Economic Feasibility of Different Cropping Systems in Newfoundland and Labrador

By

Muhammad Musa Khan

A thesis submitted to the School of Graduate Studies

In partial fulfillment of the requirement for the degree of

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Abstract

The economic viability of cropping systems is largely determined by the costs of production and price premiums. Therefore, economics plays a dominant role in the adoption of cropping systems. This study was conducted over a period of five years (2017-21) under boreal climatic conditions in Newfoundland and Labrador (NL). The research utilized cost of production, gross return and gross margin, crop yield, and cost-benefit ratio to investigate the economic feasibility of nine crops, including potatoes, beets, cabbage, carrots, rutabagas and turnips, blueberries, cranberries, raspberries, and strawberries. The objective of this research was to identify the most economically feasible crop among the nine studied crops. The results of the study showed that potatoes had the highest total cost of production among all crops grown in NL, followed by rutabagas, turnips, carrots, cabbage, strawberries, beets, raspberries, and cranberries. In terms of gross revenue, rutabagas and turnips had the highest average gross revenue compared to other crops. The gross revenue was highest in 2021, reflecting higher crop yields in that year, and declined gradually across the years after the initial year. The gross margins of the cropping systems showed a declining trend over time due to increasing operating costs and decreasing crop yields. However, rutabagas and turnips had the highest gross margin compared to all other crops. All crops had similar cost/benefit ratios, with cranberries having the highest cost/benefit ratio and beets having the lowest. The cost/benefit ratio showed a gradual increase across the years, except for 2019. The economic feasibility of crops evaluates whether cultivating a particular crop will result in financial profitability for farmers. Based on these findings, it can be concluded that rutabagas and turnips are economically feasible crops for producers in NL. Adopting these crops can enhance production levels and farm profitability under current economic conditions and production practices. These results provide valuable insights for farmers and policymakers in the region to make informed decisions about crop selection and management practices.

Dedication

First and foremost, I would like to express my gratitude to Almighty ALLAH who has always blessed humanity infinitely and provided us with this opportunity to explore our multifarious talent and competence in the practical genre. I wish to articulate my deepest gratitude to my supervisor, Dr. Morteza Haghiri, whose expertise, and knowledge enhanced my understanding and provided me extensive personal and professional guidance and taught me a great deal about both scientific research and life in general. I am also grateful for his moral support in some difficult time and circumstances. As a teacher and mentor, he has taught me more than I could ever give him credit for here. He has shown me, by his example, what a good scientist (and person) should be.

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Last but not the least, I am thankful to my parents, siblings and family members for their affection, love and unconditional support during completion of my degree program.

Muhammad Musa Khan

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List of Abbreviations

ANOVA: Analyses of Variance

CBA: Cost Benefit Analysis

CBR: Cost-Benefit Ratio

COGS: Cost of Goods Sold

FAO: Food and Agriculture Organization

GHS: Green House Gases

GIS: Geographic Information Systems

ha: Hectare

IFPRI: International Food Policy Research Institute

LSD: Least Significant Difference

Mg: Mega Gram

Mt: Mega Ton

NB: New Brunswick

NE: Northeast

NL: Newfoundland and Labrador

NS: Nova Scotia

PEI: Prince Edward Island

US: United States

USDA: United States Department of Agriculture

Chapter 1

Introduction

1.1 Background

The province of Newfoundland and Labrador (NL), located on the eastern coast of Canada, possesses a unique set of environmental and geographical characteristics that significantly influence agricultural activities. The region experiences a cool climate with a short growing season, which limits the range of crops that can be cultivated successfully. Additionally, NL's soil types vary widely, encompassing a mix of acidic and organic-rich soils. These conditions necessitate careful consideration of cropping systems that are suitable for the region's specific requirements.

1.2 Problem Statement

The economic feasibility of different cropping systems in NL is not extensively documented or analyzed, leaving farmers and agricultural stakeholders with limited knowledge to make informed decisions about crop selection and resource allocation. This knowledge gap poses challenges for enhancing agricultural productivity, profitability, and sustainability in the region. Therefore, there is a need to conduct a comprehensive study to evaluate the economic feasibility of different cropping systems in NL, considering various factors such as input costs, available technologies, market demand, and the unique environmental conditions of the region.

Land use patterns are changing significantly in the North American Great Plains (Willer and Lernoud, 2019). In recent years, these changes have been primarily driven by growing global market demands, rising input costs, increasing concerns over environmental degradation and food security (Willer and Lernoud, 2019). Farmers are diversifying and extending their crop rotations by adding legumes and oilseeds while reducing summer fallows and using conventional tillage.

This helps reduce fossil fuel and synthetic nitrogen use and improves air, water, and soil quality. (Zentner et al., 2002).

The number of organic farm producers are, interestingly, increasing by managing organic production practices and employing their low input, to minimize dependence on acquired inputs and enhance value to their produce (Willer and Lernoud, 2019). The adoption of alternative or new production systems by the producers will ultimately rely on their ability of these systems to reduce costs of production, maximize net revenue, or decrease gross economic risks in comparison with existing cropping techniques (Zentner et al., 2002).

Few studies, however, have thoroughly explored the comparative economic advantages of various land-use modification under NL's conditions. The economic boom of the Canadian agricultural industry is critical to its long-term sustainability while maintaining our natural resource assets and increasing resilience to stresses and threats. The Canadian prairies, dominated by modern agriculture systems, are often highly productive but still incur many environmental and social problems that are alarming for the sustainability of the agricultural industry. These problems include higher costs of input and energy, emissions of greenhouse gases (GHS), imbalances in the ecosystems, the depletion of land water resources, trade concentration, worldwide competition in production of bulk commodities, and a continuous reduction in agriculture land (Kremen and Miles, 2012).

In the Canadian Prairies, the total number of registered farms has increased up to 34%, from 2014 to 2018 i.e., from 1465 to 1975 (Canada Organic Trade Association, 2019). There were 45% increase observed in the land area occupied by organic farms in Canada from 2011 to 2017 (Canada Organic Trade Association, 2019). This figure was further expanded in 2018, to include 1.27 millions ha of land (Willer and Lernoud, 2019). A surge in demand for organic food commodities has been observed in Canada as well as globally, which is the major reason for the increase in organic farm management.

The value of the organic market in Canada was about 5.4 billion Canadian dollars during 2017, which was 54% increased than 2012 market value. In comparison to conventional tillage techniques, the implementation of no-till and reduce-till managements for yearly crop production allows the farmers to minimize soil erosion, enhance soil moisture conservation, increase soil carbon sequestration, and decrease the emissions of GHG (Acton and Gregorich, 1995).

However, these approaches bring additional issues in terms of weed management and nutrient availability (Derksen et al., 2002). In the case of monocultural cereal rotation, researchers have observed an improvement in crop production comparing conventional tillage to conservational tillage techniques (McConkey et al., 1996). When conservation tillage is linked with mixed crop rotation (cereal-oilseed-pulse), consistent production improvements are more prevalent (Miller et al., 2001).

Several factors have been attributed to the synergism that occurred between mixed cropping systems and conservation tillage methods, including the increased the availability of soil moisture through improved snow traps, decreased the rate of evaporation, and reduced moisture usage of some crops such as pulses, enhanced crop establishment as a result of improved soil surface moisture factors; increased the efficiency of nutrient utilization as a result of improved synchronization through mineralization, previous crop residues release the nutrients and these nutrients are intake by present crop and improved pest and weeds control (Derksen et al., 2002).

According to the findings of economic analyses of conservation tillage strategies in these areas, monoculture cereal crops and fallow-based cropping system (agricultural practice where a portion of land is intentionally left uncultivated (fallow) for a specific period to allow the soil to rest, regenerate nutrients, and control pests and diseases before planting crops in rotation) offer little-to-no economic benefit over conventional tillage operations (Zentner et al., 1996). Although lowering tillage intensity reduces fuel, labour, machine repair, and administrative expenses, these savings are often outweighed by higher nitrogen (N) fertilizers and herbicide costs.

However, considerable economic benefits are frequently observed with conservation tillage practices in mixed crop rotations due to the combination of significant higher crop yields, higher valuable commodities production, and in certain situations, lower costs of production (Zentner et al., 2002).

Generally, agriculture production depends on availability of water and fertilizers, crop selection, culture practices, soil quality, climate conditions, disease and pest management. These practices are also necessary to preserve soil health and natural resources, to promote the recovery of deep soil nutrients, and to reduce the impact of crop pest (Government of Canada, 2006).

Transitioning to organic farming also frequently entails significant transition expenses, such as the cost of investing in soil-building crops and organic amendments to increase the level of organic matter in soil and reload the soil nutrients. Additional costs are often associated with making the necessary adjustments to a producer's equipment inventory. Furthermore, producers must expend a significant amount of effort and time to understand and learn production processes, record the procedures employed, and identify and secure market prospects.

Though, once certified, most organic commodities may be sold at higher prices than conventionally produced commodities, and this generation of higher revenues, along with savings in inorganic fertilizer and chemical costs, may result in overall increases in net farm profitability (Zentner et al., 2011).

According to studies on the economic benefits of farming, the primary factors affecting profitability are the relative yield produced by crops, the amount of money saved by using less non-renewable resources, and purchased inputs, the existence of commodity price premiums, and the duration and magnitude of the revenue loss observed (Smith et al., 2004).

1.3 Agriculture in Canada

Canada plays a significant role in the global agriculture sector. After the European Union, USA, Brazil, and China, it is the world's fifth-largest exporter of agri-food and basic agricultural products (pulses, oats and durum wheat), and also the 6^{th} largest importer of the world in agri-food and agriculture products (Agriculture and Agri-Food Canada, 2022; Issac et al., 2018).

According to Agri-Food Canada (2022), the agri-food and agriculture sector provided 1 in 9 jobs in Canada; employed 2.3 million people, accounting for 11% of the Canadian employment. The agri-food and agriculture system contributed $143.8 billion to Canada's overall GDP in 2022, accounting for 7 percent of the total GDP (Agriculture and Agri-Food Canada, 2022).

Significant changes have been observed in the Canadian agriculture sector: the average farm area, cultivated land, and the livestock number per farm grown over the last 30 years (1981–2011), demonstrating growing intensification and concentration of output despite a decline in the overall number of farms (Clearwater et al., 2016).

In 2022, there were 62.2 million ha of total farmland in Canada; however, in 2017, there were 64.8 million ha of total farmland, with an average farm size (315 ha) (Agriculture and Agri-Food Canada, 2022). The way Canadian farming is set up has shifted, and in 2022, there were 189,874 farms. In 2016, the number of farms dropped by 1.9 percent, leaving 193,492 farms (Statistics Canada, 2017; Agriculture and Agri-Food Canada, 2022).

According to data from Statistics Canada, industrial agriculture has become more prevalent in Canada. From 2011 to 2016, the amount of land used for conventional tillage, commercial fertiliser, pesticides, and field crops grew by 5 %, 13 %, 39 %, and 6 %, respectively (Ching, 2018).

The support of Canadian government for export oriented agriculture has a long history and is built based on standardisation, mechanisation, and economies of scale, which is in opposition to programmes intended to considerably increase the production of agro-ecological commodities (Bouchard, 2002; Qualman, 2011). Canada is considered as one of the world's largest emitters of GHGs (Sabau, 2017). In 2017, total GHG emissions (716 Mt CO_2) equivalent (Environment and Climate Change Canada, 2019) to per capita of 20.1 tonnes CO_2 in 2015.

Agriculture accounts for 10% of total emissions in Canada, with agricultural activities such as food processing, industrial agricultural production, food waste and transportation (Statistics Canada, 2017) contributing to emissions, whereas agricultural facilities account up to 20% worldwide anthropogenic GHG emissions (IPCC, 1996). While contributing to climate change, rising planet temperatures, extended summer, poor soil quality, contaminated water and air also degraded the sustainability of Canada's food production (Food Secure Canada, 2017).

Based on the results of the Canadian Community Health Survey (2019-2020), 9.6 % of Canadian families experienced food insecurity in 2020 (Polsky and Garriguet, 2022). As a result, feeding 7.96 billion people is not only a task for Canada, but also a challenge for the rest of the globe (Population Reference Bureau, 2022).

1.4 Agriculture in Newfoundland and Labrador

Because of its isolated nature, NL faces unique challenges in feeding its inhabitants. Furthermore, the province's agriculture industry is being harmed by a shrinking and ageing farmer population (Abdulai, 2018).

According to the Canadian Community Health Survey (2011-2012), 7.8 % of families in NL province were food insecure (food insecurity refers to the condition in which individuals or households do not have consistent access to enough nutritious food to lead a healthy and active life, often due to financial constraints or limited availability of food). According to some estimates, up to 90% of all food and other consumables are imported into the province from outside sources, meaning that the residents of NL are suffering with a shortage of both local food provision and agri-food production (Evans, 2017; Food First NL, 2016).

Major health, economical, environmental, and social issues still exist in the province, particularly a high prevalence of chronic diseases, a climatic change, an unstable energy dependent economy, and persistently high rates of food insecurity and poverty. Indigenous people, particularly those living in Nunatsiavut communities in Labrador, suffer difficulties, such as access to traditional foods and wild foods being hampered by economical, environmental, and social factors, as well as the high pricing, scarce supply, and lower quality of food purchased at store (Food First NL, 2016).

Among the Canadian provinces, NL had the lowest number of farms in 2016, contributing less than 1% of the total number of farms in Canada (Statistics Canada, 2017). Conferring to the most recent statistics, (collected in 2022) 344 farms exist in the province, representing a 15.5 % decrease from the last census in 2016. In NL, farm operators numbers fell by 10 % from 500 in 2016 to 450 in 2021 (Statistics Canada, 2022).

In 2016, the total farm area in NL was 28,630 ha, with an average farm size of 57.3 ha. However, by 2021, the total farm area had decreased (-30.2 %) to 20,002 ha, with the average farm size rising to 58.2 ha (Statistics Canada, 2022). More importantly, from 2016 to 2021, the amount of land used for growing crops decreased by 1.6 %, mainly because of urbanization.

Additionally, according to reports, In NL the number of cows fell by 10 % from 2011-2016 to 9995 heads (including cows, calves and heifer), dairy cows fell by 10.5%, whilst from 2011-2016 the number cattle (beef) fell by 28.5 % i.e., 528 heads (farms reporting beef cattle 23.8% decline) (Statistics Canada, 2017).

It is critical that nearly every aspect of NL agriculture is in decline. Should this continue, the residents of NL would become increasingly susceptible to higher food costs results in minimizing crop production in other provinces?

Moreover, because natural hazards such as winter storms commonly interrupt both land and sea transportation in NL, the province frequently experiences shortages in fresh foods commodities. As a result, residents often opt to purchase highly processed goods that have a prolonged shelf life (Everybody Eats, 2015).

Based on the recent Food First NL research report, many families struggle to purchase enough nutritious food and rely on food banks or friends and family in the absence of emergency food assistance. The province of NL has Canada's lowest rate of vegetable and fruit consumption also the country's prominent rates of diabetes and obesity (Everybody Eats, 2015).

These challenging conditions illustrate many ongoing food security problems in NL. Global warming projections could be positively impacted the agriculture of NL in the upcoming decades, such as shortening in frost days and prolong growing season. But continued increase in temperature also creates new problems such as shifting of diseases, expansion in range of contamination, soil erosion and intense rainstorms (Fitzpatrick, 2017).

For example, hurricanes caused flooding and rainstorms wiped away agriculture fields and rendered accessible routes unusable for several days. If any component, such as temperature, frost, rainfall, or fertility, is not met, "it might reduce the yield and will increase food prices in an effort to make up for the loss caused by disasters."(Fitzpatrick, 2017).

The agricultural sector has major contributions in GHG emissions such as carbon dioxide is emitted by cultivation of soil and operating farming machinery driven by combustion of fuels, and nitrous oxides are generated from the chemical use of fertilisers in the agriculture sector, and methane gas is produced from the waste of livestock. Although NL has lower emissions from agriculture than other provinces (such as Manitoba), emissions from solid waste disposal still outpace those from agriculture. Agriculture in NL contributed 91 kt of CO_2 equivalent emissions in 2015 as compared to waste's 776 kt (Fitzpatrick, 2017).

Farmers have been experimenting with new varieties, irrigation and cropping systems in an effort to better understand the potential benefits of a longer growing season.

Agriculture plays a vital role in sustaining rural economies and ensuring food security (Willer and Lernoud, 2019). However, the economic feasibility of cropping systems can vary significantly depending on the local environmental conditions and market dynamics (Willer and Lernoud, 2019). In the province of NL, with its unique climate and geographical characteristics, understanding the economic viability of different cropping systems is of paramount importance for farmers, policymakers, and agricultural stakeholders (Abdulai, 2018).

NL presents a challenging agricultural landscape, characterized by a cool climate, short growing season, and diverse soil types. These factors pose significant constraints on the selection of crops and farming practices. Additionally, market demand and accessibility to potential buyers further influence the profitability and sustainability of agricultural ventures (Fitzpatrick, 2017). Therefore, a comprehensive analysis of the economic feasibility of various cropping systems becomes imperative to guide decision-making and optimize agricultural productivity in this region.

The ultimate goal of this thesis is to evaluate and compare the economic feasibility of different cropping systems in NL. By examining the costs, returns, and market potential of selected crops, we seek to provide valuable insights into the viability and profitability of alternative agricultural practices. Through this analysis, we aim to assist farmers in making informed decisions regarding crop selection and resource allocation, ultimately contributing to the sustainable growth of the agricultural sector in the province.

To achieve this objective, mixed-methods approach were employed, combining quantitative analysis and qualitative assessments. Initially, the relevant data were collected and analyzed on crop yields, input costs, labor requirements, and market prices from statistics Canada across different regions of NL. These insights will guide policy makers to develop effective strategies and recommendations for improving agricultural practices in the future.

By conducting a comprehensive analysis of the economic feasibility of different cropping systems in the province, this research will contribute to the existing body of knowledge on agricultural economics in the region. The findings of this study will not only benefit farmers in making informed decisions but also provide valuable information to policymakers and agricultural organizations to support the development of sustainable and profitable agricultural practices in NL.

1.5 Research Question

How do interactive crop budgets, assessing overall crop profitability, cost-benefit analysis, and economic feasibility help find the suitable crops for NL, offering advice to boost agricultural productivity and profits?

1.6 Research Objectives

The feasibility of crops involves evaluating the practicality and suitability of cultivating crops, profitability assesses the ability to generate more revenue than expenses, and productivity measures the efficiency in achieving crop yields with available resources. This research aims to enhance comprehension of the feasibility, profitability, productivity, and perception of cropping systems in NL. To achieve this, it is crucial to conduct an economic evaluation of the cropping systems, which involves making comparisons and assessing their feasibility.

Main objectives:

- Develop interactive crop budget for each crop.
- To evaluate the profitability of the entire cropping system and enable comparisons between crops.
- Perform cost-benefit analysis to determine probability of net returns.
- To assess the economic feasibility of different cropping systems in NL, considering factors such as input costs, market demand, available technologies and environmental conditions.
- To identify the most economically viable cropping systems for the province's specific climate, soil conditions, and market dynamics.

- To provide recommendations and insights to farmers and policymakers for optimizing crop selection and resource allocation in order to enhance agricultural productivity and profitability in NL.

1.7 Significance of the Study

According to a wide range of studies, organic cropping systems may preserve ecological integrity, promote environmental stewardship, and offer economic benefits. A wide range of tactics can be used in organic production systems. By generating cost analyses that highlight the financial consequences of adopting each of the systems investigated in the project to enable producers to assess their viability in marketplaces.

Enterprise budgets will be prepared using the previous methodology suggested by Tourte et al., (2009). These methods are created to dynamically reflect differences in field operations, inputs, and crop performance, which an improvement above static models that are currently accessible to farmers. The goal of this thesis is to promote on-farm research while also contributing to the growth of agricultural production for different crops and assessing the possible economic rewards for farmers.

There is a knowledge gap in the role of different cropping system approaches in determining crop yields. Numerous system experiments have been conducted in various climatic regimes to address grain or, less frequently, cropping systems, but none have replicated the unique farm improvements used in this study. Making decisions about farm output and pricing requires an understanding of how cropping system affect crop yields as well as production costs. By examining the interactions and trade-offs between soil fertility, weeds, pests, and economics, this long-term holistic approach can provide some light on farmer difficulties.

Alternate agriculture management systems prioritize eco-friendly practices like organic farming, permaculture, and precision agriculture to boost productivity sustainably, preserve resources, and reduce environmental harm. Farmers are always looking for innovative ways to improve their cropping systems, such as alternate management systems and innovative crops. This study aimed to evaluate the impact of cultivating different crops on long-term production levels, costs, net return, and overall economic profitability. This will facilitate identification of the most profitable cropping systems for the farmers of the NL.

1.8 Organization of the Thesis

This study has been structured into five chapters, each dedicated to examining the economic viability of different cropping systems within the province of NL. The content of each chapter is outlined as follows:

Chapter 1st : The introductory chapter of the paper provides a comprehensive overview of the topic, highlighting the background, problem statement and economic benefits of agriculture in Canada and NL, and outlining the research objectives, questions, and significance of the study.

Chapter 2nd : The subsequent chapter focuses on a literature review of current agricultural practices in NL and Canada, with a specific emphasis on agricultural sustainability, crop production, and their role to the Canadian economy and budget enterprises.

Chapter 3rd : This chapter details the research methods employed, including theoretical concepts, sampling, data collection, and analysis.

Chapter 4th : This chapter indicates the findings of the study along with figures and analysis of data.

Chapter 5th : A discussion of the findings is also provided, with comparisons drawn to existing literature, and consideration given to the impact of different inputs and procedures on crop production and profitability. The chapter concludes with a summary of the objectives of research and findings, suggesting future of research be conducted on economic assessments of cropping systems using different procedures, while acknowledging certain limitations of the present study.

Chapter 2

Literature Review

The Agricultural Sector in Atlantic Canada, encompassing the provinces of Nova Scotia (NS), New Brunswick (NB), Prince Edward Island (PEI), and NL, plays a significant role in the region's economy and food production (Wilson et al., 2020). However, NL stands out with a unique agricultural landscape compared to its neighboring provinces (Schaller et al., 2018). While NS, NB, and PEI have long-established agricultural sectors, characterized by diverse crop production, livestock farming, and agri-food processing industries, NL faces distinct challenges due to its geographical location and climatic conditions (Ochs et al., 2021).

In NL, the agricultural sector is relatively smaller in scale and primarily focuses on livestock production, including beef, dairy, and poultry. (Caro et al., 2014). The province's rugged terrain, shorter growing season, and limited arable land present limitations for large-scale crop production. As a result, NL's agricultural industry is more specialized and oriented towards niche markets, such as organic farming, specialty meats, and locally produced fruits and vegetables (Paracchini et al., 2020).

In contrast, NS, NB, and PEI benefit from more favorable agricultural conditions, including fertile soils, moderate climates, and larger agricultural land bases (Laamrani et al., 2021). These provinces have a more diverse agricultural sector, encompassing a wide range of crops, such as grains, fruits, vegetables, and specialty crops (Chapagain, 2017). They also have a higher concentration of agri-food processing facilities, which contribute to value-added activities and the export of agricultural products. (Van Huellen and Abubakar, 2021)

The differences in the place of the Agricultural Sector between NL and the other provinces in Atlantic Canada can be attributed to various factors, including historical agricultural development, resource availability, and market opportunities. While NS, NB, and PEI have a longer history of agricultural settlement and have been able to leverage their favorable conditions for agricultural production, NL's agricultural sector has evolved in response to its unique challenges and opportunities (Kraly et al., 2022).

It is important to note that NL's Agricultural Sector, despite its smaller scale, plays a crucial role in the province's food security, rural development, and sustainable land use. Local food production and agricultural activities contribute to the regional economy, support employment in rural areas, and promote self-sufficiency in food production (Dubbeling et al., 2017).

In conclusion, while the Agricultural Sector in NL differs from that of the other provinces in Atlantic Canada, it holds a distinct place within the region's agricultural landscape (Molin et al., 2017). The agricultural industry in NL predominantly emphasizes livestock production and specialized niche markets, while NS, NB, and PEI have more diversified crop production and agri-food processing sectors (Parvez et al., 2021). Recognizing the unique challenges and opportunities of NL's agricultural sector is essential for formulating policies and strategies that support its growth, enhance sustainability, and contribute to the overall development of the regional agricultural sector (Unc et al., 2021).

2.1 Management of Cropping Systems

A cropping system refers to the specific arrangement and management of crops within an agricultural system. It involves the selection of crops, their spatial and temporal arrangement, as well as the associated practices and techniques employed throughout their growth cycle (Gaba et al., 2012).

Cropping systems are a fundamental component of agricultural practices and encompass the strategic arrangement and management of crops within a farming system. They involve the selection, sequencing, and spatial distribution of crops, as well as the integration of various agricultural practices to optimize productivity, sustainability, and resource management (Gaba et al., 2012). The literature on cropping systems highlights the importance of factors such as crop rotation, intercropping, monoculture, and agroforestry in shaping agricultural landscapes and addressing key challenges such as disease and pest control, soil fertility management, environmental sustainability and water usage efficiency (Dawson et al., 2019). Researchers have explored diverse cropping system designs, ranging from traditional practices to innovative approaches, emphasizing the need for site-specific and context-specific strategies to meet the diverse goals of farmers, consumers, and environmental stewardship (Isgren et al., 2020).

