6.25%
Not interested or ignorant	37.50%

5.6 Most specific environmental problems respondents wanted to address

Farmers in Newfoundland and Labrador always have the challenge of climate change variability (as identified by 6.25 percent of the respondents), such as late spring frost, frequent drought, rain storms, excessive heat etc. Some mentioned that they need to install water pumps for irrigation in the drought period. Over using fossil fuels, chemical fertilizers and non-organic pesticides in the farm causes environmental degradation, which is rigorously addressed by 6.25 percent of the respondents for each of these conditions. Erosion of top soil, due to high winds and rains (identified by 6.25 percent of the respondents), decreases the soil's health and nutrients and is harmful for crop production. Food storage as well as hay producing all over the year are other big challenges for the farmers, as an indicated by 6.25 percent of the respondents for each (Table 5.7).

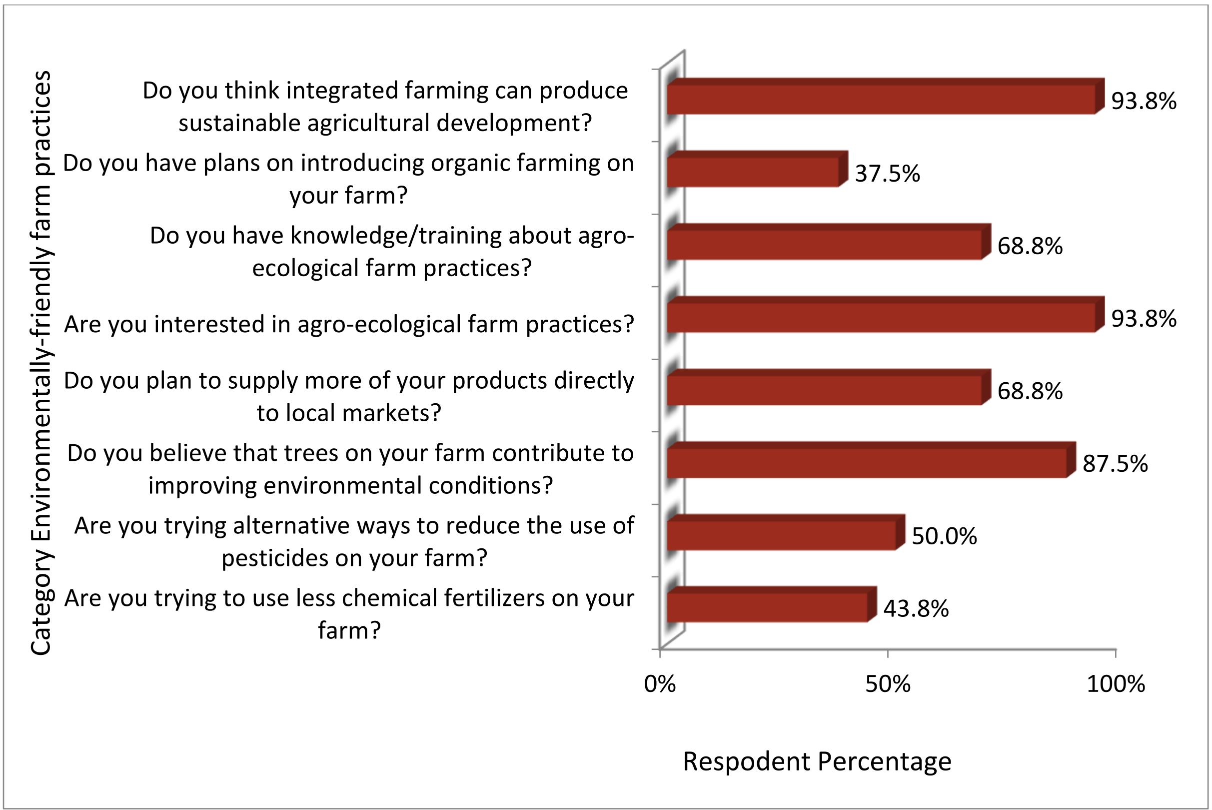
Table 5.7: Most specific problems respondents wanted to address

Specific environmental problems identified by respondents	**% of respondents**
Climate change variability problem	6.25%
Frequent drought (need to setup irrigation infrastructure)	6.25%
Soil erosion and high winds	6.25%
Weeds	6.25%
Food storage problem	6.25%
Hay producing full time	6.25%
Plastic waste	6.25%
Overuse of chemical fertilizers	6.25%
Overuse of fossil fuels (need to produce electricity from solar or wind power)	6.25%
Over use of non-organic pesticides	6.25%
Not answered	31.3%

5.7 Willingness to introduce environmentally-friendly farm practices

Environmentally-friendly farm practices reduce the greenhouse gas emissions, increase food security and food production for the present and future generations and promote the health of the ecosystem. Figure 5.12 indicates that 93.8 percent of the respondents have a positive opinion about integrated farming and they believe that integrated farming can reduce the climate change impact and reduce the risks of crop failure. The survey results indicate that 68.8 percent of the respondents have agro-ecology knowledge/training, and 93.8 percent of the respondents showed an interest as well as wanted to implement agro-ecology farm practices after finding out the definition of agro-ecology and its advantages. Moreover, 87.5 percent of the respondents believed that agro-forestry can contribute to improving environmental conditions, and protect the soil from erosion and the crops from high winds. Figure 5.17 shows that 50.0 percent and 43.8 percent of the respondents, respectively, are trying to use less chemical pesticides and fertilizers to make their farms more environmentally friendly, whereas the remaining respondents mentioned that they have no plan to reduce the use of chemical pesticides and fertilizers as they used minimum recommended doses.

Figure 5.17: Respondents' desire to follow more environmentally-friendly farm practices



5.8 Support received and expected from the federal/provincial government

The survey results indicate that farmers in NL have received financial support from the federal as well as the provincial government under the Canadian Agricultural Partnership (CAP), and the Provincial Agrifoods Assistance Program (PAAP). The Way Forward program was also mentioned by 18.7 percent of the respondents (Fisheries and Land Resources, 2018). A government report shows that the provincial and federal governments under CAP have committed over $5.8 million for 87 projects in NL and the provincial government has also committed $2.75 million in 2018 under the PAAP for land development and agricultural infrastructure (Fisheries and Land Resources, 2018). Both governmental projects focus on environmental sustainability, climate change issues, encouraging young people to enter this sector, introduce in the province a secondary food processing facility, food self-sufficiency and risk mitigation for the NL agriculture industry. Table 5.8 shows that 37.5 percent of the respondents didn't respond to this question and we can infer that they did not take advantage of these government support programs, but other respondents received financial and other type of support from government programs, such as support for purchasing equipment (18.7 percent), clearing and development of land (12.50 percent), producing green manure (6.25 percent), and setup environmental farm planning (6.25 percent).

According to the response of farmers, this study identified some sectors where farmers expect more support from the provincial and federal governments. The survey respondents expect some facilities from both the provincial and federal governments to make their farm practices more sustainable. This study identified that there is a lack of a dedicated education program and training for the farmers in NL. Some respondents (6.25 percent) stated that it will be very helpful for them if government introduced institutionalized agricultural courses and diploma programs either at Memorial University of Newfoundland or at the College of North Atlantic in the province. Few farmers (6.25%) claimed that their farm is environmentally friendly and their carbon emissions are very low. Therefore, they expect that a carbon credit will encourage them to manage their farms in a more sustainable way. The fact that the NL climate change action plan exempts farmers from the carbon tax introduced in January 2019, as a form of support. Technical support is expected by 6.25 percent of the respondents as well as lower prices for farm equipment is also important for 6.25 percent of the respondents in the study area (Table 5.8).

Table 5.8: Federal and provincial government support received or expected by respondents

Did you benefit from any programs/projects of the provincial or federal government?	% of Respon -dents	What kind of support do you expect from provincial or federal government?	% of Respon -dents	Do you have any other ideas about how to control the consequences of climate change?	% of Respon -dents
Supports received from CAP and PAAP and The Way Forward	18.7%	Expect more training and agriculture related information	6.25%	Reduce transportation costs and sell product locally	6.25%
Received supports from government for purchasing farm equipment	18.7%	Expect technical support	6.25%	Grow more heat tolerant plant and increase their use	6.25%
Received help for producing green manure crops	6.25%	Secondary food processing facility	6.25%	Long-run plan is needed to fight with climate change	6.25%
Grants for land clearing and development	12.50%	Agricultural education program at college and university level	6.25%	Reduce fossil fuel use and find new renewable energy sources (wind, geothermal)	12.5%
Government support to implement environmental farm planning	6.25%	Government should provide carbon credit	6.25%	Reduce use of chemical fertilizers	12.5%
Financial and technical support from government	6.25%	Reducing price of farm equipment	6.25%	More emphasis on biological innovation rather than mechanical	6.26%
Did not respond	37.5%	More financial support and best management practices	6.25%	Due to short growing season it would make sense to grow short-season crops or use greenhouses more than we do now	6.25%
		Did not respond	56.25%	Did not respond	50%

Industrial or large scale farming basically depends on using chemical fertilizers, synthetic pesticides and monocropping that does not ensure sustainable food provision and ecosystem protection for farms impacted by climate change. Answering a question about their own ideas about ways to control the consequences of climate change, 50 percent of the respondents presented interesting ideas. The respondents emphasized the importance of using less chemical fertilizers (12.50 percent of the respondents) and fossil fuels (12.50 percent) for farming activities. A percentage of 6.25 percent also suggested that in order to reduce fuel consumption, farmers should be selling more of their products in local markets. To deal with the short-growing seasons, 6.25 percent of the respondents suggested producing short season crops as well as building more greenhouses so that farmers can produce more vegetables in the winter season. To mitigate climate change impacts, long-term government plans and development projects are also needed, as indicated by 6.25 percent of the respondents.

In conclusion, it can be said that industrial farming practices are contributing to environmental degradation and climate change and that a good number of farmers are trying to apply alternative methods, such as intensive and diversified farming, using organic fertilizers and pesticides, bio-control, sterile insect techniques, and using renewable energy. Though organic farming is not popular among the farmers surveyed in the study area, but a large number of famers are interested in integrated and agro-ecological practices. The transition from industrial agriculture to agro-ecological practices needs federal and provincial governments attention and support, like financial and technical support, training and education programs and proper management of the transition.

Chapter VI

General Features and Practices of Surveyed Dairy Farms

Newfoundland and Labrador has a well-established dairy industry with 39 registered producers (Fisheries and Land Resources, 2018). The average farm size was 144 cows and the total number of cows was 5,600 in the province; these cows produced over 48.5 million liters of milk in 2006 valued at $ 37.8 million (Fisheries and Land Resources, 2018). According to the report of Agriculture and Agri-Food Canada (2016), Newfoundland and Labrador province had 6,153 cows in 2011, which indicates that the number of cows increased compared to 2006. Another report shows that the number of dairy cows in Newfoundland and Labrador decreased by 13.9 percent from 6,153 in 2011 to 5,299 head in 2016 and, at the same time, the number of dairy farms declined by 10.5% (Statistics Canada, 2017). But due to better management, improved nutrition and genetics, the amount of milk produced has increased by 1.8 percent. This chapter presents the results of the primary data collection using a survey of the dairy farms in the study area.

6.1 General features of dairy farms in Newfoundland and Labrador

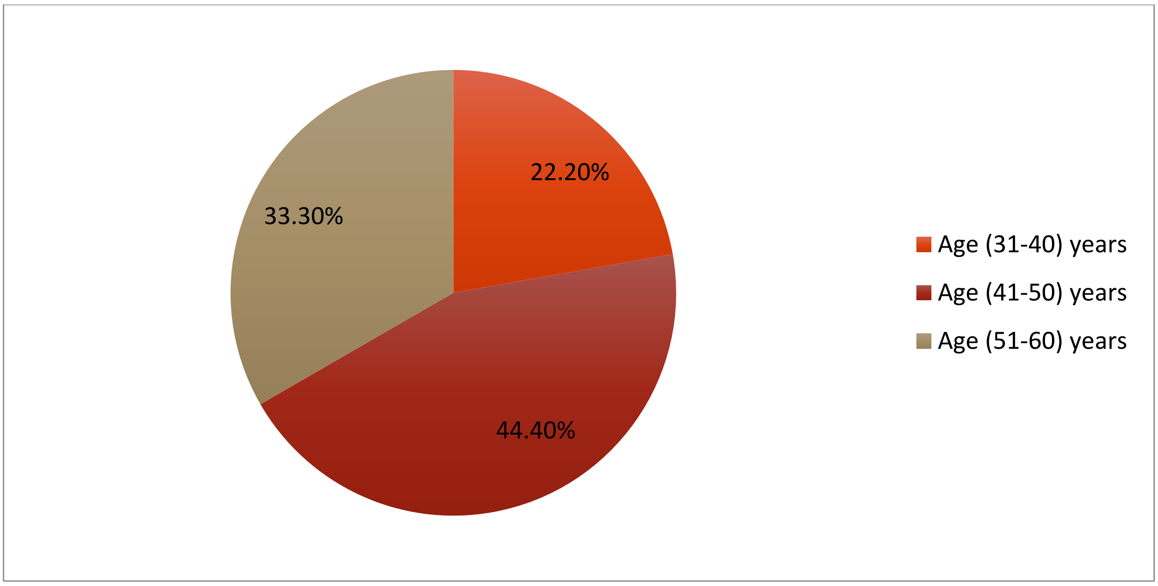
6.1.1 Age distribution of the dairy farmers in Newfoundland and Labrador

The field survey shows that all of the dairy farm owners are middle aged, with an age range from 31 to 60 years. There are no young dairy farmers below 31 years, or old age farmers 61 years or more. However, the survey has shown that some farms are family owned farms where young family members are also involved in the farm activities and there is a chance that they will handle the business in the future. Table 6.1 indicates that 44.4 percent of the farm owners' age is between 41-50 years, and 33.3 percent of the responders' age is between 51-60 years.

Table 6.1: Age of farmers as indicated by respondents

Range of age	Percentage(%)
21-30	0.0
31-40	22.2
41-50	44.4
51-60	33.3
61-70	0.0
71 or more	0.0

Figure 6.1: Age distribution for dairy farmers



6.1.2 Years of farming and farm size

The average year of the dairy farm operation is 26, where the maximum year of farm operation is 40, and minimum is 16 years (Table 6.2). Therefore, some farms started their operation before establishment of the Dairy Farmers of Newfoundland and Labrador organization in 1983. The organization is responsible for the effective promotion, control and regulation of the production and marketing of milk within the province (Fisheries and Land Resources, 2018).

Table 6.2: Years of farm operation and number of cows as identified by farmers surveyed

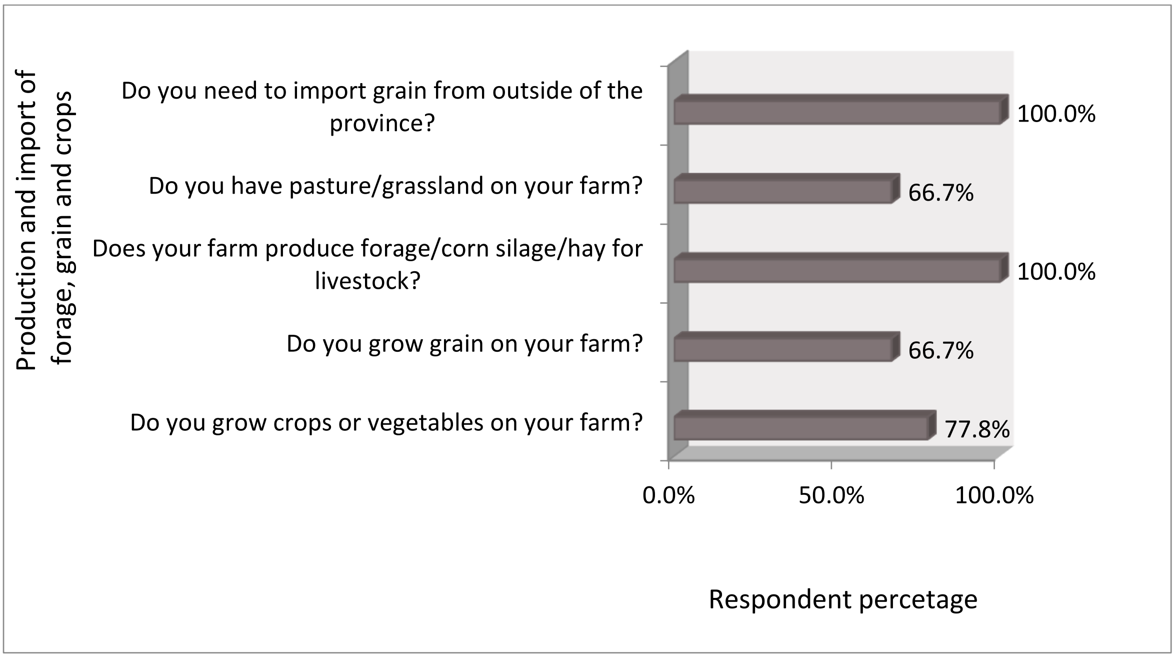
Year of farming and number of cattle	Maximum	Minimum	Average
Year of farming/age of farm (years)	40	16	26
Number of dairy cows	400	100	213
Number of total cattle (cows and calves)	850	150	352

The average number of dairy cows is 213 in the surveyed farms, while the maximum farm size is 400 and the minimum is 100. The survey results show that the average farm size has increased compared to the average farm size (144) in 2006. While considering the number of dairy cows and calves together, the average farm size increases to 352 and the largest farm contains 850 cattle and the smallest one contains 150. This estimate is more accurate, as when studying about dairy farms it is wise to consider calves also because calves also have an impact on farm's income and costs.

6.1.3 Animal feed and crop production of dairy farms

The most important discussion about dairy farms is their feed supply, the quality of feed and feed management. Due to the short growing seasons and poor soil quality, farmers can't produce 100 percent of the necessary feed on their own farm. Sometimes farmers find it difficult to preserve forage or corn silage and keep the nutrition intake for their animals for the whole year because of the long winter with heavy snow and shortage of storage. All the farmers in the survey area produce forage or corn silage for their livestock and 66.7 percent also produce grains. Though more than half of the farmers produce grains for their dairy farms, the amount produced is not sufficient to meet up the demand. That is why 100 percent of the farmers import feed grains from other provinces, which is expensive and challenging for the farmers. Figure 6.2 shows that 66.7 percent of the farms have pasture or grassland which is the best natural supplier of nutrients like carotene, vitamin E, conjugated linoleic acids (CLA) and omega-3 fatty acids (Schivera, 2003). Previous studies have shown that eating livestock products like meat and milk can benefit human health and the environment, particularly when the animals are raised on a pasture-based fresh green diet rather than eating only grains (Schivera, 2003). More importantly, 77.8 percent of the farmers grow crops and vegetables on their dairy farms, which basically represents the integrated farming practice and also helps the dairy farms directly or indirectly as the farmers use the wastage crops and vegetables as feed for the cows.

Figure 6.2: Production and import of crop, forage and grain as identified by respondents



6.1.4 Percentage of animal feed production and import

It is known from previous reports that the dairy industry in Newfoundland and Labrador is approximately 85 percent self-sufficient in forage production relative to fluid milk production (Fisheries and Land Resources, 2018). The survey report has shown that on average 90 percent of the forage or corn silage has been produced by the respondents in the study area irrespective of the farm size, whereas 75.56 percent of the animal feed has been produced by their own. On average, 24.44 percent of the animal feed has been imported from other provinces and most of these are grains, with very little forage or corn silage (Table 6.3).

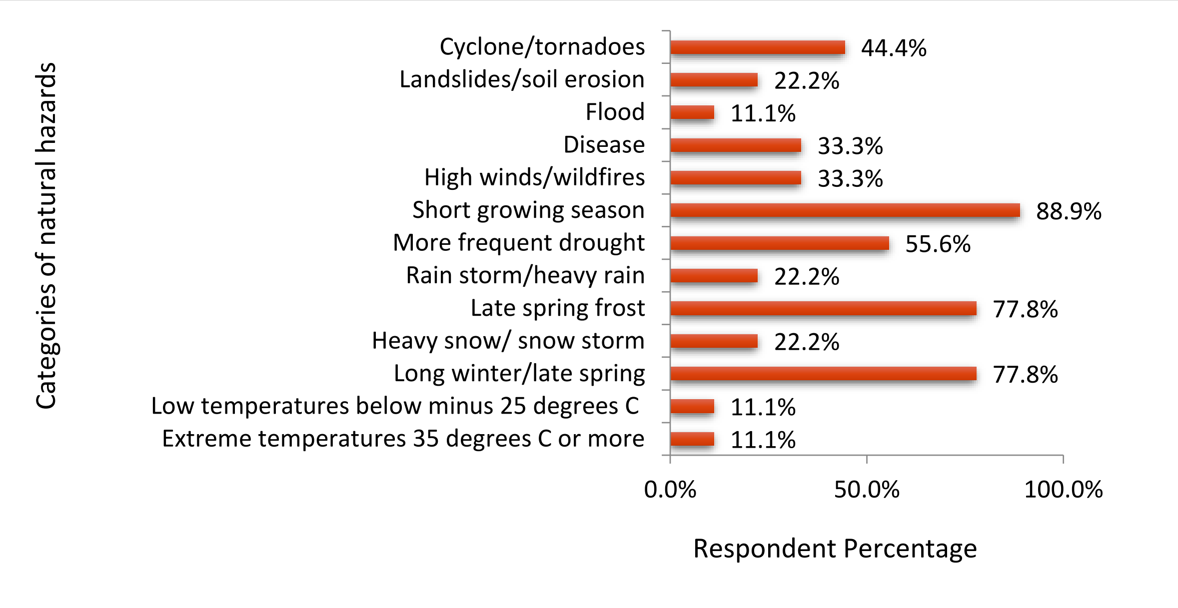
Table 6.3: Percentage of animal feed produced on the farm, as identified by respondents

Number of total cattle	Number of milking cows	Percentage of forage produced on the farm	Percentage of animal feed produced on the farm	Percentage of animal feed imported from other provinces
850	400	95	80	20
200	180	100	90	10
250	150	100	85	15
220	100	80	45	55
350	200	90	80	20
150	150	75	70	30
200	115	90	85	15
550	375	80	75	25
400	250	100	70	30
Average 352	Average 213	Average 90%	Average 75.56%	Average 24.44%

6.2 Natural hazards affecting dairy production

Natural hazards not only affect crop and vegetable production but also affect dairy production in the NL province. The survey results indicate that 88.9 percent of the respondents identified short growing seasons as one of the major problems for dairy farms followed by late spring frost (77.8%) and long winters (77.8%), which are also reducing the farm production. Drought is becoming a big problem day by day in this province, as mentioned by 55.6 percent of the respondents. Cyclones (44.4%) and high winds (33.3%) are other environmental hazards that have been identified by respondents as affecting the farm activities. Low temperatures (below minus 25 degrees C) or high temperatures (35 degree C or more) have been identified by 11.1 percent of the respondents as a natural problem since respondents mentioned that dairy cows are kept in cow sheds which protect animals from extreme cold weather or heat. All of the natural hazards mentioned in Figure 6.3, basically directly or indirectly affect the animal feed production, feed transportation and import, feed processing and storage and milk transportation, which have an impact on farm's production.

