Taking the Pulse of Canada's Industrial Food System

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

In the context of catastrophic climate change, reducing climate implications of food systems is a central challenge. Shifting diets away from meat towards protein-rich pulses reduces climate change-related pressures while offering myriad agronomic benefits. Yet *how* we produce pulses and not just *that* we produce pulses matters if those benefits are to be realized. Despite rapid growth, little research on industrial pulse sustainability exists. This research explored connections between world views and food systems in order to assess sustainability claims made by Canada's industrial pulse sector. First, I distinguished the underlying productivism rooted in mechanistic models and ecologism rooted in holistic models, distinguishing food science from food systems paradigms and how they affect evidence. After contextualizing Canada's pulse sector, I conducted a discourse analysis revealing shortcomings of conventional narratives on the concepts of choice, efficiency and safety. Next, I analysed eight lock-ins driving Canada's industrial food system. Finally, I tested two Pulse Canada sustainability claims -- low carbon foot print and soil health—finding these claims ignore the reliance of industrial food systems on 1) petrochemicals and other mined inputs, and 2) excessive fossil energy. Canada's pulse sector is vulnerable to both ecological shocks associated with industrial production and to social shocks associated with climate unrest and with policy changes that could curtail access to certain pesticides. By forcing pulses to conform to the economics of industrial production, Canada's farm community bypasses pulses as transition crops toward a truly regenerative agriculture. Given the reality of unavoidable catastrophic climate breakdown, scholars must confront the elephant in the room that is globalized corporate capitalism driving unsustainable approaches to food systems. This paper calls for a radical re-orientation of the economy in the direction of food commons.

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I would like to acknowledge the essential contributions of Steffanie Scott and Andrea Collins in shaping this thesis from conception and Rob De Loe, Dan McCarthy, and Goretty Dias for their patient and thorough committee work; the support and teachings from Prateep Nayak, Stephen Quilley, Bob Gibson, and Derek Armitage whose guidance and reading lists contributed to the substance of this paper; Jennifer Clapp, Caitlin Scott, Emily Mann, Sarah Rotz, Katie Kish, the ERS Salon, and the Waterloo Food Interest Group for providing an active community of scholars within which to test and stretch ideas; Steffanie Scott's Scholarship Circle participants for their feedback and critique during the research process; Trace Machado for her companionship and support during this project; The Architexts; Steven Wolff at Cornel University for his support in developing my ideas further; Walter Hatch and the Oak Institute for setting me on this course of inquiry that could not be satiated with a four month fellowship; mentors Cathleen Kneen and Shiv Chopra who are no more yet whose wisdom and challenges continue to mentor me; Brewster Kneen, Av Singh, and Wayne Roberts to whom I owe a debt of gratitude for forming my analytical approach and for their supportive debates; Francis Moore Lappe whose work developed my critical thinking on food systems and whose encouragement of me to publish; Dr. Vandana Shiva for directing my interest in researching this topic and for her ongoing mentorship; Dan Longboat and Diane Longboat, Ray Owl, Willie Pine, Sue Chiblow, and Winona LaDuke for engaging me in the struggle of Truth before Reconciliation and for the foundational teachings I've received from each that help inform the normative position of this research; my children Rowan and Caedon for their support while I developed this work and who are both quite through hearing about climate change and pulses, yet nonetheless maintain their lifelong love of red lentil dal; and my parents Jo-Anne and Don Haycock, without whose material, spiritual, and emotional support such a journey would have been an impossibility.

Dedication

This research is dedicated to Bija Didi, Navdanya Institute's Seed Guardian, and the innovators whose thousands of years of collective work she and other Seed Guardians regenerate for the benefit of future farmers and future food.

"Food is medicine, and only nutrient dense food from healthy ecological systems can create healthy animals and healthy human beings." – Dr. Elaine Ingham Montreal 2015.

Land Acknowledgement

This research was conducted at the University of Waterloo, located within the boundaries of the Six Nations Confederacy and the Haldimand Tract – a six mile stretch along what we call the Grand River and a fraction of the original and rightful territories of the Anishnaabeg, Haudenosaunee, and Attawanderon (Neutral) Peoples. I recognize the governments that have afforded me the rights and freedoms I enjoy have failed to honour the Treaties and respect the agreements made orally with the generous First Peoples of these territories. I endeavour to undo the colonialism, patriarchy and racism that continues to harm our hosts and neighbours.