2.2 Types of Cropping Systems

There are different types of cropping systems which are as following.

2.2.1 Monoculture:

Monoculture refers to the practice of growing a single crop species on a given piece of land for an extended period. While monoculture simplifies management practices and may be economically efficient for specific crops, it can lead to increased vulnerability to pests, diseases, and soil degradation due to the lack of crop diversity.

2.2.2 Crop Rotation:

Crop rotation involves the planned sequence of different crops on the same field over time. It is designed to break pest and disease cycles, improve soil fertility, and enhance overall sustainability. By rotating crops with different nutrient requirements, disease susceptibilities, and growth characteristics, farmers can maintain soil health, optimize resource utilization, and reduce the dependence on chemical inputs.

2.2.3 Intercropping:

Intercropping involves growing two or more different crops simultaneously on the same field. It can take various forms, such as mixed intercropping (randomly mixed crops), row intercropping (distinct rows of different crops), or relay intercropping (different crops planted at different times within the same field). Intercropping can provide complementary resource use, enhance pest and disease control, and increase overall yield stability.

2.2.4 Agroforestry:

Agroforestry integrates trees or shrubs with agricultural crops, creating a multi-layered system. Agroforestry systems offer multiple benefits, including enhanced biodiversity, improved soil fertility, increased carbon sequestration, and diversified income streams. Examples include alley cropping (crops grown between rows of trees), silvopasture (combining trees, forage crops, and livestock), and forest farming (intercropping with tree crops).

2.2.5 Polyculture:

Polyculture involves the simultaneous cultivation of multiple crops in the same field without a specific spatial arrangement. It promotes biodiversity, reduces pest and disease risks, and provides ecological resilience. Polyculture systems can be traditional, reflecting local practices and crop combinations, or innovative, incorporating new combinations or companion planting strategies.

2.2.6 Specialized Cropping Systems:

Some cropping systems are designed for specific purposes or environments. For instance, hydroponics and aeroponics are soil-less systems that grow crops in nutrient-rich water or mist.

Protected cultivation, such as greenhouse or high tunnel farming, provides controlled environments for year-round production. These specialized systems often require sophisticated technology, but they offer advantages in terms of yield, quality, and resource efficiency.

2.3 Pros and Cons of Each Cropping Systems

Different cropping systems offer various benefits and drawbacks. Monoculture provides simplified management practices and economies of scale, but it increases vulnerability to pests, diseases, and soil degradation (Nicholls et al., 2017). Crop rotation breaks pest and disease cycles, improves soil fertility, and enhances overall sustainability, yet it requires careful planning and can have economic implications. Intercropping efficiently utilizes resources, enhances pest control, and increases yield stability, but it presents management complexities and challenges in weed control (Kumar et al., 2020). Agroforestry provides multiple products and benefits, such as timber and improved soil fertility, but requires longer establishment periods and management knowledge. Polyculture enhances biodiversity and reduces pest pressure but necessitates complex management and may have economic considerations (Levin, 2022). Specialized cropping systems enable controlled environments and potential higher yields but involve higher initial investments and potential reliance on artificial inputs (Magrini et al., 2016). Understanding the pros and cons of each cropping system is crucial for making informed decisions to optimize agricultural productivity, sustainability, and resource management (McLennon et al., 2021).

2.3.1 Monoculture:

Pros:

- Simplified management practices and economies of scale.
- Efficient use of machinery, labor, and inputs specific to the chosen crop.

- Streamlined harvesting and marketing processes.

Cons:

- Increased vulnerability to pests, diseases, and weeds due to the absence of crop diversity.
- Soil degradation and nutrient imbalances due to the continuous cultivation of the same crop.
- Reduced resilience to climate variability and environmental stresses.

2.3.2 Crop Rotation:

Pros:

- Breaks pest and disease cycles, reducing the need for chemical inputs.
- Improves soil fertility by balancing nutrient demands and reducing nutrient depletion.
- Enhances soil structure, water-holding capacity, and overall soil health.

Cons:

- Requires careful planning and knowledge of crop compatibility and rotation sequences.
- Potential challenges in managing crop-specific pests and diseases.
- Economic implications due to variations in market demand and crop profitability.

2.3.3 Intercropping:

Pros:

- Efficient utilization of resources, such as light, water, and nutrients, through complementary interactions between crops.
- Enhanced pest and disease control through natural mechanisms, such as repelling or attracting beneficial organisms.
- Increased yield stability and reduced yield losses during environmental fluctuations.

Cons:

- Management complexities, including crop-specific requirements, competition for resources, and harvest logistics.
- Possible yield reduction in certain combinations of crops due to competition for resources.
- Challenges in weed management, as different crops may have different weed susceptibilities.

2.3.4 Agroforestry:

Pros:

- Provides multiple products and benefits, such as timber, fruits, fodder, and improved biodiversity.
- Enhances soil fertility through nutrient cycling, nitrogen fixation, and organic matter accumulation.

- Offers climate change mitigation potential through carbon sequestration.

Cons:

- Longer establishment periods and potential competition for resources during early stages.
- Management challenges related to tree-crop interactions, such as shading and root competition.
- Requires knowledge of tree selection, spacing, and pruning techniques for optimal outcomes.

2.3.5 Polyculture:

Pros:

- Enhanced biodiversity and ecological resilience.
- Reduced pest and disease pressure due to the diversity of crops.
- Potential for synergistic interactions, such as nutrient cycling and biological pest control.

Cons:

- Complex management requirements, including varying crop-specific needs and harvesting schedules.
- Potential challenges in weed management due to diverse crop types and growth habits.
- Economic considerations due to variations in market demand and crop profitability.

2.3.6 Specialized Cropping Systems:

Pros:

- Controlled environments allow year-round production, independent of seasonal variations.
- Efficient use of resources, such as water, nutrients, and space.
- Potential for higher yields and superior crop quality.

Cons:

- Higher initial investment costs for infrastructure and technology.
- Increased energy requirements for climate control and lighting.
- Limited crop diversity and potential reliance on artificial inputs.

2.4 Benefits of Cropping Systems Management

Effective management of cropping systems offers numerous benefits for agricultural productivity, environmental sustainability, and socio-economic well-being (Giarè et al., 2018). Firstly, by implementing diverse cropping systems such as crop rotation, intercropping, and agroforestry, farmers can enhance soil health and fertility (Mugwe et al., 2019). These practices promote nutrient cycling, reduce soil erosion, improve water retention, and minimize the need for synthetic inputs, resulting in improved long-term soil productivity (Tully and Rayls, 2017). Secondly, cropping systems management plays a vital role in pest and disease control. Through strategies like crop rotation and intercropping, the risk of pest and disease outbreaks can be mitigated as diverse crops disrupt the life cycles of pests and help maintain a healthy balance of beneficial organisms (Richard et al., 2022). Additionally, efficient resource utilization is achieved through the complementary use of light, water, and nutrients in well-designed cropping systems, maximizing overall productivity while minimizing waste (Kozai and Niu, 2020). Furthermore, cropping systems management contributes to biodiversity conservation by providing habitat and food sources for a wide range of organisms (Grass et al., 2019). It also helps preserve genetic diversity by promoting the cultivation of diverse crop varieties. Lastly, sustainable cropping systems can provide economic benefits by reducing input costs, improving resilience to market fluctuations, and diversifying income streams through the production of multiple crops or value-added products (Valencia et al., 2019). Overall, effective management of cropping systems plays a crucial role in ensuring sustainable and resilient agriculture, benefiting farmers, ecosystems, and society as a whole (Kremen and Miles, 2012).

2.5 Sustainability of Cropping System

Sustainable cropping systems are essential for meeting the needs of the present generation without compromising the ability of future generations to meet their own needs (Borowski and Patuk, 2018). By carefully managing cropping systems, we can optimize resource utilization, minimize negative environmental impacts, and ensure long-term agricultural productivity (Lemaire et al., 2015). Taking into account the issue of managing cropping systems allows us to address key sustainability challenges. This includes promoting soil health and fertility through practices like crop rotation and intercropping, which enhance nutrient cycling, reduce soil erosion, and minimize the need for synthetic inputs. Effective management also contributes to biodiversity conservation by providing habitat and food sources for diverse organisms, preserving genetic diversity, and supporting ecosystem services (Tamburini et al., 2020). Moreover, sustainable cropping systems help mitigate climate change by sequestering carbon in soils and reducing greenhouse gas emissions through improved resource efficiency (Ntinyari and Gweyi-Onyango 2021). By considering the issue of managing cropping systems within the framework of sustainability, we can foster resilient and productive agricultural systems that balance ecological, economic, and social dimensions, ensuring food security, environmental stewardship, and the well-being of farming communities (Petersen-Rockney et al., 2021).

Locally, studies in specific regions of the United States have examined the impacts of different cropping systems on soil health, water quality, and yield performance. For instance, research conducted in the Midwest has explored the benefits of crop rotation in reducing soil erosion, improving nutrient cycling, and mitigating pests and diseases (Yu et al., 2022). These studies have highlighted the importance of integrating diverse crops, such as corn, soybeans, wheat, and cover crops such as mustard, alfalfa, rye, clovers, to enhance overall sustainability and resilience.

At the provincial level, individual states in the US have conducted research to assess the economic viability and environmental benefits of cropping systems. For example, studies in California have examined the advantages of integrated farming systems that combine field crops with livestock, emphasizing the potential for enhanced nutrient cycling, reduced fertilizer inputs, and improved soil health (Sekaran et al., 2021).

In the Canadian Prairies, wheat growers have long depended on continuous cropping systems comprising cereal-summer-fallow cropping or cereal-cereal cropping with mechanical tillage (Zentner et al., 2002). A continuous cropping system is the practise of continually sowing the same crop species in the same site (Cook and Weller, 2004).

The majority of farmers that grow industrial crops follow a continuous cropping system due to its additional profitability compared to changing crops every year. A continuous cropping system fosters increasing mechanisation for spreading fertilisers and pesticides across a vast area of land utilising specialised agricultural equipment for planting, harvesting, and distribution.

These approaches reduce the labour requirements for production while increasing efficiency. As a result, continuous cropping systems reduce production costs by minimizing labour expenditures. Regardless of the benefits, this method has a negative impact. A continuous cropping system offers a suitable environment for crop-specific diseases, weeds, and pests.

It is necessary to apply herbicides and pesticides because some diseases, insect pests and weeds have the ability to disperse quickly across a crop if each plant in a field has a same level of susceptibility (Thomas and Kevan, 1993).

Nationally, organizations like the USDA (United States Department of Agriculture) have funded and supported research on various cropping systems and their impacts. The USDA's Sustainable Agriculture Research and Education (SARE) program has funded projects on crop rotation, cover cropping, and agroforestry, among other topics. These studies have aimed to evaluate the ecological and economic benefits of different cropping systems and provide recommendations for farmers to adopt sustainable practices.

Internationally, research on cropping systems has been conducted across different countries such as US, China and Netherland. For example, studies from the International Center for Tropical Agriculture (CIAT) have focused on agroforestry systems in tropical regions, demonstrating their potential for improving soil fertility, increasing carbon sequestration, and enhancing biodiversity.

To conduct a thorough literature review, it is recommended to search scholarly databases, such as PubMed, Google Scholar, or agricultural journals, using relevant keywords like "cropping systems," "sustainable agriculture," and "case studies." This will help us identify specific studies conducted locally, provincially, nationally, and worldwide, providing a more comprehensive understanding of the research landscape in the context of managing cropping systems.

2.6 Agricultural Sustainability and Soil Quality

Sustainability in agriculture is a concept that encompasses the integration of environmental stewardship, economic viability, and social equity in agricultural management systems (Kremen et al., 2012). This recognizes the interdependence between the natural environment, human well-being, and long-term food production. Sustainable agriculture aims to meet present needs while ensuring the ability of future generations to meet their own needs (Duran et al., 2015). It involves the responsible use of natural resources, the preservation and enhancement of ecosystem services, and the promotion of resilient and equitable agricultural practices (Rao et al., 2015). Key principles of sustainability in agriculture include minimizing environmental impacts, conserving biodiversity, optimizing resource efficiency, promoting soil health and fertility, ensuring food security, and supporting the livelihoods of farming communities (McLennon, et al., 2021). By adopting sustainable agricultural practices, we can strive for a balance between productivity, environmental protection, and social well-being, fostering a more resilient and regenerative agricultural system for the present and future generations (Friedrichsen et al., 2021).

One of the primary reasons why practicing sustainable farming is crucial for the sustainability of the agricultural system is its positive impact on environmental conservation (Pretty et al., 2018). Sustainable farming methods prioritize the protection of natural resources and the environment. Through techniques such as crop rotation, agroforestry, and water management systems, farmers can minimize soil erosion, enhance soil fertility, and reduce the reliance on chemical inputs (Srinivasarao et al., 2021). These practices help preserve biodiversity, safeguard water sources, mitigate the adverse effects of climate change, and prevent land and ecosystem degradation. By conserving and protecting the environment, sustainable farming contributes to the overall sustainability of the agricultural system (Postel., et al., 2005).

Another vital aspect of sustainable farming is its emphasis on soil health and fertility. Healthy soil is the foundation of a successful agricultural system. Sustainable farming practices, such as the use of organic fertilizers, cover cropping, and integrated pest management, prioritize the nurturing of soil health (Mugwe et al., 2019). By maintaining soil fertility and structure, these practices enable farmers to cultivate crops that are resilient to pests, diseases, and adverse weather conditions (Altieri et al., 2015). Moreover, healthy soil promotes efficient nutrient absorption and water retention, reducing the need for excessive irrigation and fertilizers. By focusing on soil health, sustainable farming ensures the long-term viability and productivity of agricultural lands (Panhwar et al., 2019).

In addition to environmental and soil benefits, sustainable farming practices also contribute to economic and social sustainability. By reducing the dependence on expensive chemical inputs, sustainable farming can lower production costs and increase profitability for farmers. Moreover, it promotes diversified and resilient farming systems, which can enhance food security and provide economic opportunities for rural communities (Adenle et al., 2017). Additionally, sustainable farming practices often prioritize the well-being of farmworkers and local communities, promoting fair labor practices and community engagement (Arabska, 2021)

The concept of soil quality encompasses the inherent properties, processes, and functions of soil that determine its capacity to support healthy plant growth, sustain ecosystem services, and maintain long-term productivity (Bünemann et al., 2018). Soil quality extends beyond mere chemical fertility and incorporates physical, biological, and ecological attributes (Ling et al., 2016). It encompasses characteristics such as soil structure, nutrient content, organic matter content, water-holding capacity, microbial activity, and the presence of beneficial organisms (Jangir et al., 2019). A high-quality soil provides a favorable environment for root development, nutrient availability, and water infiltration, ultimately supporting optimal crop growth (Hartmann and Six, 2023) Furthermore, soil quality influences numerous ecosystem functions, including nutrient cycling, carbon sequestration, water filtration, and resilience to environmental stresses. Sustainable practices of soil management, such as crop rotation, cover cropping and organic matter additions, play a vital role in maintaining and enhancing soil quality (Norris and Congreves, 2018). By prioritizing soil quality in agricultural systems, we can ensure long-term productivity, environmental sustainability, and the resilience of our food production systems in the face of climate change and other challenges (Esham et al., 2018).

It is crucial to employ diverse farming practices while continuously considering soil quality for sustainable agriculture (Teklewold et al., 2013). The adoption of different farming practices, such as crop rotation, cover cropping, conservation tillage, and integrated pest management, can help maintain and improve soil quality over time (Crystal-Ornelas et al., 2021). These practices contribute to the preservation of soil structure, organic matter content, nutrient cycling, and microbial activity, ultimately enhancing overall soil health. By implementing a variety of practices, farmers can mitigate the negative impacts of monoculture, reduce pest and disease pressure, minimize soil erosion, and improve water infiltration and retention (Haney et al., 2018). Moreover, integrating sustainable farming practices into agricultural systems promotes the long-term sustainability and resilience of food production (Shah et al., 2021).

Locally, studies in the United States have investigated the relationship between sustainable agricultural practices and soil quality. For instance, research conducted in the Midwest region has explored the impact of conservation practices, such as no-till farming and cover cropping, on soil erosion reduction, carbon sequestration, and water quality improvement (Chen et al., 2023).

The ecosystems functional and structural integrity of Canadian prairie has been severely compromised by the conversion of natural areas into agricultural areas and the use of extremely unsustainable farming techniques (Martens et al., 2013). Agriculture sustainability is characterized as an enduring methodical arrangement that combines social responsibility, environmental preservation, and economic viability.

Agricultural system sustainability is dependent on plant nutrient management, soil quality, weeds and disease incidence, economics and interaction of climate (Hulugalle and Scott, 2008). For agricultural production, effective soil management is essential, such as environmental sustainability at regional and global level and human health as well. Projected increase in global population results in higher demand for food, clean water and energy are linked with soil management efficiency (Valin et al., 2014). The soil stands as a crucial natural resource, exerting influence on economic and socioeconomic capacities. It helps to produce basic food and raw materials, trash recycling, and water filtration and storage and also preserves the plants and animals' diversity (Weil and Brady, 2017a).

Studies at the state of California have focused on the role of sustainable farming practices in mitigating soil degradation and preserving soil health in diverse cropping systems (Dring et al., 2023). Nationally, organizations like the USDA have funded research initiatives to evaluate the impacts of sustainable practices on soil quality, aiming to provide farmers with science-based recommendations for enhancing soil health and sustainability (Toor et al., 2021). At the international level research conducted by organizations such as the Food and Agriculture

Organization (FAO) and international research institutions have examined the relationship between sustainable agriculture and soil quality in various regions worldwide (Kassam et al., 2015). These studies have explored the benefits of sustainable practices, such as agroforestry, soil conservation techniques, and precision farming, in promoting soil quality and sustainable agricultural systems (Pretty and Bharucha, 2014).

2.7 Crop Diversification

Crop diversification refers to the practice of cultivating a variety of crops within a specific agricultural system or region, instead of relying heavily on a single crop. It involves the intentional introduction of different crop species, varieties, or cultivars, as well as the rotation of crops over time (Currie et al., 2015). Crop diversification aims to increase the range and diversity of crops grown in an area, promoting resilience, sustainability, and productivity in agricultural systems. It offers an alternative to monoculture, where a single crop dominates the landscape (Frison, 2016). By diversifying crops, farmers can mitigate the risks associated with pests, diseases, and extreme weather events. It can also contribute to improved soil health, nutrient cycling, and reduced reliance on synthetic inputs (Garibaldi et al., 2019). Furthermore, crop diversification can enhance biodiversity, provide greater market opportunities, and support local food systems. Through the intentional integration of diverse crops, farmers can foster more resilient and sustainable agricultural practices that contribute to long-term food security and environmental stewardship (Marchetti et al., 2020).

2.8 Technical and Economical Aspects of Crop Diversification

Diversifying cropping systems is crucial from both technical and economic perspectives. From a technical standpoint, crop diversification helps mitigate risks associated with pests, diseases, and environmental stresses (Altieri et al., 2017). By cultivating a variety of crops, farmers can reduce the vulnerability of their agricultural systems to specific pests and diseases that target certain crop species (McCord et al., 2015). Additionally, diversification can provide natural pest control as some crops act as repellents or trap crops, disrupting pest life cycles. Moreover, different crops have varying root structures and nutrient requirements, which can enhance soil health and nutrient cycling (Wezel et al., 2014). Crop rotation, a form of diversification, helps break pest and disease cycles, replenish soil nutrients, and reduce soil erosion. From an economic perspective, diversifying cropping systems can offer several advantages (Shah et al., 2021). It provides farmers with a wider range of income streams, reducing their dependence on a single crop and mitigating the risks of market price fluctuations. If one crop fails or experiences low prices, revenue from other crops can compensate for the loss (Tadesse et al., 2015). Furthermore, crop diversification can create opportunities for value-added products and niche markets, allowing farmers to capture higher prices and increase their profitability. Additionally, diversification can reduce input costs by minimizing the need for chemical inputs and improving resource use efficiency (Giller et al., 2021). By considering both technical and economic aspects, crop diversification emerges as a crucial strategy to enhance the resilience, sustainability, and profitability of agricultural systems (Makate et al., 2016).

Crop diversification brings about important economic advantages, especially when considering the concept of relative prices of inputs and outputs (Ahmadzai, 2017). Relative prices refer to the relationship between the prices of different inputs (e.g., fertilizers, pesticides, labor) and the prices of outputs (crop yields). When input prices are high or output prices are low for a particular crop, diversification allows farmers to allocate their resources towards alternative crops that may have more favorable price ratios (Feuerbacher et al., 2018). For example, if the price of a specific input, such as chemical fertilizers, increases substantially, farmers can opt to shift their production towards crops that require lower input investments, such as legumes or cover crops that fix nitrogen naturally (Parr et al., 2020). Similarly, if the market prices for a particular crop decline, farmers can explore diversifying into higher-value crops or specialty crops to capture better prices and diversify their revenue streams (Mithiya et al., 2018). However, it is important to note that changes in relative prices can influence crop diversification decisions. For instance, if the prices of inputs needed for a particular crop decrease while the prices of its outputs rise, farmers may choose to allocate more resources to that crop, leading to reduced diversification (Manjunatha et al., 2013). Therefore, understanding and responding to changes in relative prices is crucial in determining the optimal mix of crops within a diversified farming system.

Crop diversification is advantageous for soil conservation, nutrient cycling, disease management, and ecological diversification (Smith et al., 2015). In a crop rotation system, various crops can require particular skills about their development and management, and certain pests and diseases (Saskatchewan Pulse Growers, 2017).

The advantages of incorporating pulse crops into cereal-based farming systems in a rotational manner have been recognized for an extended period. Policies and programmes that support the use of pulse crops are promoted because they have positive economic and environmental effects on Canadian agriculture (Gan et al., 2002; Johnston et al., 2007).

Studies in Canadian prairies shown that oilseed crops are most feasible to cold climate and their addition might increase net returns while lowering profitability risk due to increased production stability (Zentner et al., 2002).

Studies in the US have investigated the benefits of crop diversification in different regions (Lancaster and Torres, 2019). For example, research in the Midwest has focused on the advantages of incorporating cover crops into cropping systems to enhance soil health, reduce erosion, and improve water quality (Plastina et al., 2020). In addition, studies in California have examined the potential of diversifying crop rotations to manage pests and diseases, reduce chemical inputs, and improve overall sustainability (Kröbel et al., 2021). Nationally, organizations like the USDA have supported research initiatives on crop diversification, exploring its economic and environmental benefits and providing recommendations for farmers. At the international level research conducted by the International Food Policy Research Institute (IFPRI) has highlighted the importance of crop diversification in improving food security, enhancing farm incomes, and promoting sustainable agriculture in various regions around the world (Blesh et al., 2023).

2.9 Economics of Agriculture Production

The economics of agricultural production refers to the application of economic principles and analysis to the agricultural sector (Velasco-Muñoz et al., 2021). It involves studying the production, distribution, and consumption of agricultural goods and services, as well as the factors that influence agricultural decision-making. The economics of agricultural production seeks to understand the allocation of scarce resources, such as land, labor, and capital, to maximize agricultural output and profitability (Fernández et al., 2020). It examines the relationships between input costs, output prices, production technologies, and farm management strategies. This field of study encompasses various aspects, including production economics, farm management, agricultural markets, agricultural policy, and the impact of external factors such as government regulations and environmental constraints (Chavas et al., 2010). By analyzing the economics of agricultural production, researchers and policymakers can gain insights into the efficiency, competitiveness, and sustainability of agricultural systems, and develop strategies to optimize resource use, enhance farm incomes, and ensure food security (Garibaldi et al., 2017).

When examining the economics of agricultural production, several factors should be considered to gain a comprehensive understanding of the complex dynamics involved. First, input costs play a crucial role, encompassing factors such as the prices of seeds, fertilizers, pesticides, machinery, and labor. These costs directly influence the profitability and competitiveness of agricultural operations (Asai et al., 2018). Second, output prices are vital as they determine the revenue farmers receive for their agricultural products. Fluctuations in market prices can significantly impact farm incomes and the viability of agricultural enterprises (Acs et al., 2010). Third, technological advancements and innovations in farming practices have a substantial influence on agricultural economics. Adoption of improved production techniques, mechanization, precision agriculture, and genetic enhancements can enhance productivity, reduce costs, and improve overall profitability (Walter et al., 2022). Additionally, the availability and accessibility of financial resources, such as loans, subsidies, and insurance, have a significant impact on agricultural production economics. Government policies and regulations related to trade, subsidies, taxation, and environmental stewardship also shape the economic landscape of agriculture (Vogt-Schilb and Hallegatte, 2017). Crop productivity is vital for Canada's economy, contributing through direct revenue, rural employment, and supporting related industries (Saayman et al., 2018). Exporting agricultural goods is crucial for the country's trade balance, while a stable food supply is essential for food security and public health (Barrios et al., 2020). Efficient crop production also aligns with Canada's environmental goals. Recognizing these factors can help policymakers and stakeholders promote growth, food security, and sustainability in the Canadian agricultural sector (Shah et al., 2021).