Figure 6.3: Natural hazards affecting dairy production as identified by farmers surveyed



6.3 Farm activities contributing to climate change

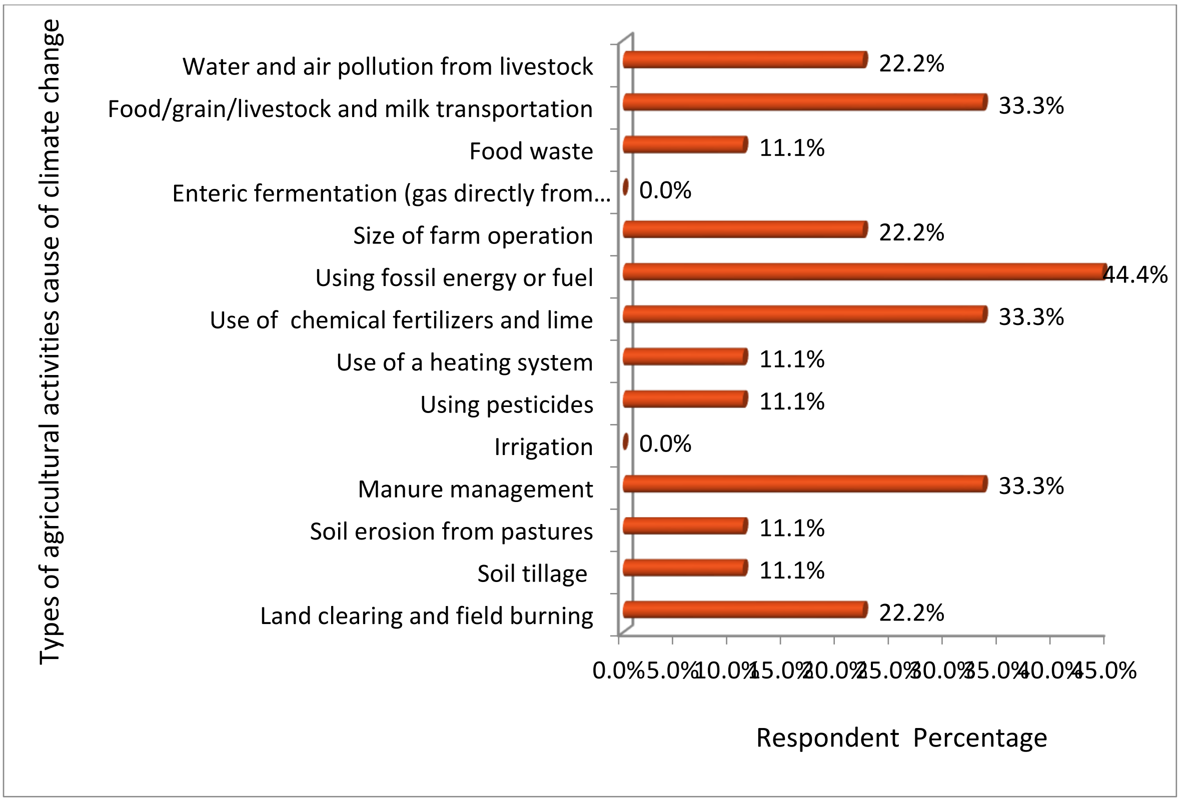
The feed production for dairy cows, the enteric fermentation and their manure produce greenhouse gas emissions, such as methane, nitrous oxide and carbon oxide as well as contribute to environmental degradation and climate change (WWF, 2019). Milk production and farm operation impact the environment in different ways, and the scale of these impacts depends on the practices and managements of the dairy farmers and feed growers. Poor handling of manure and fertilizers can degrade local water resources from down streams. At the same time, unsustainable dairy farming and feed production can lead to loss or degradation of ecologically important areas, such as prairies, wetlands, pastures, and forests (WWF, 2019). But farmers can significantly reduce their farms' environmental impacts through better management practices and using improved technologies (WWF, 2019). The survey data has shown that 44.4 percent of the dairy farmers believed that dairy industry or large scale dairy or crop farming are contributing to climate change globally, whereas two-third of the respondents didn't believe that (Appendix B, Table B-1 and B-2). For some reason, respondents have indicated that large production systems have smaller carbon footprint per unit produce and they also have better financial ability to invest in improved technologies and efficient and sustainable management systems (Appendix B, Table B-3). Canadian dairy farms follow a national strategy for sustainable development with a vision to produce safe, nutritious food in an economically, socially and environmentally sustainable way to the benefit of Canadian society (Dairy Farmers of Canada, n.d). The study shows that Canadian dairy farmers manage the carbon cycle on their farms through the responsible use of soil, fuels, fertilizers, water and electricity to clean their buildings, produce and harvest their crops and milk their cows.

> According to the study by the Dairy Farmers of Canada (n.d.), the "carbon equivalent emissions from dairy farms have been reduced by over 25 % from 1981 to 2006, as a result of efficiency gains made on farms. The trend shows a steady decline in GHG emissions from dairy farms of approximately 1% per year."

Federal and provincial governments have strict regulations to address the impacts of agriculture on the environment, and the Dairy Farmers of Canada organization has commissioned a research to carry out a full environmental and socio-economic Life Cycle Assessment (LCA) of milk production. LCA is an internationally recognized approach used to evaluate the environmental and social impacts of a product or service through its entire life.

The survey results have shown that 44.4 percent of the respondents have identified fossil fuels as contributing to climate change, followed by 33.3 percent of the farmers who believe that manure management, using chemical fertilizers and lime, and food and milk transportation have impacts on environmental degradation and climate change. The most important elements of the environment, namely water, soil and air are polluted by dairy farm operations as mentioned by 22.2 percent of the farmers. The same percentage of farmers indicated that land clearing and field burning as well as big farm operations contributes to pollution. A very small number of respondents (11.1 percent) have identified soil tillage and soil erosion from pasture grazing as reducing the soil nutrition and health. This study has found that none of the respondents believed that enteric fermentation or gas coming directly from the cattle has an impact on climate change. Some respondents have mentioned as a positive aspect, that they do not need heaters for heating the cowshed since the heat coming from cows' bodies was enough to keep warm the shed in winter seasons.

Figure 6.4: Farm activities contributing to climate change in Newfoundland and Labrador



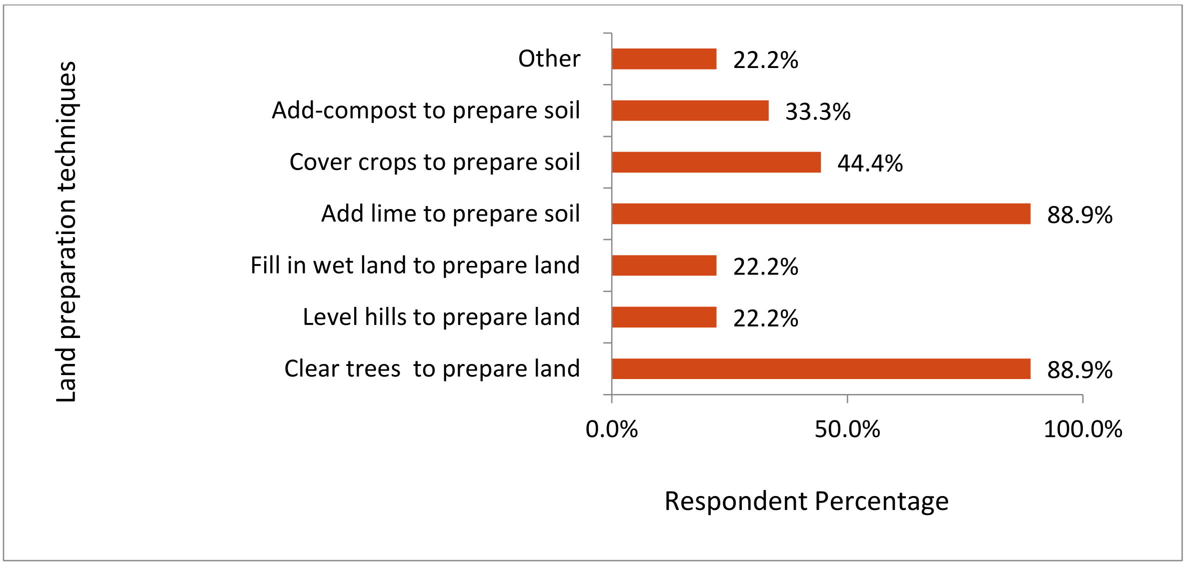
6.4 Agro-ecological practices

6.4.1 Land preparation techniques

To prepare the land for grass, crops and grains production, 88.9 percent of the respondents add lime, and 33.3 percent use compost, which are the basic requirements for soil in this province to maintain pH and nutrition level (Figure 6.5). The land area of this province is

40.1 million hectares, of which 23.2 million hectares (57.85%) are covered by forest (Government of Newfoundland and Labrador, 2014; Statistics Canada, 2017). Therefore, to prepare land for crops and dairy firms, farmers need to clear trees as indicated by 88.9 percent of the respondents. Producing cover crops, like legumes, grasses, brassicas or buckwheat, improves soil quality, reduces compaction and improves soil structure, reduces nutrient losses, reduce pest populations, adds organic matter and reduces soil erosion (Verhallen, 2013; Magdoff, 2012). Figure 6.5 has shown that 22.2 percent of the farmers level hills and fill in wet lands in order to prepare the farm land, which decreases the biodiversity and degrades the ecosystem.

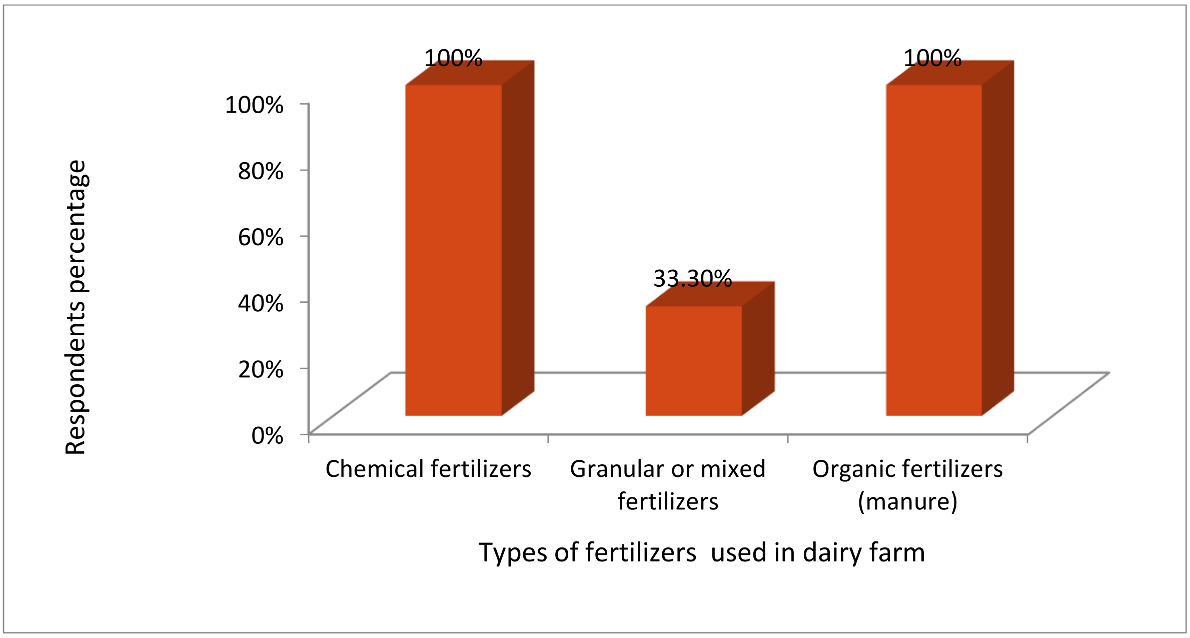
Figure 6.5: Land preparation techniques as indicated by respondents surveyed



6.4.2 Amount of chemical fertilizer and manure applied in the field

Chemical fertilizers, like urea, potash and phosphate, are important inputs of conventional farm operation and the survey results have shown that 100 percent of the farmers use chemical fertilizers in different ratios. More importantly, 100 percent of the respondents use organic fertilizers or manure produced by the dairy cows in the crop and grain fields, together with chemical fertilizers, which is a way of reducing dependency on chemical fertilizers. Some farmers (33.3%) use granular or mixed fertilizers which supply nutrient to the plants very slowly, but have advantages of longevity and the fact that plants can absorb them easily (Gorry, 2019).

Figure 6.6 Use of fertilizers as identified by respondents



The respondents use chemical fertilizers as well as manure in their fields to get better production of crops, grain and forage. The average amount of chemical fertilizer used by the respondents is 69.2 thousand kg per year, irrespective of the farm size, where the maximum amount is 160 thousand kg and minimum is 11 thousand kg per year. Normally, dairy farmers spread almost all the manure produced by their cows on the crops, vegetables, grass and grain fields and they don’t sell their manure to other farms. The average amount of manure used is 3,255.5 thousand kg per year, while the large farm produces around 9,000 thousand kg per year manure and small farms produce 1,000 thousand kg per year (Table 6.4). The results of this survey have shown that dairy farmers have a greater chance to use more organic fertilizer and less chemical fertilizer compared to the crop farms that have no livestock. Therefore, integrated farming, one of the principles of agro-ecology, has double benefit by reducing the cost of using chemical fertilizers and by using more organic fertilizers to reduce environmental pollution.

Table 6.4: Use of chemical and organic fertilizer in the crop and vegetables fields ('000 kg)

Category of fertilizers	Minimum	Maximum	Average
Amount of chemical fertilizer used (kg/per year)	11	160	69.2
Amount of manure/organic fertilizer used (kg/per year)	1,000	9,000	3,255.5

6.4.3 Use of pesticides in the crop/corn/grass field

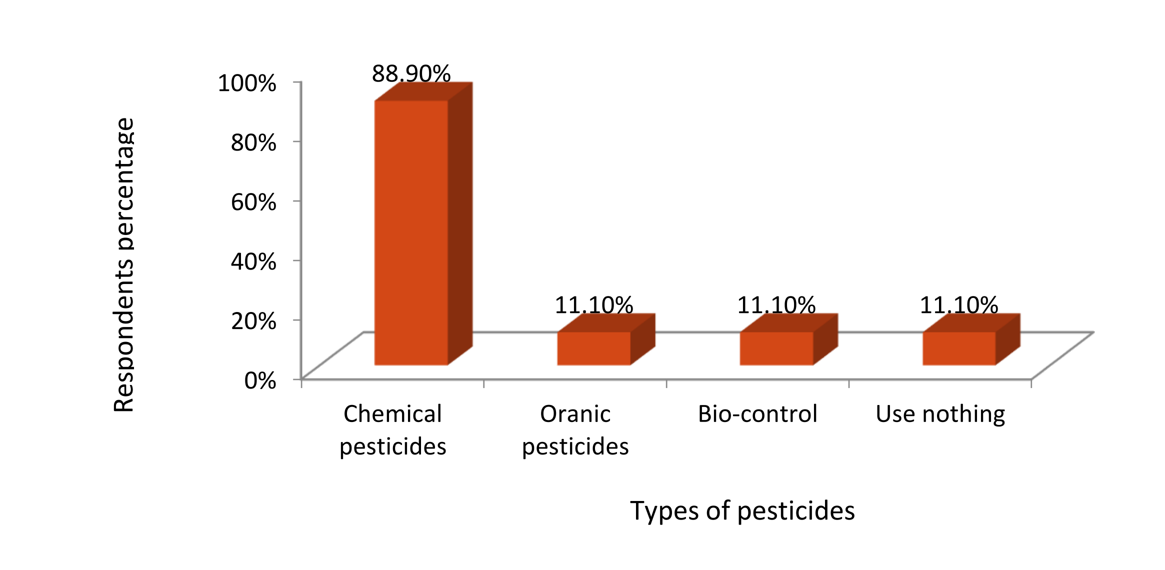
The average use of chemical pesticides by the respondents is 218.8 liters per year. The maximum amount of pesticides used by a dairy farm per year is 720 liters, while minimum amount is zero, indicating that some respondents did not use any pesticides in their fields (Table 6.5).

Table 6.5: Amount of chemical pesticides farmers use in their farm per year

Pesticides	Minimum	Maximum	Average
Amount of pesticides used on the farm (liters/per year)	0	720	218.8

As seen in Figure 6.7, 88.90 percent of the respondents use chemical or synthetic pesticides while 11.10 percent of the respondents use organic pesticides. Though the bio-control system has some side-effects (it also attacks non-targeted species), but if the farmers use this method properly, then it is better than the use of chemical pesticides. It is also interesting to note that 11.10 percent of the respondents didn't use any pesticides, due to fewer pest attacks and considering the possible environmental consequences.

Figure 6.7: Types of pesticides as indicated by respondents



6.4.5 Application of antiseptics, medicine and hormones

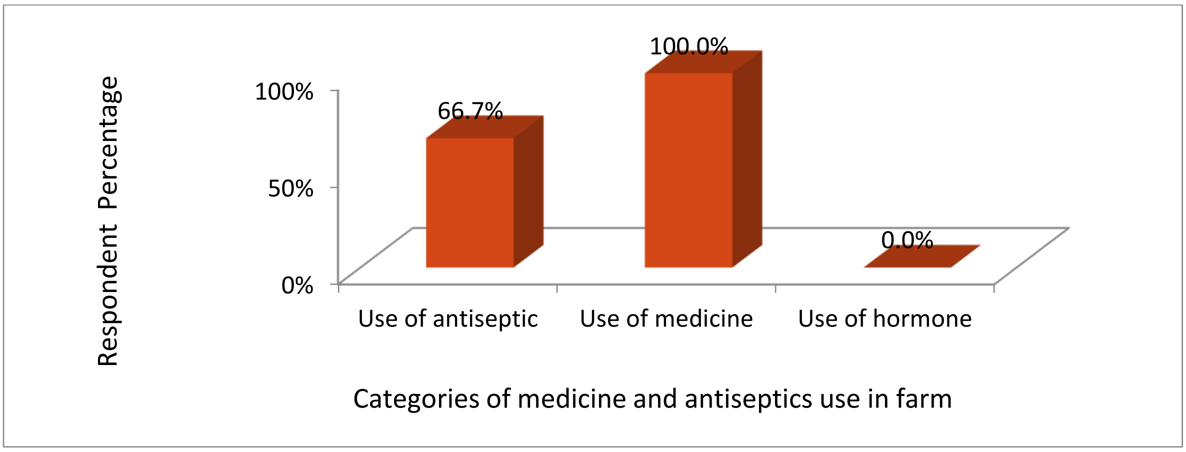
To clean the farms and the farm equipment and to reduce the spread and attack of diseases, farmers normally use antiseptics. The average yearly use of antiseptics by the sample is 164.4 liters, with maximum amount of 1,005 liters per year. The minimum use of antiseptics is zero indicating that some farmers don’t use any antiseptics. If the farmers don’t use antiseptics for cleaning the milking equipment, then there is a chance to spread disease on the farms. Also, overuse and improper use of antiseptics pollutes the water, wetlands and soils near the farms.

Table 6.6: Amount of antiseptics used in dairy farms to clean the farm and farming equipment

	Minimum	Maximum	Average
Amount of antiseptics used on the farm (liters/per year)	0	1,005	164.4

The survey results have shown that 100 percent of the respondents needed to use medicine for treatment of their animals (Figure 6.8). Most of the respondents stated that they use medicine when their animals are attacked by diseases or getting sick, but they always try to use medicine according to the prescription of the veterinary physician. It is a good sign that no respondents use growth hormone on their animals for increasing milk production in the surveyed area. Farmers are very conscious and aware about the bad effects of the growth hormone. Some respondents warned that all farmers should handle medicine residues in proper way otherwise they may mix with water which may pollute the environment and harm biodiversity.

Figure 6.8: Use of antiseptics and medicine as indicated by respondents



6.4.6 Manure management

Production, use and management of manure are important tasks of dairy farmers. Proper management and use of manure helps to produce more crops and forage and produce less GHG emissions. On average, each dairy farm produces 3.72 million kg manure per year with large size farms producing maximum 9 million kg and small size farms producing 1 million kg manure per year (Table 6.7). The respondents of the surveyed area are spreading all of the manure in their crop/vegetables/grass lands directly.

Table 6.7: Production and use of manure as indicated by respondents

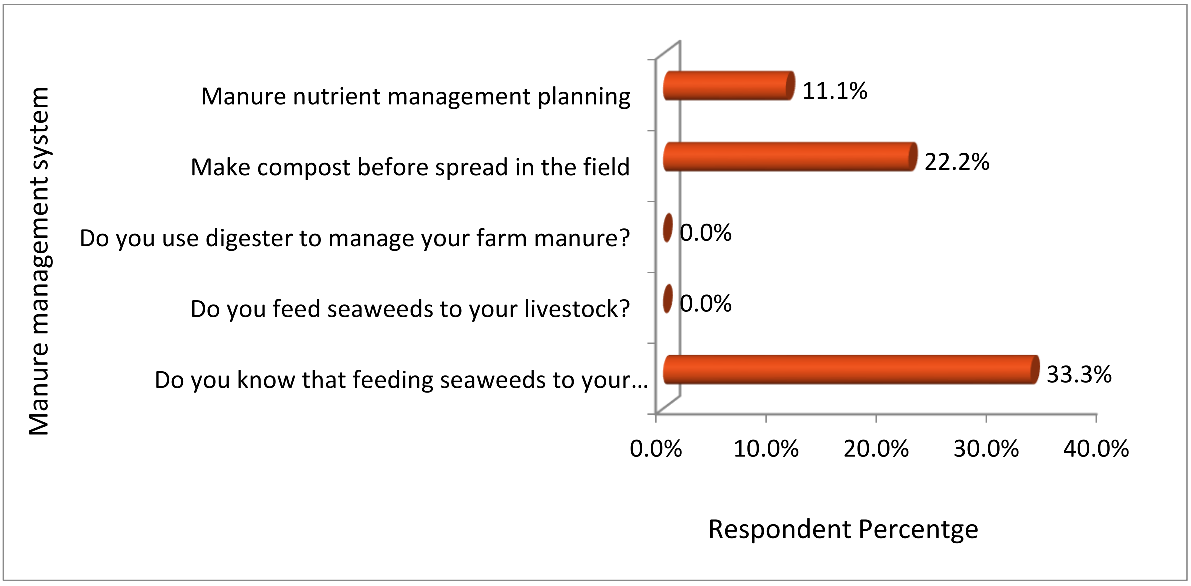
Production and use of manure	Minimum	Maximum	Average
Amount of manure produced on the farm (kg/per year)	1,000,000	9,000,000	3,722,222
Percentage of manure used on own farm	100%	100%	100%
Percentage of manure sold to other farms	0%	0%	0%

Manure is the main source of methane which is considered a greenhouse gas contributing to climate change. But proper management of manure can convert it in an important source of clean energy. An anaerobic digester will partially convert manure to energy in the form of biogas which contains methane that can be used by livestock farmers for heating cowsheds and water (PennState Extension, 2012). Meyer (2011, page 3) has found that an "anaerobic digester with the capture and use of methane is effective in reducing pathogens, reducing emissions (methane, hydrogen sulfide, ammonia, and volatile organic compounds), stabilizing manure and reducing solids". The survey results have shown that respondents of the study area have no anaerobic digesters to produce energy and fertilizer from manure. But the good news is that Canadian dairy farmers have started turning waste into energy through anaerobic digesters. Research has shown that the energy produced by using certain bio-digesters can provide enough electricity to heat as many as 300 households (Dairy Farmers of Canada, n.d.).

The most worrisome issue is that experts have found that global livestock emissions account for more than a seventh of all man-made GHG emissions, and methane is considered to be up to 30 percent more harmful than carbon dioxide, as scientists have discovered (McKenna, 2017; Mernit, 2018). Temple (2018) has mentioned that the global impact of greenhouse gas emissions from livestock is equivalent to the impact of transportation industry. He has also claimed that the greenhouse gases pumped out from livestock production each year have the effect of more than 7 gigatones of carbon dioxide. MIT (Massachusetts Institute of Technology) researchers have identified that by adding a small amount of seaweed to the animal feed can cut the cows' methane production by nearly 60 percent (Temple, 2018).

Similarly, the researchers of James Cook University in Australia have found that adding 2 percent seaweed to dried animal food can reduce methane emissions by 99 percent, but this research used an artificial cow's stomach in a laboratory. The Canadian researchers have used real-life livestock and the result has shown that feeding seaweed can cut cows' methane emissions by 20 percent, and sheep's methane emissions by 70 percent when 2 percent seaweed was added to their died (McKenna, 2017). The current study has found that 33.3 percent of the respondents know about the benefit of seaweed in feed but no respondents (0%) use seaweed with the cows' feed. Moreover, some respondents were concerned that feeding seaweed reduces the milk production of their cows but there is no such evidence in the existing research. As a side effect, Dr. Andy Reisinger said, when cows are eating seaweed, bromoform is produced in cows' stomachs, a gas that has previously been shown to deplete the ozone layer. The question is that if cows start emitting bromoform instead of methane, it is just a transfer from one environmental problem to another (McKenna, 2017). Figure 6.9 has indicated that 22.2 percent of the respondents make compost with manure before spreading it in the field but this type of simple composting cannot reduce methane emissions as an anaerobic digester can.

Figure 6.9: Manure management systems on the farm



Some respondents (11.1%) in the study area reported that they use the nutrient management technique for processing manure, a technique depending on soil category, type of crops, nutrient requirements, manure storage facility, animals and manure application equipment which reduces the risk of nutrient loss to air and water and provides a good interaction among soil, plants, nutrients and the environment (Alberta Agriculture and Food, 2010).

6.4.7 Fuel and electricity consumption by the dairy farms

Dairy farms need fossil fuels for running farm equipment, vehicles and burning these fossil fuels produces huge amounts of greenhouse gas like carbon dioxide. The average fuel consumption of the surveyed farms is 42,181.15 liters per year where the maximum amount is 150,000 liters and minimum is 13,000 liters per year. Most of the electricity (95%) in this province is produced from clean sources such as hydro and the remaining 5 percent is produced from gas or oil. The average electricity bill the respondent farmers have to pay is $ 19,024.04 per year and the range is between $8,300 and $ 60,000 per year (Table 6.8).