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Acronyms

CDC	Center for Disease Control (USA)
CLA	Causal Layered Analysis
COTA	Canada Organic Trade Association
DAFS	Diverse Agroecological Food Systems
EP	Ecological Paradigm
ETC Group	Action Group on Erosion, Technology and Concentration
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gases
GlyBH	Glyphosate-based herbicides
GPC	Global Pulses Confederation
GRAIN	Genetic Resources Action International
HACCP	Hazard Analysis and Critical Control Points
IAASTD	International Assessment of Agriculture Knowledge, Science and Technology for Development
	International Development Research Centre (IDRC)
IPCC	International Panel on Climate Change
IPES-Food	International Panel of Experts on Sustainable Food Systems
LCA	Life Cycle Analysis
LGBTQ+	Lesbian Gay Bisexual Transgender Questioning Plus
PEP	Productivist-Extractivist Paradigm
PIC	Protein Industries Cluster
RAFI	Rural Advancement Foundation International
SDGs	Sustainable Development Goals
SIFS	Specialized Industrial Food Systems
SOM	Soil Organic Matter
UNCTAD	United Nations Conference on Trade and Development

Chapter 1

Introduction

Food science rather than food systems approaches dominate Canadian research in agriculture. Analyses of the socio-ecological systems contexts in which food is produced, traded, and consumed are largely absent or underdeveloped in agriculture and nutrition research design. As a result, publicly funded research in Canada almost exclusively pursues productivity-based and technological solutions within a specialized, industrial food system model. This lack of a reflective analysis of Canada's food system is more than a disciplinary debate about framing research questions. In the context of catastrophic climate change, reducing the climate implications of our food production choices is a central challenge for Canadian agriculture, and the possible responses are deeply connected to what questions researchers ask.

Rising to this challenge, a growing number of researchers are pursuing interdisciplinary, systems-based approaches to analyzing and critiquing the food system. Scholars offer various systemic conceptualizations, including Francis Moore Lappe's 1972 book *Diet for a Small Planet*, the Stockholm Resiliency Centre's 2009 Nine Planetary Boundaries, Singh and Shiva's 2011 *Nutrition per Acre*, and economist Kate Raworth's 2014 *Doughnut Economics*. While these socio-ecological systems concepts remain largely outside the scope of inquiry of agriculture and nutrition research, an emergent interdisciplinary evidence base from food systems scholars within Canada is challenging the discursive environment currently dominated by food science perspectives (Davidson et al. 2016; Clapp 2016; Koc et al. 2008; Martin 2010; Blay-Palmer et al. 2014). And while food systems critiques have focused on the harmful impacts of industrial grain and livestock sectors, Canada's emerging pulse sector has made sustainability claims with little scrutiny in the literature from a socio-ecological systems perspective.

1.1 Problem Statement

In the context of catastrophic climate change, reducing the climate implications of our food production systems is a central challenge for Canada. Food systems industrialization is a leading cause of climate change, with the global rise in consumption of animal products over the past century considered a key driver (Lappe 1972; Barlow 2014; Weis 2013; Rockstrom et al. 2009). Livestock production alone accounts for some 18% of greenhouse gases (GHG) output, thus reducing the amount of meat and livestock products consumed globally would have an immediate and measurable impact on GHG release (UNCTAD 2013; Raney, Steinfeld and Skoet, 2009; Weis 2013).

Adding pulses — dried beans and peas, lentils, chick peas and fava beans— to the diet helps eaters address the climate crisis by reducing animal protein consumption (Weis 2007) while improving health outcomes by providing micronutrient-rich plant protein options (Shiva 2016; Jason, Malone and Eathorne-Malone 2016; FAO 2016).

Pulses also offer myriad agronomic benefits for farmers in Canada seeking to adapt to and mitigate climate change (FAO 2016; Pulse Canada 2016; Global Pulse Confederation 2017). Pulses offer not only an ecological but an economic good news story for Canada's shrinking farming sector. After four decades of canola, wheat, corn and soy dominance that has seen incomes stagnate while input expenses climb, Canadian farmers are turning to pulses for relief (Carlyle 2002; Aitkins 2015).

Though measurable improvements within industrial systems occur when pulses are added to rotations (FAO 2016; Pengali 2012; Gan et al 2017), substituting pulse crops for grain crops in Canada without altering the industrial food system in which that pulse production occurs trades one set of sustainability issues for another. *How* we produce pulses and not just *that* we produce pulses matters if Canada's goal is long-term socio-ecological health. This research explores the connections between world views and food systems perspectives in order to assess sustainability claims made by Canada's industrial pulse sector.