Finally, external factors like weather patterns, climate change, and market volatility need to be considered as they introduce uncertainties and risks that affect agricultural economics; risk refers to things we can measure and plan for, like weather and market changes, while uncertainty is about unpredictable events, like unexpected situations or policy shifts, that can also affect farming results. (Eakin et al., 2016). By examining and analyzing these factors, researchers, policymakers, and farmers can make informed decisions, develop strategies, and implement policies to optimize agricultural production, improve economic outcomes, and foster sustainable and resilient agricultural systems (Das and Ansari, 2021).

The concept of economics of agricultural production has been extensively explored in the literature across various scales, including local, provincial, national, and global contexts. Locally, studies in the US have examined the economics of agricultural production within specific regions (Hoang Thanh et al., 2018). For instance, research conducted in the Midwest has analyzed the cost-effectiveness of adopting precision agriculture technologies, such as GPS-guided machinery and variable rate application of inputs, to optimize resource use and increase farm profitability (Hundal et al., 2023). Studies at the state level e.g., California have investigated the economic implications of water scarcity and irrigation management in the state's agricultural sector, highlighting the need for efficient water allocation and sustainable practices. Nationally, research conducted by organizations like the USDA has focused on the economic analysis of different crop production systems, assessing factors such as input costs, output prices, farm structure, and government policies (Rouillard, 2022). For example, studies have explored the profitability of organic farming, the impact of trade policies on agricultural markets, and the economic implications of climate change for the US agriculture. Internationally, literature on the economics of agricultural production has encompassed diverse regions and countries. For instance, research from the

International Food Policy Research Institute (IFPRI) has examined the economic factors influencing agricultural productivity and food security in developing countries. Additionally, at the international level research conducted by the World Bank and the Food and Agriculture Organization (FAO) have provided insights into the economic challenges and opportunities in global agricultural systems.

2.10 Crop Productivity Impact and Contribution to the Canadian Economy

The productivity of crops has a significant impact on the Canadian economy, making substantial contributions through direct revenue from crop sales, employment generation in rural areas, and stimulation of related industries (Saayman et al., 2018). The export of agricultural commodities plays a crucial role in Canada's trade balance, while a stable food supply ensures food security and promotes public health (Khan et al., 2020). Additionally, efficient crop production practices contribute to environmental sustainability, aligning with Canada's environmental goals (Barrios et al., 2020). Recognizing the interplay of factors influencing crop productivity and understanding its economic significance can inform policymakers and stakeholders in fostering growth, ensuring food security, and promoting sustainable practices in the Canadian agricultural sector (Shah et al., 2021).

Productivity, in the context of agriculture, refers to the measure of output or yield obtained from a given set of inputs or resources. It represents the efficiency and effectiveness with which resources are utilized to generate agricultural products (Gadanakis et al., 2015). Crop productivity specifically refers to the measure of the output or yield of crops in relation to the resources invested, including land, labor, capital, water, fertilizers, and other inputs (Mozumdar, 2012). It provides insights into the efficiency and effectiveness of agricultural practices, technologies, and management strategies in achieving optimal crop yields (Sagar et al., 2018). High crop productivity is crucial for meeting the increasing global demand for food, feed, fiber, and bioenergy. It contributes to food security, farm profitability, and rural development. Improving crop productivity requires a multifaceted approach that includes the adoption of improved crop varieties, sound agronomic practices, efficient irrigation techniques, effective pest and disease management, and soil fertility management (Acevedo et al., 2018). Additionally, advancements in agricultural technologies, such as precision agriculture, remote sensing, and genetic engineering, offer opportunities for enhancing crop productivity. By focusing on crop productivity, researchers, farmers, and policymakers can develop strategies and interventions to optimize resource use, increase agricultural output, and ensure sustainable and resilient food production systems (Xi et al., 2022).

2.11 Difference Between Crop Productivity and Crop Efficiency

Crop productivity and crop efficiency are two distinct but interrelated concepts in agriculture. Crop productivity refers to the quantity of crops, typically measured in terms of yield or output, that can be obtained from a specific piece of land or area during a given growing season or time period (Ali et al., 2008). It focuses on the quantity of crop produced and is often measured in terms of weight or volume. Crop productivity is influenced by various factors, including genetics, crop management practices, input use, and environmental conditions (Araus et al., 2018). It is a key indicator of the effectiveness of agricultural systems in generating sufficient crop yields to meet the demands of food, feed, and fiber (Singh and Ryan, 2012).

On the other hand, crop efficiency refers to the ability to maximize the output of crops while minimizing the use of resources, such as water, fertilizers, pesticides, and energy. It assesses how effectively resources such as land, water, fertilizers, labor, and capital are converted into crop yield (Toma et al., 2017). Crop efficiency takes into account the productivity achieved relative to the inputs used and is often measured as the input-output ratio or the amount of yield produced per unit of input. Higher crop efficiency indicates that the same level of output or yield is achieved with fewer resources, indicating more optimal resource utilization (Linn and Maenhout, 2019).

In essence, crop productivity focuses on the overall output or yield of a crop, whereas crop efficiency evaluates how effectively resources are used to achieve that output. While crop productivity is important for meeting production goals and addressing food security concerns, crop efficiency emphasizes resource conservation, cost-effectiveness, and sustainable production practices (Busetto et al., 2017). Both concepts are critical in agricultural systems as they provide insights into the effectiveness of crop management strategies and help guide decision-making to enhance productivity, reduce waste, and promote sustainable agricultural practices (Pogutz and Winn, 2016).

Numerous studies have shown the possibility of higher yields when cropping systems are diversified with pulse crops (Miller et al., 2006). As per Zentner et al. (2004), the total energy input for pulse crops was reportedly 53% less than that for continuous wheat. Burgess et al. (2012) conducted a study between the two cropping systems, shown that even while there were no significant difference in the chemical consumptions and energy inputs, pulse crops generated favourable rotational advantages on subsequent wheat output compared to wheat after wheat.

Research in the US has investigated the effects of crop productivity on farm profitability and sustainability. For instance, studies have shown that improved crop productivity through the adoption of advanced technologies and management practices can lead to higher yields, increased income, and improved livelihoods for farmers (Mwangi and Kariuki, 2015). Moreover, enhanced crop productivity can contribute to local economic development by generating job opportunities and supporting rural communities (Rotz et al., 2019).

At the state level studies in California, known for its diverse agricultural production, have examined the impact of crop productivity on water usage and resource management. Research has shown that increasing crop productivity while minimizing water consumption is crucial for addressing water scarcity challenges and achieving long-term sustainability in the region (Bommarco et al., 2013). Additionally, improved crop productivity has been linked to reduced dependence on synthetic inputs, like pesticides and fertilizers, resulting in environmental benefits and improved ecosystem health (Clark and Tilman, 2017).

The United States agriculture has highlighted the importance of crop productivity for food security and economic growth. For example, studies have demonstrated that sustained increases in crop productivity have played a significant role in meeting the growing demand for food and feed, reducing dependency on imports, and supporting domestic agricultural industries (Keesstra et al., 2016). However, concerns have also been raised about the negative environmental consequences associated with intensive crop production, such as soil degradation, water pollution, and biodiversity loss (Tittonell and Giller, 2013). Therefore, efforts to balance increased crop productivity with environmental sustainability have gained attention in the literature.

Globally, research by the Food and Agriculture Organization (FAO) and the International Food Policy Research Institute (IFPRI) has explored the impact of crop productivity on global food security and poverty reduction (John and Fielding, 2014). These studies have emphasized the need for sustainable intensification of agriculture, where improved crop productivity is achieved through environmentally friendly practices and technologies. Furthermore, research has shown that increasing crop productivity in developing countries can have significant positive effects on rural livelihoods, poverty alleviation, and overall economic development (Merga and Haji, 2019).

By reviewing the literature on the concept of crop productivity impact at different scales, we gain insights into the multifaceted effects it has on local, provincial, national, and global levels. Understanding these impacts helps inform policies, management strategies, and technological innovations that promote sustainable and resilient agricultural systems, both in the neighboring location of the United States and worldwide.

2.12 Budget Enterprises

The process of decision-making at the farm level involves a complex set of considerations and choices that farmers must make to effectively manage their agricultural operations (Mankad, 2016). It encompasses a series of steps that farmers undertake to analyze and evaluate various options, assess risks, and determine the most suitable course of action. The decision-making process begins with identifying the goals and objectives of the farm, which may include maximizing profits, optimizing resource use, ensuring sustainability, or achieving specific production targets (Waas et al., 2014). Once the goals are established, farmers gather information on factors such as market conditions, input costs, weather patterns, and technological advancements. They, then analyze and evaluate different alternatives, weighing the potential benefits, risks, and trade-offs associated with each option (Mutenje et al., 2019). This evaluation takes into account factors such as crop selection, input use, timing of operations, pricing decisions, and resource allocation. Farmers may use tools and techniques such as cost-benefit analysis, financial modeling, and risk assessment to aid in their decision-making process (DeVincentis et al., 2020).

The decision-making process at the farm level is influenced by a range of factors, including farm size, available resources, farmer's experience and knowledge, financial constraints, market conditions, government policies, and environmental considerations (Bryan et al., 2009). Additionally, farmers often make decisions in the context of uncertainty and changing conditions, which require flexibility and adaptability. Effective decision-making at the farm level is crucial for achieving farm sustainability, profitability, and resilience (Robert et al., 2016). It plays a vital role in optimizing resource use, managing risks, adopting appropriate technologies, and responding to market dynamics. By understanding the decision-making process at the farm level, policymakers, researchers, and agricultural professionals can provide support, information, and tools that help farmers make informed decisions and enhance the overall performance of agricultural systems (Liu et al., 2018).

2.13 Factors Affecting Farmers' Decisions

Farmers' decisions are influenced by a wide range of factors that shape their decision-making process. These factors can vary based on the specific context, farm characteristics, and individual farmer preferences and their attitude towards risks (Hoek et al., 2021). First, economic factors such as market prices for crops, input costs and government policies and subsidies play a crucial role in farmers' decisions. Input and output prices, market conditions, and the potential for profitability greatly impact the choices farmers make regarding crop selection, production techniques, and resource allocation. Access to credit, government subsidies, and insurance schemes also affect decision-making by influencing the availability of financial resources and risk management options (Ullah et al., 2016).

Second, environmental factors like weather conditions, soil quality, water availability and quality, and the potential impact of farming practices on biodiversity and ecosystems are important considerations for farmers. Soil fertility, water availability, climate conditions, and pest and disease pressures all influence farmers' decisions regarding crop selection, irrigation practices, and pest management strategies. Environmental regulations and sustainability concerns also play a role in shaping decision-making by encouraging the adoption of practices that minimize negative environmental impacts and promote conservation (Dorgbetor et al., 2022).

Third, social and cultural factors impact farmers' decisions. Family traditions, community norms, and cultural values can influence the choice of crops, farming methods, and the adoption of new technologies. Additionally, labor availability and the social networks within the farming community may influence decisions related to hiring, cooperation, and knowledge-sharing (De Giusti et al., 2019).

Furthermore, technological factors play a significant role in farmers' decision-making. The availability and accessibility of agricultural technologies, such as improved seed varieties, precision farming tools, and mechanization options, can impact decisions regarding input use, productivity enhancement, and cost reduction (Tantalaki et al., 2019). Farmers' knowledge and understanding of these technologies also affect their willingness to adopt and implement them.

Finally, policy and institutional factors that shape farmers' decisions include government regulations, subsidies, trade agreements, agricultural extension services, access to credit and insurance, and the presence of farmer cooperatives or associations. Government policies, regulations, and support programs can influence choices related to crop diversification, land use, conservation practices, and market participation (Kassie et al., 2015). The availability and effectiveness of extension services, farmer organizations, and agricultural research also play a role in farmers' decision-making by providing information, training, and access to resources (Norton and ALwang, 2020).

The experience of farmers significantly influences the decision-making process. Years of working on the land and observing the outcomes of different practices provide farmers with valuable knowledge and insights that influence their decision-making process (Bwambale, 2015). Through firsthand experience, farmers develop an understanding of the local conditions, climate patterns, soil characteristics, and pest and disease pressures specific to their farming operation (Šūmane et al., 2018). This accumulated experience helps farmers anticipate and respond to challenges and opportunities, making more informed decisions (Farooq et al., 2019).

The experience of farmers also enables them to assess the feasibility and practicality of different options. They learn which crops are best suited to their local conditions, which varieties perform well, and which management practices yield favorable outcomes (Giller et al., 2011). This experience-based knowledge empowers farmers to make efficient use of resources and optimize their production systems. They can draw on their past successes and failures to fine-tune their decision-making, improving the profitability and sustainability of their farms (Munir et al., 2018).

Moreover, farmers' experience provides them with a deep understanding of the economic and social dynamics of their farming operation. They become familiar with market fluctuations, buyer preferences, and marketing channels through their interactions with buyers and consumers over time (Krishnan, 2018). This knowledge allows them to make decisions regarding crop selection, timing of planting and harvesting, and market participation.

However, it is important to recognize that farmers' experience is not static. It evolves over time as farmers adapt to changing circumstances, adopt new technologies, and learn from emerging practices (Šūmane et al., 2018). Continuous learning and the willingness to experiment are crucial for farmers to enhance their experience and make better decisions. Additionally, while experience is valuable, it is essential for farmers to complement it with up-to-date information, scientific research, and extension services to ensure their decision-making remains current and relevant (Van Etten et al., 2019).

2.14 Essential Reasons of Farmer's Budgeting

Budgeting is an essential practice for farmers as it serves multiple purposes and provides numerous benefits (Levidow et al., 2014). First, budgeting helps farmers plan and allocate their financial resources effectively. By creating a budget, farmers can estimate their income and expenses, allowing them to make informed decisions about the allocation of funds for inputs, equipment, labor, and other operational costs (Ferris et al., 2014). It enables farmers to set financial goals, track their cash flow, and make adjustments as needed to optimize their financial position.

Second, budgeting provides farmers with a tool for risk management and decision-making. Through budgeting, farmers can assess the financial viability and profitability of different enterprises or production practices (Sarri et al., 2020). They can evaluate the costs and potential returns associated with various crops, livestock, or value-added activities, aiding in the selection of the most profitable and sustainable options (De Corato et al., 2018). Budgeting also helps farmers identify potential financial risks and develop contingency plans to mitigate them, contributing to improved farm resilience (Levidow et al., 2014).

Third, budgeting facilitates long-term planning and investment decisions. By forecasting future income and expenses, farmers can make informed choices regarding farm expansion, machinery purchases, infrastructure development, and technology adoption (Si et al., 2022). Budgeting allows farmers to evaluate the financial feasibility of these investments, assess their impact on profitability, and determine the most appropriate timing for implementation. It provides a basis for capital planning and financing arrangements, ensuring that resources are allocated efficiently and effectively (Peterson, 2009).

Moreover, budgeting supports communication and collaboration with lenders, suppliers, and other stakeholders (Peterson, 2009). A well-prepared budget demonstrates the farmer's understanding of the financial aspects of their operation and enhances their credibility when seeking financing or negotiating contracts. It facilitates dialogue with suppliers, enabling farmers to negotiate favorable terms and pricing for inputs (Markets, 2008). Budgeting also helps farmers communicate their financial needs and requirements to advisors, accountants, and consultants, enabling them to provide tailored guidance and support (Hikens et al., 2018).

Previous studies conducted in the US have examined the use of budget enterprise analysis to assess the financial performance and profitability of individual farming operations (Folajinmi and Peter, 2020). For example, research has focused on developing comprehensive budgeting tools and methodologies that enable farmers to estimate production costs, analyze revenues, and evaluate the economic viability of different enterprises within their farm. These studies have highlighted the importance of budget enterprise analysis in guiding farmers' decision-making, resource allocation, and risk management strategies (Valenti et al., 2018).

The state-level literature, (e.g., CA) has explored the application of budget enterprise analysis to assess the economic impacts of specific crops and commodities (Cuppari et al., 2021). These studies have examined factors such as input costs, yield potentials, market prices, and production technologies to develop comprehensive budgets for various agricultural enterprises (Chianu et al., 2012). By analyzing the financial performance and returns of different crops or commodities, researchers have provided valuable insights into the relative profitability and risks associated with specific enterprises in different regions (Kouvelis et al., 2011).

Literature on the US agriculture has focused on budget enterprise analysis as a tool for policy analysis and farm management decision-making. Studies have examined the financial implications of policy changes, such as modifications in government subsidies, price supports, or trade regulations, on different agricultural enterprises (Stuart and Gillon, 2011). These analyses have helped policymakers and stakeholders understand the potential impacts of policy decisions on farm profitability, competitiveness, and sustainability (Prager and Freese, 2009).

At the international level research by the Food and Agriculture Organization (FAO) and other international research institutes has emphasized the importance of budget enterprise analysis in supporting sustainable agricultural development and poverty alleviation (Fouilleux et al., 2017). These studies have explored the application of budgeting tools and methodologies in different regions and countries to estimate production costs, analyze income generation, and evaluate the financial viability of agricultural enterprises (Kanter et al., 2018). Examples include budget enterprise analysis for staple crops in Africa or cash crops in Southeast Asia, providing insights into the economic potentials and constraints of specific agricultural activities in different global contexts (Kruseman et al., 2020).

2.15 Cost-Benefit Analysis

Farming assessment involves the evaluation and analysis of various aspects of agricultural operations to assess their performance, sustainability, and potential for improvement (Kamble et al., 2020). There are different types of farming assessments that serve different purposes and provide valuable insights for farmers, researchers, and policymakers (Clark et al., 2016).

I. Productivity Assessment

Productivity assessment focuses on measuring the output and efficiency of farming systems, such as crop yield per unit of land or livestock productivity per head. It helps identify areas where productivity gains can be achieved through improved practices, technology adoption, or resource optimization (Molden et al., 2007).

II. Economic Assessment

Economic assessment evaluates the financial aspects of farming, including income, expenses, profitability, and return on investment. This assessment involves analyzing the costs of production, revenue streams, market trends, and pricing mechanisms (Aleskerova et al., 2018). It helps farmers determine the financial viability of their operations, make informed decisions regarding resource allocation, and identify opportunities for cost reduction or revenue enhancement (Awulachew, 2019).

III. Environmental Assessment

Environmental assessment examines the environmental impacts of farming practices, such as soil erosion, water use, greenhouse gas emissions, and biodiversity conservation (Stubenrauch et al., 2022). It helps identify potential risks and vulnerabilities associated with farming activities and supports the adoption of sustainable practices that minimize negative environmental impacts and promote conservation (Prokopy et al., 2019).

IV. Social Assessment

Social assessment considers the social dimensions of farming, including labor conditions, community engagement, and the well-being of farm workers and rural communities (Wei and Gao, 2017). This assessment evaluates the social impacts of agricultural practices and policies, aiming to promote social equity, inclusivity, and the enhancement of livelihoods (Bennett, 2018).

V. Resilience Assessment

Resilience assessment focuses on evaluating the ability of farming systems to withstand and recover from shocks and stresses, such as climate variability, market fluctuations, or pest outbreaks (Meuwissen et al., 2019). It examines the adaptive capacity, risk management strategies, and diversification options that farmers employ to build resilience in their operations (Williams et al., 2019).

These different types of farming assessments are interrelated and provide a holistic understanding of farming systems. Integrating multiple assessment approaches allows for a comprehensive evaluation of agricultural performance, sustainability, and resilience (Koohafkan et al., 2012). It helps identify areas for improvement, guides decision-making, and supports the development of targeted interventions and policies that enhance the overall performance of farming systems (Pretty et al., 2018). By conducting these assessments, farmers, researchers, and policymakers can work together to ensure that farming practices are economically viable, environmentally sustainable, socially responsible, and resilient in the face of changing challenges and opportunities (Williams et al., 2019).

2.16 Farm Assessment Methods

Farm assessment methods encompass a range of approaches and tools that are utilized to evaluate and analyze various aspects of agricultural operations (Kamilaris et al., 2017). These methods enable researchers, farmers, and policymakers to gain insights into the performance, sustainability, and potential for improvement of farming systems. One commonly used method is farm surveys, which involve collecting data directly from farmers through interviews, questionnaires, or on-farm observations (Ssebunya et al. 2019).

I. Surveys

Surveys provide valuable information on production practices, input use, yields, and economic aspects of farming (Mcfadden et al., 2022).

II. Financial Analysis

This method involves assessing the financial performance of farming operations through the examination of income statements, balance sheets, and cash flow statements (Magli et al., 2018). Financial ratios, such as return on investment or gross margin, are calculated to evaluate profitability and financial efficiency (Bordeianu and Radu, 2020). This method helps identify areas of financial strength and weakness, enabling farmers to make informed decisions regarding resource allocation and investment (Zorn et al., 2018).

III. Field Observations

Field observations and measurements play a crucial role in farm assessment. By conducting field visits and collecting data on soil quality, water availability, nutrient levels, and pest presence, researchers can assess the environmental and agronomic aspects of farming systems (Vazquez et al., 2021). This method provides insights into the health of the soil, the efficiency of resource use, and the potential environmental impacts of farming practices (Wnag et al., 2022).

IV. Remote Sensing and Geospatial Analysis

Remote sensing and geospatial analysis have become increasingly popular in farm assessment (Liu et al., 2011). Satellite imagery, aerial photographs, and geographic information systems (GIS) are used to gather data on land use, vegetation growth, and other landscape features (Karakus et al., 2015). These tools enable researchers to assess changes in land cover, monitor crop health, and identify areas where resource management practices can be optimized (Wulder et al., 2008).

Overall, farm assessment methods encompass a diverse range of approaches, including surveys, financial analysis, field observations, remote sensing, geospatial analysis, and modeling (Sarkar et al., 2016). Combining these methods allows for a comprehensive evaluation of farming systems, enabling stakeholders to identify strengths, weaknesses, and opportunities for improvement (Kanter et al., 2018). By applying these assessment methods, farmers, researchers, and policymakers can make informed decisions, implement targeted interventions, and promote sustainable and resilient farming practices (Glover et al., 2019).

2.17 Cost-Benefit Analysis Method

In the context of my thesis, I chose the cost-benefit analysis (CBA) method for several reasons.

I. CBA is a widely recognized and established approach for evaluating the economic feasibility and efficiency of projects or interventions (Mechler, 2016). It provides a systematic framework to compare the costs and benefits associated with a particular decision or action, allowing for a comprehensive assessment of the potential outcomes (Carter et al., 2016).

II. CBA enables a quantitative analysis of costs and benefits, which facilitates a more objective evaluation of different alternatives (Browne and Ryan, 2011). By assigning monetary values to costs and benefits, CBA allows for a direct comparison and measurement of the net impact (Culyer and Chalkidou, 2019). This quantitative nature of CBA helps in making informed and evidence-based decisions, especially when dealing with limited resources and competing priorities (Brownson et al., 2017).

III. Additionally, CBA takes into account both direct and indirect costs and benefits, considering the broader impacts beyond the immediate financial implications (Kull et al., 2013). It allows for the consideration of externalities, such as environmental or social impacts, which may not be captured by traditional financial analysis methods (O'Mahony, 2021). This aspect of CBA is particularly relevant in the agricultural sector, where the sustainability and broader societal implications of farming practices are crucial considerations (Jeswani et al., 2010).

IV. Furthermore, CBA provides a framework for discounting future costs and benefits, recognizing the time value of money (Cordes, 2017). By discounting future values, CBA accounts for the opportunity cost of investing resources in a particular project or decision (Campos et al., 2015). This helps in assessing the long-term economic viability and sustainability of the chosen course of action (Williams, 2012).

Overall, the choice of the cost-benefit analysis method for my thesis is based on its recognized effectiveness in evaluating the economic feasibility and efficiency of agricultural projects or interventions (Mutenje et al., 2019). It provides a quantitative and systematic approach, considers broader impacts, incorporates the time value of money, and promotes transparent decision-making (Kadigi et al., 2021). By employing CBA, I aim to assess the costs and benefits of different agricultural practices or policies, supporting evidence-based decision-making for sustainable and economically viable farming systems (Andrieu et al., 2017).

Risk and uncertainty play a crucial role in the process of cost-benefit analysis (CBA) as they introduce variability and potential deviations from expected outcomes (Burhenne et al., 2013). In CBA, risk refers to the possibility of different outcomes occurring, each associated with a certain probability. Uncertainty, on the other hand, refers to situations where the probabilities of different outcomes are unknown or difficult to estimate (Mousavi, and Gigerenzer, 2014). Incorporating risk and uncertainty into CBA is essential to provide a more realistic assessment of the costs and benefits associated with a decision or project (Watkiss et al., 2015).

Cost-benefit analysis recognizes the importance of addressing risk and uncertainty. Methods such as sensitivity analysis, scenario analysis, and Monte Carlo simulation are commonly employed to explore the impact of different risk factors and uncertainties on the results of a cost-benefit analysis (Abba et al., 2022). These techniques allow for the examination of a range of possible outcomes under varying conditions, enhancing the robustness and reliability of the analysis (Afzal et al., 2020).