Table 6.8: Yearly use of fuel and cost of electricity

Type of energy	Minimum	Maximum	Average
Use of fuel (liters/year)	13,000	150,000	42,181.15
Cost of electricity ($/year)	8,300	60,000	19,024.04

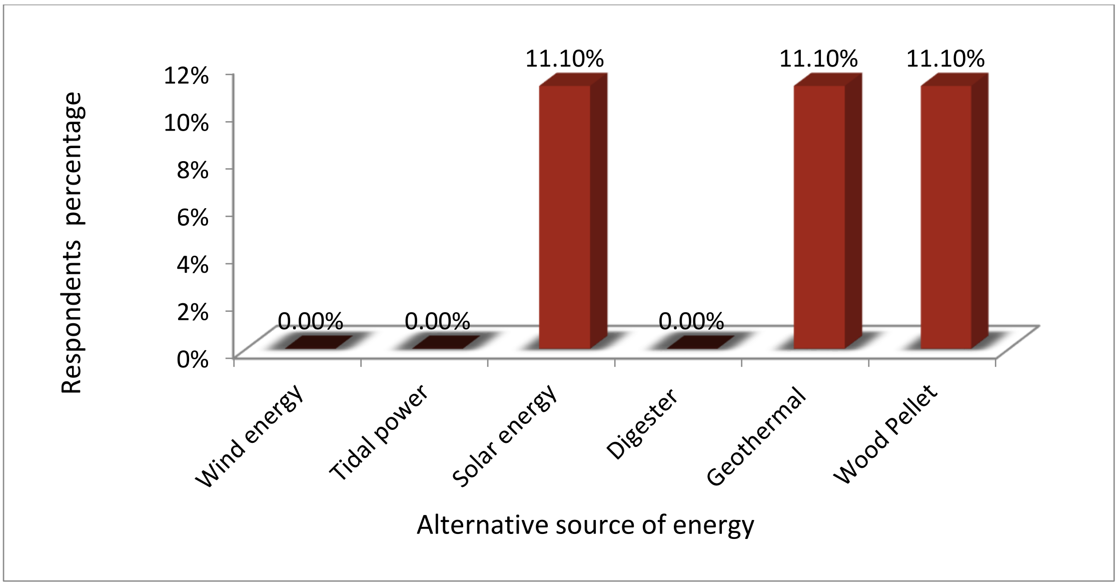
The correlation analysis has shown that there is a strong (positive) linear relationship between number of livestock (cows and calves) and fuel use, as the value of the correlation coefficient r is +0.785 indicating that if the number of livestock increases then the fuel consumption also increases (Rumsey, 2019). There is a weak positive linear relationship between farm size and electricity cost, as the coefficient value is +0.341, indicating that farm size and electricity cost move in the same direction but their correlation is not very strong.

Table 6.9: Correlation between farm size and use of fuel and electricity

Number of livestock (cows and calves)	Fuel consumption (liters/year)	Electricity cost ($/year)
150	30,000	36,000
200	16,000	13600
200	25,000	45,000
220	26,000	18,000
250	35,000	25,000
350	60,000	60,000
400	38,000	30,000
550	13,000	8,300
850	150,000	60,000
Correlation coefficient value	0.785	0.341

The NL province is rich in geothermal, tidal and wind energy (E4tech, 2010) but the survey result has shown that no dairy farmers produce electricity from these two renewable sources. Lack of research and government support and the absence of permission to produce electricity at private level, are the reasons why farmers cannot produce electricity for their own use or sell it to the national grid (Mercer, 2019). A small percentage (11.10% for each) of the respondents produces electricity by using solar panels, geothermal energy and wood pellets. According to the research report and the Canadian national strategy for sustainable development, anaerobic digesters would be a safe and novel fresh source of energy and good quality fertilizer, but the respondents of the surveyed area did not use digesters for management of the manure (Dairy Farmers of Canada, n.d.).

Figure 6.10: Alternative sources of energy as identified by respondents surveyed



6.4.8 Water use for farm management

Water is one of the most important elements of the environment as well as for farm operation. Excessive use of ground water and releasing used farm water without proper treatment are both harmful for the environment. The surveyed respondents use on average 6.81 million liters of water per year with a maximum amount of 10.95 million liters and a minimum use of 0.2 million liters per year (Table 6.10).

Table 6.10: Use of water for farm activities as identified by respondents

Use of Water	Minimum	Maximum	Average
Amount of water used for irrigation and farm cleaning (liters/per year)	200,000	10,950,000	6,816,111

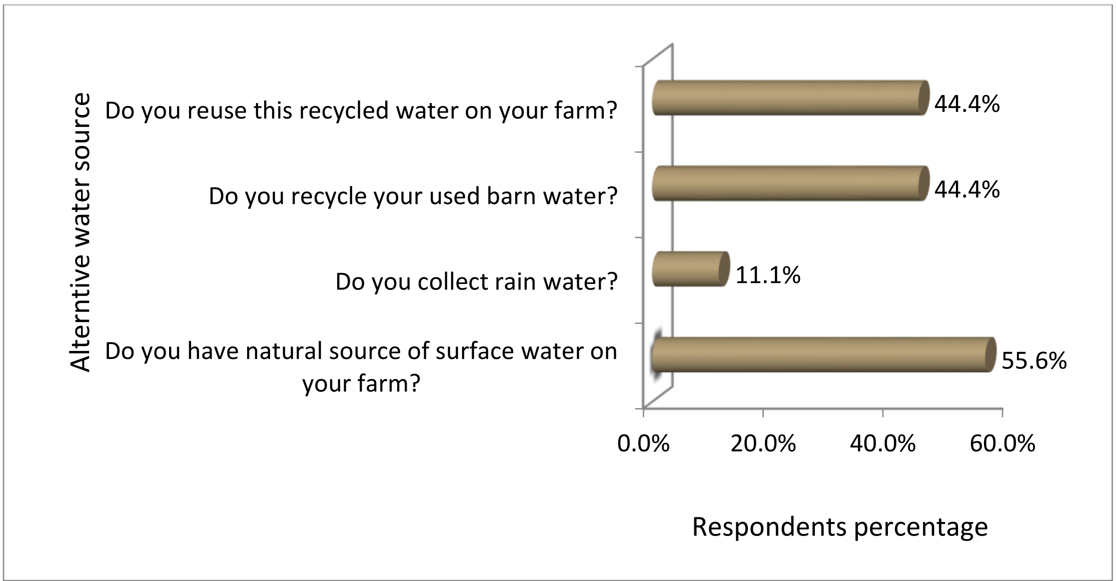
Table 6.11 is showing the correlation between the number of livestock and water use. The value of the correlation coefficient is -0.360 indicating a weak negative linear relationship. This negative relationship may be explained by the fact that some large farms use less water as the respondents recycle their used water and reuse it or they have fewer crops or forage land.

Table 6.11: Correlation between farm size and water use

Number of livestock (cows and calves)	Water use (million liters/year)
150	10
200	5
200	9.1
220	10
250	10.95
350	7
400	1.09
550	0.2
850	8
Correlation Coefficient value	-0.360

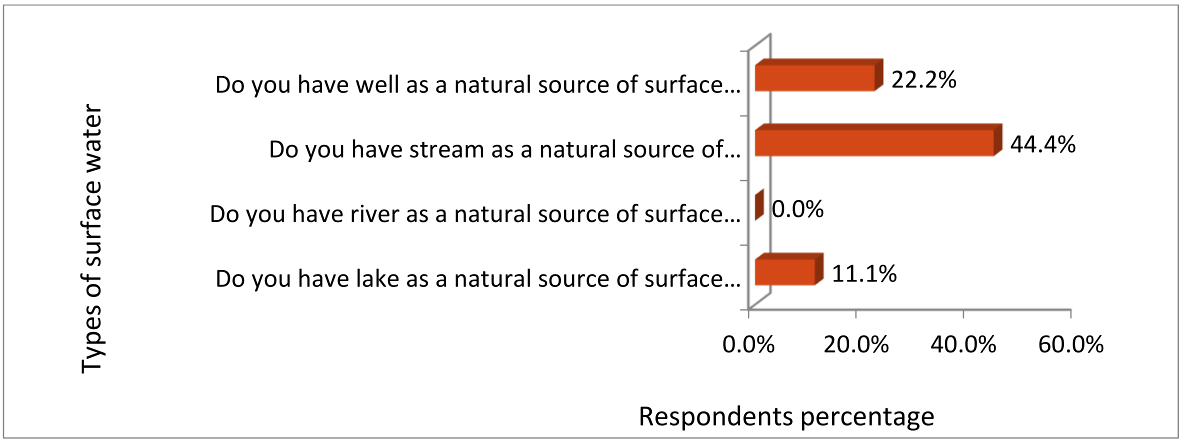
As an alternative to the groundwater, farmers can collect and use rain water, recycle the used water or can use surface water. Figure 6.8 is showing that 44.4 percent of the respondents recycle their used farm water and reuse it for farm operation. Only 11.10 percent of the respondents collect and use rain water for their farm operation. As indicated by respondents, 55.6 percent of the farmers have access to surface water sources, like lakes, rivers or streams, but they don't use these surface water sources for farm operation.

Figure 6.11: Alternative sources of water as identified by respondents surveyed



Using surface water will reduce the pressure on ground water and also affect less climate change (Stauffer and Spuhler 2019). Due to high temperature and drought, as well as to soil compaction by use of agriculture machinery (Wohlleben, 2017), the ground water level goes down in the summer in the study area and irrigation cost increases. The report has shown that using surface water reduces the irrigation cost and reduces the environmental impact. It has been found that 44.4 percent of the respondents have streams near the farms, 22.2 percent have wells and 11.1 percent have lakes that can be used as surface water sources.

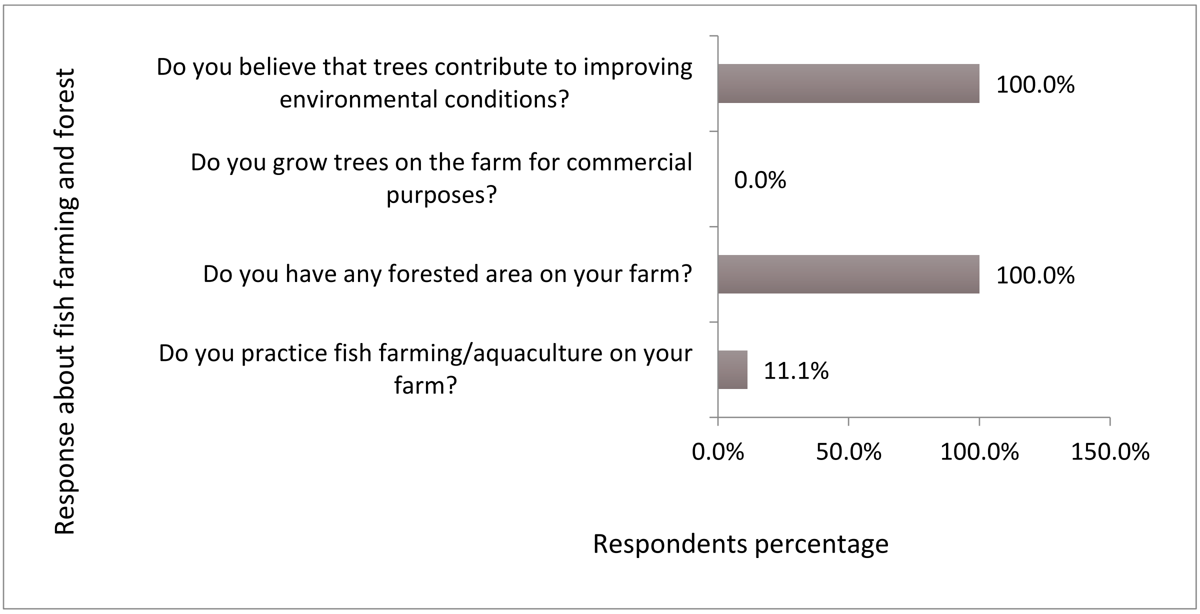
Figure 6.12: Natural sources of surface water



6.4.9 Fish farming and forest in the farm area

Fish farming or aquaculture and agroforestry are important components of agro-ecological and integrated farm practices. Both practices in dairy farms can help to maintain ecosystem health and biodiversity and also can be additional earning sources for the farm owner. According to Statistics Canada (2017) data, only 4 percent (929,088 ha) of the forested area is owned privately, whereas 96 percent (22,298,112 ha) of the forested area is owned publicly. Due to this reason, no respondents in the study area produce trees for commercial purposes. The results of this study have shown that 100 percent of the respondents know the environmental benefits of trees on the farm (they reduce soil erosion and act as wind breakers) and they also have some trees on the farm, but not for commercial use. Aquaculture or fish farming on farms is almost absent in this province, but very few respondents (11.1%) are producing Tilapia as an integrated farming with the dairy farm (Figure 6.13).

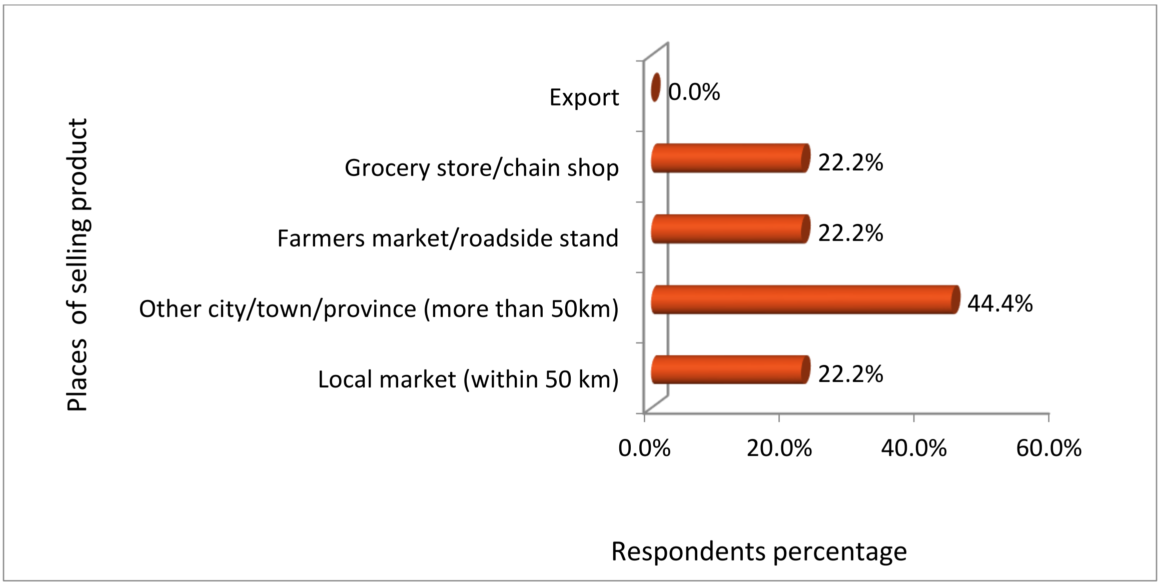
Figure 6.13: Fish farming and forest area as indicated by respondents



6.4.10 Marketing/selling milk, crop and vegetable products

The respondents identified that selling farm products locally is good for the environment, as well as for the food security, as it reduced greenhouse gas emissions and the production cost from food transportation. Another benefit is that local people get fresh foods at lower price as well as the market price will be stable (Appendix B, Table B-4). There are two milk processing plants in Newfoundland and Labrador, namely Scotsburn and Central Dairy, which are the main players in the fluid milk market in the province. Central Dairy is a division of Farmers Cooperative Dairy Limited based in Halifax, Nova Scotia and operates one processing plant in NL since 1980, whereas Scotsburn is also a Nova Scotian company which has started their business in 1984. Both companies process their milk in Mount Pearl (sister city to the provincial capital St. John's) and collect raw milk directly from farmers (Connelly, 2010). Therefore, dairy farmers have no permission to process their milk or sell it in local stores or to the people. According to Figure 6.14, 44.4 percent of the respondents sell their crops and vegetables to other cities or provinces that are more than 50 km away from the farm, and only 22.2 percent sell their product to local markets (within 50 km from the farm), and the same percentage (22.2 percent) to grocery stores/chain shops and farmers markets. No products from the dairy farms are being exported.

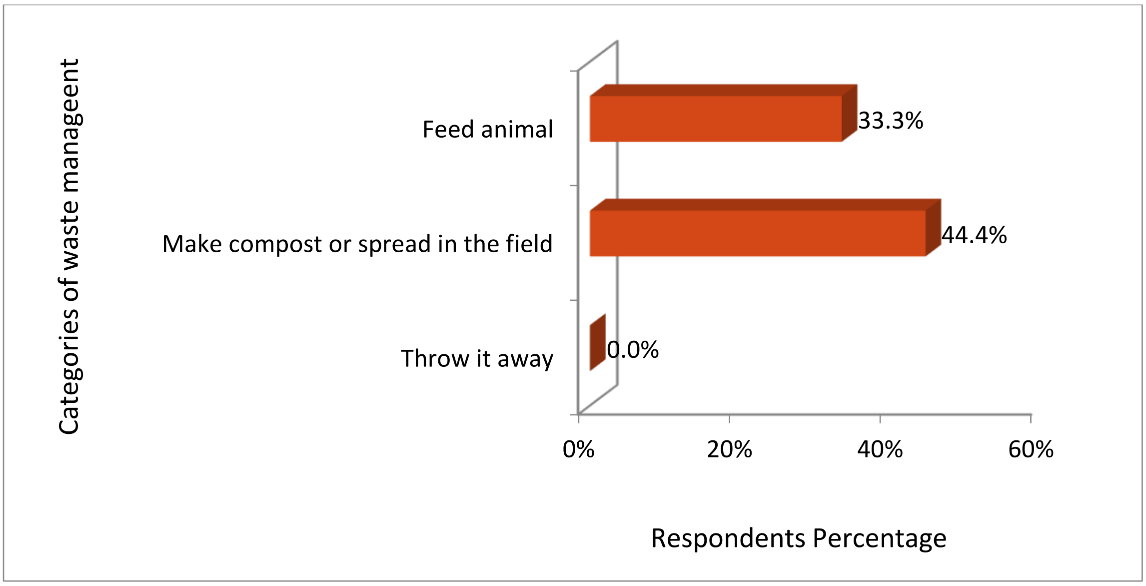
Figure 6.14 Marketing of farm products as identified by respondents surveyed



6.4.11 Waste management on dairy farms

Proper management of waste on dairy farms is an urgent issue for reducing environmental pollution and greenhouse gas emissions. There is no possibility to waste milk on the dairy farms since everything is handled by automatic systems and every farm has storage facilities. According to the respondents, on average less than 1 percent food is wasted (which is a very small amount) and waste is managed properly (Appendix B, Table B-5). The respondents of the study area manage their waste crops and vegetables in a proper way, as 44.4 percent compost them, and 33.3 percent feed them to their animals for diversifying their diet and for getting more milk.

Figure 6.15 Waste management as identified by respondents surveyed

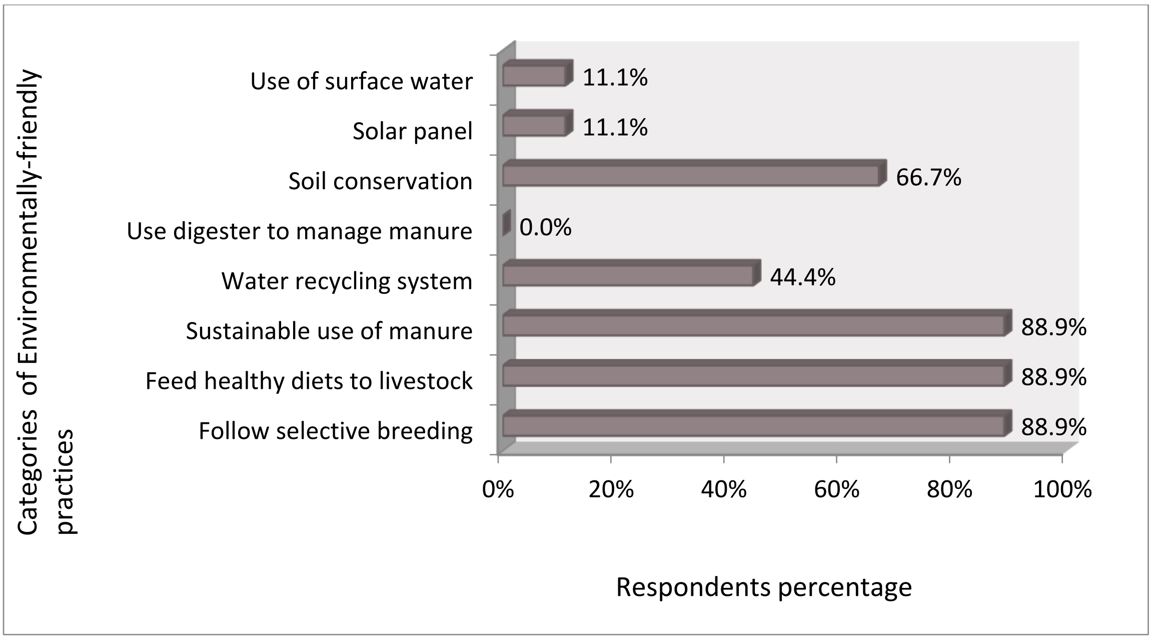


6.5 Environmental-friendly practices as mentioned by respondents

Studies show that some good and environmentally-friendly practices followed by dairy farm owners can make their farm more sustainable (Sorensen, 2018). As a good practice, 88.9 percent of the respondents (Figure 6.16) follow selective breeding in their dairy farms in the study area, which not only increases the meat and milk production and profit but also makes the farm more sustainably effective. Experts show that selective breeding also helps to produce fitter, stronger, disease free animals and enhances the sustainable food chain (Ayres, 2015). The survey result has shown that 88.9 percent of the dairy farmers of the study area provide healthy diets to their animals like forage, corn silage, grain and waste crops/vegetables but no growth hormone. Most of the respondents (88.9%) manage their manure properly through making compost or spreading it on the crop field. There is a chance of soil erosion and loss of soil fertility of the pasture and crop land due to over grazing by cattle, more tilling, mono cropping, as well as high winds and runoff surface water (Forge, 1998).

This research project has indicated that 66.7 percent of the respondents follow methods of soil conservation, as soil conservation is an important part of the overall challenge of sustainable agriculture, along with manure management, and wise use of pesticides and chemical fertilizers (Forge, 1998). Though the dairy farmers in the study area clear trees in the process of preparing land for farming but they also use organic fertilizers (manure), add limestone, use conservation tillage, rotate crops, grow legumes as well as restrict the number of animal stocking, using rotational grazing, protecting vegetations and controlling weeds (Acton, Cooteand Eilers, 2015). Using surface water (11.1%) and recycling used farm water (44.4%) are considered good practices which reduce the pressure on ground water. Some dairy farmers stated that they wanted to produce electricity from wind power but, they cannot as NL Hydro has the monopoly power to produce, supply and distribute electricity in the province. However, 11.1 percent of the respondents use solar panels as a renewable source of energy on their farm.

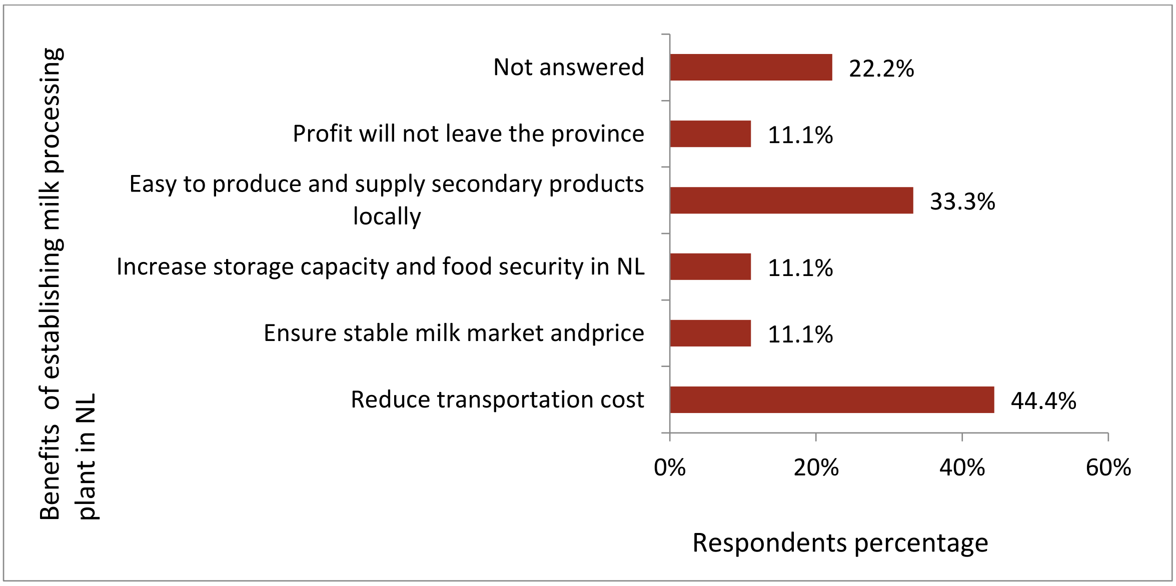
Figure 6.16 Environmental-friendly practices followed by respondents surveyed



6.6 Benefit of establishing a primary and secondary milk processing plant in NL

Central Dairy and Scotsburn are the two milk processing companies running their business in NL but both industries are owned by Nova Scotia entrepreneurs. More importantly, surplus milk is produced in this province but the people of the province spend more money to buy milk compared to other provinces. The study found that the price of milk in Atlantic Canada is 15 to 48 percent higher than the average national price at $1.22 per-liter of 2 percent milk in a 4 liter container and it is most expensive in St. John's NL, at $1.85 a liter in a two-liter container (Kelly, 2018). All of the respondents of the study area believe that there are numerous benefits in opening a locally owned primary and secondary milk processing plant which will increase production and supply (33.3%), ensure food security (11.1%), reduce the price of milk and milk products (11.1%), reduce transport cost and pollution (44.4%), and increase profit (11.1%), which will remain in this province and be reinvested (Figure 6.17).

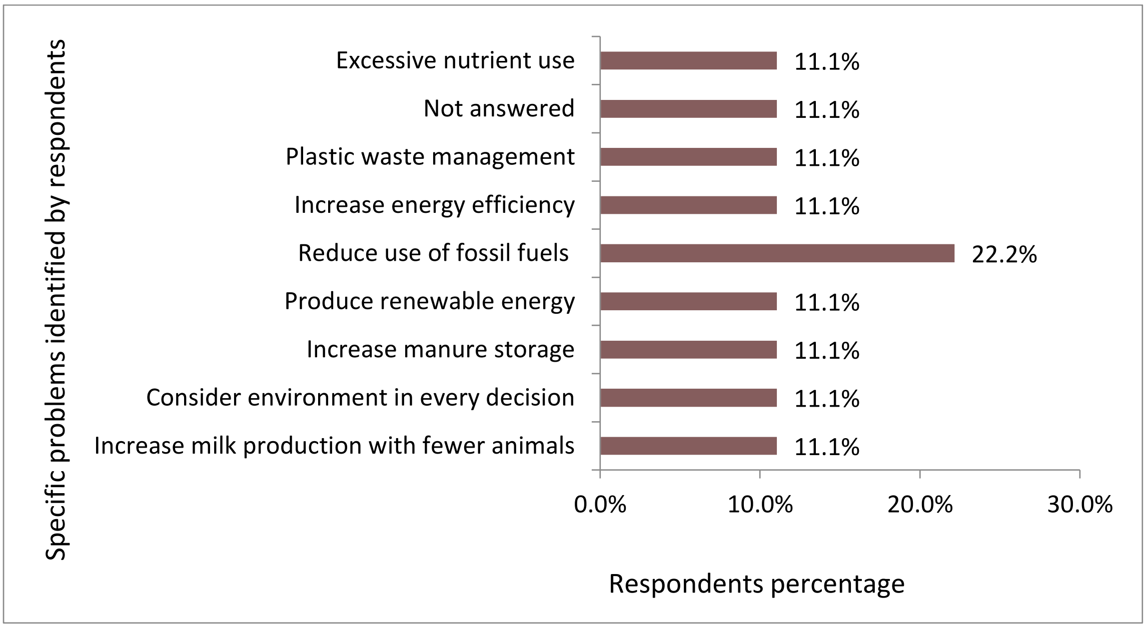
Figure 6.17 Benefits of establishing a milk processing plant in NL as identified by respondents surveyed



6.7 More specific environmental problems respondents want to see addressed

This survey asked respondents to identify one specific environmental problem they wanted to see addressed and Figure 6.18 is showing the responses. Most of the respondents have emphasized the issue of energy consumption (22.2%) and possibility to produce renewable energy at farm level (11.1 percent). Some respondents have referred to productive efficiency (producing more milk with fewer cows) so that less pollution will occur from dairy farms. The study has identified that improvements in efficiency for milk production in Canada can be achieved through research and innovation: Canada needs 50 percent fewer cows to produce enough milk for Canadian population, compared to 40 years ago (Dairy Farmer of Canada, n.d).

Figure 6.18More specific environmental problems respondents want to see addressed



6.8 Respondents' opinion about integrated, organic and agro-ecological farm practices

Integrated farming is an effective method of increasing food production and food security in this province, as indicated by 100 percent of the respondents surveyed (Table 6.12). Most of the dairy farmers of the study area have no interest in organic farming, as it is not feasible for large farms, and not cost effective. However, 88.9 percent of the respondents want to implement agro-ecological practices on their farms, to keep the balance between present and future generations' needs and sustainable development.

Table 6.12 Respondents' opinion about integrated, organic and agro-ecological farm practices

Questions related to integrated, organic and agro-ecological practices	Percentage
Are you interested in agro-ecological farm practices?	88.9%
Do you have knowledge/training about agro-ecological farm practices?	77.8%
Do you have plans on introducing organic farming on your farm?	11.1%
Do you think integrated farming can produce sustainable agricultural development?	100.0%

6.9: Government support for dairy farmers

Most of the respondents of the study area have received federal or provincial government support for running their businesses. According to Table 6.13, 33.3 percent of the respondents have received government support for land clearing and development, 22.2 percent of the respondents have benefitted from government knowledge transfer programs. The federal or provincial government provides support to the farms using more energy efficient (LED) lighting and new technology (22.2%). Some respondents (11.1%) have also received support under the CAP (Canadian Agricultural Partnership) and PAAP (Provincial Agrifoods Assistance Program) projects.

According to the results of the survey, the dairy farmers of NL expect more technical and financial support from both the federal and provincial government. A significant number of farm owners (22.2%) want to produce renewable energy from solar or wind power and they expect government regulations and support to produce and supply electricity. Some dairy farmers (11.1%) are seeking cost sharing facilities to upgrade their farm equipment, to increase their farm size, to improve productivity of milk production, or for hiring external expertise or consultants for improving farm efficiency or productivity. Under the Dairy Farm Investment Program (DFIP), the Canadian government has offered a five-year support plan (2017-2018 to 2021-2022) to provide $250 million to help Canadian licensed cow's milk producers to improve productivity through upgrades to their equipment (Agriculture and Agri-Food Canada, 2019).

Table 6.13 Federal and provincial government support received, expected and advice provided by respondents

Did you benefit from any programs/projects of the provincial or federal government?	% of Respon -dents	What kind of support do you expect from provincial or federal government?	% of Respon -dents	Do you have any other ideas about how to control the consequences of climate change?	% of Respon -dents
Support received from CAP and PAAP	11.1%	Expect more training and technical support	11.1%	Local slaughtering facilities to reduce transportation impacts on pollution and beef production	11.1%
Received fund from government for purchasing farm equipment	22.2%	Expect cost sharing program	22.2%	Hoping to install solar panel in the future	11.1%
Benefit received from government's knowledge transfer program	11.1	Need monetary support	11.1%	Make environmental projects as priority	11.1%
Grants for land clearing and development	33.3%	Expect permission to set up solar panel/wind turbine to produce renewable energy and sell surplus electricity to the grid	22.2%	Have extra funding available	11.1%
Energy efficient LED lighting and introducing new technology	22.2%	Continued partnership of research and development projects between federal and provincial government	11.1%	Need initiatives to supply grain with cheap cost and more easily	11.1%
Received support from nutrient specialist	11.1%	Support to purchase new electric farm equipment	11.1%	Need more expertise and regulation/policy	11.1%
Did not respond	11.1%	Need more expertise and regulation/policy	11.1%	Did not respond	11.1%
		Did not respond	11.1%		

The respondents have shared their ideas and suggestions to improve the farm productivity and food security of this province. Opening local slaughter houses can reduce transportation impacts on pollution and beef production, as indicated by 11.1 percent of the respondents. All the dairy farmers surveyed import grain for feed from other provinces which is expensive and creates greenhouse gas emissions through transportation. Some respondents (11.1%) suggested that the government should subsidies the cost of importing grains. Priority government support should be given to every environmental project at farm level as suggested by 11.1 percent of the respondents. Financial support as well as research and innovation are necessary for the sustainable development of the dairy sector of this province.

Therefore, the number of dairy farms as well as cows is declining which ultimately affects food security and food nutrition condition in this province. Supplying quality feed and feed management is a great challenge for the dairy farmers due to the short growing season, poor soil quality and lack of storage facility. Dairy farmers were trying to handle manure properly but still they did not use anaerobic digesters to produce electricity and fertilizer from manure. Due to lack of permission to produce electricity from solar energy or wind power, farms are heavily depended on fossil fuels. Absence of primary and secondary milk processing units is the cause of exporting milk to other province which creates loss for the dairy farmers and consumers. Government supports are expected by dairy farmers to set up anaerobic digesters, secondary milk processing units and easier access to credit for investing in more capital equipment.

Chapter VII

Results and Discussion

This chapter is an attempt to answer the thesis research objectives and questions as developed in the introductory chapter. Based on a literature review and primary data collection (surveys of crop farmers and dairy farmers), this study has investigated the climate change impacts on agricultural production and practices and overall food security of the NL province. It has also discussed the agricultural activities responsible for environmental degradation and climate change and the measures taken by farmers in the study area to deal with climate change. Moreover, it has assessed whether these measures and practices are helpful for agro-ecological farm practices. Assuming that agro-ecological practices are the possible solution to both environmental degradation and food insecurity, this chapter will analyze the ecological sustainability condition of the agriculture sector in NL using agro-ecological principles.

7.1 Natural hazards affecting the crop and dairy production in Newfoundland and Labrador

To fulfill the first objective and answer the first question of this study, the researcher asked the respondents several questions about natural hazards which are more acute at present and got the following responses described in Table 6.1. It has found that 37.5 percent of the crop farmers face the challenge of extreme temperatures, as they need more water for irrigation and the quality of the vegetables and crop is also deteriorated. Ruth Mottram, an environmental expert of the Danish Meteorological Institute warned that, 2019 is going to be a temperature record-breaking year for the North Pole as the icebergs or large chilly ice in the North Atlantic Ocean started melting at the beginning of June 2019 (The Daily Prothom Alo, June 19, 2019). The weather station Kana in Greenland recorded 17.3 Degrees Celsius on June 12, 2019 which was zero point three (0.3) Degrees Celsius far from the temperature recorded on June 03, 2012. Newfoundland and Labrador is near Greenland and this high temperature has a chance of affecting its agriculture. At the same time, very few dairy farmers (11.1 percent) faced problems due to high temperature, since the dairy cows are kept in sheds most of the time and farmers are growing corn and forage which are heat tolerable. As Table 6.1 has shown, 43.8 percent of the crop farmers indicated that low temperatures reduced the growth of plants and delayed maturing of crops with poor yields and quality, but temperatures below -25 degrees C may damage or kill the vegetables, forages, winter annuals or the tender fruit trees. Manitoba, Alberta, Saskatchewan, British Colombia and Ontario also face freezing temperatures every 3-4 years or more often, but the farmers use passive methods (site selection, land clearing, crop management and plant and harvest) and active methods (covering, heating, wind machines, and sprinkling) to protect the crops and vegetables. These methods are costlier sometimes (Brown and Blackburn, 1987; OMAFRA, 2019, May 14). NL dairy farmers were not very much affected by high and low temperatures, as they run their operations under sheds. However, long winters mean short growing seasons, which are a major challenge for the farm operations in NL, as identified by 75 percent of the crop farmers and 77.8 percent of the dairy farmers. Sometimes, farmers have to wait until mid-June to start their farm operations, which increases the harvesting risk since early winter may damage the crops, forages and corn. Similarly, short growing seasons limit the opportunity of growing more than one crop in the same field in a year. The dairy farmers need to preserve more forage and grain for long winters, needing more storage space, and are not able to use their pasture for grazing cattle. Similarly, to long winters, the same percentage of respondents (75% for crop farmers and 77.8% for dairy farmers) face challenges due to late spring frost or early fall frost that affects both the yield and quality of cereal crops, silage and grain corn. Additionally, late spring frosts during blooming period, reduces production more frequently and makes harder to store the crops (Brown and Blackburn, 1987; OMAFRA, 2019, May 14).

Table 7.1 Natural hazards affecting the crop and dairy production as identified by respondents

Natural disaster affecting the farmers	Crop farm (% of "yes" respondents)	Dairy farm(% of "yes" respondents)
Extreme temperatures: high +35 degrees C or more	37.5	11.1
Low temperatures: below -25 degrees C	43.8	11.1
Long winter/late spring	75.0	77.8
Heavy snow/snow storm	25.0	22.2
Late spring frost	75.0	77.8
Rain storm/heavy rain	25.0	22.2
More frequent drought	56.3	55.6
Short growing season	75.0	88.9
High winds/wildfires	37.5	33.3
Pest/disease outbreak	37.5	33.3
Flood	18.8	11.1
Land slide/soil erosion	12.5	22.2
Wet season	25.0	-
Cyclone/tornadoes	-	44.4

The survey report indicated that 25 percent of the crop farmers and 22.2 percent of the dairy farmers were affected by heavy rains and rain storms and they raised the question whether the sudden rain storms are a normal occurrence or is the result of climate change. The report refers to Sean Dyke, a cranberry farmer in Wooddale South, who faced floods on two occasions from rain storms in his seven years of farm operation, which washed away newly constructed berms and filled parts of his fields with debris (Fitzpatrick, 2017). Sometimes, the rain storms or floods have washed out the crop fields and access roads which remained impassable for seven days.

"Newfoundland and Labrador is in the throes of the 'most intense storm' on the planet, according to a meteorologist in Gander" (CBC News, 2015, November 15) and sometimes the wind and waves were so strong that the island was shaking (CBC News, 2015, November

16). The high winds or storms are very dangerous for young plants and they destroyed vegetables, crops, fruits and hey harvest as identified by 37.5 percent of the crop farmers and 33.3 percent of the dairy farmers. The effects of high temperatures and global warming due to climate change have started being observed by the farmers of NL, since more than 50 percent of the farmers mentioned that they used more water for irrigation due to more frequent droughts and some farmers are planning to install new water pumps on their farm. Several independent studies have claimed that drought and heat are major abiotic stresses that reduce crop yields by as much as 50 percent and weaken regional as well as global food security (Lamaoui et al. 2018, Feb 19). Nonetheless, even the mildest heat and drought stress negatively affects crop and vegetable yields as stated by the experts (Lamaoui et al. 2018, Feb 19). In 2018, not only Newfoundland and Labrador, but also most of Manitoba, Ontario, New Brunswick, Alberta and Saskatchewan, have been ranked as abnormally dry (Tait, 2017, Sep 8). A stressful environment due to a changing climate is predicted to impact negatively the diversity and abundance of insect-pests, and ultimately to extend the damage to economically important agricultural crops (Fand, Kamble and Kumar, 2012). Outbreaks of insect-pests and diseases have significant consequences on crop production, and existing research has shown that more than 40 percent of crop losses are due to pests worldwide (Oerke, 2006). The farm operators in NL face insect-pests problems as indicated by 37.5 percent of the crop farmers and 33.3 percent of the dairy farmers, and they use synthetic as well as organic pesticides to control pests and diseases. The insect-pests not only affect perilously the agricultural production but also the livelihood of farmers who are directly depending on climate sensitive sectors such as agriculture (Fand, Kamble and Kumar, 2012). An environmental expert claimed that the climate change forecasts would seem to suggest good news for agriculture in NL in the coming decades, but there is a forewarning, as ongoing changes also provide conditions ripe for shifts in disease, and expanded range of some pests (Fitzpatrick, 2017). Though few respondents (12.5 percent of the crop farmers and 22.2 percent of the dairy farmers) have indicate that landslide and soil erosion hampered the crop production after clearing trees and leveling hills for land development, mono cropping and tilling, as well as rain storms/floods may increase the landslide or soil erosion problem in this province. The respondents (25 percent of the crop farmers, dairy farmers were not asked this question) worry that the crop production will be affected by the wet season, as experts mentioned that more rain and more storms are expected, with warm temperatures in this province. Frequent rain and dull weather may create difficulty to access the farm and may decrease the crop yield (Fitzpatrick, 2017).

The result of this research confirm that climate change is impacting the NL province, and its sensitive agriculture industry, affecting crop and dairy production in Newfoundland and Labrador and increasing the food insecurity problem. The most important finding of this research is that provincial farmers need to change the way of doing farming by taking into account the changing climate, and by applying new techniques and methods to protect their crops and livestock as well as by implementing sustainable farm practices.

7.2 Agricultural activities contributing to climate change

Greenhouse gas emissions from industrial, energy, transportation and agriculture sectors are contributing to global warming and climate change. Agriculture, especially industrial or conventional agriculture, has an impact on climate change, as it is causing approximately 30 percent of total greenhouse gas emissions, mainly due to use of chemical fertilizers, fossil fuels, pesticides and animal wastes (IAEA, 2019). However, elements of healthy ecosystems (soils, standing trees etc.) remove carbon dioxide from the atmosphere, by sequestering carbon in biomass, trees, dead organic matter and soil, which offsets approximately 20 percent of the emissions from the agriculture sector (FAO, 2014).

To answer the second part of the first research question, the researcher has explored some farm practices and the farmers' perception about contribution of agriculture to climate change. The survey results have shown that 43.8 percent of the crop farmers (Appendix A, Table 2) and 44.4 percent of the dairy farmers (Appendix B, Table B-1) believed that industrial or conventional farming contributes to climate change. The remaining respondents both crop and dairy farmers believed that their farm practices were not contributing to climate change, as they make efforts to apply best management methods. Table 7.2 revealed that 25 percent of the crop farmers agreed that mono cropping had negative effects on soil depletion and contributes to reduction in diversity of soil nutrients. This single cropping system is commercially efficient and profitable, but provides an unbuffered niche for parasitic species, increasing crop vulnerability to opportunistic insects, plants, and microorganisms, and also increasing dependency on pesticides and artificial fertilizers. Using more chemical fertilizers and synthetic pesticides ultimately increases the greenhouse gas (N_2O) emissions. The field survey indicated that 87.5 percent of the crop farmers and 88.9 percent of the dairy farmers clear trees to prepare the farm land, but 37.5 percent of the crop farmers and 22.2 percent of the dairy farmers indicated that land clearing and field burning contribute to greenhouse gas emissions and climate change. Indeed land clearing and field burning enhance greenhouse gas emissions in two ways, when farmers cut trees (deforestation) for preparing the land for agriculture, and when they burn crop residues in the field releasing carbon dioxide into the atmosphere. At the same time, both activities destroy the green plants which take in carbon and release oxygen during photosynthesis and reduce the carbon sequestration capacity of the ecosystems (Gorte and Sheikh, 2010). The soil quality and structure is not optimal, being rocky, less fertile and more acidic, in the NL province and an increased number of tillage is necessary for preparing the soil. As Table 7.2 indicated, 25 percent of the crop farmers and 11.1 percent of the dairy farmers agreed that tillage is related to greenhouse gas emissions, and they were trying to reduce the number of tillage or applying minimum/zero tillage techniques. Mangalassery et al. (2014) have shown that soil tillage techniques have a deep influence on the physical properties of soil and on the greenhouse gas balance (store minus release).They also recorded a significantly (26-31 percent), higher net global warming potential under conventional farming, than with zero tillage farming. At present, conservation tillage practices, such as reduced/minimum/zero tillage, and direct drilling are widely getting popularity to protect soil against erosion and degradation of structures, to increase carbon sequestration, to enhance soil organic matter content and to mitigate greenhouse gas emissions (Petersen et al. 2011; West and Post, 2002; Kong et al. 2009).

Table 7.2 : Agricultural activities contributing to climate change as identified by respondents

Agricultural activities contributing to climate change	Crop Farms (% of "yes" respondents)	Dairy Farms (% of "yes" respondents)
Mono cropping	25.0	-
Land clearing and field burning	37.5	22.2
Soil tillage	25.0	11.1
Manure management	25.0	33.3
Irrigation	12.5	0.0
Using pesticides	31.3	11.1
Use of chemical fertilizers	37.5	33.3
Use of fossil energy or fuels	37.5	44.4
Size of farm operation	25.0	22.2
Food waste	12.5	11.1
Food production/processing	12.5	-
Food transportation	31.3	33.3
Enteric fermentation (gas directly from cattle)	-	0.0
Water and air pollution from livestock	-	22.2
Soil erosion from pastures	-	11.1
Use of a heating system	-	11.1

Manure management has a profound contribution to greenhouse gas emissions, especially methane emissions, if it is not handled properly. A number of farmers surveyed (22.2 percent of the crop farmers and 33.3 percent of the dairy farmers) were aware about the negative consequence of improper manure management and with the help of environmental farm plans (supported by a national program) they compost manure or spread/incorporated it in the crop land during the spring and fall, according to the recommended way. Most dairy farmers surveyed did not use feed additives (like seaweeds) or feeding strategies to reduce methane or bad odor of the manure. They also have no aerobic digesters to produce renewable energy and fertilizer without any air, water or soil pollution. Farm Environmental Management in Canada (FEMC) indicates that there are differences between the provinces with respect to manure management practices. For NL farmers, more information and support is needed about the farming practices related to agri-environmental topics such as manure handling, water management, chemical inputs and sustainable land management (Beaulieu, 2004).

The farmers surveyed use chemical or synthetic pesticides as one of the several tools to control, prevent, destroy or mitigate pest-insects and diseases in the crop and vegetables field. Due to introduction of organic pesticides and bio-control methods and increased awareness of the farmers about the negative health and environmental effects of chemical pesticides, the use of chemical pesticides is gradually decreasing in the study area. Canadian farmers strictly follow the regulations of pesticides use, enforced by the federal, provincial and municipal governments, and because of this reason, very few respondents (31.3% of the crop farmers and 11.1% of the dairy farmers) believed that their use of chemical pesticides has an impact on environmental pollution and climate change.

Using chemical fertilizers for crops, vegetables and grain production has direct effects on producing greenhouse gas emissions, and water and soil pollution. These effects are more serious in NL, as farmers need using more chemical fertilizers to reduce soil acidity and maintain pH and nutrients levels of soil and cost-effective production (Buckler, 2018). Though most of the farmers in the surveyed area are trying to use organic fertilizers alongside chemical fertilizers and limestone, only 37.5 percent of the crop farmers and 33.3 percent of the dairy farmers believed that the chemical fertilizers and the limestone they used in the fields have negative impacts on the environment. Studies show that chemical fertilizers have an impact, as they do contaminate everything in the environment and their residues are found everywhere in soil, water, land and air (Sharma and Singhvi, 2017). From the respondents' comments, it was found that dairy farmers have the opportunity to use more organic fertilizers from their own farms compared to the crop farmers.

Due to shortage of labor and manpower, Canadian agriculture requires numerous tractors, harvesters, and farm equipment which are running on fossil fuels. Farmers also use fossil fuels for personal vehicles and for food/grain transportation which produce greenhouse gases and increase global warming. Survey results indicate that 37.5 percent of the crop farmers and 44.4 percent of the dairy farmers mentioned that fossil fuel was one of the major sources of air pollution and climate change. Ontario has recently imported one tractor from US which is running on renewable solar energy, but the researcher did not find any electric vehicles or farm equipment running on renewable energy in the NL province. With its new action plan on climate change, the Way Forward on Climate Change, the provincial government imposed a carbon tax on fossil fuels in NL, but this program will not reduce pollution created by agricultural farms as this sector is exempted from the carbon tax (Government of Newfoundland and Labrador 2018; The Way Forward, 2018).

Large size farms operation which is specific to industrial or commercial farm practices basically depends on mono cropping, and massive application of chemical fertilizers and pesticides. The average farm size in NL increased from 153 acres in 2011 to 173 acres in 2016, which means that industrial as well as mono cropping farm practices are increasing and will enhance greenhouse gas emissions. As Table 7.2 indicated, 25 percent of the crop farmers and 22.2 percent of the dairy farmers believe that large scale farm operation contributes to environmental pollution and climate change. According to the findings of this study, more than 75 percent of the crop farmers and 77.8 percent of the dairy farmers have also stated there are advantages in small-scale farming. Though the discussion about existence of economies of scale in farming is controversial, but the fact is that the industrial agriculture's drive to achieve economies of scale is the reason for increasing the size of the farms (Kislev and Peterson, 1986; Taylor, 2014).