The state level studies in the US, agriculture have utilized cost-benefit analysis to assess the economic feasibility and viability of specific agricultural projects or practices. For instance, research has examined the cost-effectiveness of implementing precision agriculture technologies, taking into account the uncertainties associated with yield variability, input costs, and market prices (Mitbaa et al., 2018). These studies have highlighted the importance of considering risk and uncertainty in decision-making and resource allocation (Sefeedpari et al., 2019).

At the national level, cost-benefit analysis has been used to assess the economic implications of agricultural regulations and environmental policies (Cai et al., 2015). For instance, studies have examined the costs and benefits of implementing water quality regulations to reduce agricultural runoff in Lahore, Pakistan (Olmstead, 2010). By accounting for uncertainties in pollutant loadings, treatment costs, and the value of ecosystem services, these analyses contribute to informed decision-making and policy design (Keeler et al., 2012).

Cost-benefit analysis has explored its application in assessing the economic impacts of agricultural practices in different countries and regions (Söderqvist et al., 2021). Examples include studies on the benefits and costs of adopting sustainable farming techniques in developing countries such as India, Brazil and Vietnam or the economic evaluation of large-scale agricultural investments in food security programs (Adenlen et al., 2019). These global examples demonstrate the importance of incorporating risk and uncertainty considerations in assessing the economic feasibility and sustainability of agricultural projects on a broader scale (Schuhbauer and Sumaila, 2016).

Incorporating methods to address risk and uncertainty enhances the reliability and the robustness of cost-benefit analysis results (Shreve and Kelman, 2014). Local, regional, national, and global studies in the field of US agriculture and beyond demonstrate the application of cost-benefit analysis to evaluate the economic viability and impacts of various agricultural decisions, policies, and programs (Watkiss et al., 2015). By accounting for risk and uncertainty, cost-benefit analysis provides a comprehensive framework for informed decision-making, supporting sustainable and economically sound agricultural practices (Mechler, 2016).

Chapter 3

Materials and Methods

The present study was conducted using a range of research methods that are appropriate for investigating economic efficiency of different cropping systems under boreal climatic conditions for five years (2017-21).

The use of dialectical principles and system analysis methods suggests that the study was focused on understanding the complex relationships and interactions between different economic phenomena i.e.:

I. Inflation: where prices of goods and services rise over time,
II. Reducing the purchasing power of money.
III. Unemployment: which occurs when individuals actively seeking work are unable to find jobs, leading to economic and social implications.
IV. Income inequality: which refers to the unequal distribution of income among individuals and can impact social mobility and overall economic stability.
V. Economic growth: the increase in production of goods and services within an economy over time, serving as a measure of development.
VI. Fiscal and monetary policy: where governments and central banks use taxation, government spending, and interest rates to influence economic activity.
VII. Market forces of supply and demand: determining prices and quantities in markets; trade imbalances, such as trade deficits or surpluses, affecting international trade relationships and economies.

VIII. Technological advancements: which drive innovation, productivity growth, and economic transformation.

These are just a few examples of the vast and interconnected economic phenomena studied within the field of economics in NL. The use of analysis and synthesis, scientific abstraction, and expert evaluation indicates that the study sought to integrate diverse perspectives and sources of information to gain a comprehensive understanding of the topic.

The use of economic analysis and statistical analysis methods suggests that the study was focused on generating quantitative data and insights to inform its conclusions. These methods are commonly used in economic research and are appropriate for investigating the economic feasibility of different cropping systems. The study is based on data collected (2017-21) from the published literature, the government of NL, and Statistics Canada.

3.1 Area of the Study

Agriculture in NL showcased a diverse range of activities. Notably, greenhouse and nursery operations played a significant role, accounting for 6.4 % of total farm revenue. During 2020, vegetable production saw a positive trend with a 6.5 % increase, reaching $7.0 million, led by turnips and potatoes as the top vegetable crops. In berries production, cranberries blueberries and strawberries were the highest-valued fruit crop produced in Newfoundland. The primary agricultural commodities in NL consist of Dairy, Poultry (Chicken and Eggs), Greenhouse and Nursery products, and Vegetables.

NL entails examining factors such as the challenging northern climate, which limits the range of viable crops, favoring those adapted to colder conditions like root vegetables and berries. Assessing the economic feasibility of crop cultivation in NL compared to other Canadian provinces, is a multifaceted endeavor. Understanding local market preferences and the potential limitations posed by NL's remote location, which affects input costs and market access, is crucial.

Additionally, considering environmental concerns, and exploring diversification strategies all play pivotal roles in determining the economic viability of crops in this region as shown in figure 1. These factors, which differ across provinces, ultimately shape the study of the economic feasibility of various crops in NL.

Figure 1. Examination of the economic feasibility of various crops within a specific region, considering NL as the context.

3.2 Crop Selection

Selecting a crop for economic feasibility involves considering various factors to ensure profitability and sustainability (Tanaka et al., 2002). Different regions and situations may require different considerations, but some key factors to assess when choosing a crop are:

I. Climate and Growing Season: NL's northern location and short growing season limit the range of viable crops compared to provinces with longer, more temperate growing periods like British Columbia and Ontario.

II. Crop Suitability: NL's crops are typically those well-suited to colder climates, such as root vegetables, berries, and some grains. Prairies provinces have more flexibility to grow a broader variety of crops, including fruits and vegetables.

III. Market Demand: Local and regional market preferences influence crop choices. While NL may have unique preferences, provinces with larger populations offer broader markets and demand for a wider range of crops.

IV. Input Costs: Input costs, such as land, labor, and fertilizers, can vary due to NL's remote location. Limited access to certain inputs may affect production costs compared to provinces with better infrastructure.

V. Yield Expectations: NL's colder climate and shorter growing season can impact crop yields, potentially affecting economic viability compared to provinces with more favorable conditions.

VI. Government Support: Policies, subsidies, and programs differ between provinces, influencing economic feasibility. Understanding specific support and incentives is crucial for informed decision-making.

VII. Risk Management: Unique risks in NL, including weather and market fluctuations, require careful consideration when choosing crops.

VIII. Environmental Impact: NL's ecosystems and regulations may influence crop selection and profitability, particularly in comparison to provinces with different environmental concerns.

IX. Market Access: NL's relative isolation may pose challenges in accessing markets compared to provinces with better transportation links.

X. Crop Diversification: Crop rotation and diversification strategies can impact long-term sustainability, with some provinces offering more opportunities for diversification.

Based on the above factors nine different crops were selected for this study.

These crops included:

1. Potatoes
2. Beets
3. Cabbage
4. Carrots
5. Rutabagas and turnips
6. Blueberries
7. Cranberries
8. Raspberries
9. Strawberries

For the above-mentioned crops, the total arable land in NL is 730.8 ha in 2021. Codroy Valley, Robinsons, Humber Valley, Musgrave town, and St. John's are recognized agricultural regions within the province of NL. The following is the contribution of crops to the total area of cultivation; Potatoes 26% (192.2 ha), Beets 2.5% (19 ha), Cabbage 7.2% (53 ha), Carrot 9.1% (66.7 ha), Rutabagas and turnip 9.5 % (70 ha), Blueberries 33.2% (242.8 ha), Cranberries 6.1 % (44.9 ha), Raspberries 1 % (8 ha), and Strawberries 4.6 % (33.9 ha).

For NL, data from 2017 to 2021 were used for the analysis, and all management operations, pesticides, fertilizer, and seed used for all crop recorded annually. Additionally, this study will provide the Crop Sequence Calculator, a computer information product that provides producers with information about short-term rotational effects.

3.3 Cost of Production

The detailed analysis was performed to estimate the annual costs of production for each crop in each year (Appendix I). The analysis included input costs for seed, fertilizers & pesticides, machinery and fuel, as well as labor hours compensated for pre-seeding operations operation, seeding, harvesting and post-harvest practices.

The labor costs were estimated based on the hours spent on each machinery operation per hectare, while fuel costs were estimated based on the amount of fuel used on each machinery operation. For each crop, crop enterprise budgets were designed based on production and management practices, using specific 2017–2021 seed, fertilizer & pesticides labour and machinery & fuel costs (Zollinger et al., 2016; Lazarus, 2015; Swenson and Haugen, 2015).

Additionally, machinery costs were also considered, which included oil and fuel, repairs and maintenance, depreciation, labor, and overhead costs, such as interest, insurance, and housing costs. The data used the average annual input and out nominal prices received from Statistics Canada for the years 2017 to 2021 to determine the prices in NL.

3.4 Gross Revenue and Gross Margin

Gross revenue refers to the total sales or revenue generated by a company from its primary business activities before deducting any expenses. It represents the total amount of money earned from the sale of goods or services. Gross revenue includes both cash and credit sales and is calculated by multiplying the number of units sold by the price per unit. Gross margin, on the other hand, is a measure of profitability that indicates the percentage of revenue remaining after deducting the cost of goods sold (COGS). It represents the amount of money a company has left to cover other operating expenses and generate a profit. Gross margin is calculated by subtracting COGS from gross revenue and dividing the result by gross revenue, then multiplying by 100 to express it as a percentage.

For NL, the crop yield data was measured annually, while the commodity prices were obtained from Statistics Canada (2017-21). The commodity prices used in the analysis were sourced from Statistics Canada for the year 2017-21 (Appendix III, Appendix IV). While Statistics Canada data is valuable for understanding national price trends, it may not fully capture the specific price dynamics in the research area, particularly in NL, Atlantic Canada, and the Northeast (NE) region.

To ensure the accuracy and relevance of the analysis, it is crucial to collect price information that is specific to NL, Atlantic Canada, and the NE region. This can be achieved through various means, such as conducting local market surveys, accessing data from government agricultural departments, reaching out to agricultural associations and organizations, and using data from local price reporting agencies.

By gathering price information that is tailored to the study area, the research study can provide a more comprehensive understanding of the economic realities faced by farmers and producers in NL, Atlantic Canada, and the NE region. This localized context is vital for drawing meaningful conclusions, making relevant policy recommendations, and offering insights that are directly applicable to the agricultural community in the specific research region. Ensuring the use of regionally relevant price data enhances the overall quality and applicability of the thesis findings, leading to more informed decision-making and fostering agricultural development in the studied area.

To calculate the gross revenue, we multiplied the crop yield for each year within each crop by its corresponding commodity price.

This would give the total revenue generated from the sale of the crops for each year. To estimate the gross margin, subtracted the operating costs from the gross revenue. Operating costs refer to the expenses incurred in producing the crops, such as seeds, fertilizer & pesticides, labour, machinery & fuel and other expenses. The gross margin represents the profit earned from the sale of the crops, after deducting the operating costs. (Fernandez et al., 2019b).

3.5 Cost-Benefit Ratio

The cost-benefit ratio (CBR) is a measure commonly used in the cost-benefit analysis to determine the economic feasibility of a project or investment. The CBR is calculated by dividing the total benefits of a project by the total costs (Daneshvar and Kaleibar, 2010).

If the CBR is greater than one, it indicates that the project's benefits outweigh its costs, and the project is considered economically feasible. In other words, for every dollar invested in the project, more than one dollar of benefits is expected to be generated.

Comparing CBRs between multiple projects can help to identify the most financially viable project. The project with the highest CBR is typically considered the most preferable, as it is expected to generate the greatest amount of benefits relative to its costs. In agricultural research and decision-making, the evaluation of farming practices is crucial to identify financially viable projects. Numerous methods exist to assess the economic feasibility of these projects, including Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period, Cost-Benefit Ratio (CBR), and Sensitivity Analysis. Among these, the CBR method stands out for its simplicity and effectiveness in comparing the benefits and costs of different projects. The Cost-Benefit Ratio (CBR) method calculates the ratio of the present value of expected benefits to the present value of costs over the project's lifespan. This approach allows decision-makers to determine which project offers the most favorable outcome by achieving the highest CBR. Projects with higher CBRs are expected to yield greater benefits in relation to their costs, making them a more preferable choice.

The CBR method is selected due to its practicality and ease of use in comparing farming projects. It helps in making informed decisions by offering a clear numerical representation of the potential economic gains. Additionally, the CBR method is well-suited for evaluating farming practices, as it aligns with the industry's focus on achieving profitable outcomes. However, the implementation of the CBR method is not without challenges. One significant problem lies in accurately estimating cash flows for the projects, especially when dealing with long-term ventures. The authenticity of the results heavily based on the precision of projected benefits and costs over time. Intangible benefits, such as environmental or social impacts, can be challenging to quantify in monetary terms, potentially leading to an incomplete assessment of project benefits.

To account for the impact of different discount rates on project evaluations, sensitivity analysis is essential. By applying various discount rates to the cash flows of each project, we can observe how the results change accordingly. Higher discount rates tend to favor projects with quicker returns on investment and shorter payback periods, as future cash flows are significantly discounted. Conversely, lower discount rates give preference to projects with longer-term benefits and longer payback periods, as future cash flows are less heavily discounted. Through sensitivity analysis, we can identify the discount rate range where the project's financial viability shifts, allowing decision-makers to make more informed choices based on their risk tolerance and time horizon. This analysis adds depth to the evaluation process and offers valuable insights into the robustness of the selected farming projects.

In conclusion, the CBR method proves to be a valuable tool for comparing farming projects and identifying the most financially viable options (Appendix V). Its simplicity and clarity make it an appealing choice in agricultural decision-making. However, careful attention should be given to cash flow estimations and the consideration of intangible benefits to ensure a comprehensive evaluation. Sensitivity analysis with different discount rates adds a layer of understanding and helps decision-makers account for varying financial scenarios, leading to more robust and well-informed choices regarding farming practices.

3.6 Statistical Analysis

For statistical analysis, data were analyzed using analysis of variance (ANOVA). An analysis of variance was conducted annually for all the data. The analysis was conducted utilizing (XLSTAT Premium, Perpetual version 2018.1.1, NY, USA) software. To identify significant differences ($P \leqslant 0.05$) among treatment means, least significant difference tests were employed.

The ANOVA is a statistical method used to compare means across multiple groups to determine if there are any significant differences between them. In the context of agricultural research, ANOVA is particularly valuable for evaluating the effects of different factors or treatments on crop yields, agricultural practices, or other relevant variables. The randomized complete block design, a common experimental design in agriculture, helps control for variability and ensures a more robust analysis.

Pros

I. Identification of Differences: ANOVA can effectively determine if there are significant differences between the means of multiple groups, allowing researchers to pinpoint which treatments or factors lead to distinct outcomes.

II. Efficient Analysis: ANOVA efficiently analyzes data from multiple groups simultaneously, reducing the need for multiple pairwise comparisons and minimizing the risk of type I error (false positives).

III. Control of Confounding Variables: Randomized complete block designs in ANOVA help control the influence of confounding variables, enhancing the accuracy and reliability of the results.

IV. Applicability to Various Designs: ANOVA can be applied to different experimental designs, making it a versatile tool for agricultural researchers working with various setups.

Cons

I. Assumptions: ANOVA relies on certain assumptions, such as the normality of data and homogeneity of variances. Violation of these assumptions can impact the validity of the results.

II. Interpretation Complexity: While ANOVA determines if there are significant differences, further analysis, such as post-hoc tests, may be required to identify specific group differences.

III. Sample Size: For ANOVA to yield meaningful results, an adequate sample size is crucial. Insufficient data can limit the power of the analysis.

IV. Limited to Means Comparison: ANOVA assesses means differences but may not capture the entire distribution of data or identify patterns beyond average values.

Shapiro-Wilk residuals test were conducted for normality. Crops were modeled as fixed effects, and significant differences among treatment means were determined using least significant difference tests (Rodriguez et al., 2020) with a significance level of $P \leqslant 0.05$. The significance level, often denoted as alpha (α), is the probability threshold used to determine whether the results of a statistical test are statistically significant. It represents the level of risk a researcher is willing to take when making a decision based on the test results.

Least Significant Difference (LSD): LSD is a method used in statistical hypothesis testing, particularly in the context of ANOVA. It is employed for post hoc pairwise comparisons when there are more than two groups or treatments. The purpose of LSD is to identify which specific group means are significantly different from each other after finding a significant overall difference among groups through ANOVA.

Calculation: LSD is calculated by estimating the standard error of the differences between group means and multiplying it by a critical value from the Studentized range distribution (also known as the Studentized range statistic). This critical value is chosen based on the desired level of significance (e.g., 0.05 or 0.01).

Pairwise Comparisons: After calculating LSD, researchers use it to perform pairwise comparisons between group means. If the difference between the means of two groups exceeds the LSD value, those two groups are considered significantly different from each other.

Lettering: Groups that have a mean difference larger than the LSD value are typically labeled with different letters. Groups with the same letter are not significantly different from each other, while groups with different letters are significantly different.

For example, if you have three groups labeled "a", "b", and "c", and your LSD analysis shows that "c" and "b" have the same letter (e.g., 'a'), it means that the difference between the groups means "a" and "b" is not significant. However, if group "c" has a different letter (e.g., 'b'), it indicates that group "c" is significantly different from groups "a" and "b".

This lettering system simplifies the presentation and interpretation of the results, making it easier to identify and communicate which groups are statistically distinct from each other after conducting multiple pairwise comparisons.

The two most common significance levels are 0.05 (5%) and 0.01 (1%). These levels are chosen for specific reasons:

1. **0.05 (5%) Significance Level:** This is the most commonly used significance level in many fields, including agricultural research. Choosing a 5% significance level means that the researcher is willing to accept a 5% chance of making a Type I error (false positive). In other words, if the p-value of the test is less than or equal to 0.05, the result is considered statistically significant, and the researcher can reject the null hypothesis.

2. **0.01 (1%) Significance Level:** This level is more conservative and used when there is a need for a higher degree of certainty in the results. A 1% significance level implies that the researcher is only willing to accept a 1% chance of making a Type I error. Consequently, the bar for rejecting the null hypothesis is set higher, requiring even stronger evidence for statistical significance (i.e., a smaller p-value).

The choice of significance level depends on the specific research question and the consequences of making a Type I error. A more stringent significance level (e.g., 0.01) is typically chosen when the cost of a false positive is high or when strong evidence is needed to support a claim. On the other hand, a less stringent level (e.g., 0.05) may be sufficient for exploratory analyses or when the consequences of a false positive are relatively low.

All costs and returns for this study were expressed in CAD. When presenting economic data, there are two primary ways to account for the effects of inflation and changes in purchasing power: nominal prices and real prices.

I. **Nominal Prices:** Nominal prices represent the actual prices or values of goods, services, or financial variables at the current point in time. In this context, expressing costs and returns in nominal CAD means that the data reflects the prices prevailing in the specific fiscal year under consideration without adjusting for inflation or changes in the value of money over time.

II. **Real Prices:** Real prices, on the other hand, take into account the impact of inflation and changes in purchasing power. To convert nominal prices into real prices, an adjustment is made using a price index or inflation rate to reflect the value of money in a particular base year.

In the absence of additional information in the provided context, it is unclear whether the costs and revenue were expressed in nominal or real prices. If real prices were used, the fiscal year chosen as the base year would be critical. The base year serves as a reference point to which prices in other years are compared to measure changes in the value of money.

For instance, if the data were presented in real prices with the base year 2021, all costs and revenue would be adjusted to reflect the value of the Canadian dollar in 2021, allowing for a meaningful comparison of values across different years.

As for the statistical analysis section, it requires more explanations to provide clarity on the specific statistical methods used, the hypotheses tested, the level of significance chosen, and the interpretation of the results. Additional information on the variables studied, the research objectives, and the rationale for selecting certain statistical tests would enhance the readers' understanding of the findings and their implications. Moreover, the explanation should include details on how the data was collected, the assumptions made in the analyses, and any limitations that may affect the generalizability of the results. Providing clear and comprehensive explanations in the statistical analysis section ensures that readers can accurately interpret and assess the validity of the study's conclusions.

Chapter 4

Results

In this chapter, a detailed explanation was presented based on the findings. Figures are included for better understanding and carefully examining the collected data.

The provided data (Statistics Canada) represents the agricultural expenses for various crops over a span of five years (2017-2021). The expenses are categorized into different cost components, including seed, fertilizer and pesticides, labor, machinery and fuel, and other operating expenses. Let's explain these data for each crop according to the year (Figure 2).

Figure 2 outlines the cultivation expenses for various crops from 2017 to 2021. Across multiple crops, including beet, cabbage, carrot, rutabaga & turnip, strawberries, and potatoes, expenses exhibited a consistent upward trend over the years. Notably, 2021 saw substantial increases in labor and other operating expenses across most crops. Blueberries and raspberries experienced relatively stable expenditure patterns, while cranberries witnessed a decrease in costs over the years. Overall, these summaries emphasize the general increase in cultivation expenses, particularly in 2021, highlighting the financial challenges faced by farmers in managing their crop production.

These data provide a detailed breakdown of the expenses associated with each crop's cultivation over five years. They reflect variations in costs, with some crops experiencing significant increases in certain expense categories, especially in the year 2021. These trends can be valuable for budgeting and decision-making in agricultural practices.

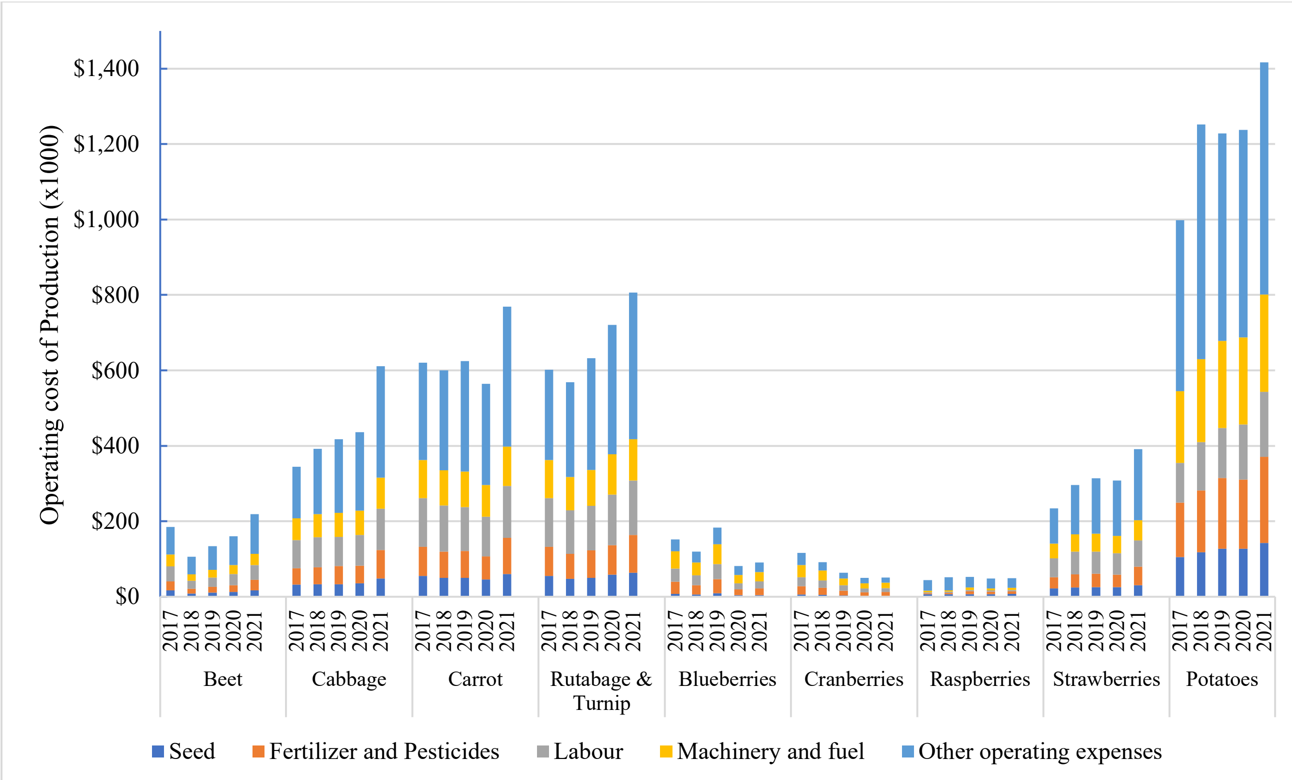

Figure 2. Operating Costs ($CAD) by item for each crop from 2017-2021 (Statistics Canada). Breakup of operating cost of production by cropping system (2017-2021). All phases of the operating cost present each year.
Other operating expenses includes building cost, repair, insurance, land taxes, farm utility costs, plus certification and inspection fees.

4.1 Operating Costs of Production

The crops grown in NL had a significant impact on the total cost of production (Figure 3); however, the year and their interaction across all crops were not significant. As mentioned in Appendix I, potatoes had the highest average total cost of production ($1,226,591). Rutabagas, turnips, and carrots had similar production costs (averaged $650,745), followed by cabbage ($440,235), strawberries ($308,930), and beets ($160,915). Furthermore, total production costs were lowest for raspberries ($49,154).