Food transportation is one of the big sources of environmental pollution, as mentioned by 31.3 percent of the crop farmers and 33.3 percent of the dairy farmers surveyed. Though Newfoundland and Labrador is a less populated province, but the communities are scattered and a large number of people live in rural areas. Most of the farmers sell their products in the nearest city, grocery stores or farmers markets and sometimes they offer home delivery and they need to travel more frequently and farther distances which increase greenhouse gas emissions. There is no alternative option to supply food products like public transportation, carpooling or shuttle services in the surveyed area.

Enteric fermentation occurs when methane (CH_4) is produced in the rumen as microbial fermentation takes place in the ruminant animal's (cattle, sheep, buffalo, and hog) multi-chambered stomach (FAO, 2016). A recent study has shown that in Australia, ruminant animals account for over half of the greenhouse gas contribution from methane emissions and the enteric methane emissions vary due to feed quality, animal size and environmental temperature (FAO, 2016; Australian Greenhouse Offices, 2007). None of the surveyed dairy farmers indicated that enteric methane emissions from cattle contribute to climate change. However, decreasing the production of enteric CH_4 from ruminants, by changing the animal's diet, without reducing animal production is desirable, in order to reduce global greenhouse gas emissions (Martin, Morgavi and Doreau, 2010).

Dairy farms are responsible for water and air pollution near the farm area as identified by 22.2 percent of the dairy farmers surveyed. The liquid manure stored in a pond, lagoon or water body may pollute the water and create bad odor. The pollution may also occur from manure when the liquid or dry manure is spread in the field, but it can take a longer time if injected or incorporated with soil.

Only 11.1 percent of the dairy farmers believed that soil erosion occurred in pastures because of grazing cows, but 88.9 percent did not believe that, since due to the long winters in the NL province, there is little chance that pastures are overused for grazing. In the same way, the dairy farmers claimed that they do no need to install heating machines in the winter season, since the cows' body temperature is enough to keep the shed warm.

Finally, more than 50 percent of the respondents believed that large scale farm operation has no or, has minimum impact on climate change, but according to the remaining respondents all kind of farm practices are contributing more or less to greenhouse gas emissions. Among these, land clearing and field burning, using chemical fertilizers and pesticides, as well as fossil fuels, and manure management have significant impact on climate change. In addition, the dairy farmers need to import most of the grain for feeding their animals from another province, which is a huge source of GHG emissions and a high cost for dairy farmers. At the same time, it is difficult to ignore that climate change effects are more severe in the agriculture sector, which ultimately is increasing the pressure on food production and food security in NL as well as worldwide.

7.3 Measures taken by the NL farmers to reduce the GHG emissions and keep the environment intact

According to Agriculture and Agri-Food Canada (2017), the agriculture and agri-food sector generated $111.9 billion of gross domestic product (GDP) in 2017, which accounted for 6.7

percent of Canada's total GDP. Canadian agriculture also dominated the international agricultural market, as it was the 5th largest exporter of agricultural commodity in 2016 (Agriculture and Agri-Food Canada, 2017). The average farm size in Canada was 820 acres in 2016 (Statistics Canada, 2017). This means that Canadian farmers' practices belong to industrial or commercial farming, but the farmers, including the NL farmers, have to follow strict rules and regulations when using fertilizers and pesticides, as well as for land development, waste management and the safety of human health and the environment.

To cover the first part of the second objective and to answer the second question, the researcher focused on the measures taken by the respondents. The respondents of the surveyed area used large amounts of fossil fuels but, at the same time, some of the respondents (18.8 percent of the crop farmers and 22.2 percent of the dairy farmers) are interested to try produce energy from alternative sources, like solar power, wind and tidal energy or even geothermal. But due to lack of provincial government permission and monopoly power of Newfoundland and Labrador Hydro (Nalcor Energy) farmers have no right to produce renewable energy and sell the surplus to the national grid (Mercer, 2019).

The respondents know about the effects of chemical fertilizers on the environment and many of them (43.8 percent of the crop farmers and 77.8 percent of the dairy farmers) are trying to use less chemical fertilizers. In order to do so, they are trying to: follow the minimum recommended doses, discuss with the specialists about soil health and nutrition, use granular fertilizer (a mix of chemical and natural fertilizer), plant green manure crops, use all natural amendment and use more organic/manure (93.7 percent of the crop farmers and 100 percent of the dairy farmers use manure). A positive initiative is that 25 percent of the crop farmers did not use any chemical fertilizers, considering the negative environmental and human health effects. After the introduction of organic pesticides and of integrated pest management techniques, most of the farmers in the study (50 percent of the crop farmers and 55.6 percent of the dairy farmers) have tried using less synthetic pesticides. Moreover, as alternative techniques, they are trying to apply bio-control, crop rotation, cover crops, spreading sawdust at the edge of farm and sterile insect techniques to control pests attack.

Table 7.3: Measures taken by the farmers to reduce GHG emissions and keep the environment intact

Various measures	Crop farms (% of "yes" respondents)	Dairy farms (% of "yes" respondents)
Trying to use alternative energy sources	18.8	22.2
Trying to use less chemical fertilizers	43.8	77.8
Use no chemical fertilizers	25.0	00.0
Use organic fertilizers/manure	93.7	100.0
Trying to use alternative pesticides	50.0	55.6
Collect rain water for farm usage	37.5	11.1
Recycling used water	6.3	44.4
Using surface water	43.8	11.1
Crop diversification	62.5	-
Crop rotation	68.8	-
Practice intercropping	31.3	-
Soil conservation	62.5	66.7
Sustainable use of manure	-	88.9
Having trees in the farm area	87.5	100
Plan to supply more product to local markets	68.8	100

To reduce the pressure on ground water and benefit the environment, 37.5 percent of the crop farmers and 11.1 percent of the dairy farmers collect rain water, 44.4 percent of the dairy farmers use recycled water, and 43.8 percent of the crop farmers and 11.1 percent of the dairy farmers use surface water. As Table 7.3 highlighted, 62.5 percent of the crop farmers grow diversified crops, 68.8 percent apply crop rotation and 31.3 percent practice intercropping to increase soil health, reduce the need of chemical fertilizers and pesticides, increase the farm income and reduce the risk of crop loss. All these practices, directly and indirectly, benefit the environmental. Crop rotation, crop diversification, intercropping, using organic fertilizers, and producing green manure plants are beneficial to soil conservation and 62.5 percent of the crop farmers and 66.7 percent of the dairy farmers follow these practices. The survey results have shown that 87.5 percent of the crop farmers and 100 percent of the dairy farmers have trees in the farm area. This is one of the environmentally-friendly practices, as tree or forests are the best carbon sequesters and keep the weather cool. To reduce the effects of carbon emissions from transportation and reduce their costs, most of the respondents (68.8 percent of the crop farmers and 100 of the dairy farmers) are trying to supply agricultural produce in the local markets.

Overall, it can be said that respondents are more or less conscious about the environmental effects of their agricultural activities and about the challenges they face in food production and food security due to climate change. Most of them have taken several mitigation measures and also have plans to transition to more environment friendly farm practices.

7.4 Transition to agro-ecology to make current agricultural practices more resilient to global climate change

The present trend in Canadian agriculture is that the number of farms is decreasing but the average size of farms is increasing (from 779 acres in 2011 and 820 acres in 2016) (Statistics Canada, 2017), indicating that industrial agriculture may be hurting the traditional small-scale family farm in Canada. The industrial agriculture model may increase short-term yields of targeted crops in certain geographies and climatic zones; however, it is also linked to a number of environmental problems, and contributes to a new array of social problems, including widespread income inequality, financial indebtedness of farmers, loss of farmer knowledge, increasing the number of agrifood corporations and forcing small farm owners out of business (Isaac et al. 2018). To develop diverse pathways of resistance to these challenges, a growing number of farmers, social movement organizations, and institutions are recognizing the importance of agro-ecology as a prominent component of agricultural production and of the food sovereignty movement (Wittman, Desmarais and Wiebe, 2010; Pimbert, 2017). An agro-ecological approach recognizes the multifunctional dimensions of agriculture and helps to extend toward achieving a broad range of socially equitable and sustainable goals, such as increasing ecological resilience, improving health and nutrition, conservation of natural resources, economic stability, climate change mitigation and increased social resilience and institutional capacity (IAASTD, 2009). On the basis of the field survey information, the researcher has tried to assess the feasibility of extending agro-ecological practices in NL.

To increase ecological resilience and reduce the risk of changing environmental conditions, more than 50 percent of the respondents of the study area are using crop rotation, soil conservation, crop diversification, and make efforts to use less chemical fertilizers and pesticides, and also have plans to produce renewable energy from solar, or wind power. Almost 100 percent of the respondents apply animal manure, have trees in the farm area and have access to surface water sources like lakes, streams and rivers that are significant for preservation of the ecosystem (Martens, Entz and Wonneck, 2013). All these practices help to reduce greenhouse gas emissions and climate change vulnerability, as well as enhance ecological resilience in NL. The survey results mentioned that 68.8 percent of the crop farmers and 88.9 percent of the dairy farmers have plans to make their farm more environmentally-friendly, which increases the expectation of implementation of agro-ecology principles.

Table 7.4 Farm practices that help agro-ecology as identified by respondents

Farm practices that help agro-ecology	Crop farms (% of "yes" respondents)	Dairy farms (% of "yes" respondents)
Did your farm increase the size of production or livestock in the last 5 years?	62.5	55.6
Do you have plans to increase the size of production or livestock in the near future?	50.0	22.2
Do you also practice integrated farming (livestock and crops) on your farm?	43.8	77.8
Do you think that there are advantages in small scale farming?	75.0	77.8
Do you have a plan for making your farm more environmentally-friendly?	68.8	88.9
Do you have knowledge about agro-ecological farm practices?	68.8	77.8
Are you interested in agro-ecological farm-practices?	93.8	88.9
Do you have plans to introduce organic farming on your farm?	37.5	11.1
Do you think that integrated farming can promote sustainable farming on your farm?	93.8	100
Did you benefit from any program/financial support from the provincial or federal government for promoting sustainable agricultural development in NL?	62.5	88.9

Improving human health and nutrition requires more diverse, nutritious and fresh food. This can be achieved by reducing the incidence of chemical fertilizers and pesticides which are poisoning the farmers, consumers and the environment. Though the respondents use a high amount of chemical fertilizers, at the same time, a large percentage of farmers use organic fertilizers and are trying to use less chemical fertilizers and pesticides. More importantly, most of the agricultural commodities produced in this province were sold locally, but the amount is only 10 percent of the total demand. Therefore, it is a big challenge for the farmers of NL to supply fresh and nutritious food, as 90 percent of the food is imported. As Table 7.4 indicated, 62.5 percent of the crop farmers and 55.6 percent of the dairy farmers increased the farm size in the last 5 years and, at the same time, 50.0 percent of the crop farmers and 22.2 percent of the dairy farmers have plans to increase their farm size in the near future. This may enhance the supply of fresh food and help to achieve the provincial government's goal of increasing provincial food production from 10 to 20 percent (The Way Forward, 2018). Though organic production or certified organic production fails to capture the multiple dimensions of agro-ecological practices and motivations, the number of Canadian farms cultivating organic products has increased 65 percent between 2011 and 2016, indicating a trend towards increased ecological farming across the country and possibly a transition to the adoption of more ambitious agro-ecological practices. In the entire Newfoundland and Labrador, only 1.2 percent of the farms in 2016 have produced organic products (Statistics Canada, 2017), and the survey results show that 37.5 percent of the crop farmers and 11.1 percent of the dairy farmers have plans to introduce organic products.

Conservation of natural resources, like organic matter in the soil, biodiversity, water quality, and ecosystem services, like pollination, are significant to increase ecosystem productivity. The plants and microbes help to degrade chemical pollutants and organic wastes and cycle nutrients through the ecosystem. Pollinators, such as bees and butterflies, provide important environmental and economic benefits to agricultural and natural ecosystems with more crop diversity and food productivity (PLTA, 2011). Everybody knows that NL bees and honey are of exceptional quality and nobody is allowed to import bees from outside NL, in order to protect the health of local bees. The farmers surveyed in this study were adding lime and chemical fertilizers and pesticides to the soil. That is not good for soil health and the surrounding environment, as the chemical pesticides they used have a chance to kill useful microbes and insects. According to the survey results, almost all the crop farms and dairy farms have trees around the farm land and more than fifty percent of the farms have surface water bodies that are significant for maintaining ecosystem services.

Economic stability in agriculture refers to a more diversified cropping system, to integrated farm practices, and to the spread of labor requirements and production benefits over time as well as to reduced vulnerability to single commodity price swings (IAASTD, 2009). The field survey information indicated that 62.5 percent of the crop farmers practice diversified cropping and 31.3 percent practice intercropping in the study area (Table 7.3). This is economically more profitable and reduces the risk of single crop failure and increases soil fertility and moisture availability (Issac et al. 2018). The study found that 43.8 percent of the crop farmers and 77.8 percent of the dairy farmers (Table 7.4) practice integrated farming (crop and dairy) which spreads the income sources but increases the labor requirements. Of the farmers surveyed, 93.8 percent of the crop farmers and 100 percent of the dairy farmers (Table 7.4) indicated that they believed that integrated farming enhances the sustainable income sources and the food security of the province. Moreover, 87.5.8 percent of the crop farmers and 100 percent of the dairy farmers (Table 7.3) have forest area on the farm, but they do not use it for commercial purposes and very few dairy farmers (around 10%, according to the survey) have ponds for aquaculture. If the respondents have access to forest and surface water sources for aquaculture, then the farms could be more integrated and could offer more employment and could earn more money (Issac et al. 2018). Most of the respondents in the NL province are running rather large scale farm operations, but interestingly, 75.0 percent of the crop farmers and 77.8 percent of the dairy farmers believed that small scale farming is more efficient and sustainable, since smaller farm can be managed more easily. This belief is confirmed by a FAO report that stated that small scale farmers produce over 70 percent of the world's food needs and provide employment for millions (FAO, 2013).

Climate change mitigation through increased energy efficiency, reduced dependency on fossil fuels and fossil fuel-based agricultural inputs (fertilizers), increased carbon sequestration and water capture in the soil are some of the goals of agro-ecological practices (IAASTD, 2009). According to the survey report, 22.2 percent of the dairy farmers received financial support from the government to use energy efficient LED lighting, but the researcher could not find any energy efficient vehicles used by respondents. The survey report also mentioned that 18.8 percent of the crop farmers and 22.2 percent of the dairy farmers are trying to use renewable energy from either geothermal or solar power (Table 7.3). Due to lack of government permission to produce renewable energy at individual level, and due to recent government regulations that exempt the agriculture sector from carbon pricing, there is a little chance to reduce dependency on fossil fuels and fossil fuel-based inputs in the NL agriculture. The surveyed respondents produced cover crops and green manure plants and used organic fertilizers and also had trees on the farms that have the potential to enhance the carbon sequestration and water holding capacity of the soil. Extending these practices to all the NL farmers would be a necessary step towards the transition to an agro-ecological agricultural industry in the NL province.

Agro-ecological knowledge, training, scientific research (Altieri et al. 2015), as well as government and non-government support networks play positive roles in increasing social resilience and institutional capacity which are main goals of agro-ecological practices. As Table 7.4 pointed out, 68.8 percent of the crop farmers and 77.8 percent of the dairy farmers in the study area haves knowledge about or training in agro-ecological farm practices, and 93.8 percent of the crop farmers and 88.9 percent of the dairy farmers are interested in agro-ecological farm practices. The provincial as well as the federal government provide several support programs through Agriculture and Agri-Food Canada, NL Federation of Agriculture, Environmental Farm Plan, the CAP, PAAP, The Way Forward programs, Young Farmers'

Forum, and Food First NL to make NL's agriculture and the food supply system more secure, resilient to climate change and sustainable.

The overall discussion in this chapter shows that the NL agriculture industry is at the more or less middle stage of adopting agro-ecological farm practices. Farmers are highly interested about more environmentally-friendly agro-ecological farm practices and to achieve these goals more initiatives, research, training and supports are needed.

Chapter VIII

Policy Recommendations and Conclusion

8.1 Policy recommendations

Based on the respondents' opinions, on current trends of agricultural practices in NL, in Canada and worldwide, and on the existing plans and programs of the provincial government, the researcher developed the following list of policy recommendations which could assist in the transition to a more sustainable agriculture and food production system in the province, by extending agro-ecological practices in NL agriculture industry. These policy suggestions are not fully comprehensive in order to mitigate climate change impacts and promote agro-ecological practices within the province, but it is the hope of the researcher that they would help to increase food security in the province, reduce the negative impact of natural hazards and enhance sustainable ways of practicing agriculture, by using agro-ecological practices in NL. The 14 policy recommendations suggested by the researcher are as follows:

1. To stop decreasing the total farm area and the number of farms in NL, the government should make available sufficient, affordable and suitable land and allocate it specifically to small-scale and young farmers that are interested in applying agro-ecological and environmentally sustainable principles of farming. A study of the way the 64 hectares of new and devoted to agriculture have been allocated by the provincial government starting in February 2017 (Fisheries and Land Resources, 2017) would be a good first step in increasing the trend in this area.

2. To maintain the soil pH level and soil nutrients intact, farmers should be encouraged to apply less lime and chemical fertilizers and to apply traditional knowledge like using organic fertilizer (manure), compost, green manure plants, fishery discards and cover crops. To apply organic fertilizers (manure), crop farmers who have no

livestock can introduce dairy and beef farming or make a collaboration to buy surplus manure from dairy or beef farms.

3. To increase the total area and operations of greenhouses for supplying fresh vegetables in winter, the government should develop separate plans to provide financial and technical support to interested people.

4. Take an initiative to build a separate campus of Memorial University of Newfoundland in central Newfoundland which will offer specialized programs related to sustainable agriculture, agro-ecology farming practices, agri-business, agricultural sciences, agro-technology, veterinary science and apiculture.

5. The provincial and federal government should provide dedicated funds to the students and faculty members of Saint John's, and Grenfell Campuses of MUN and CONA for sustainable agricultural research and innovation and for building collaboration between universities, agricultural farms, the general public and the government and non-government organizations, for raising general awareness about environmental and human health benefits of agro-ecology.

6. To create new entrepreneurs and encourage more family members to enter family farming and young people to enter farm business, more agricultural related courses and diploma programs should start at college and university levels throughout the province. In this case, the Young Farmers Forum, the CAP and PAAP programs can provide initial financial support with easy conditions and necessary training to start the business, since it is difficult to manage big funds for young people and it may discourage them to enter the business.

7. Government can provide support to farm owners who offer summer jobs for the students of MUN and CONA, an initiative which has two sided benefits: it will satisfy the excess demand of labor force in the provincial agriculture sector, while the students will get practical experience on farming.

8. To speed up the increase of the organic farming sector, the government should arrange training and education programs on how interested farmers can obtain organic certification, information and necessary inputs. Organic assistance and subsidies should be available for the farmers to buy costly organic fertilizers and pesticides and introduce integrated pest management systems.

9. Improvements are required in green transportation and green energy sector through reducing consumption of fossil fuels and producing more energy from renewable sources. Renewable energy pilot programs should be initiated, such as for wind turbine energy, solar panel or tidal power energy for producing electricity at farm level. Remodeling the greenhouses and dairy farms to heat and light them by geothermal/wind/solar energy. Support investment in anaerobic digesters at every dairy farm to produce renewable energy and green manure.

10. Government should reward and assist the farmers who currently practice or wish to incorporate integrated farming (crop, livestock, forest and aquaculture) or at least are producing multiple crops (polyculture) or mixed crops (crops and fruits trees/livestock), or intercropping instead of mono-cropping. Government should develop and enact regulations to encourage integrated farming approaches and sustainable practices. For instance, farmers should be allowed to produce trees in the farm area, renewable energy from wind or solar power and supply the surplus energy

to the national/provincial grid or to produce electricity from cows manure by using anaerobic digesters and/or produce fish in the ponds or lakes around the farm.

11. To support farms in buying electric tractors (running by solar energy), cars, and trucks, the government can develop partnerships with Solectrac, owned by inventor Steve Heckeroth, who has been doing electric conversions on cars, trucks, race cars and tractors for 25 years (Lyseng, 2019). Applying minimum or zero tillage methods, carpooling, shuttle services, public transport and energy saving LED lighting can reduce energy consumption. The Newfoundland and Labrador government can get technical support from Quebec government for introducing electric vehicles, hydrogen fuel-cell vehicles and plug-in hybrids in NL.

12. Government should encourage and support secondary processing of milk and dairy produce, industrial eggs and poultry, cranberries, fruit and vegetables and meat in the province.

13. Preparation and execution of crop and livestock insurance is required to reduce mental stress and financial risks of the farmers. Mentoring and mental health services should be provided by the NL Federation of Agriculture. Agro-forestry as well as diversified and integrated farming approaches can reduce financial risks and mental pressure of farmers. Facilitate establishment of commercial links between agricultural farms and tourism industry to increase the demand for local and sustainable food, attract more tourists to visit the province and enhance agri-business sector.

14. Financial support needs to be available for farmers who wish to adopt new advanced technology in agro-ecology practices. Low interest loans or subsidies should be made

available for farmers to buy equipment for constructing greenhouses, to buy tractors, harvesters or threshers, to install renewable energy systems, setup recycling water plants, anaerobic digesters, build water reservoirs and digging ponds or dugouts at farm level.

8.2 Conclusion

Newfoundland and Labrador has a food security issue due to lack of suitable agricultural land, short growing seasons and unsustainable agricultural policies promoting conventional industrial farming practices with a limited supply of agricultural produce (milk, eggs and poultry) and no facilities for secondary processing of these. The food security issue has been exacerbated in the last decades by climate change events (extreme temperatures, heavy rains and more frequent droughts) which have negatively impacted the province's agricultural industry. It is also challenging to achieve the target of doubling food production by 2022 with inadequate agricultural land, declining farming population and existing government policies. Both crop and dairy farmers are more or less aware about climate change impacts on agricultural activities and have taken some measures to reduce GHGs emissions, but these are not sufficient to fight serious climate change impacts. In the case of using chemical fertilizers, fossil fuels, and manure management, farmers should give more attention to reducing the negative environmental effects. In the attempt to solve these multi-faceted problems, one important solution is pursuing an agro-ecological approach to farming in the province. Integrated and small, diversified farming is one sustainable alternative to industrial farming which can make the current agricultural practices more resilient to global climate change (GCC), can enhance food security as well as reduce the impact of industrial agricultural practices on GCC. The current research has shown that there are incipient agro-ecological practices in the province, and that farmers are aware about climate change and the need to adopt more environmentally friendly farming practices. New policy frameworks and work plans are needed to speed up the transition from the current unsustainable farming practices to small-scale, organic, energy efficient and high yielding agriculture. Provincial as well as federal government support, and collaboration among educational and research institutions, agricultural farms, non-government organizations and the general public will contribute to agricultural diversification and integration and more environmentally-friendly farm practices within the province. These will ameliorate to food security issue, by increasing the supply of local fresh and healthy food, will provide additional financial benefits to farm holders and will protect the local as well as the global environment.

References

Abdulai, A. (2018). Motivating the future farmers? Understanding farmer attraction and retention policy interventions in Newfoundland and Labrador's Agriculture. Master thesis. School of Science and the Environment/School of Graduate Studies/Environmental Policy Institute, Grenfell Campus, MUN, NL, CA

ACORN (2013). Newfoundland and Labrador organic and ecological sector, Profile and strategic plan. Atlantic Canadian Organic Regional Network (ACORN).

Acton, D. F., Coote, D. R. and Eilers, W. (2015). Soil conservation. The Canadian Encyclopedia. Retrieved from: https://www.thecanadianencyclopedia.ca/en/article/soil-conservation

Adams, D. (2014). Atlantic Coastal Gardening: Growing inspired, resilient plants by the sea Canadian Electronic Library (Distributor). Canadian publisher's collection. Nimbus Publishing Limited 2014. Halifax, Canada.

Aerts, J. and Droogers, P. (2004). Climate change in contrasting river basins: adaptation strategies for water, food, and environment. The Netherlands; CABI publishing, pp. 1-264.

AFSA (2016). Agro-ecology: The bold future of farming in Africa. In AFSA and TAM,eds. Farrelly, M.. Westwood, G., C. and Boustred, S. 86. Dares Salaam, and Tanzania. ISBN 978- 9976-89-8514. http://afsafrica.org/wp-content/uploads/2017/02/Agroecology-the-bold-future-of-farming-in-Africa-ebook1.pdf.