Production costs showed minimal variation across years for all crops but tended to increase in years with more favorable growing conditions. This was primarily attributed to elevated costs related to harvesting, transportation, and storage of higher crop yields. Additionally, the need for extra weed control measures in these years contributed to the overall higher production costs. The highest cost of production was observed in 2021 ($489,406), whereas the year 2017 ($366,240) had the lowest production cost. Operating costs were heavily dependent on other operating expenses (45% of the total) and fuel (17% of the total) costs (Figure 2). According to Figure 2, potatoes had the highest additional operating cost ($622,872) in 2018, while costs for fuel ($258,083), fertilizer and pesticides ($228,364), labor ($172,705), and seed ($142,378) were highest in 2021.

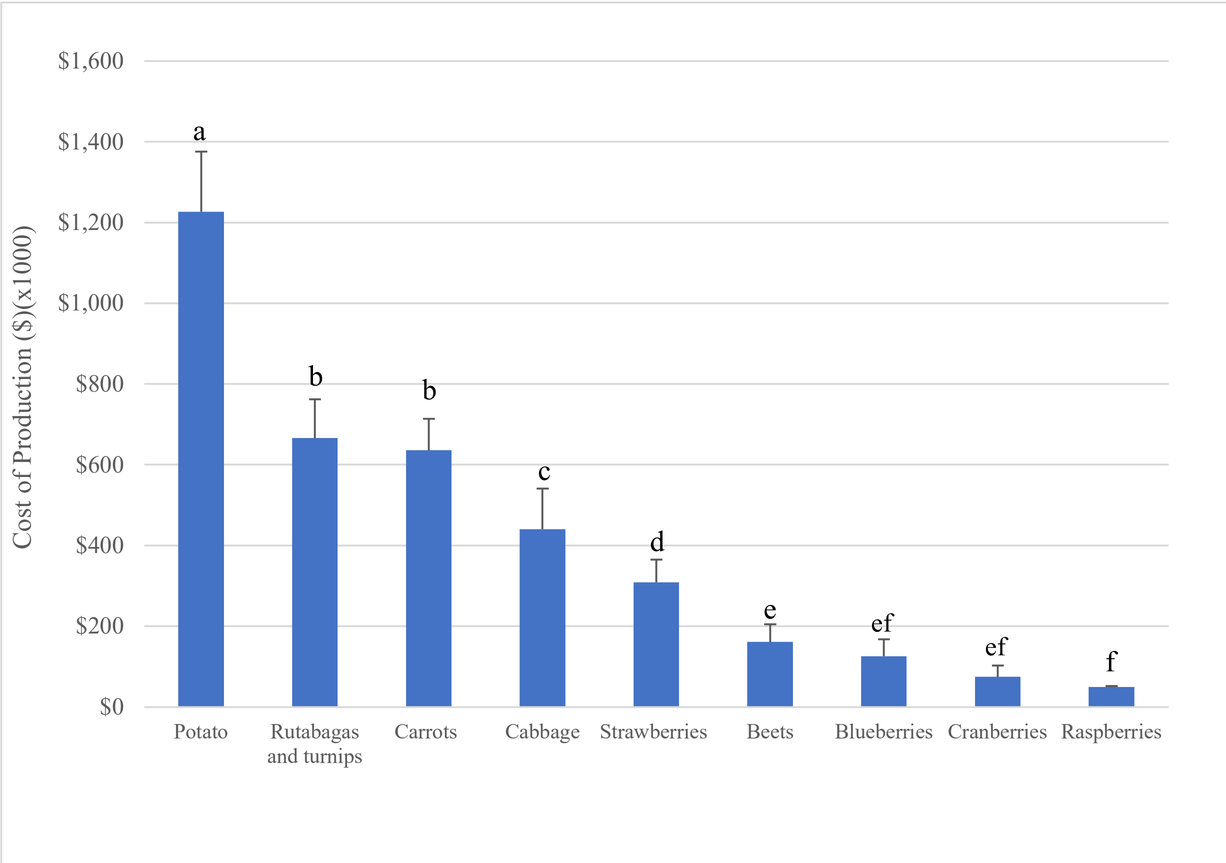

Figure 3. The average production costs (CAD$) for total area for each crop in Newfoundland and Labrador from 2017 to 2021 (Statistics Canada). Groups that have a mean difference larger than the LSD value are typically labeled with different letters. Groups with the same letter are not significantly different from each other, while groups with different letters are significantly different. Values with different alphabetical superscripts indicate significant differences ($p < 0.05$).

4.2 Crop Yield

Significant variation in crop yields was observed across the crops grown in NL, as shown in Figure 4. Potato was found to be a good crop for producing benchmark yield (3169 Mg) among all crops, with 62% higher crop yield than the next followed crop i.e., rutabagas & turnips (1208 Mg). Similar crop yield was observed for rutabagas & turnips and carrot (averaged 1183 Mg), followed by cabbage (916 Mg) and cranberries (328 Mg) (Appendix II). Blueberries, strawberries, and raspberries all had similar and lowest crop yields (averaged 67 Mg) (Figure 4). However, crop yield did not have a significant effect on yearly variation and their interaction with crops. The highest crop yield was produced in 2017 (902 Mg), whereas the lowest crop yield was observed in 2020 (722 Mg). Despite 2021 having the highest gross revenue, there was a decline in crop yield in yearly variation.

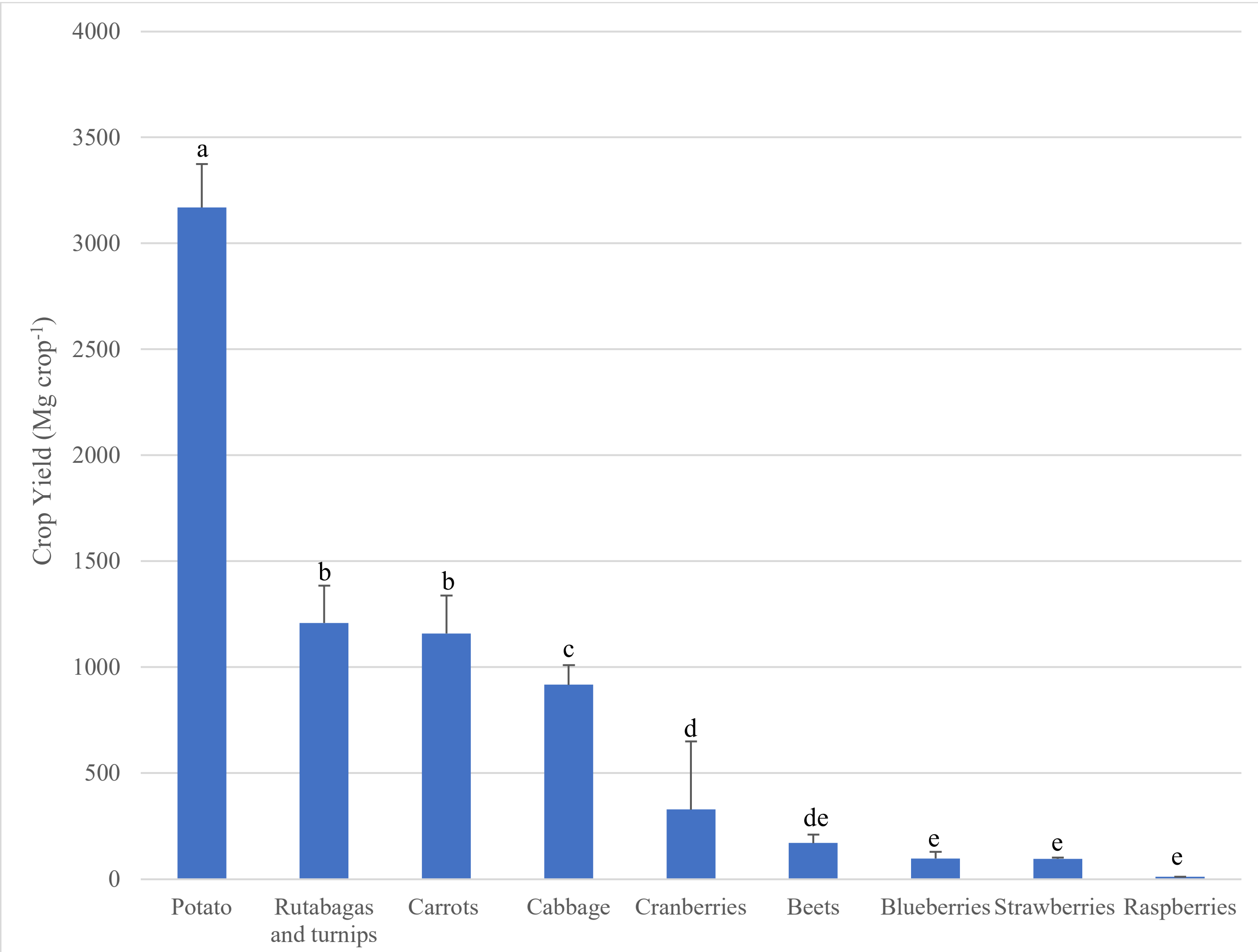

Figure 4. The average crop yield (Mg) for total area for each crop in NL from 2017 to 2021(Statistics Canada). Groups that have a mean difference larger than the LSD value are typically labeled with different letters. Groups with the same letter are not significantly different from each other, while groups with different letters are significantly different. Values with different alphabetical superscripts indicate significant differences ($p < 0.05$).

4.3 Gross Revenue

Overall, in cropping systems, gross revenue were significantly affected by crops while the gross revenue had not been significantly influenced by years and their interaction with crops. The significantly highest gross revenue was earned by rutabagas and turnips (averaged $1,896,800), given that product prices were generally increased (Figure 5). Potatoes generated the 2nd most gross revenue across all crops (averaged $1,477,010). Furthermore, carrots and cabbage produced similar gross revenue (averaged $1,055,900), followed by strawberries ($188,800). Cranberries, blueberries, beets, and raspberries produced the lowest similar gross revenue (averaged $163,150) (Figure 5). In 2021, gross revenue for all crops (averaged $827,800) was the highest, represents the maximum crop yields in that year (Appendix III). After the first year (2017), gross revenue declined; however, a gradual increase had been observed across the years. In 2018 there were stable prices of the products due to decline in grass revenue means that this period had a minimum gross revenue (averaged $679,431). Results showed that 2021 had 18% higher gross revenue compared to the year 2018.

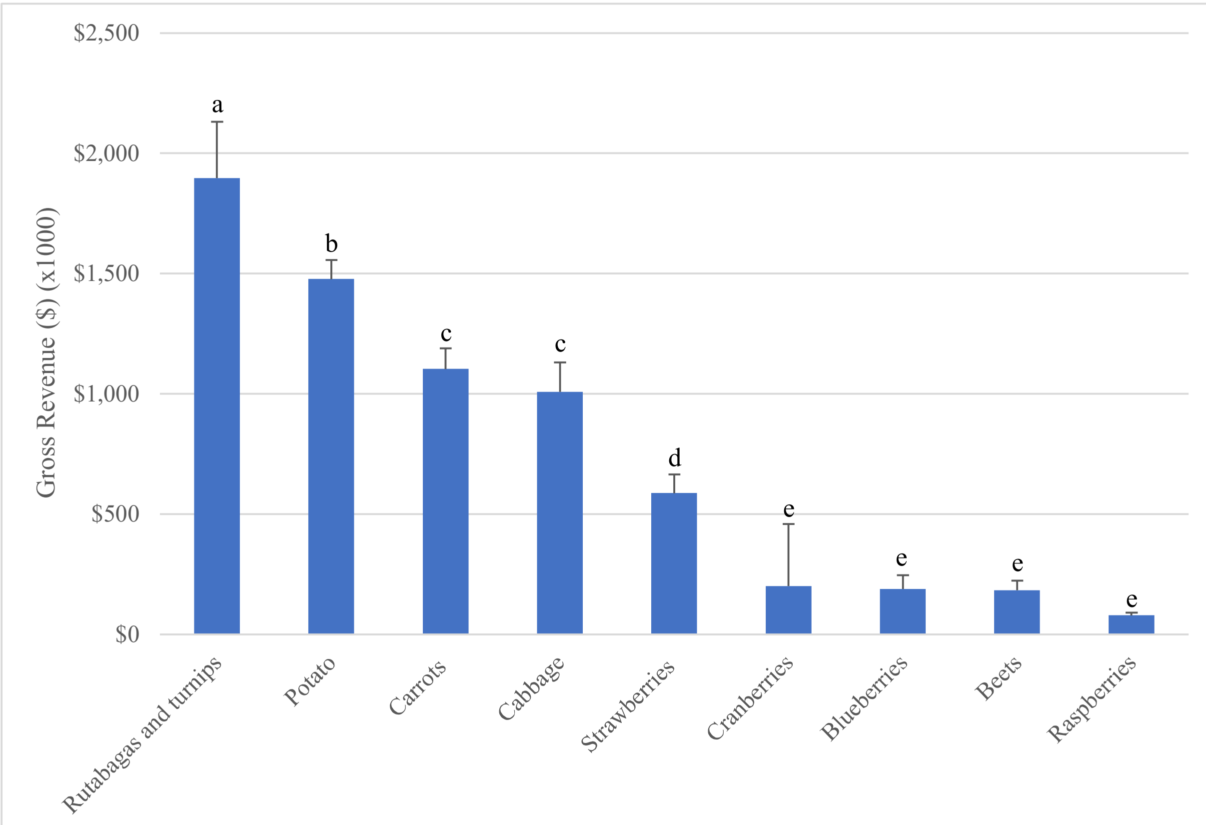

Figure 5. The average gross revenue (CAD$) for total area for each crop in Newfoundland and Labrador from 2017 to 2021(Statistics Canada). Groups that have a mean difference larger than the LSD value are typically labeled with different letters. Groups with the same letter are not significantly different from each other, while groups with different letters are significantly different. Values with different alphabetical superscripts indicate significant differences ($p < 0.05$).

4.4 Gross Margin

Over time, there was a declining trend in gross margins attributed to rising operating costs and decreasing crop yields in the later years.. The highest gross margin was observed in the year 2017 (averaged $408,404), whereas 2018 had the least gross margin (averaged $292,999) across all periods. Although the gross margin showed nonsignificant effects over the years and their interactions with crops, crops had a significant impact on the gross margin (Figure 6). Among crops, the highest rutabagas and turnip yields were the main cause for the increased gross margins (averaged $1,230,971). The gross margin for rutabagas and turnip had a 54% higher margin than the next followed crop, i.e., cabbage (averaged $568,364). The minimum gross margin was expressed in raspberries and beet, having a similar gross margin (averaged $26,465) (Figure 6). These findings indicate a significant potential to enhance the profitability of crop production systems, particularly under higher price premiums, provided that the productivity of the system can be sustained.

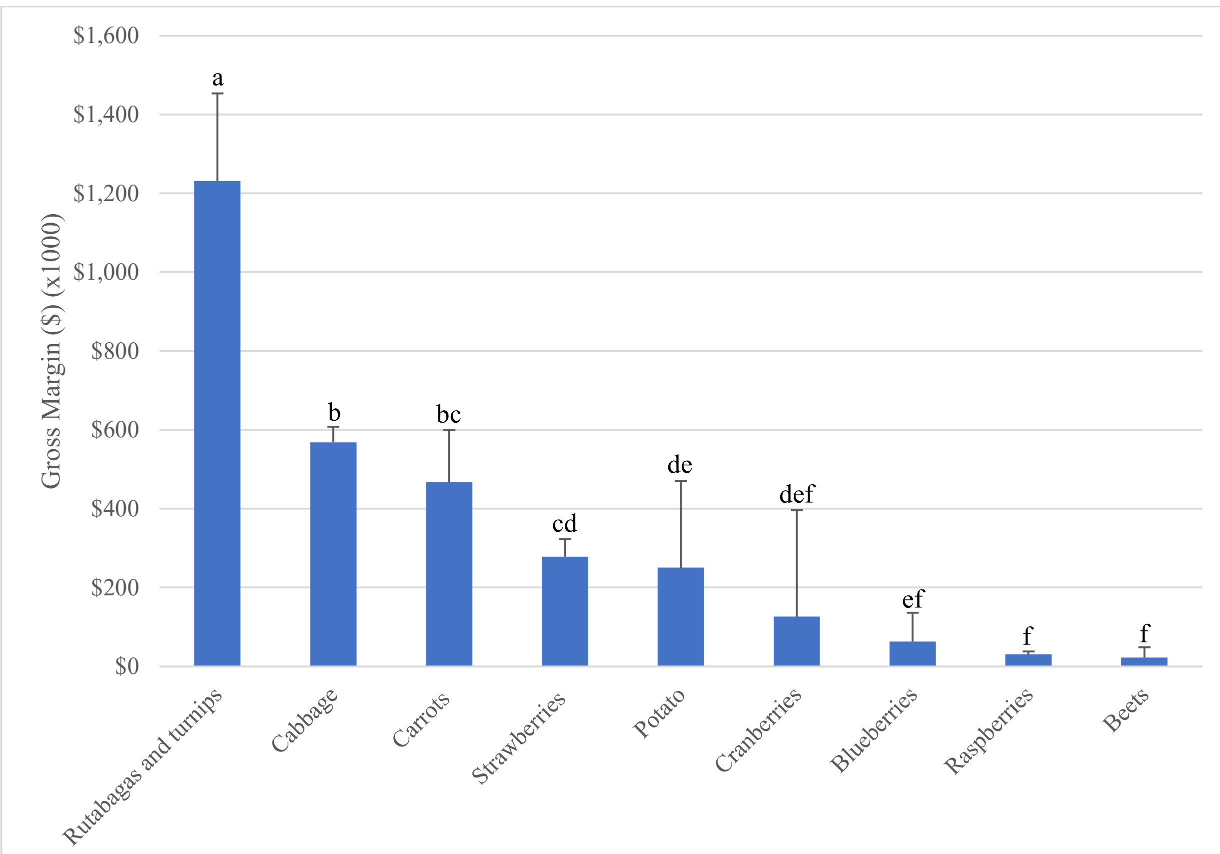

Figure 6. The average gross margin (CAD$) for total area for each crop in Newfoundland and Labrador from 2017 to 2021(Statistics Canada). Groups that have a mean difference larger than the LSD value are typically labeled with different letters. Groups with the same letter are not significantly different from each other, while groups with different letters are significantly different. Values with different alphabetical superscripts indicate significant differences ($p < 0.05$).

4.5 Cost-Benefit Ratio

The cropping systems had a significant effect on the cost/benefit ratio (Figure 7), whereas the years and their interaction with crops did not exhibit a significant influence on the cost/benefit ratio. All the crops had statistically similar cost/benefit ratios. Cranberries had the highest benefit/cost ratio of 3.44 and the lowest cost/benefit ratio was estimated for beets (Figure 7). The ranking of these farming systems, based on their cost-to-benefit ratio, demonstrates the relative profitability and efficiency of each crop. Cranberries emerged as the most financially rewarding, with a cost-to-benefit ratio of 3.4, signifying that for every unit of cost invested, it yielded a substantial return. Following closely were rutabagas and turnips at 2.8, cabbage at 2.3, and strawberries at 1.9. These crops were also considered economically viable with favorable returns. On the other hand, beets and potatoes had the lowest ratios of 1.1 and 1.2, respectively, indicating that they were less economically efficient compared to the other crops. Thus, every crop showed a better cost/benefit ratio than beets (Figure 7). Due to the surge in commodity prices, a gradual increase had been observed across the years, except 2019, which had the lowest cost/benefit ratio (1.8). The maximum cost benefit ratio was observed in 2021 (2.8).

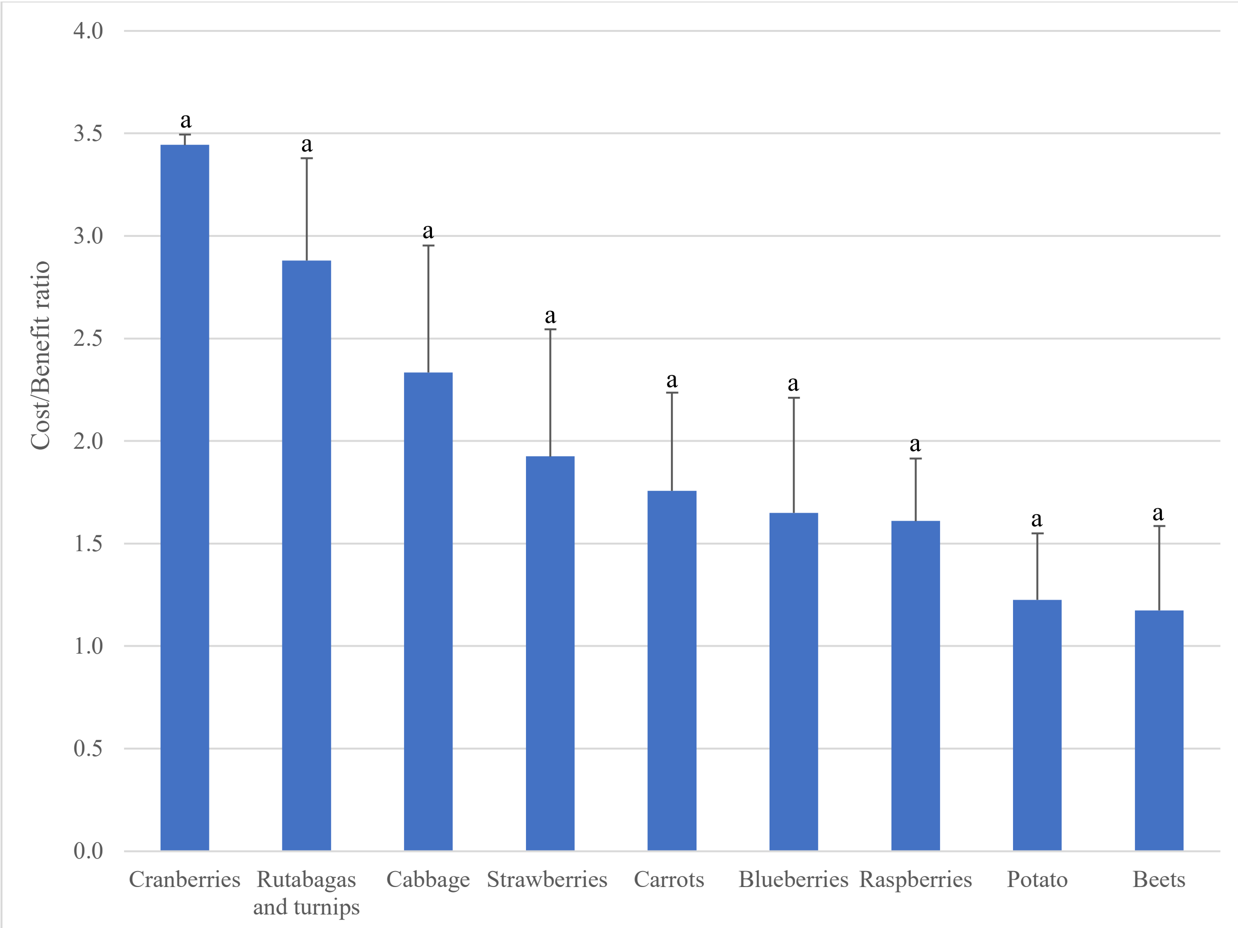

Figure 7. The cost/benefit ratio for each crop in NL from 2017 to 2021 Groups that have a mean difference larger than the LSD value are typically labeled with different letters. Groups with the same letter are not significantly different from each other, while groups with different letters are significantly different. Values with different alphabetical superscripts indicate significant differences ($p < 0.05$).

Chapter 5

Discussion and Conclusion

5.1 Operating Cost of Production

The cost of production for crops has been a topic of interest for researchers, and studies have shown that the cost of production can exceed that of conventional crops (Klonsky, 2012; Ostapenko et al., 2020). The increased costs are linked to elevated energy consumption resulting from increased mechanical tillage operations, along with the higher expenses related to fertilizers and amendments associated with organic management.

A study (2011 to 2015) found that the operating costs for high tillage treatments were higher (12 CAD\$ ha^{-1}) than that for low tillage treatments, with organic seed and fuel costs heavily influencing the operating costs (Dayananda et al., 2021). Seed costs increased over the study period (2010-15), with the highest cost observed in 2014. The elevated production cost was mainly attributed to the increased seed costs for field pea and forage pea. The increased fuel costs for the high tillage treatment were a result of the additional tillage operations (Dayananda et al., 2021).

In another study, the estimated variable cost for an organic cropping system in the Brown soil zone was 155 CAD\$ per hectare (Hamm and Hugh 2015). There were variations in production costs among crops, with corn exhibiting the highest costs and soybean having the lowest. Barley, wheat, and alfalfa incurred slightly higher production costs than soybean. The increased costs associated with corn production were primarily attributed to higher expenditures on seed, fertilizer, and drying charges, significantly surpassing those of the other crops (Meyer et al., 2006).

According to a study on various crop rotations, costs of production were higher than those reported in an earlier study for the period of 1988 to 2002 (Zentner et al., 2006). The increase in costs was mainly due to higher pesticide expenses and machinery costs.

Among the crop rotations studied, fallow wheat had the lowest average total cost per hectare, while continuous wheat and wheat-canola-wheat-dry pea had the highest costs. The increased cost of producing legume wheat was mainly due to additional seed and field operations such as planting and tillage, but this was partly offset by lower pesticide costs and lower nitrogen fertilizer rates and costs for wheat following legume wheat due to nitrogen credit (smith et al., 2017).

In terms of individual crops, N costs were highest for Canola and lowest for dry pea, while pesticide costs were lowest for legume wheat and wheat-Canola-wheat-dry pea and highest for the wheat rotations. Repairs, labor, and machinery overhead accounted for a similar percentage of average total production costs across the rotations. The proportion of costs allocated to crop insurance increased with reduced fallow, from 2.5% to 5%, with crop insurance costs highest for Canola and dry pea and lowest for wheat (smith et al., 2017).

Overall, the cost of production for organic crops can exceed that of conventional crops due to increased energy consumption and higher costs of organic fertilizers and amendments. The cost of production varies across crops and crop rotations, with corn having the highest costs and fallow wheat having the lowest costs. The costs of individual inputs such as seed, fertilizer, and pesticides also vary across crops and rotations, with Canola having the highest costs for many inputs and dry pea having the lowest costs.

5.2 Crop Yield

Crop sequencing and management play crucial roles in developing sustainable and profitable crop production systems. Diverse crop rotations have been shown to increase crop productivity significantly (Anderson, 2005). For example, it has been reported that crop rotation can enhance spring wheat yield by 12 to 35%, corn yield by 5 to 30%, and soybean yield by 8 to 16% (Crookston et al., 1991; Copeland et al., 1993; Lund et al., 1993; West et al., 1996; Singer and Cox, 1998; Miller et al., 2002).

Crop diversity has declined in the US over the past 30 years, which is a cause for concern (Aguilar et al,. 2015). When considering the impact of crop rotation for overall management strategy, it is important to include the relevant tillage system. In US for major crops such as wheat, corn, soybeans and cotton, strip-till and no-till systems have been implemented in 39% of the total area (Wade et al., 2015).

In the Northern Great Plains, the adoption of these systems has been notably prevalent, with 49% of the area for these crops cultivated using no-till or strip-till. This proportion is even higher in the wheat-growing sections of this region, where 63% of the wheat area employs these systems (Wade et al., 2015).

The disease and weed presence competition did not significantly affect corn, soybean, wheat, and alfalfa yields. Nevertheless, barley yields exhibited a declining trend over time, influenced in part by the growing population and severity of net blotch in the later years of the study. Crop yield variability varied among different crops, with alfalfa displaying the highest variability and wheat the lowest (Wade et al., 2015).

Meyer et al. (2006) found that in both tillage systems, the lowest yields were observed in continuously planted corn, while the highest yields were observed following the planting of alfalfa or red clover. In the chisel plow system, corn yields following soybeans were 0.55 Mg ha^{-1} (7.4%) higher than those in continuous corn but 0.40 Mg ha^{-1} (5.1%) lower than the average yield for the three rotations that included a forage legume. The notable differences in yield between continuous and first-year corn in the chisel plow system could be attributed, in part, to the relatively greater yield reduction associated with chisel plowing when corn followed corn. In comparison to the moldboard system, continuous corn yields were 0.65 Mg ha^{-1} (8.2%) lower in the chisel system. However, for other rotations, the initial-year yield reductions due to chisel tillage were much smaller, with the most significant reductions observed after soybean and wheat under seeded with red clover. The soybean-soybean-corn-corn rotation experienced the largest yield reduction, with yields averaging 0.36 Mg ha^{-1} (4.1%) less than continuous corn. A study in Wisconsin also reported similar yield differences between second-year corn following soybean and continuous corn (Porter et al., 1997).

5.3 Gross Return

The studies by Brandt et al. (2003), Dayananda et al. (2021), Fernandez et al. (2019b), Hamm and Hugh (2015), and Smith et al. (2017) all provide valuable insights into the factors that affect the gross returns of cropping systems in Canada.

Brandt et al. (2003) found that the gross returns of cropping systems were influenced by the prevailing growing conditions, with peak returns in 1999 and lowest returns in 2002. This suggests that weather patterns and other environmental factors play a significant role in determining the profitability of cropping systems.

In 2011 Dayananda et al. (2021) reported the highest gross returns due to good crop yields but declined significantly in the following years. They found that the tillage treatment and crop rotation also influenced gross returns, with high tillage resulting in higher returns in some years and diversified rotations leading to higher returns than simplified rotations.

Fernandez et al. (2019b) identified spring soil and low growing season precipitation NO_3-N levels as the main reasons for the decline in wheat and mustard yields, whereas flax yields were primarily affected by increased weed competition and available soil NO_3-N levels. This highlights the importance of soil management practices in maintaining crop yields and profitability.

Hamm and Hugh (2015) found that the legume- hard red spring wheat (HRSW) -oat system had an average gross return of CAD$637 ha^{-1}, with the high tillage treatment resulting in slightly higher returns than low tillage. This suggests that crop diversity and organic price premiums can contribute to higher gross returns.

Smith et al. (2017) found that the wheat-canola-wheat-dry pea rotation generated the highest average revenue, due to higher wheat yields and prices, as well as higher revenue from dry pea. Legume wheat, Canada Prairie spring wheat, and fallow wheat rotations also had higher average revenue than fallow wheat, highlighting the importance of crop diversity and soil management practices in increasing profitability.

Overall, these studies suggest that weather patterns, soil management practices, crop diversity, and organic price premiums are all important factors that can influence the gross returns of cropping systems in Canada.

5.4 Gross Margin

The study conducted by Dayananda et al. (2021) found that gross margins for organic crop production systems exhibited a falling trend over time, due to rising in costs of operation and declining crop yields in subsequent years.

However, high tillage treatments consistently yielded higher gross margins than low tillage treatments, primarily attributable to superior wheat yields. The simplified crop rotation outperformed the diversified rotation in terms of gross margin in 2011 and 2012, but this pattern reversed in 2013 and 2015. During these years, the diversified rotation recorded a significantly higher gross margin, primarily driven by increased prices of mustard and lentil. However, in the absence of organic price premiums, the average gross margins experienced a notable decrease for both high and low tillage treatments, underscoring the potential to enhance profitability through augmented price premiums.

Kirchmann et al. (2008) noted that limited means of improving soil productivity and greater weed competition and lower nutrient availability could impede the productivity of organic crop production.

Meyer et al. (2006) found that continuous corn planting resulted in lower yields and higher expenses for insecticide application, leading to a lower gross margin than first-year corn planted in rotation. The selection of rotation crops did not affect the gross margin of first-year corn in the moldboard system. However, in the chisel system, incorporating crops other than corn led to an increase in the gross margin. Rotations involving barley and alfalfa yielded the highest gross margin for first-year corn in the chisel system. The inclusion of red clover did not augment the gross margin compared to rotations without a cover crop, as it incurred additional expenses related to chemical control measures.

For second-year corn following soybeans, the gross margin was lower than continuous corn. Yet, using a chisel plow instead of a moldboard plow resulted in a higher gross margin for soybeans, as reported by Yin and Al-Kaisi (2004). Tillage did not impact the gross margin of wheat or first-year barley. However, in the second year of barley, the yield penalties attributed to chisel plowing led to a reduction in gross revenue. The influence of tillage on gross revenue, whether in the first or second year of alfalfa, was negligible.

5.5 Cost-Benefit Ratio

According to Mandal et al. (2014), the tomato, maize, and sunflower systems had a greater benefit/cost ratio than other crops, while the rice-fallow-rice system had the lowest returns. Bastia et al. (2008) also found that the rice-maize-cowpea and rice-maize-green gram systems had better net economic returns.

In contrast, sweet potato production is considered a valuable cash crop for poverty relief strategies in China, as it yields higher benefits than other reference crops, such as cotton, potato, maize, and Jerusalem artichoke, as reported in studies such as Yilmaz et al. (2005), Mohammadi et al. (2008), Liu et al. (2015), and Fang et al. (2018).

The size of the farm did not have a significant impact on economic benefits, according to the study. However, small-size farms (<2.0 ha) had slightly better economic benefits due to lower chemical inputs and free land rent. This finding is consistent with a study on crop production in Northern China, which showed an inverse relationship between plantation area and productivity in most small-sized farms (Zhang et al., 2021).

Wang et al. (2017) also reported that smaller farms (<6.7 ha) had better revenue based on yield-based profit in grain production. The inclusion of oilseeds, pulses, and vegetables in rice systems can potentially enhance the economic situation of small and marginal farmers by increasing productivity and improving market prices. The surge in market prices of vegetable crops due to a significant increase in demand has become a significant factor for incorporating these crops.

5.6 Conclusion

NL agricultural sector is experiencing a significant transformation in response to various economic, environmental, and political factors. A growing number of producers are adopting extended cropping systems that are considered more economically sustainable.

Various aspects related to crop production in NL were studied such as total cost of production, gross revenue, gross margin, crop yield and cost/benefit ratio. It also provides insights into the yield of different crops and their variation across years.

According to the current study (2017-2021), potatoes had the highest total cost of production among all crops grown in NL, followed by rutabagas, turnips, carrots, cabbage, strawberries, beets, raspberries, and cranberries. Production costs remained relatively consistent over the years but inclined to be higher in favorable growing conditions due to increased expenditures associated with harvesting, transporting, storing higher crop yields, and the necessity for additional weed control measures.

In terms of gross revenue, rutabagas and turnips had the highest average gross revenue, followed by potatoes, carrots, cabbage, strawberries, cranberries, blueberries, beets, and raspberries. Reflecting higher crop yields in 2021, the highest gross revenue were recorded and declined gradually across the years after the initial year.

The gross margins of the cropping systems showed a declining trend over time due to increasing operating costs and decreasing crop yields. Rutabagas and turnips had the highest gross margin, followed by cabbage, carrots, cranberries, blueberries, strawberries, potatoes, beets, and raspberries. All crops had similar cost/benefit ratios, with cranberries having the highest cost/benefit ratio and beets having the lowest. The cost/benefit ratio showed a gradual increase across the years, except for 2019, which had the lowest cost/benefit ratio.

Finally, the study also provides information on the crop yields of different crops grown in NL. Potatoes had the highest crop yield, followed by rutabagas and turnips, carrots, cabbage, cranberries, blueberries, strawberries, and raspberries. The highest crop yield was produced in 2017, and the lowest was observed in 2020. However, crop yield did not have a significant effect on yearly variation and their interaction with crops.

5.7 Future Research

Although this study sheds light on the economical feasibility of various cropping systems, but still require further exploration. The precision of the results could be improved with the addition of more data, which can be collected through ongoing trials of the cropping system.

To enhance the parametric approach of modeling yields, historical yield distributions can be compared to different simulations (i.e., normal, gamma, and beta) using goodness-of-fit tests such as Kolmogorov-Smirnov, Shapiro-Wilkes, Chi-squared and Anderson-Darling.

By extending sensitivity analysis, this approach could also provide insights into crop insurance and risk management. This study can be used to enhance effectiveness for risk-neutral farm operations, a risk-averse farmer may consider implementing system (High Intensity) to mitigate risk through crop diversification.

Future research can use computer programming to investigate risk and develop professional optimization models to understand the decision-making processes of risk-averse farmers.

The research community strongly advocates for systems experiments, and this study is one of the few long term cropping system studies in NL.

However, given the vast variations in climates, regions, markets, and cultural preferences, there are countless other potential cash crop combinations that may be more suitable. Although this study utilized a carefully constructed cropping system, and there is still much to learn from exploring alternative crop rotations.

Ultimately, this project's relevance to practical farm operations is substantial. However, extending the findings to larger commercial farms could provide additional insights into economic scale. Additionally, exploring different markets such as retail partnerships with national supermarket chains, international retailers, and food service industries could offer valuable perspectives on economic dynamics.

References

Abba, Z.Y.I., Balta-Ozkan, N. and Hart, P., (2022). A holistic risk management framework for renewable energy investments. *Renewable and Sustainable Energy Reviews*, *160*, p.112305.

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. 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 and Labrador, Canada.

Acevedo, M.F., Harvey, D.R. and Palis, F.G., (2018). Food security and the environment: Interdisciplinary research to increase productivity while exercising environmental conservation. *Global food security*, *16*, pp.127-132.

Acs, S., Hanley, N., Dallimer, M., Gaston, K. J., Robertson, P., Wilson, P., & Armsworth, P. R. (2010). The effect of decoupling on marginal agricultural systems: implications for farm incomes, land use and upland ecology. *Land use policy*, *27*(2), 550-563.

Acton, D.F. and Gregorich, L.J. (1995). The Health of Our Soils: Towards Sustainable Agriculture in Canada. Publication No. 1906/E. Centre for Land and Biological Resource Research, Ottawa, ON, Canada.

Adenle, A.A., Wedig, K. and Azadi, H., (2019). Sustainable agriculture and food security in Africa: The role of innovative technologies and international organizations. *Technology in Society*, *58*, p.101143.

Afzal, S., Mokhlis, H., Illias, H.A., Mansor, N.N. and Shareef, H., (2020). State-of-the-art review on power system resilience and assessment techniques. *IET Generation, Transmission & Distribution*, *14*(25), pp.6107-6121.

Agriculture and Agri-Food Canada (2022). An overview of the Canadian agriculture and Agri-food system (2022). Agriculture and Agri-Food Canada (AAFC), Government of Canada.

Aguilar J, Gramig GG, Hendrickson JR, Archer DW, Forcella F and Liebig MA (2015) Crop species diversity changes in the United States:1978–2012. *PLoS ONE* 10, e0136580.

Ahmadzai, H. (2017). Crop diversification and technical efficiency in Afghanistan: *Stochastic frontier analysis (No. 17/04). CREDIT Research Paper*.

Aleskerova, Y., Mulyk, T., & Fedoryshyna, L. (2018). Improving credit protection analysis methods Reports of main agricultural enterprises. *Baltic Journal of Economic Studies*, *4*(2), 1-7.

Ali, M. H., & Talukder, M. S. U. (2008). Increasing water productivity in crop production—A synthesis. *Agricultural water management*, *95*(11), 1201-1213.

Altieri, M. A., Nicholls, C. I., & Montalba, R. (2017). Technological approaches to sustainable agriculture at a crossroads: An agroecological perspective. *Sustainability*, *9*(3), 349.

Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for sustainable development*, *35*(3), 869-890.

Anderson RL (2005) Improving sustainability of cropping systems in the central Great Plains. *Journal of Sustainable Agriculture* 26, 97–114.

Andrieu, N., Sogoba, B., Zougmore, R., Howland, F., Samake, O., Bonilla-Findji, O., Lizarazo, M., Nowak, A., Dembele, C. and Corner-Dolloff, C., (2017). Prioritizing investments for climate-smart agriculture: Lessons learned from Mali. *Agricultural Systems*, *154*, pp.13-24.

Arabska, E. (2021). From farm to fork: Human health and well-being through sustainable agri-food systems. *Journal of Life Economics*, *8*(1), 11-27.

Araus, J. L., Kefauver, S. C., Zaman-Allah, M., Olsen, M. S., & Cairns, J. E. (2018). Translating high-throughput phenotyping into genetic gain. *Trends in plant science*, *23*(5), 451-466.

Awulachew, S. B. (2019). Irrigation potential in Ethiopia: Constraints and opportunities for enhancing the system. *Gates Open Res*, *3*(22), 22.

Barrios, E., Gemmill-Herren, B., Bicksler, A., Siliprandi, E., Brathwaite, R., Moller, S., Batello, C. and Tittonell, P., (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. *Ecosystems and People*, *16*(1), pp.230-247.

Bastia, D.K., Garnayak, L.M., Barik, T. (2008). Diversification of rice *(Oryza sativa)*-based cropping systems forhigher productivity, resource-use efficiency and economics. *Indian J. Agron.* 53:22–26.

Bennett, N. J. (2018). Navigating a just and inclusive path towards sustainable oceans. *Marine Policy*, *97*, 139-146.

Blesh, J., Mehrabi, Z., Wittman, H., Kerr, R.B., James, D., Madsen, S., Smith, O.M., Snapp, S., Stratton, A.E., Bakarr, M. and Bicksler, A.J., (2023). Against the odds: Network and institutional pathways enabling agricultural diversification. *One Earth*, *6*(5), pp.479-491.

Bommarco, R., Kleijn, D., & Potts, S. G. (2013). Ecological intensification: harnessing ecosystem services for food security. *Trends in ecology & evolution*, *28*(4), 230-238.

Bordeianu, G. D., & Radu, F. (2020). Basic Types of Financial Ratios Used to Measure a Company's Performance. *Economy Transdisciplinarity Cognition*, *23*(2).

Borowski, P. and Patuk, I. (2018). Proceedings: 2nd International Conference on Food and Agricultural Economics: Selected aspects of sustainable development in agriculture (No. 2315-2019-4836).

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

Brandt, S.A., Ulrich, D., Thomas, A.G., and Olfert, O.O. (2003). Alternative cropping systems in the Canadian Prairies: Effects of input level and cropping diversity on crop production. In Proceedings of the Dynamic Cropping Systems: Principles, Processes, and Challenges, Bismarck, ND, August 4–7, 2003. p. 224–228.

Browne, D. and Ryan, L., (2011). Comparative analysis of evaluation techniques for transport policies. *Environmental Impact Assessment Review*, *31*(3), pp.226-233.

Brownson, R.C., Baker, E.A., Deshpande, A.D. and Gillespie, K.N., (2017). *Evidence-based public health*. Oxford university press.

Bryan, E., Deressa, T.T., Gbetibouo, G.A. and Ringler, C., (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental science & policy*, *12*(4), pp.413-426.

Bünemann, E.K., Bongiorno, G., Bai, Z., Creamer, R.E., De Deyn, G., De Goede, R., Fleskens, L., Geissen, V., Kuyper, T.W., Mäder, P. and Pulleman, M. (2018). Soil quality–A critical review. *Soil Biology and Biochemistry*, *120*, pp.105-125.

Burgess, M., P. Miller, and C. Jones. (2012). Pulse crops improve energy intensity and productivity of cereal production in Montana, U.S.A. *J. Sust. Ag*. 36:699–718. doi:10.1080/10440046.2012.672380.

Burhenne, S., Tsvetkova, O., Jacob, D., Henze, G.P. and Wagner, A., (2013). Uncertainty quantification for combined building performance and cost-benefit analyses. *Building and Environment*, *62*, pp.143-154.

Busetto, L., Casteleyn, S., Granell, C., Pepe, M., Barbieri, M., Campos-Taberner, M., Casa, R., Collivignarelli, F., Confalonieri, R., Crema, A. and García-Haro, F.J. (2017). Downstream services for rice crop monitoring in Europe: From regional to local scale. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *10*(12), pp.5423-5441.

Bwambale, N. (2015). *Farmers' knowledge, perceptions, and socioeconomic factors influencing decision making for integrated soil fertility management practices in Masaka and Rakai districts, central Uganda* (Doctoral dissertation, Iowa State University).

Cai, Y., Judd, K.L., Lenton, T.M., Lontzek, T.S. and Narita, D. (2015). Environmental tipping points significantly affect the cost− benefit assessment of climate policies. *Proceedings of the National Academy of Sciences*, *112*(15), pp.4606-4611.

Campos, J., Serebrisky, T. and Suárez-Alemán, A. (2015). Time goes by: recent developments on the theory and practice of the discount rate. *Inter-American Development Bank*.

Canada Organic Trade Association (2019) Canada Organic Agriculture Data Report. https://www.pivotandgrow.com/wp-content/uploads/2019/05/Topic-1-COTA-Report.

Caro, D., Davis, S. J., Bastianoni, S., & Caldeira, K. (2014). Global and regional trends in greenhouse gas emissions from livestock. *Climatic change*, *126*, 203-216.

Carter, D.P., Weible, C.M., Siddiki, S.N. and Basurto, X. (2016). Integrating core concepts from the institutional analysis and development framework for the systematic analysis of policy designs: An illustration from the US National Organic Program regulation. *Journal of Theoretical Politics*, *28*(1), pp.159-185.

Chapagain, T. (2017). Farming in northern Ontario: untapped potential for the future. *Agronomy*, *7*(3), 59.

Chavas, J. P., Chambers, R. G., & Pope, R. D. (2010). Production economics and farm management: a century of contributions. *American Journal of Agricultural Economics*, *92*(2), 356-375.

Chen, L., Rejesus, R.M., Aglasan, S., Hagen, S. and Salas, W. (2023). The impact of no-till on agricultural land values in the United States Midwest. *American Journal of Agricultural Economics*, *105*(3), pp.760-783.

Chianu, J. N., Chianu, J. N., & Mairura, F. (2012). Mineral fertilizers in the farming systems of sub-Saharan Africa. A review. *Agronomy for sustainable development*, *32*, 545-566.

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

Clark, M., & Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters*, *12*(6), 064016.

Clark, W.C., Tomich, T.P., Van Noordwijk, M., Guston, D., Catacutan, D., Dickson, N.M. and McNie, E. (2016). Boundary work for sustainable development: Natural resource management at the Consultative Group on International Agricultural Research (CGIAR). *Proceedings of the National Academy of Sciences*, *113*(17), pp.4615-4622.

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.

Cook, R.J., and D.M. Weller. (2004). In defense of crop monoculture. Paper presented at: New directions for a diverse planet. Proceedings of the 4th International Crop Science Congress, Brisbane, Australia.

Copeland PJ, Allmaras RR, Crookston RK and Nelson WW. (1993). Corn-soybean rotation effects on soil water depletion. *Agronomy Journal* 85, 203–210.

Cordes, J.J. (2017). Using cost-benefit analysis and social return on investment to evaluate the impact of social enterprise: Promises, implementation, and limitations. *Evaluation and program planning*, *64*, pp.98-104.

Crookston RK, Kurle JE, Copeland PJ, Ford JH and Lueschen WE. (1991). Rotational cropping sequence affects yield of corn and soybean. *Agronomy Journal* 83, 108–113.

Crystal-Ornelas, R., Thapa, R. and Tully, K.L. (2021). Soil organic carbon is affected by organic amendments, conservation tillage, and cover cropping in organic farming systems: A meta-analysis. *Agriculture, Ecosystems & Environment*, *312*, p.107356.

Culyer, A. J., & Chalkidou, K. (2019). Economic evaluation for health investments en route to universal health coverage: cost-benefit analysis or cost-effectiveness analysis?. *Value in Health*, *22*(1), 99-103.

Cuppari, R. I., Higgins, C. W., & Characklis, G. W. (2021). Agrivoltaics and weather risk: A diversification strategy for landowners. *Applied Energy*, *291*, 116809.

Currie, T.E., Bogaard, A., Cesaretti, R., Edwards, N.R., Francois, P., Holden, P.B., Hoyer, D., Korotayev, A., Manning, J., Garcia, J.C.M. and Oyebamiji, O.K. (2015). Agricultural productivity in past societies: Toward an empirically informed model for testing cultural evolutionary hypotheses. *Cliodynamics*, *6*(1), pp.24-56.

Daneshvar, S., Kaleibar, M.M. (2010). The minimal cost-benefit ratio and maximal Cost-Benefit ratio. 2nd International Conference on Engineering System Management and Applications, *ICESMA, art.* no. 5542690.

Das, U., & Ansari, M. A. (2021). The nexus of climate change, sustainable agriculture and farm livelihood: contextualizing climate smart agriculture. *Climate Research*, *84*, 23-40.

Dawson, I.K., Park, S.E., Attwood, S.J., Jamnadass, R., Powell, W., Sunderland, T. and Carsan, S. (2019). Contributions of biodiversity to the sustainable intensification of food production. *Global Food Security*, *21*, pp.23-37.

Dayananda, B., Fernandez, M. R., Lokuruge, P., Zentner, R. P., & Schellenberg, M. P. (2021). Economic analysis of organic cropping systems under different tillage intensities and crop rotations. *Renewable Agriculture and Food Systems*, *36*(5), 509-516.

De Corato, U., De Bari, I., Viola, E. and Pugliese, M. (2018). Assessing the main opportunities of integrated biorefining from agro-bioenergy co/by-products and agro-industrial residues into high-value added products associated to some emerging markets: A review. *Renewable and Sustainable Energy Reviews*, *88*, pp.326-346.

De Giusti, G., Kristjanson, P., & Rufino, M. C. (2019). Agroforestry as a climate change mitigation practice in smallholder farming: evidence from Kenya. *Climatic Change*, *153*(3), 379-394.

Derksen, D.A., Anderson, R.L., Blackshaw, R.E., and Maxwell, B. (2002). Weed dynamics and management strategies for cropping systems in the northern Great Plains. *Agronomy Journal* 94:174–185.

DeVincentis, A.J., Solis, S.S., Bruno, E.M., Leavitt, A., Gomes, A., Rice, S. and Zaccaria, D., (2020). Using cost-benefit analysis to understand adoption of winter cover cropping in California's specialty crop systems. *Journal of environmental management*, *261*, p.110205.

Dorgbetor, I. K., Ondrasek, G., Kutnjak, H., & Mikuš, O. (2022). What If the World Went Vegan? A Review of the Impact on Natural Resources, Climate Change, and Economies. *Agriculture*, *12*(10), 1518.

Dring, C.C., Newman, L. and Wittman, H. (2023). Assessing governability of agricultural systems: Municipal agricultural planning in Metro Vancouver, Canada. *Frontiers in Sustainable Food Systems*, *6*, p.855684.