Agriculture and Agri-Food Canada (2010). Environmental Sustainability of Canadian Agriculture. Agri-Environmental Indicators Report Series, Report # 4. Clearwater, R. L., Martin, T. and Hoppe, T. (Eds). Agriculture and Agri-Food Canada.

Agriculture and Agri-Food Canada (2016). An overview of the Canadian agriculture and Agri- food system 2016. Agriculture and Agri-Food Canada (AAFC), Government of Canada.

Agriculture and Agri-Food Canada (2016). Environmental Sustainability of Canadian Agriculture. Agri-Environmental Indicators Report Series, Report # 4. Ed. Clearwater, R. L., Martin, T. and Hoppe, T. Agriculture and Agri-Food Canada.

Agriculture and Agri-Food Canada (2017). An overview of the Canadian agriculture and Agri- food system 2017. Agriculture and Agri-Food Canada (AAFC), Government of Canada.

Agriculture and Agri-Food Canada (2019). Dairy Farm investment program: Applicant guide. Agriculture and Agri-Food Canada. http://www.agr.gc.ca/eng/programs-and-services/dairy-farm-investment-program/applicant-guide/?id=1494010428766

Agriview (2018). Off the beaten path: Ashley Hann's Riverside Farm. Agriview, Newfoundland and Labrador Agriculture, 2(12).

Agroecology in Action (2019). What is agroecology? Agroecology in Action, Agroecological knowledge and technologies into practices.

Alberta Agriculture and Food (2010). Nutrient Management Planning Guide. Alberta Agriculture and Agri-food, Canada.

Altieri, M.A. (2004). Linking ecologists and traditional farmers in the search for sustainable agriculture. Front. Ecol. Environ. (2), pp.35–42.

Altieri, M. A., Funnes-Monzote, F. R. and Petersen, P. (2012). Agroecologically efficient agricultural systems for smallholder farmers: contributions to food sovereignty. Agron. Sustain. Dev., 32, pp 1-13.

Altieri, M. A. (2012). Convergence or divide in the movement for sustainable and just agriculture. Sust agric Rev 9, p. 1-9. http://nature.berkeley.edu/~maguel-alt/what_is_agroecology.html

Altieri, M. A. and Nicholls, C. I. (2012). Agroecology scaling up for food sovereignty and resiliency. Sust Agric Rev 11, p. 1-29. Doi: 10.1007/978-94-007-5449-2_1

Alieri, M., Nicholls, C.I., Henao, A. and Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. Agron. Sustain. Dev. 35, pp. 869-890.

Amiraslany, A. (2010). The impact of climate change on Canadian agriculture: A Ricardian Approach. Doctoral thesis. Department of Bioresource Policy, Business and Economics, University of Saskatchewan.

Anderson, K. and Hayami, Y. (1986). The political economy of agricultural protection: East Asia in international perspective, Boston, Allen and Unwin in association with the Australia-Japan Research Centre.

APHA (2007). Toward a healthy sustainable food system. American Public Health Associaltion (APHA). https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2014/07/29/12/34/toward-a-healthy-sustainable-food-system

Australian Greenhouse Office (2007). "National Greenhouse Gas Inventory", Canberra ACT, March 2007. Department of Climate Change, Australian Government.

Aydinalp, C. and Cresser, M. S. (2008). The effects of global climate change on agriculture. American-Eurosian J. Agric. & Environ. Sci., 3(5), p.672-676.

Ayres, C. (2015). 16 main advantages and disadvantages of selective breeding. Green Garage. Retrieved from: https://greengarageblog.org/16-main-advantages-and-disadvantages-of-selective-breeding

Ayres, R.; van den Bergh, J. and Gowdy, J. (2001). Viewpoint: Weak versusu Strong Sustainability, Environmental Ethics, 23: pp. 155-168.

Beaulieu, M. S. (2004). Manure management in Canada. Farm Environmental Management in Canada, 1(2). Government of Canada.

Beddington, J., Asaduzzaman M., Fernadex, A., Clark, M., Guillou, M., Jahn, M. and Wakhungu, J. (2011). Achieving food security in the face of climate change. Summary for policy makers from the commission on sustainable agriculture and climate change, CGIAR research program on climate change. Agriculture and food security (CCAFS). Copenhagen, Denmark. www.ccafs.cgiar.org/commission.

Beghin, R. H. and Kherallah, M. (1994). Political institutions and international patterns of agricultural protection. The Review of Economics and Statistics, 76, p. 482-489.

Bird, L. (2018). With far fewer farmers, how can N.L. grow more food? CBC News, Canada. https://www.cbc.ca/news/canada/newfoundland-labrador/nl-agriculture-problem-getting-new-farmers-in-industry-1.4916521

Bogner, J., Pipatti, R., Hashimoto, S., Diaz, C., Mareckova, K., Diaz, L. et al.(2008). Mitigation of global greenhouse gas emissions from waste: conclusion and strategies from the IPCC. Fourth Assessment Report. Working Group III (Mitigation). Waste management and Research. https://journals.sagepub.com/doi/pdf/10.1177/0734242X07088433

Bourque, L.B. (2003). In Fielder E. P. (Ed.), How to conduct self-administered and mail surveys (2nd ed.). Los Angeles: SAGE publications Inc. DOI: 10.5135/9781412984430.

Bouchard, R. (2002). Plaidoyer Pour une Agriculture Paysanne: Pour la Santé du Monde; Les Éditions Écosociété :Montré al, QC, Canada.

Brand, F. (2009). Critical natural capital revisited: Ecological resilience and sustainable development. Ecological Economics, 68, 605–612.

Brown, D. M. and Blackburn, W.J. (1987). Impact of freezing temperatures on crop production in Canada. Canadian journal of plant science, 67(4), pp. 1167-1180. https://doi.org/10.4141/cjps87-156

Brown, S., Lincke, D., Nicholls, R. J., & Hinkel, J. (2015). The impacts of sea-level rise on European coasts in a 2°C world.

Buckler, L. (2018). The hidden dangers of chemical fertilizers. Occupational Health and Safety.https://ohsonline.com/Articles/2017/12/07/The-Hidden-Dangers-of-Chemical-Fertilizers.aspx

Burley, H., Becheva, S. Hallows, P. and Bebb, A. (2006). Eating from the farm: The social, environmental and economic benefit of local food systems. Brussels: Friends of the Earth. htt p s :/ /w ww .researc hg a te .n e t/ p u b li c a ti on / 30 59 0 12 01 _ Eatin g_ f ro m _ th e_ Fa rm _ th e _ so c i a l_environmental_and_economic_benefits_of_local_food_systems

Cadigan, S. (1998). Agriculture. Heritage Newfoundland and Labrador. Newfoundland Heritage .Website. http://www.heritage.nf.ca/articles/economy/agriculture.php%20Accessed%20on%2010-May-2017

Canadian Agricultural Human Resource Council (2014). Newfoundland and Labrador agricultural labour market forecastto 2025. https://cahrc-ccrha.ca/sites/default/files/files/Labour-Employment/factsheet_NFLD_E.pdf

Canada Organic Trade Association (2016). Investing in organic agriculture. A path to clean, inclusive, economic growth. Canadian Organic Growers, Canada Organic

Trade Association and USC Canada and Organic Federation of Canada Agriculture and Agri-Food Canada.

Capper, J. L., Castaneda-Gutierrez, E., Cady, R.A. and Bauman, D. E. (2008). The environmental Impact of recombinant bovine somatotropin (rbST) use in dairy production. Proc. Natl. Acad. Sci. USA, 105, p. 9668-9673.

Capper, J. L., Cady, R. A. and Bauman, D. E. (2007). The environmental impact of dairy production: 1944 compared with 2007. https://academic.oup.com/jas/article-abstract/87/6/2160/731307

Capra, F. (2015). Industrial Agriculture, Agro-ecology and Climate Change. Retrieved from: https://www.ecoliteracy.org/article/industrial-agriculture-agro-ecology-and-climate-change

CBC (Jan 16, 2016). N.L. could soon see more organic farms, advocates say. Retrieved from: https://www.cbc.ca/news/canada/newfoundland-labrador/n-l-could-soon-see-more-organic-farms-advocates-say-1.3407200

CBC News (2015, November 15). Most intense storm on the planet pounding Newfoundland and Labrador.https://www.cbc.ca/news/canada/newfoundland-labrador/winds-shut-down-newfoundland-1.4906415

CBC News (2015, November 16). Seismic records show Newfoundland was literally shaking from wind and waves. https://www.cbc.ca/news/canada/newfoundland-labrador/seismic-records-wind-storm-shake-1.4908372Change 2014: Mitigation of Climate Change. Contribution of Working Group III to

Ching, L. L. (2018). Agroecology for sustainable food systems. Environment and Development series 19. Third World Network, Penang, Malaysia.

Ching, L. L. (2016). Towards the transformation of our agricultural and food systems. (SDG 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture). Spotlight on sustainable development. Report by the Reflection Group on the 2030 Agenda for sustainable development. 192. https://www.reflectiongroup.org/en/node/604

Claire, K., Iles, A. and Bacon, C. (2012). Diversified farming systems: An agroecological, systems-based alternatives to modern industrial agriculture. Ecology and Society, 17(4)44.

Clearwater, R.L., Martin, T., Mackay, R. and Lefebvre, L. (2016). Environmental Sustainability of Canadian Agriculture. Agri-Environmental Indicators Report Series, Report 4. Agriculture and Ari-Food Canada.

Cline, W. (2007). Global warming and agriculture: Impact estimates by country. Centre for Global Development. Closing the Gender Gap for Development. FAO, Rome.

COG (2017). Organic agriculture: A foundation for food security in Canada. Canadian Organic Growers (COG). Organic Federation of Canada.

Connelly, M. (2010). Does Newfoundland and Labrador really justify two milk producers? Atlantic Business magazine, January February 2010. Retrieved from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=14&cad=rja &ua ct=8&ved=2ahUKEwiq7dSKwLTiAhWjxVkKHeHsAUAQFjANegQIAxAC&url=https%3A%2F%2Fwww.atlanticbusinessmagazine.net%2Fwp-

content%2Fuploads%2F2013%2F12%2Fv21n1_overflowing-Manufacturing.pdf&usg=AOvVaw16a6MZUeOj-B4rRz3YFP7s

Cook, C. D., Hamerschlag, K. and Klein, K. (2016). Farming for the future. Organic and agroecological solutions to feed the world, 23. UK and USA: Friends of the Earth.

Coolsaet, B. (2016). Towards an agro-ecology of knowledge: Recognition, cognitive justice and farmer's autonomy in France. Journal of Rural Studies, 47, pp. 165-171.

Coulthrd, G. S. (2014). Red Skin White Masks: Rejecting the colonial politics of reorganization; University of Minnesota Press: Minneapolis, MN, USA.

Cox, S. (2019, May 22). Mercury rising: how the Muskrat falls dam threatens Inuit way of life. The Narwhal. https://thenarwhal.ca/mercury-rising-muskrat-falls-dam-threatens-inuit-way-of-life/

Cunningham, M. (2017). What is the green revolution? - Definition, Benefits, and Issues. Retrieved from: http://study.com/academy/lesson/what-is-the-green-revolution-definition-benefits-and-issues.html.

Daly, H. and Farley, J. (2014). Ecological Economics. Island Press.

Dairy Farmers of Canada (n.d.) A national strategy for sustainable development. Retrieved from:

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact =8&ved=2ahUKEwjkmKDd_bbiAhWyg-AKHagjD6AQFjAEegQIABAC&url=https%3A%2F%2Fwww.dairyfarmers.ca%2Fconte nt%2Fdownload%2F1104%2F12648%2Ffile%2Fsustainable-development-EN.pdf&usg=AOvVaw1slLI9UJdyRu1cCX-_Qyb2

Demeter (2016). Production Standards for the use of Demeter, biodynamic and related trademarks. Demeter-International e.V. Retrieved from: http://www.demeter.net/certification/standards Accessed on 20-May-2017.

Department of Fisheries and Aquaculture (2001). Marine Plants. Emerging Species Profile Sheets. Government of Newfoundland and Labrador, in partnership with the Centre for Sustainable Aquatic Resources, Marine Institute of Memorial University of Newfoundland. Retrieved from: http://www.fishaq.gov.nl.ca/research_development/fdp/pdf/marine_plants.pdf Accessed on 01-Jul-2017.

Department of Natural Resources (2004). An overview of the Newfoundland and Labrador agri-foods industries. Government of Newfoundland and Labrador. Land Resources Stewardship Division. http://www.faa.gov.nl.ca/publications/pdf/nlai_overview_04.pdf, Accessed on: 22 April, 2017

Desmarais, A. and Wittman, H. (2014). Farmers, foodies and First Nations: Getting to food sovereignty in Canada. J. Peasant Stud. (41), pp. 1153–1173.

Diaz, R. J., and Rosenberg, R. (2008). Spreading dead zones and consequences for marine ecosystems. *Science* 321 (5891):926-929. http://dx.doi.org/10.1126/science.1156401

Dominion Bureau of Statistics (1945). Causes of Newfoundland and Labrador, 1945. Vol. 2. Government of Canada. Print text held in the center for Newfoundland studies, MUN libraries. http://collections.mun.ca/cdm/ref.collection/cns_tools/id/123264. Accessed on 29 June, 2017.

Dracup, J. A. and Vicuna, S. (2005). An overview of hydrology and water resources studies on climate change: the California experience, pp. 1-12.

Drouin, R. (2015). Wood pellets: green energy or new source of CO_2 emissions? Yale School of Forestry and Environmental Studies.

https://e360.yale.edu/features/wood_pellets_green_energy_or_new_source_of_co2_e miss ions

Dudal, R. and Roy, R.N. (eds) (1995). Integrated plant nutrition system. FAO fertilizer and plant nutrition bulletin, Rome, Vol. 12.

E4tech (2010). Newfoundland and Labrador Energy Innovation Roadmap: Priority Identification (Phase 1). E4tech, orioninnovations, Wade Locke Economic Consulting.

Ekins, P., Simon, S., Deutsch, L., Folke, C., De Groot, R. (2003). A framework for the practical application of the concepts of critical natural capital and strong sustainability. Ecological Economics, 44, 165–185.

Elo, S. and Kyngas, H. (2008). The qualitative content analysis process. Journal of Advance Nursing, 62(1), pp. 107-105. doi: 10.1111/j.1365-2648.2007.04569.x.

Environment and Climate change Canada (2019). Greenhouse gas emissions. Canadian Environmental Sustainability Indicators. Canada.

EPA (2019, Jan, 19). Sources of greenhouse gas emissions, Greenhouse gas emissions. Environmental Protection Agency, United States. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#agriculture

Evans, S. (2017). Transition to a sustainable food system in Newfoundland and Labrador: The promise of organic agriculture (Master thesis). Environmental Policy Institute. Memorial University of Newfoundland, Canada.

Everybody Eats (2015). A discussion paper on food security in Newfoundland and Labrador. Food First NL.

Fand, B. B., Kmble, A. K. and Kumar, M. (2012). Will climate change pose serious threat to crop pest management: A critical review? International Journal of Scientific and Research publications, 3(11).

FAO (2003). Agroecology definitions. Agroecology Knowledge Hub. Food and Agricultural Organizations of the United Nations (FAO). http://www.fao.org/agroecology/knowledge/definitions/en/?page=3&ipp=6&no_cache=1&tx_dynalist_pi1[par]=YToxOntzOjE6IkwiO3M6MToiMCI7fQ==

FAO (2003). Agroecology, Scaling and Interdisciplinary. Agroecology Knowledge Hub. Food and Agricultural Organizations of the United Nations (FAO). http://www.fao.org/agroecology/database/detail/en/c/893008/

FAO (2006). Livestock a major threat to environment, Remedies urgently needed. Food and Agriculture Organization of the United Nations (FAO).

FAO (2010). The Second Report on the State of the World's Plant Genetic Resources Systems. FAO, Rome. Rev. 2 – 2009.

FAO (2011). The State of Food and Agriculture 2010-2011. Women in Agriculture – Sustainable Food Systems, Brussels. www.ipes-food.org

FAO (2013). Coping with the food and agricultural challenge: Smallholder's agenda. Food and Agricultural Organization of the United Nations, Rome

FAO (2014). Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks. Climate, Energy and Tenure Division, Federation of Agricultural Organization (FAO).

FAO (2015). The impact of natural hazards and disasters on agricultural and food security and nutrition. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2015a). Natural capital impacts in agriculture. Supporting better business decision making. 118. Rome: FAO.

FAO (2015b). Report on the multi-stakeholder consultation on agroecology in Asia and the Pacific, FAO, Bangkok. Accessed November 24-26, 2015. 58.

FAO (2016). Enteric fermentation. Improving food security and livelihoods by reducing enteric methane emissions. Food and Agricultural Organizations of United nations (FAO). New Zealand.

FAO (2019, June 29). Food loss and food waste. Food and Agricultural Organization of the United Nations (FAO). http://www.fao.org/food-loss-and-food-waste/en/

FCRN (n. d.). Why food and climate. Food is a convergence issue. Retrieved from: Food Climate Research Network (FCRN). http://www.fcrn.org.uk/about/why-food-and-climate.

Fisheries and Land Resources (2018). Dairy, Forests an agrifoods. Government of Newfoundland and Labrador, Canada. https://www.faa.gov.nl.ca/agrifoods/animals/livestock/dairy.html

Fisheries and Land Resources (2018). Provincial, federal governments committed to help the agricultural sector. Government of Newfoundland and Labrador

Fisheries and Land Resources (2018, Nov 28). Provincial government providing more land for agriculture development. Fisheries and Land Resources, Government of Newfoundland and Labrador. https://www.releases.gov.nl.ca/releases/2017/ffa/1128n04.aspx

Fitzpatrick, A. (2017). Newfoundland and Labrador farmers affected by climate change. The Northern Pen. Retrieved from: http://www.northernpen.ca/business/newfoundland-and-labrador-farmers-affected-by-climate-change-27928/

FoodPrint (2019). How industrial agriculture affects our soil. https://foodprint.org/issues/how-industrial-agriculture-affects-our-soil/, Accessed on June 30, 2019.

Food First NL (2012). Seaweed. Retrieved from Food First NL website (Achieve): http://www.foodfirstnl.ca/rcr-archive/2012/05/seaweed

Food First NL (2015). Nikigijavut Nunatsiavutinni: Our food in Nunatsiavut. Annual Report 2014 – 2015. Retrieved from Food First NL Website: http://www.foodfirstnl.ca/our-resources/2016-annual-report Accessed on 14-Feb-2017.

Food First NL (2016). Annual Report 2015 – 2016. Retrieved from Food First NL Website: http://www.foodfirstnl.ca/our-resources/2016-annual-report Accessed on 14-Feb-2017.

Food Secured Canada (2017). From patchwork to policy coherence: principles and priorities of Canada's National Food policy. Food Secure Canada (FSC). Retrieved from: https://foodsecurecanada.org/patchwork-policy-coherence-principles-and- priorities-canadas-national-food for Food and Agriculture. FAO, Rome.

Forests Ontario (2019). Study Guide 2019, Agroecology. 2019 Ontario Envirothon Study Guide.

https://www.google.com/search?client=firefox-b-d&ei=tOwlXe7GNsOQtAbJq5zwBA&q=Study+Guide+2019%2C+Agroecology.+&oq=Study+Guide+2019%2C+Agroecology.+&gs_l=psy-ab.12..33i160.12398.12398..13724...0.0..0.187.187.0j1......0....1..gws-wiz.......0i71.KfnvMrGCOBk

Forestry and Agrifoods (2017). Soil health. Fisheries and resources. Government of Newfoundland and Labrador, NL, Canada

Forestry and Agrifoods (2017). Soil survey. Government of Newfoundland and Labrador. Department of Fisheries and land Resources. Forestry and Agri-food website. Retrieved from: http://www.faa.gov.nl.ca/agrifoods/land/soils/soilsurvey.html Accessed on 19-May-2017.

Forestry and Agrifoods (2016). Newfoundland and Labrador farm guide 2016. Government of Newfoundland and Labrador, NL, Canada

Forge, F. (1998).Agriculture soil conservation in Canada. Science and Tchnology Division. Parliamentary Research Branch. Government of Canada. http://publications.gc.ca/Collection-R/LoPBdP/MR/mr151-e.htm

Fraser, E. (2012). Feeding nine billion: Introducing solutions to the Global Food Crisis.

https://www.youtube.com/watch?v=raSHAqV8K9c&feature=youtu.be

Gaiaeducation (2019). Renewable energies for sustainable development. Gaiaeducation. UNITAR and the University of Strathclyde.

Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming

Gliessman, S. R. (2015). *Agro-ecology: The ecology of sustainable food systems*. Third Edition, CRC Press, Taylor & Francis Group, New York.

Gorry, S. C. 92019, June 26). How to fertilizing basics? It plays to know why, what, how, and when to feed your plants. https://www.finegardening.com/article/fertilizing-basics

Gorte, R. W. and Sheikh, P. A. (2010). Deforestation and climate change. Congressional Research Service. CRS report for congress.

Government of Canada (2010). Status of Climate Change Adaptation in Canada's Agricultural Sector. Research Paper. Government of Canada

Government of Canada (2016). Complementary actions to reduce emissions. Retrieved from: https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/complementary-actions-reduce-emissions.html

Government of Newfoundland and Labrador (2014). Provincial sustainable forest management strategy 2014-2024. Growing our renewable and sustainable forest economy. Retrieved from: https://www.faa.gov.nl.ca/publications/pdf/psfms_14_24.pdf

Government of Newfoundland and Labrador (2018). Canadian Agricultural Partnership. Program Guide, Newfoundland and Labrador. Government of Newfoundland and Labrador, Canada

Government of Newfoundland and Labrador (2018). Provincial government releases federally-approved Made-in-Newfoundland and Labrador approach to carbon pricing. Municipals Affairs and Environment, Finance and Natural Resources, Government of Newfoundland and Labrador.

Government of Newfoundland and Labrador (2019). Comprehensive review f provincial solid waste management strategy and senior appointments announced. Executive Council, Municipal Affairs and Environment, Government of Newfoundland and Labrador.

Government of Saskatchewan (2019). Managing manure as a fertilizer. Soils, fertility and nutrients. https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/soils-fertility-and-nutrients/managing-manure-as-a-fertilizer

GRAIN (2011). Food and Climate Change: The Forgotten Link. Retrieved from: https://www.grain.org/article/entries/4357-food-and-climate-change-the-forgotten-link

Hediger, W. (1998). ‘Ecosystem management and sustainability: An ecological-economic model’, in: Sarah Dwyer, Udo Ganslosser, and Martin O’Connor (eds), *Life Science Dimensions: Ecological Economicsand Sustainable Use*. Filander Verlag, Fürth, Germany; pp. 133-156.

Hediger, W. (2004). Weak and Strong sustainability, Environmental conservation and economic growth. Agricultural and Food Economics, Swiss Federation Institute of Technology Zurich, Switzerland.

Hicks, J. R. (1946). The value of Capital, 2nd edition, Oxford: Oxford University Press.

Hidden Costs (n.d.) http://www.ucsusa.org/food_and_agriculture/our-failing-food-system/industrial-agriculture/hidden-costs-of-industrial.html#.WhJCYTdrzIU

Hoogezand, B. (2013). The effect of natural disasters on agricultural protection: a panel data analysis. Analyzing the impact of large scale natural disasters on agricultural protection. Agricultural Economics and Rural Policy Group, Development Economics Group.

Horrigan, L., Lawrence, R. and Walker, P. (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental health perspectives* 10(5):445. http://www.agassessment.org

Hynes, D. (2009). The household economy of Newfoundland and Labrador outports. Heritage Newfoundland and Labrador. Newfoundland and Labrador Heritage website.

IAASTD (2009). Agriculture at a Crossroads. International Assessment of Agricultural Knowledge, Science and Technology for Development. Island Press, Washington, DC

IAASTD (2009). Agroecology provides a robust set of solutions to the environmental pressures and crisis facing agriculture in the 21st century. International Assessment of Agricultural Knowledge, Science and Technology for Development.

IAEA (2019). Greenhouse gas reduction. International Atomic Energy Agency (IAEA). https://www.iaea.org/topics/greenhouse-gas-reduction

IFAD (2013). Smallholders, food security, and the environment, International Fund for Agricultural Development (IFID).http://www.unep.org/pdf/SmallholderReport_WEB.pdf/, accessed 20.09.2014

19. IFOAM 2014 Global Organic Statistics 2014 and Organic 3.0,

IFPRI (n.d.). Impact of irrigation on agricultural productivity, nutrition, health and women's empowerment in Ghana. International Food Policy Research Institute (IFPRI). Washington, USA

IIED (2011). Adapting agriculture with traditional knowledge (briefing). The International Institute for Environment and Development (IIED).

Imbruce, V. (2015). From farm to canal street: Chinatown' s alternative food network in the global marketplace. Ithaca, NY: Cornell University Press.

Industries Harnois (n.d.). The benefits of a greenhouse for organic production. https://www.harnois.com/es/blog/greenhouses-en-es/benefits-greenhouse-for-organic-production/. Accessed on, 22 May 2019.

Intergovernmental Panel on Climate Change (1995). Climate Change 1995: The Science of Climate Change, eds. Houghton, J. T., MeiraFilho, L. G., Bruce,J., Lee, H., Callender,

B. A., Haites, E., Harris, N. &Maskell, K. (Cambridge Univ. Press, Cambridge, U.K.).

International Federation of Organic Agricultural Movements (2017). The world of organic agriculture; Statistics and emerging trends 2017.

IPCC (1996). Climate Change 1995: Impacts, adaptations and mitigation of climate change: Scientific-Technical Analysis. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

IPCC (2001). Climate Change: Synthesis Report 2001. Contribution of Working Groups I, IIand II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Wembley, United Kingdom.

IPES-Food (2016). From uniformity to diversity: A paradigm shift from industrial agriculture to diversified agroecological systems. International Panel of Experts on Sustainable Food Systams, Brssels. www.ipes-food.org

ISOFAR (2018). Indigenous agroecology in the Canadian context. International Society of Organic Agriculture Research (ISOFAR).

Issac, M. E., Isakson, S. R. Dale, B. et al. (2018). Agroecology in Canada: Towards an integration of agroecological practices, movement and science. Sustainability, 10, 3299,; doi:103390/su10093299

Johnson, S. W. (2018). Peat and its uses as fertilizer and fuel. The project Gutenberg EBook#26412. Originally published in 1866. Orange Judd & Co. New York. Retrieved: http://www.gutenberg.org/ebooks/26142

Kang, Y., Khan, S. and Ma, X. (2009). Climate change impacts on crop yield, crop water productivity and food security-A review. Natural Science, (19), pp. 1665-1674.

Kemp, A. C., Horton, B. P., Donnelly, J. P., Mann, M. E., Vermeer, M. and Rahmsorf, S. (2011). Climate related sea-level variations over the past two millennia. Proceedings of the National Academy of Sciences, 108(27). https://doi.org/10.1073/pnas.1015619108

Kelly, R. (2018, June 27). Who pays most for the milk? Study finds prices vary widely by city. CTV News. Retrieved from: https://www.ctvnews.ca/canada/who- pays-the-most-for-milk-study-finds-prices-vary-widely-by-city-1.3991348

Kislev, Y. and Peterson, W. (1986). Economies of scale in agriculture: A survey of the evidence. Development Research Department, Economics and Research Staff, World Bank

Knezevic, I., Blay-Palmer, A., Levkoe, C., Mount, P. and Nelson, E. (Eds.) (2017). Nourishing Communities. From Fratured Food Systems to Transformative Pathways. Springer International Publishing.

Kong A. Y. Y., Fonte S. J., van Kessel C. and Six J. (2009).Transitioning from standard to minimum tillage: Trade-offs between soil organic matter stabilization, nitrous oxide emissions, and N availability in irrigated cropping systems. Soil Tillage Res. (104), pp. 256–262.

Kremen, C. and Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming system: benefits, externalities, and trade-offs. Ecology and Society, 17(4) 44

Kremen, C., A. Iles, and C. Bacon(2012). Diversified farming systems: An agroecological, systems-based alternative to modern industrial agriculture. *Ecology and Society* 17(4): 44.http://dx.doi.org/10.5751/ES-05103-170444

Kumar, S. (2018). What are the advantages of intercropping? Retrieved from: https://www.quora.com/What-are-the-advantages-of-intercropping

Lafontaine, H. O. and Jannoyer, M. L. (edit.) (2014). Sustainable Agriculture Reviews 14. Agroecology and Global Change. DIO: 10.1007/978-3-319-06016-3.

Lamaoui, M., Jemo, M., Datla, R. and Bekkaoui, F. (2018, Feb 19). Heat and drought stresses in crops and approaches for their mitigation. Frontiers in Chemistry. https://www.frontiersin.org/articles/10.3389/fchem.2018.00026/full

Lamm, F. R. (2002). Advantages and disadvantages of subsurface drip irrigation. Paper presented at the international meeting on advances in drip/micro irrigation, Puerto de La Cruz, Tenerife, Canary Islands, Instituto Canario de Investigaciones.

La Via Compesina (2019, June 30). The international peasant's voice, globalizing hope, globalizing the struggle! La Via Compesina, International peasant's movement. https://viacampesina.org/en/international-peasants-voice/

Lyseng, R. (2019). Electric tractors hit Canadian fields with a whir. The western producer. https://www.producer.com/2019/04/electric-tractors-hit-canadian-fields-with-a-whir/

Lopes, A.P. and Jomalinis, E. (2011). Agroecology: Exploring opportunities for women's empowerment based on experiences from Brazil. The Association for Women's Rights in Development (AWID). http://www.observatoriodegenero.gov.br/ menu/noticias/2fpttec-agroecology-eng1.pdf

Lynch, D. H. (2014). Sustaining soil organic carbon, soil quality and soil health in organic field crop management system, pp. 107-132. In Martin, R.C. and MacRae, R. (Eds), Managing Energy, Nutrients and Pests in Organic Field Crops. CRC press.

Magdoff, F. (2012). Types of cover crops. Sustainable Agriculture Research and Education. Retrieved from: https://www.sare.org/Learning-Center/Books/Building-Soils-for-Better- Crops-3rd-Edition/Text-Version/Cover-Crops/Types-of-Cover-Crops

Mangalassery, S., Sjogersten, S., Sparkes, D. L., Sturrock, C. J., Craigon, J. and Mooney, S. J. (2014). To what extent can zero tillage lead to a reduction in greenhouse gas emissions from temperate soils? Scientific Reports. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3975454/

Martens, J. T., Entz, M. and Wonneck, M. (2013). Ecological farming systems on the Canadian prairies, A path to profitability, sustainability and resilience. Science and Technology Branch of Agriculture and Agri-Food Canada, University of Manitoba.

Martin, C., Morgavi, D. P., Doreau, M. (2010)."Methane mitigation in ruminants: from microbe to the farm scale". *Animal. 4 (3), pp. 351–365.* doi*:*10.1017/S1751731109990620*.*

Martin, A.R. and Isaac, M.E. (2015). Plant functional traits in agroecosystems: A blueprint for research. J. Appl. Ecol. (52), pp.1425–1435.

Matthews, R. B., Kropff, M. J. and Bachelet, D. (1994). Climate Change and Rice Production in Asia. Entwicklung und Iandlicher Raum (Germany), (1), pp.16-19.

Matthews, R.B., Kropff, M. J., Bachelet, D. and H.H. van Lar, H. H. (1994). The impact of global climate change on rice production in Asia: A simulation study. Report

No.ERL-COR-821. Corvallis, OR: U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis.

McKenna, J. (2017). Can feeding seaweed to cows help fight climate change? World Economic Forum. Retrieved from: https://www.weforum.org/agenda/2017/08/can-feeding-seaweed-to-cows-help-fight-climate-change/

Méndez, V.E., Bacon, C.M. and Cohen, R. (2013). Agroecology as a transdisciplinary, participatory and action-oriented approach. Agroecol. Sustain. Food Syst. (37), pp. 3–18.

Mercer, N. (2019). Newfoundland and Labrador's "Climate Action Plan" is all bark and no bite. The Independent, Newfoundland and Labrador. https://theindependent.ca/2019/03/05/newfoundland-and-labradors-climate-action-plan-is-all-bark-and-no-bite/

Mernit, J. L. (2018).How eating seaweed can help cows to belch less methane. Yale school of forestry and environmental studies. YaleEnvironmental360. Retrieved from: https://e360.yale.edu/features/how-eating-seaweed-can-help-cows-to-belch-less-methane

Meuwissen, M.P.M., Huirne, R.B.M. and Skees, J. R. (2003). Income insurance in European Agriculture. EuroChoices, 2, p. 12-17.

Meyer, D. (2011). Manure treatment technologies: Anaerobic digesters. University of California, Agriculture and Natural Resources. https://anrcatalog.ucanr.edu/pdf/8409.pdf

Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: Synthesis, Washington, DC: Island Press.

MMSB (n.d.). Backyard Composting Guide. Multi-Materials Stewardship Board. Government of NL. Retrieved from MMSB Website: http://mmsb.nl.ca/waste-diversion-programs/organic-waste/backyard-composting/getting-started/ Accessed on 25-Jun-2017.

Mole, B. (2014). Fertilizer produces far more greenhouse gas than expected. ScienceNews, Magazine of the Society for Science &the Public. https://www.sciencenews.org/article/fertilizer-produces-far-more-greenhouse-gas-expected

Morrison, D. (2011). Indigenous Food Sovereignty: A Model for Social Learning. In Food Sovereignty in Canada:Creating Just and Sustainable Food Systems; Wittman, H., Desmarais, A.A., Wiebe, N., Eds.; Fernwood Publishing: Winnipeg, MB, Canada, pp. 97–113.

Mostafalou, S.; Abdollahi, M. (2017). Pesticides: An update of human exposure and toxicity. Arch. Toxicol, (91), pp.549–599.

National Energy Board (2018). Provincial and Territorail energy Profiles-Newfoundland and Labrador. National Energy Board, Canada. https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/nl-eng.html

Nellemann, C., MacDevette, M. Manders, T. Eickhout, B. Sivhus, B. Prins, A. G. and Kaltenborn. B. P. (2009). The environments' role in averting future food crises. A UNEP rapid response assessment, United nations environment programme . Arendal: GRID-Arendal.

Neumayer, E. (2003). Weak versus strong sustainability: exploring the limits of two opposing paradigms. Edward Elgar, Northampton.

Newfoundland and Labrador Statistics Agency (2017). Economic and Statistics Branch. Government of NL. Retrieved from the Department of Finance Website: http://www.stats.gov.nl.ca/statistics/population/PDF/Population_Estimates_CDCMA.pdf, Accessed on 10-Jul-2017.

Niggli, U., Fließbach, A., Hepperly, P. and Scialabba, N. (2009). Low Greenhouse Gas Agriculture:Mitigation and Adaptation of Susainable Farming Systems, FAO, Rome. Rev. 2-2009.

Noël, J-F., O'Connor, M. (1998). Strong Sustainability and Critical Natural Capital. In: Faucheux, S., O'Connor, M., (Eds.), Valuation for Sustainable Development: Methods and Policy Indicators. Edward Elgar Publisher, Cheltenham, pp. 75–99.

O'Riordan, J., Karlsen, E., Sandford, B. and Newman, L. (2013). Climate Change Adaptation and Canada's Crops and Food Security. Adaptation to Climate Change Team. Simon Feaser University.

Olper, A. and Raimondi, V. (2009). Electoral rules, forms of government and redistributive policy: Evidence from agriculture and food policies. Journal of Comparative Economics.

Olson, M. (1965). The logic of collective action. Cambridge: Harvard University Press.

OMAFRA (2019, May 14). Freeze protection method for crops. Ontario Ministry of Agriculture, Food and Rural Affairs. Government of Ontario, Canada. http://www.omafra.gov.on.ca/english/crops/facts/85-116.htm

Onder, M. and Kahraan, A. (2011). Global Climate Changes and their effects on field crops. 10th International MultidisciplinaryGeoconference SGEM, Conference Proceedings, Bulgaria, V(2), p. 589-592.

Onder, M., Chyhan, E. and Kahraman, A. (2011). Effects of Agricultural Practices on Environment. International Conference on Biology, Environment and Chemistry, 24, p. 28-32.

Ontario Ministry of the Environment (2011). Climate Ready: Ontario's Adaptations Strategy and Action Plan. https://docs.ontario.ca/documents/817/2-2-5-climate-ready-en.pdf

Oerke, E.C. (2006). Crop losses to pests. Journal of Agricultural Science. 144, pp. 31-43. Doi:10.1017/S0021859605005708

Pasternak, S. (2013). On jurisdiction and settler colonialism: The Algonquins of Barriere Lake against the Federal Land Claims Policy: Unpublished Ph.D. Thesis, University of Toronto, ON, Canada.

Pearson, C. J. (2007). Regenerative, semi closed systems: a priority for twenty-first century agriculture.Bioscience, 57(50), pp. 409-418.

Pelenc, J. Ballet, J. and Dedeurwaerdere, T. (2015). Weak sustainability versus strong sustainability. https://sustainabledevelopment.un.org/content/documents/6569122-PelencWeak%20Sustainability%20versus%20Strong%20Sustainability.pdf

PennState Extension (2012). Biogas from manure. College of agricultural sciences, The Pennsylvania State University, USA. Retrieved from: https://extension.psu.edu/biogas-from-manure

Perfecto, I., Vandermeer, J., Mas, A. and Pinto, L.S. (2005). Biodiversity, yield, and shade coffee certification. Ecological Economics, 54(4), pp. 435-446.

Petersen S. O., Mutegi J. K., Hansen E. M. and Munkholm L. J. (2011). Tillage effects on N_2O emissions as influenced by a winter cover crop. Soil Biol. Biochem.43, pp. 1509–1517.

Pimbert, M. P. (2017). Food sovereignty: Agroecology and biocultural diversity: constructing and contesting knowledge; Routledge: New York, NY, USA.

PLTA (2011). Economic benefit of biodiversity. Pennsylvania Land Trust Association (PLTA). https://conservationtools.org/guides/95-economic-benefits-of-biodiversity,

Population Reference Bureau (2017). 2017 World population data sheet. Retrieved from: http://www.prb.org/Publications/Datasheets/2017/2017-world-population-data-sheet.aspx

Provincial Agrifoods Assistance Program (2018). Provincial Agrifoods Assistance Program 2018-19 Guide. Department of Fisheries and Land Resources, Agricultural Business Development Division, Corner Brook, NL.

Qualman, D. (2011). Advancing Agriculture by Destroying Farms? The State of Agriculture in Canada. In FoodSovereignty in Canada: Creating Just and Sustainable Food Systems; Desmarais, A.A., Wiebe, N., Wittman, H.,Eds.; Fernwood Publishing: Halifax, NS, Canada.

Quinlan, A. J. (2012). Building Agricultural Capacity in Newfoundland and Labrador. INTRD Strategic Partnership Harris Centre. Memorial University of Newfoundland, NL, Canada.

Rae, D. W. (1971). The political consequences of electoral laws, New Haven. Yale University Press.

Randell, A. (2018). Newfoundland and Labrador hopes to double agricultural productionover five years. The Telegram. https://www.thetelegram.com/news/regional/newfoundland-and-labrador- hopes-to-double-agricultural-production-over-five-years-183467/

Rodale Institute (2011). The farming systems Trial: Celebrating 30 years. Retrieved from https://rodaleinstitute.org/wp-content/uploads/fst-30-year-report.pdf

Rosset, P. M. and Martinez-Torres, M. E. (2012). Rural social movements and agro-ecology: context, theory, and process. Ecology and Society, 17(3): 17. http://dx.doi.org/10.5751/ES-05000-170317

Rumsey, D. J. (May 23, 2019). How to interpret a correlation coefficient r? Statistics for Dummies, 2nd edition. Retrieved from: https://www.dummies.com/education/math/statistics/how-to-interpret-a-correlation-coefficient-r/

Sabau, G. (2017).Agriculture, AGRI-food and Forestry - the challenge and opportunity of climate change. Grenfell Campus, Memorial University of Newfoundland, NL, Canada.

Saylor, C.R., Alsharif, K.A. and Torres, H. (2017). The importance of traditional ecological knowledge in agroecological systems in Peru. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. (13), pp. 150–161.

Sawyer, D. (2008). Climate Change, biofuels and eco-social impacts in the Brazillian Amazon and Cerrado. Philos. T. Roy. Soc. B. 363: p. 1747-1752.

Schaer, L. (2014). The real dirt on farming. Farm and Food Care Canada. www.FarmFoodCare.org

Schivera, D. (2003). The Benefits of Raising Animals on Pasture. Maine Organic Farmers and Gardeners Association. http://www.mofga.org/Publications/The-Maine-Organic-Farmer-Gardener/Fall-2003/Pasture

Schutter, O. D. (2011). Agroecology and the right to food. General Assembly, Human Rights Council. United Nations. https://www.globalagriculture.org/report-topics/agroecology.html

Schwabe, M. (2016). N.L. could soon see more organic farms, advocates say. CBC news, Jan 16, 2016. Retrieved from: https://www.cbc.ca/news/canada/newfoundland-labrador/n-l-could-soon-see-more-organic-farms-advocates-say-1.3407200

Seguin, A.V., Lavenant, S.L., Garon,D., Bouchart, V., Gallard, Y., Blanchet, B., Diqueloe, S., Personeni, E., Gauduchon, P. and Qurry, A. (2010). Effect of agricultural and environmental factors on the hay characteristics involved in equine respiratory disease. Agriculture, Ecosystems and Environment, 135: 206-215.

Sequi, P. (1999). Impact of agriculture on the environment. In: Brufau, J. (ed.), Tacon, A. (ed.). Feed manufacturing in the Mediterranean region: Recent advances in research and technology. Zaragoza: CIHEAM, p. 223-228.

Seward, S. (2018). Building sustainable energy from the ground up in Newfoundland and Labrador. The Independent, Newfoundland and abrader, Canada.

Sharma, N. and Singhvi, R. (2017). Effects of chemical fertilizers and pesticides on human health and environment: A review. International Journal of Agriculture, Environment and Biotechnology, 10(6), pp. 675-679.

Sharifi, M., Petoukhov, K., McAuley, E. and Hull, J. (2018). Indigenous Agroecology in the Canadian Context. International Society of Organic Agriculture Research (ISOFAR).

Shennan, C. (2008). Biotic intersections, ecological knowledge and agriculture. Philosophical Transactions of the Royal Society B-Biological Sciences, 363(1492), pp. 717-739.

Smith, P. et al. (2014). Agriculture, Forestry and Other Land Use (AFOLU). In: Climate change 2014: Mitigation of climate change. Contribution of working group III to the Fifth Assessment Report of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Solow, R.M. (1974). ‘Intergenerational equity and exhaustible resources’, *Review of Economic Studies*, Symposium on the Economics of Exhaustible Resources, (14), pp.29-45.

Solow, R. (1993). Sustainability: an economist's perspective. Dorfman, N. and Dorfman, R. (Eds.), Selected readings in environmental economics. Norton, New York (1993), pp. 179-189

Sorensen, E. (2018). Environmentally friendly faring practices used by nearly one third of world's farms. Less Developed countries tend to use the largest improvements in productivity. Washington State University.

Statistics Canada (2001a). Table 12.1: Farms Classified by Certified Organic Products Produced, by Province, Census Agriculture Region (CAR) and Census Division (CD). Available online: http://www.statcan.gc. ca/pub/95f0301x/t/pdf/4198789-eng.pdf (accessed on 21 November 2017).

Statistics Canada (2006). Agriculture Overview, Canada and the Provinces, Table 1.15, Agriculture Overview, Canada and the Provinces—Farms Producing Certified Organic Products, Census Years 2006. Available online: http://www.statcan.gc.ca/pub/95-629-x/1/4123805-eng.htm#0 (accessed on 21 November 2017).

Statistics Canada (2011). More large farms in Newfoundland and Labrador. 2011 Farm and Farm Operator Data, Statistics Canada.

Statistics Canada (2013). Canadian Community Health Survey-Annual Component 2011-2012 and 2012 public use micro data file, Health Statistics Division, Statistics Canada.

Statistics Canada (2016). Focus on geography series. Province of Newfoundland and Labrador. Government of Canada, https://www12.statcan.gc.ca/censusrecensement/2016/as- sa/fogs-spg/Facts-PR-Eng.cfm?TOPIC=9&LANG=Eng&GK=PR&GC=10

Statistics Canada (2017). Greenhouse gas emissions by Canadian economic sector. Environment and natural resources. Statistics Canada.

Statistics Canada (2017). 2016 Census of agriculture. Farm and farm operator data. Statistics of Canada, Government of Canada. https://www150.statcan.gc.ca/n1/pub/95-640-x/95-640- x2016001-eng.htm

Statistics Canada (2017). Newfoundland and Labrador farms have the highest rate of direct marketing. Statistics Canada. https://www150.statcan.gc.ca/n1/en/pub/95-640-x/2016001/article/14800-eng.pdf?st=cukEHePo

Statistics Canada (2017). Canadian Agriculture: Evaluation and Innovation. https://www150.statcan.gc.ca/n1/pub/11-631-x/11-631-x2017006-eng.htm

Statistics Canada, (2017). Province of Newfoundland and Labrador. Provincial sustainable forest management strategy 2014-2024. Retrieved from: https://www.sfmcanada.org/images/Publications/EN/NL_info_Provinces_and_territories_EN.pdf

Stats Canada (2007). Agricultural overview, Canada and the provinces-certified, transitional or uncertified organic products, census year 2006. Newfoundland and Labrador. Government of Canada. Retrieved from Canada website: http://www.statcan.gc.ca/pub//95-629-x/4182477-eng.htm Accessed on 01-Jul-2017.

Stauffer, B. and Spuhler, D. (2019). Surface irrigation. SSWM university course. Retrieved from: https://sswm.info/sswm-university-course/module-4- sustainable-water-supply/further-resources-water-use/surface-irrigation

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., De Vries, W., De Wit, C. A., Folke, C., Geertsen, D.,Heinke, J., Mace, G. M.,Persson, L. M., Ramanathan,M., V., Reyers, B. and Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science 347:736 &1259855-1 to 10.

Steffen, W., Sanderson, A., Tyson, P. D., Jäger, J., Matson, P. A., More III B., Oldfield, F., Richardson, K., Schellnhuber, H. J., Turner II, B. L. and Wasson, R. J. (2004). Global change and the earth system. A planet under pressure. Executive summary, 40. www.igbp.kva.se. Stockholm: IGBP Secretariat Royal Swedish Academy of Sciences.

Steinfeld, H., Gerber, P., Wassennaar, T., Castel, V., Rosales, M. and de Haan, C. (2006). Livestock's Long Shadow – Environmental Issues and Options. Food and Agriculture Organization of the United Nations, Rome, Italy.

Steiner, R. (1924). Spiritual Foundations for the Renewal of Agriculture: A course of lectures held at Koberwitz, Silesia, June 7 to 16, 1924 (C. Creeger & M. Gardner, Trans. This translation first published 1993). Kimberton, PA: Bio-Dynamic Farming and Gardening Association Inc.

Stuart, T. (2009). "Waste: Uncovering the Global Food Scandal". Penguin, http://tinyurl.com/m3dxc9

Tait, C. (2017, Sep 8). As the climate changes, farmers look to adapt. The Globe and Mail. https://www.theglobeandmail.com/news/alberta/in-the-face-of-drought-canadian-farmers-adjust-to-a-changingclimate/article36220413/

Taylor, T. (2014). Milk production: Economies of scale, agriculture, management. Conversable Economist. https://conversableeconomist.blogspot.com/2014/12/milk-production-economies-of-scale.html

TEEB (2015). TEEB for Agriculture and Food: an interim report, United Nations Environment Programme, Geneva, Switzerland.

Temple, J. (2018). Seaweed could make cows bump less methane and cut their carbon hoofprint. MIT technology review. Retrieved from: https://www.technologyreview.com/s/612452/how-seaweed-could-shrink-livestocks-global-carbon-hoofprint/

The Daily Prothom Alo (2019, June 19). Another year of melting snow in the North Pole. The Daily Prothom Alo. Bangladesh

The Way Forward (2018). What growth potential does the agriculture sector offer to Newfoundland and Labrador? The Way Forward on Agriculture, Government of Newfoundland and Labrador. Canada

The Way Forward (2018). The Way Forward on climate change in Newfoundland and Labrador. Municipal Affairs and Environment, Government of Newfoundland and Labrador. Canada

Tibesigwa, B. and Visser, M. (2016).Assessing gender inequality in food security among small- holder farm households in urban and rural South Africa. World Development, 88, pp. 33-49.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. and Polasky. S. (2002). Agricultural sustainability and intensive production practices. *Nature* 418(6898):671-677. http://dx. doi.org/10.1038/nature01014

Tomich, T.P., Brodt, S., Ferris, H., Galt, R., Horwath, W.R., Kebreab, E., Leveau, J.H.J., Liptzin, D., Lubell, M., Merel, P. et al. (2011). Agroecology: A Review from a Global-Change Perspective. Annu. Rev. Environ. Resour. (36), pp.193–222.