Dubbeling, M., Santini, G., Renting, H., Taguchi, M., Lançon, L., Zuluaga, J., De Paoli, L., Rodriguez, A. and Andino, V. (2017). Assessing and planning sustainable city region food systems: Insights from two Latin American cities. *Sustainability*, *9*(8), p.1455.

Duran, D. C., Gogan, L. M., Artene, A., & Duran, V. (2015). The components of sustainable development-a possible approach. *Procedia Economics and Finance*, *26*, 806-811.

Eakin, H., York, A., Aggarwal, R., Waters, S., Welch, J., Rubiños, C., Smith-Heisters, S., Bausch, C. and Anderies, J.M. (2016). Cognitive and institutional influences on farmers' adaptive capacity: insights into barriers and opportunities for transformative change in central Arizona. *Regional environmental change*, *16*, pp.801-814.

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

Esham, M., Jacobs, B., Rosairo, H. S. R., & Siddighi, B. B. (2018). Climate change and food security: a Sri Lankan perspective. *Environment, Development and Sustainability*, *20*, 1017-1036.

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

Fang, Y.R.; Liu, J.A.; Steinberger, Y.; Xie, G.H. (2018). Energy use efficiency and economic feasibility of Jerusalem artichoke production on arid and coastal saline lands. *Ind. Crops Prod.,* 117, 131–139.

Farooq, M. S., Riaz, S., Abid, A., Abid, K., & Naeem, M. A. (2019). A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming. *Ieee Access*, *7*, 156237-156271.

Fernandez MR, Zentner RP, Schellenberg MP, Leeson JY, Aladenola O, McConkey BG and St. Luce M. (2019b). Grain yield and quality of organic crops grown under reduced tillage and diversified sequences. *Agronomy Journal* 111, 793–804.

Fernández, J.E., Alcon, F., Diaz-Espejo, A., Hernandez-Santana, V. and Cuevas, M.V. (2020). Water use indicators and economic analysis for on-farm irrigation decision: A case study of a super high density olive tree orchard. *Agricultural Water Management*, *237*, p.106074.

Fernandez, M.R., R.P. Zentner, B.G. McConkey, and C.A. Campbell. (1998). Effects of crop rotation and fertilizer management on leaf spotting diseases of spring wheat in Southwestern Saskatchewan. *Can. J. Plant Sci*. 78:489-496.

Ferris, S., Robbins, P., Best, R., Seville, D., Buxton, A., Shriver, J., & Wei, E. (2014). Linking smallholder farmers to markets and the implications for extension and advisory services. *MEAS Brief*, *4*(10), 13-14.

Feuerbacher, A., Luckmann, J., Boysen, O., Zikeli, S., & Grethe, H. (2018). Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy. *PloS one*, *13*(6), e0199025.

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

Folajinmi, A. F., & Peter, A. O. (2020). Financial management practices and performance of small and medium scale poultry industry in Ogun State, Nigeria. *Journal of Finance and Accounting*, *8*(2), 90.

Food First NL (2016). Annual Report 2015–2016. http://www.foodfirstnl.ca/our-resources/2016-annual-report.

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.

Fouilleux, E., Bricas, N., & Alpha, A. (2017). 'Feeding 9 billion people': Global food security debates and the productionist trap. *Journal of European Public Policy*, *24*(11), 1658-1677.

Frison, E. A. (2016). From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems.

Gaba, S., Lescourret, F., Boudsocq, S., Enjalbert, J., Hinsinger, P., Journet, E.P., Navas, M.L., Wery, J., Louarn, G., Malézieux, E. and Pelzer, E. (2015). Multiple cropping systems as drivers for providing multiple ecosystem services: from concepts to design. *Agronomy for sustainable development*, *35*, pp.607-623.

Gadanakis, Y., Bennett, R., Park, J., & Areal, F. J. (2015). Evaluating the sustainable intensification of arable farms. *Journal of Environmental Management*, *150*, 288-298.

Gan, Y., C. Hamel, J.T. O'Donovan, H. Cutforth, R. P. Zentner. (2015). Diversifying crop rotations with pulses enhances system productivity. Scientific reports, 5. 14625.

Gan, Y.T., R.P. Zentner, C.A. Campbell, V.O. Biederbeck, F. Selles, and R. Lemke. (2002). Conserving soil and water with sustainable cropping systems: research in the semiarid Canadian prairies. Paper presentation at: 12th ISCO Conference, Beijing, China.

Garibaldi, L. A., Gemmill-Herren, B., D'Annolfo, R., Graeub, B. E., Cunningham, S. A., & Breeze, T. D. (2017). Farming approaches for greater biodiversity, livelihoods, and food security. *Trends in ecology & evolution*, *32*(1), 68-80.

Garibaldi, L. A., Pérez-Méndez, N., Garratt, M. P., Gemmill-Herren, B., Miguez, F. E., & Dicks, L. V. (2019). Policies for ecological intensification of crop production. *Trends in ecology & evolution*, *34*(4), 282-286.

Giarè, F., Borsotto, P., & Signoriello, I. (2018). Social Farming in Italy. Analysis of an «inclusive model». *Italian Review of Agricultural Economics*, *73*(3), 89-105.

Giller, K.E., Delaune, T., Silva, J.V., Descheemaeker, K., van de Ven, G., Schut, A.G., van Wijk, M., Hammond, J., Hochman, Z., Taulya, G. and Chikowo, R. (2021). The future of farming: Who will produce our food?. *Food Security*, *13*(5), pp.1073-1099.

Giller, K.E., Tittonell, P., Rufino, M.C., Van Wijk, M.T., Zingore, S., Mapfumo, P., Adjei-Nsiah, S., Herrero, M., Chikowo, R., Corbeels, M. and Rowe, E.C. (2011). Communicating complexity: integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. *Agricultural systems*, *104*(2), pp.191-203.

Government of Canada (2006). Organic production systems: General principles and management standards. CAN/CGSB-32.310–2006 http://www.oacc.info/Docs/Cdn.pdf.

Hamm Wand Hugh M (2015) Organic or conventional? You decide. The economic advantages of entering the organic grain market. http:// www.pro-cert.org/economics/assets/organic_or_conventional-you_decide_2015_by_pro-cert.pdf.

Haney, R. L., Haney, E. B., Smith, D. R., Harmel, R. D., & White, M. J. (2018). The soil health tool—Theory and initial broad-scale application. *Applied soil ecology*, *125*, 162-168.

Hartmann, M., & Six, J. (2023). Soil structure and microbiome functions in agroecosystems. *Nature Reviews Earth & Environment*, *4*(1), 4-18.

Hoang Thanh, L., Ta Nhat, L., Nguyen Dang, H., Ho, T.M.H. and Lebailly, P. (2018). One Village One Product (OVOP)—A rural development strategy and the early adaption in Vietnam, the case of Quang Ninh Province. *Sustainability*, *10*(12), p.4485.

Hoek, A. C., Malekpour, S., Raven, R., Court, E., & Byrne, E. (2021). Towards environmentally sustainable food systems: decision-making factors in sustainable food production and consumption. *Sustainable Production and Consumption*, *26*, 610-626.

Hulugalle, N.R., and F. Scott. (2008). A review of the changes in soil quality and profitability accomplished by sowing rotation crops after cotton in Australian Vertosols from 1970 to 2006. *Aust. J. Soil Res*. 46(2). doi:10.1071/SR07077.

Hundal, G.S., Laux, C.M., Buckmaster, D., Sutton, M.J. and Langemeier, M. (2023). Exploring Barriers to the Adoption of Internet of Things-Based Precision Agriculture Practices. *Agriculture*, *13*(1), p.163.

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).

Isgren, Ellinor, Elina Andersson, and Wim Carton. (2020). New perennial grains in African smallholder agriculture from a farming systems perspective. *Agronomy for Sustainable Development* 40: 1-14.

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

Jangir, C.K., Kumar, S. and Meena, R.S. (2019). Significance of soil organic matter to soil quality and evaluation of sustainability. *Sustainable agriculture. Scientific Publisher, Jodhpur*, pp.357-381.

Jeswani, H.K., Azapagic, A., Schepelmann, P. and Ritthoff, M. (2010). Options for broadening and deepening the LCA approaches. *Journal of Cleaner Production*, *18*(2), pp.120-127.

John, A. and Fielding, M. (2014). Rice production constraints and 'new'challenges for South Asian smallholders: insights into de facto research priorities. *Agriculture & Food Security*, *3*(1), pp.1-16.

Johnston, A.M., G.W. Clayton, and P.R. Miller. (2007). Introduction to pulse crop ecology in North America: impacts on environment, nitrogen cycle, soil biology, pulse adaptation and human nutrition. *Agron. J*. 99:1682-1683.

Kadigi, W.R., Ngaga, Y.M. and Kadigi, R.M. (2021). Economic viability of smallholder agroforestry and beekeeping projects in Uluguru Mountains, Tanzania: A cost benefit analysis.

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2020). Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics*, *219*, 179-194.

Kamilaris, A., Kartakoullis, A. and Prenafeta-Boldú, F.X. (2017). A review on the practice of big data analysis in agriculture. *Computers and Electronics in Agriculture*, *143*, pp.23-37.

Kanter, D.R., Musumba, M., Wood, S.L., Palm, C., Antle, J., Balvanera, P., Dale, V.H., Havlik, P., Kline, K.L., Scholes, R.J. and Thornton, P. (2018). Evaluating agricultural trade-offs in the age of sustainable development. *Agricultural Systems*, *163*, pp.73-88.

Karakus, C. B., Cerit, O., & Kavak, K. S. (2015). Determination of land use/cover changes and land use potentials of Sivas city and its surroundings using Geographical Information Systems (GIS) and Remote Sensing (RS). *Procedia Earth and Planetary Science*, *15*, 454-461.

Kassam, A., Friedrich, T., Derpsch, R., & Kienzle, J. (2015). Overview of the worldwide spread of conservation agriculture. *Field Actions Science Reports. The Journal of Field Actions*, *8*.

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., & Erenstein, O. (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land use policy*, *42*, 400-411.

Keeler, B.L., Polasky, S., Brauman, K.A., Johnson, K.A., Finlay, J.C., O'Neill, A., Kovacs, K. and Dalzell, B. (2012). Linking water quality and well-being for improved assessment and valuation of ecosystem services. *Proceedings of the National Academy of Sciences*, *109*(45), pp.18619-18624.

Keesstra, Saskia D., Johan Bouma, Jakob Wallinga, Pablo Tittonell, Pete Smith, Artemi Cerdà, Luca Montanarella. (2016). The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals. *Soil*.

Khan, M.M., Akram, M.T., Janke, R., Qadri, R.W.K., Al-Sadi, A.M. and Farooque, A.A. (2020). Urban horticulture for food secure cities through and beyond COVID-19. *Sustainability*, *12*(22), p.9592.

Kirchmann H, Bergström L, Kätterer T, Andrén O and Andersson R. (2008). Can organic crop production feed the world?. In Kirchmann H and Bergström L (eds), Organic Crop

Production - Ambitions and Limitations. Dordrecht, The Netherlands: *Springer*, pp. 39–72. https://pub.epsilon.slu. se/3514/1/Organic_Crop_Production_Chapter3_2008.pdf.

Klonsky K (2012) Comparison of production costs and resource use for organic and conventional 352 production systems. *American Journal of Agricultural Economics* 94, 314–321.

Koohafkan, P., Altieri, M. A., & Gimenez, E. H. (2012). Green agriculture: foundations for biodiverse, resilient and productive agricultural systems. *International Journal of Agricultural Sustainability*, *10*(1), 61-75.

Kouvelis, P., Dong, L., Boyabatli, O., & Li, R. (2011). *Handbook of integrated risk management in global supply chains*. John Wiley & Sons.

Kozai, T., & Niu, G. (2020). Role of the plant factory with artificial lighting (PFAL) in urban areas. In *Plant Factory* (pp. 7-34). Academic Press.

Kraly, P., Weitzman, J., & Filgueira, R. (2022). Understanding factors influencing social acceptability: Insights from media portrayal of salmon aquaculture in Atlantic Canada. *Aquaculture*, *547*, 737497.

Kremen, C. and Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming systems: Benefits, externalities, and trade-offs. Ecol. Soc. 17(4). http://www.ecologyandsociety.org/vol17/iss4/art40/ [2013 Mar. 19].

Kremen, Claire, Alastair Iles, and Christopher Bacon (2012). Diversified farming systems: an agroecological, systems-based alternative to modern industrial agriculture. *Ecology and society* 17, no. 4.

Krishnan, A. (2018). The origin and expansion of regional value chains: The case of Kenyan horticulture. *Global Networks*, *18*(2), 238-263.

Kröbel, R., Stephens, E.C., Gorzelak, M.A., Thivierge, M.N., Akhter, F., Nyiraneza, J., Singer, S.D., Geddes, C.M., Glenn, A.J., Devillers, N. and Alemu, A.W. (2021). Making farming more sustainable by helping farmers to decide rather than telling them what to do. *Environmental Research Letters*, *16*(5), p.055033.

Kruseman, G., Bairagi, S., Komarek, A.M., Molero Milan, A., Nedumaran, S., Petsakos, A., Prager, S. and Yigezu, Y.A. (2020). CGIAR modeling approaches for resource-constrained scenarios: II. Models for analyzing socioeconomic factors to improve policy recommendations. *Crop Science*, *60*(2), pp.568-581.

Kull, D., Mechler, R., & Hochrainer-Stigler, S. (2013). Probabilistic cost-benefit analysis of disaster risk management in a development context. *Disasters*, *37*(3), 374-400.

Kumar, S., Meena, R.S., Datta, R., Verma, S.K., Yadav, G.S., Pradhan, G., Molaei, A., Rahman, G.M. and Mashuk, H.A. (2020). Legumes for carbon and nitrogen cycling: an organic approach. *Carbon and nitrogen cycling in soil*, pp.337-375.

Laamrani, A., Voroney, P. R., Gillespie, A. W., & Chehbouni, A. (2021). Development of a land use carbon inventory for agricultural soils in the Canadian province of Ontario. *Land*, *10*(7), 765.

Lancaster, N. A., & Torres, A. P. (2019). Investigating the drivers of farm diversification among US fruit and vegetable operations. *Sustainability*, *11*(12), 3380.

Lazarus WF (2015) Machinery Cost Estimates. St. Paul, MN: University of Minnesota Extension.

Lemaire, G., Gastal, F., Franzluebbers, A., & Chabbi, A. (2015). Grassland–cropping rotations: an avenue for agricultural diversification to reconcile high production with environmental quality. *Environmental management*, *56*, 1065-1077.

Levidow, L., Zaccaria, D., Maia, R., Vivas, E., Todorovic, M., & Scardigno, A. (2014). Improving water-efficient irrigation: Prospects and difficulties of innovative practices. *Agricultural Water Management*, *146*, 84-94.

Levin, B. (2022). Regenerative Agriculture as Biodiversity Islands. In *Biodiversity Islands: Strategies for Conservation in Human-Dominated Environments* (pp. 61-88). Cham: Springer International Publishing.

Ling, N., Zhu, C., Xue, C., Chen, H., Duan, Y., Peng, C., Guo, S. and Shen, Q. (2016). Insight into how organic amendments can shape the soil microbiome in long-term field experiments as revealed by network analysis. *Soil Biology and Biochemistry*, *99*, pp.137-149.

Linn, T. and Maenhout, B. (2019). Measuring the efficiency of rice production in Myanmar using data envelopment analysis. *Asian Journal of Agriculture and Development*, *16*(1362-2019-4201), pp.1-24.

Linquist, B.A., M.M. Anders, M.A.A. Adviento-Borbe, R.L. Chaney, L.L. Nalley, et al. (2015). Reducing greenhouse gas emissions, water use, and grain arsenic levels in rice systems. Glob. Change Biol. 21:407-417. doi:10.1111/gcb.12701.

Liu, H.; Ren, L.; Spiertz, H.; Zhu, Y.; Xie, G.H. (2015). An economic analysis of sweet sorghum cultivation for ethanol production in North China. GCB Bioenergy 7, 1176–1184.

Liu, T., Bruins, R. J., & Heberling, M. T. (2018). Factors influencing farmers' adoption of best management practices: A review and synthesis. *Sustainability*, *10*(2), 432.

Liu, X., Li, X., Tan, Z., & Chen, Y. (2011). Zoning farmland protection under spatial constraints by integrating remote sensing, GIS and artificial immune systems. *International Journal of Geographical Information Science*, *25*(11), 1829-1848.

Lund MG, Carter PR and Op linger ES (1993) Tillage and crop rotation affect corn, soybean, and winter wheat yields. *Journal of Production Agriculture* 6,207–213.

Magli, F., Nobolo, A., & Ogliari, M. (2018). The effects on financial leverage and performance: The IFRS 16. *International Business Research*, *11*(8), 76-89.

Magrini, M.B., Anton, M., Cholez, C., Corre-Hellou, G., Duc, G., Jeuffroy, M.H., Meynard, J.M., Pelzer, E., Voisin, A.S. and Walrand, S. (2016). Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. *Ecological Economics*, *126*, pp.152-162.

Makate, C., Wang, R., Makate, M., & Mango, N. (2016). Crop diversification and livelihoods of smallholder farmers in Zimbabwe: adaptive management for environmental change. *SpringerPlus*, *5*, 1-18.

Mandal, K. G., Kannan, K., Thakur, A. K., Kundu, D. K., Brahmanand, P. S., & Kumar, A. (2014). Performance of rice systems, irrigation and organic carbon storage. *Cereal Research Communications*, *42*(2), 346-358.

Manjunatha, A. V., Anik, A. R., Speelman, S., & Nuppenau, E. A. (2013). Impact of land fragmentation, farm size, land ownership and crop diversity on profit and efficiency of irrigated farms in India. *Land use policy*, *31*, 397-405.

Mankad, A. (2016). Psychological influences on biosecurity control and farmer decision-making. A review. *Agronomy for sustainable development*, *36*(2), 40.

Marchetti, L., Cattivelli, V., Cocozza, C., Salbitano, F., & Marchetti, M. (2020). Beyond sustainability in food systems: Perspectives from agroecology and social innovation. *Sustainability*, *12*(18), 7524.

Markets, R. (2008). Inclusive business in agrifood markets: evidence and action. In *A report based on proceedings of an international conference held in Beijing March* (pp. 5-6).

Martens, J.T., M.H. Entz, and M.D. Wonneck. (2013). Ecological farming systems on the Canadian prairies: a path to profitability, sustainability and resilience. http://www.umanitoba.ca/outreach/naturalagriculture/articles/ecological-farm-systems_dec2013.pdf.

McConkey, B.G., Campbell, C.A., Zentner, R.P., Dyck, F.B. and Selles, F. (1996). Long-term tillage effects on spring wheat production on three soil textures in the Brown soil zone. *Canadian Journal of Plant Science* 76:747–756.

McCord, P. F., Cox, M., Schmitt-Harsh, M., & Evans, T. (2015). Crop diversification as a smallholder livelihood strategy within semi-arid agricultural systems near Mount Kenya. *Land use policy*, *42*, 738-750.

McFadden, J. R., Rosburg, A., & Njuki, E. (2022). Information inputs and technical efficiency in midwest corn production: evidence from farmers' use of yield and soil maps. *American Journal of Agricultural Economics*, *104*(2), 589-612.

McLennon, E., Dari, B., Jha, G., Sihi, D., & Kankarla, V. (2021). Regenerative agriculture and integrative permaculture for sustainable and technology driven global food production and security. *Agronomy Journal*, *113*(6), 4541-4559.

Mechler, R. (2016). Reviewing estimates of the economic efficiency of disaster risk management: opportunities and limitations of using risk-based cost–benefit analysis. *Natural Hazards*, *81*, 2121-2147.

Merga, B., & Haji, J. (2019). Factors impeding effective crop production in Ethiopia. *Journal of Agricultural Science*, *11*(10), 1-14.

Meuwissen, M.P., Feindt, P.H., Spiegel, A., Termeer, C.J., Mathijs, E., De Mey, Y., Finger, R., Balmann, A., Wauters, E., Urquhart, J. and Vigani, M. (2019). A framework to assess the resilience of farming systems. *Agricultural Systems*, *176*, p.102656.

Miller PR, Waddington J, McDonald CL and Derksen DA (2002). Cropping sequence affects wheat productivity on the semiarid northern Great Plains. *Canadian Journal of Plant Science* 82, 307–318.

Miller, P.R., McDonald, C.L., Derksen, D.A., and Waddington, J. (2001). The adaptation of seven broadleaf crops to the dry semiarid prairie. Canadian Journal of Plant Science 81:29–43.

Miller, P.R., R.E. Engel, and J.A. Holmes. (2006). Cropping sequence effect of pea and pea management on spring wheat in the Northern Great Plains. *Agron. J*. 98:1610-1619.

Mithiya, D., Mandal, K., & Datta, L. (2018). Trend, pattern and determinants of crop diversification of small holders in West Bengal: A district-wise panel data analysis. *Journal of Development and Agricultural Economics*, *10*(4), 110-119.

Mohammadi, A., Tabatabaeefar. A., Shahin. S, Rafiee. S, Keyhani. A. (2008). Energy use and economical analysis of potato production in Iran a case study: Ardabil province. *Energy Convers. Manag*. 49, 3566–3570.

Molden, David, Theib Y. Oweis, Steduto Pasquale, Jacob W. Kijne, Munir A. Hanjra, Prem S. Bindraban, Bas AM Bouman, Henry F. Mahoo, Paula Silva, and Ashutosh Upadhyaya (2007). Pathways for increasing agricultural water productivity.

Molin, P. G., Gergel, S. E., Soares-Filho, B. S., & Ferraz, S. F. (2017). Spatial determinants of Atlantic Forest loss and recovery in Brazil. *Landscape Ecology*, *32*, 857-870.

Mousavi, Shabnam, and Gerd Gigerenzer (2014). "Risk, uncertainty, and heuristics." *Journal of Business Research* 67, no. 8: 1671-1678.

Mozumdar, L. (2012). Agricultural productivity and food security in the developing world. *Bangladesh Journal of Agricultural Economics*, *35*(454-2016-36350), 53-69.

Mugwe, J., Ngetich, F., & Otieno, E. O. (2019). Integrated soil fertility management in sub-Saharan Africa: Evolving paradigms toward integration. *Zero Hunger. Cham: Springer International Publishing*, 1-12.

Munir, M., Baumbach, S., Gu, Y., Dengel, A., & Ahmed, S. (2018). Data analytics: industrial perspective & solutions for streaming data. In *Data Mining in Time Series and Streaming Databases* (pp. 144-168).

Mutenje, M.J., Farnworth, C.R., Stirling, C., Thierfelder, C., Mupangwa, W. and Nyagumbo, I., (2019). A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics*, *163*, pp.126-137.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and sustainable development*, *6*(5).

Nicholls, C. I., Altieri, M. A., & Vazquez, L. (2017). Agroecological principles for the conversion of farming systems. In *Agroecological Practices For Sustainable Agriculture: Principles, Applications, And Making The Transition* (pp. 1-18).

Norris, C. E., & Congreves, K. A. (2018). Alternative management practices improve soil health indices in intensive vegetable cropping systems: a review. *Frontiers in Environmental Science*, *6*, 50.

Norton, G. W., & Alwang, J. (2020). Changes in agricultural extension and implications for farmer adoption of new practices. *Applied Economic Perspectives and Policy*, *42*(1), 8-20.

Ntinyari, W., & Gweyi-Onyango, J. P. (2021). Greenhouse gases emissions in agricultural systems and climate change effects in Sub-Saharan Africa. In *African handbook of climate change adaptation* (pp. 1081-1105). Cham: Springer International Publishing.

Ochs, C., Neis, B., Cullen, K., & McGuinness, E. J. (2021). Occupational safety and health in marine aquaculture in Atlantic Canada: What can be learned from an analysis of provincial occupational injury compensation claims data?. *Aquaculture*, *540*, 736680.

Olmstead, S.M. (2010). The economics of water quality. *Review of Environmental Economics and Policy*.

O'Mahony, T. (2021). Cost-Benefit Analysis and the environment: The time horizon is of the essence. *Environmental Impact Assessment Review*, *89*, 106587.

Ostapenko R, Herasymenko Y, Nitsenko V, Koliadenko S, Balezentis T and Streimikiene D (2020) Analysis of production and sales of organic products in Ukrainian agricultural enterprises. *Sustainability* 12, 3416.

Panhwar, Q.A., Ali, A., Naher, U.A. and Memon, M.Y. (2019). Fertilizer management strategies for enhancing nutrient use efficiency and sustainable wheat production. In *Organic farming* (pp. 17-39). Woodhead Publishing.

Paracchini, M.L., Justes, E., Wezel, A., Zingari, P.C., Kahane, R., Madsen, S., Scopel, E., Hérault, A., Bhérer-Breton, P., Buckley, R. and Colbert, E. (2020). Agroecological practices supporting food production and reducing food insecurity in developing countries. A study on scientific literature in 17 countries.

Parvez, A. M., Lewis, J. D., & Afzal, M. T. (2021). Potential of industrial hemp (Cannabis sativa L.) for bioenergy production in Canada: Status, challenges and outlook. *Renewable and Sustainable Energy Reviews*, *141*, 110784.