TWN and SOCLA (2015). Agroecology: Key concepts, principles, and practices. Third World Network (TWN) and SociedadCientificaLationamericana de Agroecolgia (SOCLA). Malaysia and USA.

UNEP (2011). Agriculture: Investing in natural capital. In: Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. United Nations Environment programme, Nairobi.

USC Canada (2017). Agroecology. Retrieved from: https://www.usc-canada.org/the-issues/agroecology

Vaarst, M., Escudero, A. G., Chappell, M. J., Brinkley, C., Nijbroek, R., Arraes, N. A. M., Andreasen, L., Gattinger, A., Gustavo Fonseca De Almeida, G. F.D., Bossio, D. and Halberg, N. (2017). Exploring the concept of agroecological food systems in a city-region context. Agroecology and Sustainable Food Systems. https://doi.org/10.1080/21683565.2017.1365321

Verhallen, A. (2013). Cover crops: Adaptation and use cover crops. Ministry of agriculture, food and rural affairs, Ontario. Government of Ontario, Canada. http://www.omafra.gov.on.ca/english/crops/facts/cover_crops01/cover.htm

West T. O. and Post W. M. (2002). Soil organic carbon sequestration rates by tillage and crop rotation. Soil Sci. Soc. of Am. J., (66), pp. 1930–1946.

Wittman, H., Desmarais, A. and Wiebe, N. (Eds.)(2010). Food sovereignty: Reconnecting food, nature and community; Fernwood publishing: Halifax, NS, Canada.

Wohlleben, P. (2017). The secret wisdom of nature, Vancouver/Berkeley: Greystone Books, PP. 51

World Resources Institute (WRI) (1998). World Resources 1998/99. A joint publication by The World Resources Institute. The United Nations Development Programme, the United Nations Environment Programme and the World Bank. New York, Oxford University Press.

WWF (May 20, 2019). Sustainable agriculture, dairy. World Wildlife Fund (WWF). Retrieved from: https://www.worldwildlife.org/industries/dairy

Zhang, W., Ricketts, T.H., Kremen, C. Carney, K. and Swinton, S. M. (2007). Ecosystem services and dis-services to agriculture. Ecological Economics, 64, pp. 253-260.

Appendix A

Table A-1: Do you know that lime over-application can cause decrease in soil fertility and health?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	11	68.8	68.8	68.8
	No	5	31.3	31.3	100.0
	Total	16	100.0	100.0	

Table A-2:Do you believe that industrial agricultural/commercial production systems are contributing to climate change globally?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	7	43.8	43.8	43.8
	no	9	56.3	56.3	100.0
	Total	16	100.0	100.0	

Table A-3: Have you tried using less chemical/synthetic fertilizer on the farm?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	7	43.8	43.8	43.8
	no	9	56.3	56.3	100.0
	Total	16	100.0	100.0	

Table A-4: Have you tried any alternatives to reduce the use of pesticides on your farm?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	8	50.0	50.0	50.0
	no	8	50.0	50.0	100.0
	Total	16	100.0	100.0	

Table A-5: Alternative ways to pest management as identified by respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bio-control and sterilized of greenhouse (sterile insect technique, SIT)	1	6.3	6.3	6.3
	Integrated Pest Management, safer soap/insecticidal soap	1	6.3	6.3	12.5
	Intensive farming	1	6.3	6.3	18.8
	No insect no spray	1	6.3	6.3	25.0
	Not answered	8	50.0	50.0	75.0
	Organic pesticides	1	6.3	6.3	81.3
	Spreading sawdust around the edges of fields	1	6.3	6.3	87.5
	Try to bio-control	1	6.3	6.3	93.8
	Using best pest management practices	1	6.3	6.3	100.0
	Total	16	100.0	100.0	

Table A-6: Have you experienced any new type of pest outbreaks on your farm?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	2	12.5	12.5	12.5
	no	14	87.5	87.5	100.0
	Total	16	100.0	100.0	

Table A-7: Were there any new types of disease recorded on your farm?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	1	6.3	6.3	6.3
	no	15	93.8	93.8	100.0
	Total	16	100.0	100.0	

Table A-8:Do you believe that trees on your farm contribute to improving environmental conditions, such as soil quality and assists in wind/soil erosion prevention?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	14	87.5	87.5	87.5
	no	2	12.5	12.5	100.0
	Total	16	100.0	100.0	

Table A-9:Do you plan on introducing organic farming on your farm?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	6	37.5	37.5	37.5
	no	10	62.5	62.5	100.0
	Total	16	100.0	100.0	

Appendix B

Table B-1:Do you believe the *industrial/commerciallivestockproduction systems* are contributing to climate change globally?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	4	44.4	44.4	44.4
	no	5	55.6	55.6	100.0
	Total	9	100.0	100.0	

Table B-2:Do you believe the *industrial/commercial crop production systems* are contributing to climate change globally?

		Frequency	Percent	Valid Percent	Cumulative Percent
	yes	4	44.4	44.4	44.4
	no	5	55.6	55.6	100.0
	Total	9	100.0	100.0	

Table B-3: Causes identified by respondents that industrial livestock and crop production systems are not contributing to climate change

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Due to result of high human demand of dairy and livestock products, we have to accept some environmental effect	1	11.1	11.1	11.1
	Large production system has a smaller carbon footprint per unit produced. They also have financial ability to invest in new technologies and efficient management	1	11.1	11.1	22.2
	Not emitted as much as the coal and oil industry did	1	11.1	11.1	33.3
	Not answered	6	66.7	66.7	100.0
	Total	9	100.0	100.0	

Table B-4: Benefits identified by respondents to set up milk processing industries in NL province

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	It is easy to provide cheese, yogurt and ice-cream	1	11.1	11.1	11.1
	Less transport cost	1	11.1	11.1	22.2
	Not answer	2	22.2	22.2	44.4
	Possibly provide opportunity to sold dairy products in local market	1	11.1	11.1	55.6
	Reduce freight cost	1	11.1	11.1	66.7
	Reduce transportation cost, improving reserve, improve NL food security	1	11.1	11.1	77.8

	There are two plants in this province but they also export to other provinces	1	11.1	11.1	88.9
	Transportation cost reduce/ensure stable market	1	11.1	11.1	100.0
	Total	9	100.0	100.0	

Table B-5: What is the amount of food waste from farm operation, if any?

	Number of respondent	Minimum	Maximum	Mean	Std. Deviation
What is the amount of food waste from farm operation?	9	.00	1.00	.2889	.35512
Number of respondent response	5				
Percentage	55.5%				

Appendix C (Survey)

CROP/VEGETABLE FARM

1. What is your age? ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ 71-80 ☐ 81 or old

2. In which city/town/village do you live?_____________

3. How long have you owned the farm? _________________

4. Size of your open area farm actually in production (ha):**i)** < 5 ha **ii)** 6 ha- 10 ha **iii)** 11 ha – 15 ha **iv)** 16 ha or more

5. Size of your farm under greenhouse/plastic (in square feet)______________________or (in acre)____

6. Do you also raise animals/livestock on your farm? Yes / No

7. If you answered “yes” to the previous question: How many animals do you raise on your farm? ____

8. Did your farm increase in size in the last 5 years? Yes / No

9. Do you have plans to increase the size of your farm in the near future? Yes / No

10. Do you think that there are advantages in small scale farming? Yes /No

11. If you answered “yes” to the previous question, please explain

____

12. Did you have to clear trees to prepare land for your farm? Yes / No

13. Did you have to level hills to prepare land for your farm? Yes /No

14. Did you have to fill-in wetland(s)to prepare land for your farm? Yes / No

15. How do you prepare your soil for cultivation? (select all that apply)

    i)add lime **ii)**cover crops/green manure **iii)** add compost

    iv)others (please specify) ____

16. Do you know that lime over-application can cause decrease in soil fertility and health?

    Yes / No

17. What are the natural hazards affecting your crop farm? Select all that apply.

Extreme temperatures–high (35 degrees C or more); -low (below minus 25 degrees C)	Short growing season
Long winter/late spring	High winds/wildfires
Heavy snow/snow storm	Less snow
Late spring frost	Flood
Rain storm/heavy rain	Landslides/soil erosion
More frequent drought	Wet season

18. Do you believe that industrial agricultural/commercial production systems are contributing to climate change globally? Yes/No

19. If yes, what of the following do you believe may be contributing climate change?

Mono cropping	Use of chemical fertilizers and lime
Land clearing and field burning	Use of fossil energy or fuel
Soil tillage	Size of farm operation
Manure management	Food waste
Irrigation	Food production/processing/and selling
Using pesticides	Food/grain transportation

20. Do you know that crop rotation helps to build soil fertility? Yes / No

21. Do you practice crop rotation on your farm? Yes / No

22. Do you practice inter-cropping (growing one crop alongside another) on your farm? Yes / No

23. Approximately how much fuel (heating oil, diesel or gasoline) do you use on your farm yearly (in liters)? ______________________________

24. How much you spend yearly for electricity bills for running your farm? $_____________________

25. Does your farm use an alternative energy source? Yes / No

26. If you answered "yes" to the previous question, what type of alternative energy does your farm use?

    i) Wind energy **ii)** Solar energy **iii)** Digester **iv)**Other

27. What type of chemical/synthetic fertilizer do you normally use on your farm?

    ____

28. How much chemical/synthetic fertilizer you use on your farm yearly (kg)?______

29. Have you tried using less chemical/synthetic fertilizer on the farm? Yes / No

30. If you answered "yes" to the previous question, please explain:

____

31. How much manure do you use per year on your farm (kg)? _________________

32. How much organic fertilizer do you use per year on your farm (kg)? _______________

33. Do you have a digester plant? Yes / No

34. What type of pesticides do you normally use on your farm? **i)** chemical/synthetic pesticides **ii)** organic pesticides **iii)**bio-controls **iv)**other (please specify)

35. Have you tried any alternatives to reduce the use of pesticides on your farm? Yes / No

36. If you answered "yes" to the previous question, please explain

____

37. Have you experienced any new type of pest outbreaks on your farm? Yes / No

38. If you answered "yes" to the previous question, please explain

____

39. Were there any new types of disease recorded on your farm? Yes / No

40. If you answered "yes" to the previous question, please explain

____

41. How much water is used yearly on the farm for irrigation (in liters)? __________

42. Do you collect rainwater? Yes / No

43. Do you have a natural source of water for irrigation on your farm? Yes / No

44. If you answered "yes" to the previous question, please specify: **i)** lake **ii)** river **iii)**stream **iv)**well

45. Do you practice fish farming/aquaculture on your farm? Yes / No

46. Do you recycle your used household water? Yes / No

47. Do you reuse this recycled water on your farm? Yes / No

48. If irrigation is problematic on your farm, what is the specific issue?

i) shortage of water **ii)** low pressure **iii)** low water levels **iv)** other______________

49. Do you have any forested areas on your farm? Yes / No

50. If yes, do you grow trees on the farm for commercial purposes? Yes / No

51. If "yes", what type of trees? ___________________________________

52. Do you believe that trees on your farm contribute to improving environmental conditions, such as soil quality and assists in wind/soil erosion prevention? Yes / No

53. Where do you sell your product?

i) local market **ii)**farmers market **iii)**other city/town or province **iv)**export **v)** other__________________

54. What percentage of your crop output is used in your household or locally? ___________

55. Do you plan to supply more of your product directly to the local markets?

Yes / No

56. What is cause of food waste on your farm?

i)food spoilage during harvest **ii)**during storage?

57. How do you manage your waste product?

i) throw it away **ii)** make compost **iii)** other ______________

58. Do you consider your farm to be environmentally-friendly? Yes / No

59. If yes, what are the practices that make your farm environmentally-friendly?

i) crop diversification **ii)** crop rotation **iii)**intercropping **iv)**use of organic fertilizer **v)** water recycling **vi)** digester **vii)**soil conservation **viii)**other ________________

60. Do you have a plan for sustainable farming? Yes / No

61. Do you have knowledge/training about agro-ecological *(an agro-ecological farming system that would focus on the use of techniques such as diversified cropping systems, better integration between crop and animal production, increased incorporation of trees*

*and wild vegetation, preserve environmental quality and so on, Grain, 2011)*farm practices? Yes / No

62. Are you interested in agro-ecological farm practices? Yes / No
63. Do you plan on introducing organic farming on your farm? Yes / No
64. If "no", what do you believe are some of the barriers to organic farming that prevent more crop farmers from adopting this system?________________________________

    ____
65. Do you think an integrated farming systems (includes crop, livestock, forestry and fish together) are helpful for sustainable agricultural development? Yes / No
66. Did you benefit from any programs/financial support from the provincial or federal government for sustainable agriculture in Newfoundland? Yes / No
67. If "yes", please explain

    ____

    ____
68. What kind of support do you expect from provincial or federal government for making your farm more environmentally-friendly?

    ____

    ____

    ____
69. Do you have any other ideas about how to prevent the consequences of climate change on your farm and make it more sustainable? Please share these ideas in the space below:

    ____

    ____

    ____

____

____

Thank you very much

Appendix D (Survey)

<u>DAIRY FARM</u>

1. What is your age? ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60

   ☐ 61-70 ☐ 71-80 ☐ 81 or old

2. What is the name of your farm?_________________________________
3. How long have you owned the farm? ________________
4. How many dairy cows are on your farm?___________________
5. Did your farm increase in livestock in the last 5 years? Yes / No
6. Do you have plans to increase the number of livestock in the near future? Yes / No
7. Do you believe that there are advantages in small scale farming? Yes/No
8. If you answered "yes" to the previous question, please explain

   ____

9. Do you also grow crops or vegetables on your farm? Yes / No
10. Do you grow grain or any other animal feed on your farm? Yes / No
11. If you answered "yes" to the previous question, please explain

    ____

12. Do you have pasture/grassland on your farm? Yes / No
13. Does your farm produce grass/hay for your livestock? Yes / No
14. Approximately what percentage of your animal feed is produced on

    farm?________________

15. Do you need to import grain from outside of the province? Yes/No

16. Did you have to clean trees to prepare land for your dairy farm? Yes / No

17. Did you have to level hills to prepare land for your dairy farm? Yes /No

18. Did you have to fill in wetland(s) to prepare land for your dairy farm? Yes / No

Please answer questions 19 to 29 only if you grow crops/vegetables on your farm

19. How did you prepare your soil for crop cultivation?

    i)add lime **ii)**cover crops/green manure **iii)**add compost **iv)**others (please specify)____

20. Do you know that lime over-application can cause a decrease in soil fertility and health?

    Yes/ No

21. What type of chemical/synthetic fertilizer do you normally use on your farm?

    ____

22. How much chemical/synthetic fertilizer do you use yearly on your farm (kg)?___

23. Have you tried using less chemical/synthetic fertilizer on the farm? Yes / No

24. If you answered "yes" to the previous question, please explain: ______________

25. How much manure or organic fertilizer do you use yearly on your farm (kg)?___

26. What type of pesticides do you normally use on your farm? **i)** chemical pesticides **ii)** organic pesticides **iii)** bio-control **iv)** other (please specify) __________________

27. Have you tried alternative ways to reduce the use of pesticides on your farm? Yes/No

28. If you answered "yes" to the previous question, please explain ___________________

29. What are the natural hazards affecting your livestock/dairy production?

Extreme temperatures–high (35 degrees C or more) -low (below minus 25 degrees C)	Short growing season
Long winter/late spring	High winds/wildfires

Heavy snow/ snow storm	Less snow
Late spring frost	Flood
Rain storm/heavy rain	Landslides/soil erosion
More frequent drought	Wet season

30. Do you believe the *industrial/commercial livestock production systems* are contributing to climate change globally? Yes / No
31. Do you believe the *industrial/commercial crop production systems* are contributing to climate change globally? Yes / No

32. If yes, which of the following do you believe may be contributing to climate change in livestock farming? (please choose from the table below)

Land clearing and field burning	Use of chemical fertilizers and lime
Soil tillage	Using fossil energy or fuel
Soil erosion from pastures	Size of farm operation
Manure management	Enteric fermentation (gas directly from cattle)
Irrigation	Food production/processing/and selling
Using pesticides	Food/grain/livestock and milk transportation
Use of a heating system	Water and air pollution from livestock

33. Approximately how much fuel (heating oil, diesel or gasoline) do you use on your farm yearly (in liters)? ______________________________
34. What is your average yearly spending on electricity for running your farm? $_________
35. Does your farm use an alternative energy source? Yes / No
36. If you answered "yes" to the previous question, what type of alternative energy does your farm use?

    ii) Wind energy **ii)** Solar energy **iii)** Digester **iv)** Other

37. How much manure is produced yearly on your farm (in kg)? ___________________
38. How do you manage the manure produced on the farm? _____________________

    ____

39. What percentage of your farm manure is used as fertilizer on your crop land?

____

40. What percentage of your farm manure is sold? __________________________

41. Do you know that feeding seaweeds to your livestock can reduce methane in manure?

Yes / No

42. If you answered "yes" to the previous question, then do you feed seaweeds to your livestock? Yes / No

43. Do you have a digester plant? Yes / No

44. Do you use any antiseptic to clean your livestock farm? Yes / No

45. If you answered "yes", please explain ______________________

46. Do you use any medicine/hormones to treat your livestock? Yes/ No

47. If you answered "yes" to the previous question, please explain

____

48. Were there any new types of diseases recorded on your livestock farm recently?

Yes/ No

49. If you answered "yes" to the previous question, please explain:

____

50. How much water do you use yearly for livestock operations (in liters)?

____

51. Do you collect rainwater? Yes / No

52. Do you have a natural source of water on your farm? Yes / No

53. If you answered "yes" to the previous question, please specify:

i) lake **ii)** river **iii)**stream **iv)**well

54. What are the limitations you face with the water supply on your farm?

i) shortage of water ii) low pressure iii) low water level iv) other _____________

55. Do you practice fish farming/aquaculture on your farm? Yes / No

56. Do you recycle your used household water? Yes / No

57. Do you reuse this recycled water on your farm? Yes / No

58. Do you have any forested area on your farm? Yes / No

59. If yes, do you grow trees on the farm for commercial purposes? Yes / No

60. If "yes", what type of trees? ______________________________

61. Do you believe that trees on your farm contribute to improving environmental conditions, such as soil quality and/or wind and soil erosion prevention?

    Yes / No

62. Where do you sell your product?

    i) local market **ii)** farmers market **iii)** other city/town or province **iv)** export **v)** other

    ____

63. Do you believe that a milk processing plant in the province, would benefit your farm?

    Yes / No

64. If you answered "yes" to the previous question, please explain

    ____

65. What is the amount of food waste from farm operation, if any? (in kg)

    ____

66. How do you manage your waste product? i) throw it away ii) make compost iii) other

    ____

67. Do you consider your farm to be environmentally-friendly? Yes / No

68. If yes, what are the practices that make your farm environmentally-friendly?

    i)selective breeding **ii)** feed healthy diets to your livestock **iii)** sustainable use of manure **iv)** water recycling **v)** digester **vi)** soil conservation vii solar panels **viii)** other

    ____

69. Do you have a plan for sustainable farming? Yes / No

70. Do you have knowledge/training about agro-ecological*(an agro-ecological farming system that would focus on the use of techniques such as diversified cropping systems, better integration between crop and animal production, increased incorporation of trees and wild vegetation, preserve environmental quality and so on, Grain, 2011)*farm practices? Yes / No

71. Are you interested in agro-ecological farm practices? Yes / No

72. Do you think integrated farming systems (includes crop, livestock, forestry and fish sectors together) are helpful for sustainable agricultural development? Yes / No

73. Did you benefit from any programs/financial support from the provincial or federal government for making your farm more sustainable? Yes / No

74. If "yes", please explain ____

75. What kind of support do you expect from provincial or federal government for making your farm more environmentally-friendly?

    ____

76. Do you have any other ideas about how to prevent the consequences of climate change on your farm and make it more sustainable? Please share your ideas in the space below:

    ____

    ____

    ____

    ____

    ____

    ____

Thank you so much!

Appendix E (Invitation Letter)

Dear Sir/Madam, February 7, 2019

My name is Mohammad Selim Reza, I am a Master's program candidate at the Grenfell Campus of Memorial University of Newfoundland, Canada. As part of my thesis, I am doing a research entitled "Impact of Climate Change on Agricultural Production and Food Security in Newfoundland and Labrador, Canada". The research seeks to investigate the negative consequences of climate change on food production and food security in Newfoundland and Labrador (NL) and to assess whether agro-ecological approaches could be successfully applied in the agricultural system in NL. *An agro-ecological farming system focuses on the use of techniques such as diversified cropping systems, better integration between crop and animal production, increased incorporation of trees and wild vegetation, and preservation of environmental quality*(Grain, 2011).This research is being supervised by Dr. Gabriela Sabau, Professor, School of Science and the Environment, Grenfell Campus, Memorial University of Newfoundland,Canada.

I would like to invite you (as a farmer who produces either crops or dairy) to participate in a survey included with this letter, and share with the researcher information related to global climate change that damages your crops/livestock and generally the current situation of sustainable agricultural practices on your farm. Your participation and responses will help to enrich the research results with the aim of optimizing agricultural activities for sustainable development of Newfoundland and Labrador's agriculture. If you are interested in the results of this research, I can share them with you, upon request.

I want to assure you that the information or data given will not be attributed to you personally anywhere and I will make every effort to ensure that you remain anonymous in the whole span of the research, except if you decide otherwise (please see the Informed Consent form). Please let me know if you have any questions or need any information related to this survey via email, phone or fax at: msr780@grenfell.mun.ca, 709 639 2552 (P) and 709 639 8125 (F). A response within 10 days after receiving this letter will be highly appreciated. Please fill out the survey, sign the Informed Consent form included and mail both back to me in the addressed envelope. The return envelope has a stamp on it, you do not need to pay postage. Thank you.

I greatly appreciate your time and input to this research.

Sincerely,

Mohammad Selim Reza,
Candidate of MA in Environmental Policy
Memorial University, Grenfell Campus
20 University Drive, Corner Brook
Newfoundland and Labrador, A2H5G4, Canada
E-mail: msr780@grenfell.mun.ca

Appendix F (Informed Consent Form)

Informed Consent form

Title of research: Impact of Climate Change on Agricultural Production and Food Security in Newfoundland and Labrador, Canada

Researcher: Mohammad Selim Reza, Master's Thesis Candidate; msr780@grenfell.mun.ca;Dr. Gabriela Sabau, Academic Advisor, gsabau@grenfell.mun.ca, Memorial University of Newfoundland, Grenfell Campus, Newfoundland and Labrador, Canada

This form is part of the process of informed consent. Please take time to read this carefully and to understand the information given to you. Please contact to researchers if you have any questions about the study or would like more information before you consent. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

You have been invited to participate in this research because you are a resident of Newfoundland and Labrador (NL) and are involved in farm activities. This research covers the farms related to crop and dairy production in the province. The purpose of this research is to investigate the negative consequences of climate change on food production and food security in NL. It also aims to identify the measures taken by farmers like you to reduce the greenhouse gas (GHG) emissions and to assess whether agro-ecological approaches or environmentally-friendly farm practices could be feasible for a sustainable agricultural system in the province.

Your participation involves answering about 70 questions about your farm. Answering the questions will take approximately 25-35 minutes. The questions you will be answering are related to natural hazards affecting your crop or dairy farm and the agricultural activities which produce climate change. Some questions are related to your present farm practices and measures you have taken for sustainable practices on your farm and for food security in NL. The data I collect will be analyzed and used entirely for academic purposes.

The research findings of this thesis will provide ideas to the provincial government of NL, policy makers, research institutions and the public for policy formulations. They can also help farmers like you introduce new environmentally-friendly practices on the farms. Iintend to share my results with Food First NL, Our Food Our Future, Young Farmers' Forum, Agriview NL Agriculture, which are the platforms of farmers and policy makers in NL. My research paper will be stored in the MUN library, where future students will get an opportunity to review the results.

All answers to this survey will be codified and aggregated to make it impossible to connect any information you provide with your individual identity. By aggregating the data, both your privacy and confidentially will be maintained. The completed surveys will be stored in a locked filing cabinet and any information coded electrically will be stored in a password-protected computer. The data will be kept for a minimum five years, as required by Memorial University's Policy on Integrity in Scholarly Research. There are no obvious risks associated with your participation in this research. Moreover, you can choose not answering any questions which you consider they may potentially harm your farming activities.

The proposal for this research has been reviewed by Grenfell Campus Research Ethics Board (GCREB) and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the GCREB by email at: gcethics@grenfell.mun.ca or by telephone at (709) 639-2736.

Please sign to indicate your understanding and receipt of this form and send me the signed copy in the envelope provided. Thank you.

____
Signature of Participant

____
Signature of Researcher

Date: March 18, 2019