PCC (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).

Petersen-Rockney, M., Baur, P., Guzman, A., Bender, S.F., Calo, A., Castillo, F., De Master, K., Dumont, A., Esquivel, K., Kremen, C. and LaChance, J. (2021). Narrow and brittle or broad and nimble? Comparing adaptive capacity in simplifying and diversifying farming systems. *Frontiers in Sustainable Food Systems*, *5*, p.564900.

Peterson, G. E. (2009). *Unlocking land values to finance urban infrastructure* (Vol. 7). World Bank Publications.

Plastina, A., Liu, F., Miguez, F., & Carlson, S. (2020). Cover crops use in Midwestern US agriculture: perceived benefits and net returns. *Renewable Agriculture and Food Systems*, *35*(1), 38-48.

Pogutz, S., & Winn, M. I. (2016). Cultivating ecological knowledge for corporate sustainability: Barilla's innovative approach to sustainable farming. *Business Strategy and the Environment*, *25*(6), 435-448.

Polsky JY, Garriguet D. Household food insecurity in Canada early in the COVID-19 pandemic. Health Rep. 2022;33(2):15-26. https://doi.org/10.25318/82-003-x202200200002-eng

Population Reference Bureau (2022). World population data sheet. Retrieved from: http://www.prb.org/Publications/Datasheets/2017/2017-world-population-datasheet. Aspx.

Porter, P.M., J.G. Lauer, W.E. Lueschen, J.H. Ford, T.R. Hoverstad, E.S. Oplinger, and R.K. Crookston. 1997. Environment affects the corn and soybean rotation effect. Agron. J. 89:442–448.

Postel, S. L., & Thompson Jr, B. H. (2005). Watershed protection: Capturing the benefits of nature's water supply services. In *Natural Resources Forum* (Vol. 29, No. 2, pp. 98-108). Oxford, UK: Blackwell Publishing, Ltd.

Prager, K., & Freese, J. (2009). Stakeholder involvement in agri-environmental policy making–learning from a local-and a state-level approach in Germany. *Journal of environmental management*, *90*(2), 1154-1167.

Pretty, J., & Bharucha, Z. P. (2014). Sustainable intensification in agricultural systems. *Annals of botany*, *114*(8), 1571-1596.

Pretty, J., Benton, T.G., Bharucha, Z.P., Dicks, L.V., Flora, C.B., Godfray, H.C.J., Goulson, D., Hartley, S., Lampkin, N., Morris, C. and Pierzynski, G. (2018). Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability*, *1*(8), pp.441-446.

Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Ranjan, P. and Singh, A.S. (2019). Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature. *Journal of Soil and Water Conservation*, *74*(5), pp.520-534.

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.

Rao, I.M., Peters, M., Castro, A., Schultze-Kraft, R., White, D., Fisher, M., Miles, J.W., Lascano Aguilar, C.E., Blümmel, M., Bungenstab, D.J. and Tapasco, J. (2015). LivestockPlus: The sustainable intensification of forage-based agricultural systems to improve livelihoods and ecosystem services in the tropics. *CIAT Publication*.

Richard, B., Qi, A., & Fitt, B. D. (2022). Control of crop diseases through Integrated Crop Management to deliver climate-smart farming systems for low-and high-input crop production. *Plant Pathology*, *71*(1), 187-206.

Robert, M., Thomas, A., & Bergez, J. E. (2016). Processes of adaptation in farm decision-making models. A review. *Agronomy for sustainable development*, *36*, 1-15.

Rodriguez, C., Carlsson, G., Englund, J. E., Flöhr, A., Pelzer, E., Jeuffroy, M. H., ... & Jensen, E. S. (2020). Grain legume-cereal intercropping enhances the use of soil-derived and biologically fixed nitrogen in temperate agroecosystems. A meta-analysis. *European Journal of Agronomy*, *118*, 126077.

Rotz, S., Gravely, E., Mosby, I., Duncan, E., Finnis, E., Horgan, M., LeBlanc, J., Martin, R., Neufeld, H.T., Nixon, A. and Pant, L. (2019). Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities. *Journal of Rural Studies*, *68*, pp.112-122.

Rouillard, J. (2022). *Water Resources Allocation and Agriculture: Transitioning from open to regulated access*. IWA Publishing.

Saayman, M., van der Merwe, P. and Saayman, A. (2018). The economic impact of trophy hunting in the South African wildlife industry. *Global Ecology and Conservation*, *16*, p.e00510.

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

Sagar, B.M. and Cauvery, N.K. (2018). Agriculture data analytics in crop yield estimation: a critical review. *Indonesian Journal of Electrical Engineering and Computer Science*, *12*(3), pp.1087-1093.

Sarkar, S., Parihar, S. M., & Dutta, A. (2016). Fuzzy risk assessment modelling of East Kolkata Wetland Area: A remote sensing and GIS based approach. *Environmental modelling & software*, *75*, 105-118.

Sarri, D., Lombardo, S., Pagliai, A., Perna, C., Lisci, R., De Pascale, V., Rimediotti, M., Cencini, G. and Vieri, M. (2020). Smart farming introduction in wine farms: A systematic review and a new proposal. *Sustainability*, *12*(17), p.7191.

Saskatchewan Pulse Growers. (2017). A pulse crop for every acre of Saskatchewan – pulse research. https://saskpulse.com/resources/magazine/pulse-research/articles/a-pulse-crop-for-every-acre-of-saskatchewan/.

Schaller, L., Targetti, S., Villanueva, A.J., Zasada, I., Kantelhardt, J., Arriaza, M., Bal, T., Fedrigotti, V.B., Giray, F.H., Häfner, K. and Majewski, E. (2018). Agricultural landscapes, ecosystem services and regional competitiveness—Assessing drivers and mechanisms in nine European case study areas. *Land use policy*, *76*, pp.735-745.

Schuhbauer, A. and Sumaila, U.R. (2016). Economic viability and small-scale fisheries—A review. *Ecological Economics*, *124*, pp.69-75.

Sefeedpari, P., Vellinga, T., Rafiee, S., Sharifi, M., Shine, P. and Pishgar-Komleh, S.H. (2019). Technical, environmental and cost-benefit assessment of manure management chain: A case study of large scale dairy farming. *Journal of cleaner production*, *233*, pp.857-868.

Sekaran, U., Lai, L., Ussiri, D. A., Kumar, S., & Clay, S. (2021). Role of integrated crop-livestock systems in improving agriculture production and addressing food security–A review. *Journal of Agriculture and Food Research*, *5*, 100190.

Shah, K. K., Modi, B., Pandey, H. P., Subedi, A., Aryal, G., Pandey, M., & Shrestha, J. (2021). Diversified crop rotation: an approach for sustainable agriculture production. *Advances in Agriculture*, 1-9.

Shreve, C.M. and Kelman, I. (2014). Does mitigation save? Reviewing cost-benefit analyses of disaster risk reduction. *International journal of disaster risk reduction*, *10*, pp.213-235.

Si, R., Yao, Y., Zhang, X., Lu, Q. and Aziz, N. (2022). Exploring the Role of Contiguous Farmland Cultivation and Adoption of No-Tillage Technology in Improving Transferees' Income Structure: Evidence from China. *Land*, *11*(4), p.570.

Singer JW and Cox WJ. (1998). Agronomics of corn production under different crop rotations in New York. Journal of Production Agriculture11, 462–468.

Singh, B., & Ryan, J. (2015). Managing fertilizers to enhance soil health. *International Fertilizer Industry Association, Paris, France*, *1*.

Smith, E. G., Zentner, R. P., Campbell, C. A., Lemke, R., & Brandt, K. (2017). Long-term crop rotation effects on production, grain quality, profitability, and risk in the northern great plains. *Agronomy Journal*, *109*(3), 957-967.

Smith, E.G., Clapperton, M.J., and Blackshaw, R.E. (2004). Profitability and risk of organic production systems in the northern Great Plains. *Renewable Agriculture and Food Systems* 19:152–158

Smith, E.G., H.H. Janzen, and F.J. Larney. (2015). Long-term cropping system impact on quality and productivity of a Dark Brown Chernozem in Southern Alberta. *Can. J. Soil Sci.* 95(2):177-186. doi:10.4141/cjss-2014-104.

Söderqvist, T., Nathaniel, H., Franzén, D., Franzén, F., Hasselström, L., Gröndahl, F., Sinha, R., Stadmark, J., Strand, Å., Ingmansson, I. and Lingegård, S. (2021). Cost–benefit analysis of beach-cast harvest: Closing land-marine nutrient loops in the Baltic Sea region. *Ambio*, pp.1-12.

Srinivasarao, C., Rakesh, S., Kumar, G. R., Manasa, R., Somashekar, G., Lakshmi, C. S., & Kundu, S. (2021). Soil degradation challenges for sustainable agriculture in tropical India. *Current Science*, *120*(3), 492.

Ssebunya, B. R., Schader, C., Baumgart, L., Landert, J., Altenbuchner, C., Schmid, E., & Stolze, M. (2019). Sustainability performance of certified and non-certified smallholder coffee farms in Uganda. *Ecological economics*, *156*, 35-47.

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 (2022). 2021 Census of agriculture. Farm and farm operator data. Statistics of Canada, Government of Canada. https://doi.org/10.25318/3210015301-eng

Statistics Canada (2022). Canadian Agriculture: Evaluation and Innovation. https://www150.statcan.gc.ca/n1/pub/11-631-x/11-631-x2017006-eng.html.

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). Newfoundland and Labrador Cattle inventory on farms, Census of Agriculture, 2011 and 2016. Statistics Canada https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210042401&pickMembers%5B0%5D=1.2&cubeTimeFrame.startYear=2011&cubeTimeFrame.endYear=2016&referencePeriods=20110101%2C20160101.

Stuart, D., & Gillon, S. (2013). Scaling up to address new challenges to conservation on US farmland. *Land Use Policy*, *31*, 223-236.

Stubenrauch, J., Garske, B., Ekardt, F., & Hagemann, K. (2022). European Forest Governance: Status Quo and Optimising Options with Regard to the Paris Climate Target. *Sustainability*, *14*(7), 4365.

Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., des Ios Rios, I., Rivera, M., Chebach, T. and Ashkenazy, A. (2018). Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. *Journal of Rural Studies*, *59*, pp.232-241.

Swenson A and Haugen R (2015). Projected 2016 Crop Budgets: South West North Dakota, EC1552. Fargo, ND: North Dakota State University Extension Service.

Tadesse, M. A., Shiferaw, B. A., & Erenstein, O. (2015). Weather index insurance for managing drought risk in smallholder agriculture: lessons and policy implications for sub-Saharan Africa. *Agricultural and Food Economics*, *3*, 1-21.

Tamburini, G., Bommarco, R., Wanger, T. C., Kremen, C., Van Der Heijden, M. G., Liebman, M., & Hallin, S. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. *Science advances*, *6*(45), eaba1715.

Tanaka DL, Krupinsky JM, Liebig MA, Merrill SD, Ries RE, Hendrickson JR, Johnson HA and Hanson JD (2002). Dynamic cropping systems: an adaptable approach to crop production in the Great Plains. *Agronomy Journal* 94, 957–961.

Tantalaki, N., Souravlas, S., & Roumeliotis, M. (2019). Data-driven decision making in precision agriculture: The rise of big data in agricultural systems. *Journal of Agricultural & Food Information*, *20*(4), 344-380.

Teklewold, H., Kassie, M. and Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of agricultural economics*, *64*(3), pp.597-623.

Thomas, V., and P. Kevan, (1993). Basic principles of agroecology and sustainable agriculture. *J. Agric. Environ*. Ethics. 6(1):1-19.

Tittonell, P., & Giller, K. E. (2013). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*, *143*, 76-90.

Toma, P., Miglietta, P.P., Zurlini, G., Valente, D. and Petrosillo, I. (2017). A non-parametric bootstrap-data envelopment analysis approach for environmental policy planning and management of agricultural efficiency in EU countries. *Ecological indicators*, *83*, pp.132-143.

Toor, G. S., Yang, Y. Y., Das, S., Dorsey, S., & Felton, G. (2021). Soil health in agricultural ecosystems: current status and future perspectives. *Advances in Agronomy*, *168*, 157-201.

Tourte, L., R.F. Smith, K.M. Klonsky, and R.L. De Moura. (2009). Sample costs to produce organic leaf lettuce. University of California Cooperative Extension. http://coststudies.ucdavis.edu/files/lettuceleaforganiccc09.pdf.

Tully, K., & Ryals, R. (2017). Nutrient cycling in agroecosystems: Balancing food and environmental objectives. *Agroecology and Sustainable Food Systems*, *41*(7), 761-798.

U.S. Department of Agriculture Economic Research Service (2008). Certified organic and total U.S. acreage, selected crops and livestock, 1995-2005. http://www.ers.usda.gov/Data/organic/Data/certified%20and%20total%20us%20acreage%20selected%20crops%20livestock%2095-05.xls.

Ullah, R., Shivakoti, G. P., Zulfiqar, F., & Kamran, M. A. (2016). Farm risks and uncertainties: Sources, impacts and management. *Outlook on Agriculture*, *45*(3), 199-205.

Unc, Adrian, Daniel Altdorff, Evgeny Abakumov, Sina Adl, Snorri Baldursson, Michel Bechtold, Douglas J. Cattani (2021). Expansion of agriculture in northern cold-climate regions: a cross-sectoral perspective on opportunities and challenges. *Frontiers in Sustainable Food Systems* 5: 663448.

Valencia, V., Wittman, H., & Blesh, J. (2019). Structuring markets for resilient farming systems. *Agronomy for Sustainable Development*, *39*, 1-14.

Valenti, W. C., Kimpara, J. M., Preto, B. D. L., & Moraes-Valenti, P. (2018). Indicators of sustainability to assess aquaculture systems. *Ecological indicators*, *88*, 402-413.

Valin, H., R.D. Sands, D. van der Mensbrugghe, G.C. Nelson, H. Ahamad. (2014). The future of food demand: understanding differences in global economic models. *Agric. Econ*., 45:51-67. doi:10.1111/agec.12089.

Van Etten, J., Beza, E., Calderer, L., Van Duijvendijk, K., Fadda, C., Fantahun, B., Kidane, Y.G., Van de Gevel, J., Gupta, A., Mengistu, D.K. and Kiambi, D.A.N. (2019). First experiences with a novel farmer citizen science approach: crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (tricot). *Experimental Agriculture*, *55*(S1), pp.275-296.

Van Huellen, S., & Abubakar, F. M. (2021). Potential for upgrading in financialised agri-food chains: the Case of Ghanaian Cocoa. *The European journal of development research*, *33*, 227-252.

Vazquez, C., de Goede, R. G., Rutgers, M., de Koeijer, T. J., & Creamer, R. E. (2021). Assessing multifunctionality of agricultural soils: Reducing the biodiversity trade-off. *European Journal of Soil Science*, *72*(4), 1624-1639.

Velasco-Muñoz, J. F., Mendoza, J. M. F., Aznar-Sánchez, J. A., & Gallego-Schmid, A. (2021). Circular economy implementation in the agricultural sector: Definition, strategies and indicators. *Resources, Conservation and Recycling*, *170*, 105618.

Vogt-Schilb, A., & Hallegatte, S. (2017). Climate policies and nationally determined contributions: reconciling the needed ambition with the political economy. *Wiley Interdisciplinary Reviews: Energy and Environment*, *6*(6), e256.

Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F., & Verbruggen, A. (2014). Sustainability assessment and indicators: Tools in a decision-making strategy for sustainable development. *Sustainability*, *6*(9), 5512-5534.

Wade T, Claasen R and Wallander S (2015) Conservation-practice Adoption Rates Vary Widely by Crop and Region. EIB-147.

Walter, S., Boden, B., Gunter, K., Paul, B., Lukas, F., & Lea, H. (2022). Analyze the relationship among information technology, precision agriculture, and sustainability. *Journal of Commercial Biotechnology*, *27*(3).

Wang, X.; Chen, Y.; Sui, P.; Yan, P.; Yang, X.; Gao, W. (2017). Preliminary analysis on economic and environmental consequences of grain production on different farm sizes in North China Plain. *Agric. Syst*. 153, 181–189.

Watkiss, P., Hunt, A., Blyth, W. and Dyszynski, J., (2015). The use of new economic decision support tools for adaptation assessment: A review of methods and applications, towards guidance on applicability. *Climatic Change*, *132*, pp.401-416.

Wei, L., & Gao, F. (2017). Social media, social integration and subjective well-being among new urban migrants in China. *Telematics and Informatics*, *34*(3), 786-796.

Weil, R.R., and W.C. Brady. (2017a). The soil around us. In: R.R. Weil and W.C. Brady, editors, The nature and properties of soils, 15th ed. Pearson Education, Essex, England. p. 20-48.

West TD, Grifith DR, Steinhardt GC, Kladivko EJ and Parsons SD. (1996). Effect of tillage and rotation on agronomic performance of corn and soybean: twenty-year study on dark silty clay loam soil. *Journal of Production Agriculture* 9, 241–248.

Wezel, A., Casagrande, M., Celette, F., Vian, J. F., Ferrer, A., & Peigné, J. (2014). Agroecological practices for sustainable agriculture. A review. *Agronomy for sustainable development*, *34*(1), 1-20.

Willer H and Lernoud J. (2019). The world of organic agriculture: statistics and emerging trends 2019, edited by Helga Willer and Julia Lernoud. Research Institute of Organic

Agriculture (FiBL), Frick, and IFOAM – Organics International, Bonn. Available at: https://shop.fibl.org/chen/mwdownloads/download/link/id/1202.

Williams, L.L. (2012). *Evaluating the long-term sustainability of LOGIC: The student organic garden at Southern Illinois University Carbondale*. Southern Illinois University at Carbondale.

Williams, P. A., Crespo, O., & Abu, M. (2019). Adapting to changing climate through improving adaptive capacity at the local level–The case of smallholder horticultural producers in Ghana. *Climate Risk Management*, *23*, 124-135.

Wilson, T. J., Cooley, S. R., Tai, T. C., Cheung, W. W., & Tyedmers, P. H. (2020). Potential socioeconomic impacts from ocean acidification and climate change effects on Atlantic Canadian fisheries. *PLoS One*, *15*(1), e0226544.

Wulder, M.A., White, J.C., Goward, S.N., Masek, J.G., Irons, J.R., Herold, M., Cohen, W.B., Loveland, T.R. and Woodcock, C.E. (2008). Landsat continuity: Issues and opportunities for land cover monitoring. *Remote Sensing of Environment*, *112*(3), pp.955-969.

Xi, L., Zhang, M., Zhang, L., Lew, T. T., & Lam, Y. M. (2022). Novel materials for urban farming. *Advanced Materials*, *34*(25), 2105009.

Yilmaz, I.; Akcaoz, H.; Ozkan, B. (2005). An analysis of energy use and input costs for cotton production in Turkey. *Renew. Energy*, 30, 145–155.

Yin, X., and M.M. Al-Kaisi. (2004). Periodic response of soybean yields and economic returns to long-term no-tillage. *Agron. J.* 96:723–733.

Yu, T., Mahe, L., Li, Y., Wei, X., Deng, X., & Zhang, D. (2022). Benefits of crop rotation on climate resilience and its prospects in China. *Agronomy*, *12*(2), 436.

Zentner RP, Basnyat P, Brandt SA, Thomas AG, Ulrich D, Campbell CA, Nagy CN, Frick B, Lemke R, Malhi SS, Olfert OO and Fernandez MR. (2011b). Effects of input management and crop diversity on economic returns and riskiness of cropping systems in the semi-arid Canadian Prairie. *Renewable Agriculture and Food Systems* 26, 208–223.

Zentner, R. P., Basnyat, P., Brandt, S. A., Thomas, A. G., Ulrich, D., Campbell, C. A., ... & Fernandez, M. R. (2011). Effects of input management and crop diversity on non-renewable energy use efficiency of cropping systems in the Canadian Prairie. *European journal of agronomy*, *34*(2), 113-123.

Zentner, R.P., G.P. Lafond, D.A. Derksen, C.N. Nagy, D.D. Wall, and W.E. May. (2004). Effects of tillage method and crop rotation on non renewable energy use efficiency for a thin Black Chernozem in the Canadian prairies. *Soil Tillage Res*. 77:125-136.

Zentner, R.P., Lafond, G.P., Derksen, D.A., and Campbell, C.A. (2002). Tillage method and crop diversification: Effect on economic returns and riskiness of cropping systems in a Thin Black Chernozem of the Canadian Prairies. *Soil and Tillage Research* 67:9–21.

Zhang, W.; Qian, C.; Carlson, K.M.; Ge, X.; Wang, X.; Chen, X. (2021). Increasing farm size to improve energy use efficiency and sustainability in maize production. *Food Energy Secur*., 10, e271.

Zollinger R, Christoffers M, Dalley C, Endres G, Gramig G, Howatt K, Jenks B, Lym R, Ostlie M, Peters T, Robinson A, Thostenson A and Valenti H. (2016) North Dakota Weed Control Guide, W-253. Fargo, ND: North Dakota State University Extension Service.

Zorn, A., Esteves, M., Baur, I., & Lips, M. (2018). Financial ratios as indicators of economic sustainability: A quantitative analysis for Swiss dairy farms. *Sustainability*, *10*(8), 2942.

Appendices

Appendix I.

Cost of Production (CAD) for Total Area (Acre) for Each Crop						
Serial No.	Crops	Years				
		2017	2018	2019	2020	2021
1	Beets	185338	105915	134059	160154	219110
2	Cabbage	344663	391887	417498	436419	610712
3	Carrots	620035	600187	624332	564542	769217
4	Rutabagas and turnips	601535	568413	631992	720692	806513
5	Blueberries	152121	119546	183442	81397	90772
6	Cranberries	116114	91721	63895	50158	51146
7	Raspberries	44207	51447	52599	48283	49235
8	Strawberries	234111	296563	314081	308296	391602
9	Potato	998038	1252205	1228522	1237840	1416353

Source: Statistics Canada (2017-2021)

Appendix II.

Crop Yield (Mg) for Total Area (Acre) for Each Crop						
Serial No.	**Crops**	**Years**				
		2017	**2018**	**2019**	**2020**	**2021**
1	**Beets**	234	169	132	140	175
2	**Cabbage**	910	940	837	836	1061
3	**Carrots**	1438	1177	1070	951	1159
4	**Rutabagas and turnips**	1521	1091	1138	1150	1143
5	**Blueberries**	115	125	90	110	43
6	**Cranberries**	272	203	145	127	894
7	**Raspberries**	8	12	11	10	11
8	**Strawberries**	93	88	94	99	104
9	**Potato**	3528	3136	3024	3080	3080

Source: Statistics Canada (2017-2021)

Appendix III.

Gross Revenue (CAD) for Total Area (Acre) for Each Crop						
Serial No.	**Crops**	**Years**				
		2017	**2018**	**2019**	**2020**	**2021**
1	**Beets**	195000	172000	136000	170000	245000
2	**Cabbage**	903000	1006000	941000	976000	1217000
3	**Carrots**	1214000	987000	1122000	1141000	1052000
4	**Rutabagas and turnips**	2159000	1516000	1902000	1967000	1940000
5	**Blueberries**	164000	259000	184000	228000	109000
6	**Cranberries**	125000	93000	67000	58000	661000
7	**Raspberries**	61000	88000	85000	77000	86000
8	**Strawberries**	538000	511000	563000	617000	708000
9	**Potato**	1612800	1482880	1429920	1427250	1432200

Source: Statistics Canada (2017-2021)

Appendix IV.

Gross Margin (CAD) for Total Area (Acre) for Each Crop						
Serial No.	**Crops**	**Years**				
		2017	**2018**	**2019**	**2020**	**2021**
1	**Beets**	9662	66085	1941	9846	25890
2	**Cabbage**	558337	614113	523502	539581	606288
3	**Carrots**	593965	386813	497668	576458	282783
4	**Rutabagas and turnips**	1557465	947587	1270008	1246308	1133487
5	**Blueberries**	11879	139454	558	146603	18228
6	**Cranberries**	8886	1279	3105	7842	609854
7	**Raspberries**	16793	36553	32401	28717	36765
8	**Strawberries**	303889	214437	248919	308704	316398
9	**Potato**	614762	230675	201398	189410	15847

Source: Statistics Canada (2017-2021)

Appendix V.

Cost-Benefit Ratio for Each Crop						
Serial No.	**Crops**	**Years**				
		2017	**2018**	**2019**	**2020**	**2021**
1	**Beets**	1.1	1.6	1.0	1.1	1.1
2	**Cabbage**	2.6	2.6	2.3	2.2	2.0
3	**Carrots**	2.0	1.6	1.8	2.0	1.4
4	**Rutabagas and turnips**	3.6	2.7	3.0	2.7	2.4
5	**Blueberries**	1.1	2.2	1.0	2.8	1.2
6	**Cranberries**	1.1	1.0	1.0	1.2	12.9
7	**Raspberries**	1.4	1.7	1.6	1.6	1.7
8	**Strawberries**	2.3	1.7	1.8	2.0	1.8
9	**Potato**	1.6	1.2	1.2	1.2	1.0

Source: Calculation based on data obtained from Statistics Canada (2017-2021)