1.2 Goals and Objectives

My goal in conducting this research project is to analyze political and economic lock-ins that favour industrialization within Canada's food system using pulses as a case study. How do hidden drivers influence Canada's food systems, and in light of these findings, what transitions towards sustaining food systems are possible? My analysis will reflect on hidden drivers identified in the IPES-Food eight lock-ins framework. My research challenges dominant narratives on 'choice', 'efficiency' and 'safety' that dominate food systems discussions as result of "food science" worldviews that focus on one food dimension (tradable good) at the expense of the other five food dimensions (food as: a renewable resource, essential for life, a human right, a cultural determinant, and a public good) as identified in Vivero Pol (2017). My goal will be realized through pursuing the following five objectives:

1) Distinguish the underlying world views that influence research and policy (Chapter 3).
2) Contextualize this critique of industrial food systems through a case study of Canada's growing industrial pulse sector (Chapter 4).
3) Discuss the shortcomings of conventional narratives on the concepts of "choice", "efficiency" and "safety" that dominate agriculture (Chapter 5).

4) Critique the assumptions underwriting the discursive environment dominated by food science perspectives in Canada's food and agriculture research in light of eight lock-ins that favour industrialization (Chapter 6).
5) Test the sustainability claims from Canada's industrial pulse sector regarding low carbon foot print and soil health (Chapter 7) relative to the sustainability frameworks identified in Chapter 2.

My research begins to identify strategies for shifting from a "food science" orientation towards a "food systems" one in Canada's research and policy communities.

1.3 Assumptions

This research operates under several assumptions. First, this research assumes Canada seeks to align its agriculture and food policy with its international and domestic commitments. Accordingly, the indicators for sustainability used in this research reflect Canada's commitment to realizing both the seventeen Sustainable Development Goals (UNDP 2018) and the Pan-Canadian Framework on Clean Growth and Climate Change goal of a 30 percent reduction below 2005 levels of greenhouse gas emissions (Govt of Canada 2016). The research project therefore assumes the desired outcomes of Canada's food systems-shaping policies are to encourage, if not achieve, the realization of the SDGs or the Pan-Canadian Framework on Clean Growth and Climate Change targets. Second, this research accepts the interdisciplinary data from several recent and important meta-analyses that identify industrialized food systems as inherently problematic due to a) reliance on fossil energy UNCTAD 2013); b) implications of the production regime's chemical dependence and degenerative practices on ecosystem and human health (IAASTD 2009; UNCTAD 2013; Raney, Steinfeld, and Skoet, 2009; Frison 2016); and c) the impact of the industrial food diet on population health (Weis 2007; Scrinis 2008; IPES-Food 2017). Finally, this research operates from the assumption that growing seasons over the next thirty years in Canada will be increasingly unpredictable with devastating weather events such as hail, drought, wind, or extended bursts of rain. As such, the status quo is assumed to be insufficient to manage within these new contexts and a new approach to food systems is both desirable and necessary from a socio-economic and ecological health perspective.

1.4 Contributions

This research is one of the first efforts in Canada to utilize the eight lock-ins framework identified in the 2016 IPES-Food Food report "From Uniformity to Diversity" for analyzing the Canadian context -- and to further apply that framework to pulse sector sustainability claims (Frison et al., 2016). As such, this research can serve as a model framework for food systems analysis across disciplines. Distinguishing and analyzing underlying beliefs and assumptions within food science and food systems discourses contributes to an increase in understanding across disciplines and opening doors for further interdisciplinary research in food systems sustainability. My work contributes to food systems and climate change scholarship by characterizing hidden drivers that re-enforce the status quo in food and agriculture.

In regard to the specific case study, few scholars have published on the impacts of industrializing pulses, with much of the literature on pulses concerned with agronomics and market acceptance. attention has been given to corn and soy production in North America in particular, however little is available to date in the literature investigating the rising industrialization of pulses and the implications for both "doubling down" on existing industrial production approaches and for missed opportunities to transition to regenerative agriculture systems. This research is the first to critique specific sustainability claims made by Canada's industrial pulses sector. My research contributes to food systems and climate change scholarship by analyzing narratives that re-enforce the status quo in food and agriculture to identify ways the beliefs about food and agriculture shape what possible courses of action are available.

Finally, this research contributes to society by examining contradictions within Canada's pulse strategy. On the one hand, plant-based diets offer improvements for both human and ecosystem health over meat-based diets, yet Canada's pulses have the highest glyphosate residues in the world. As such, there is a need to evaluate approaches and uncover hidden assumptions about supremacy of and sustainability of industrial food systems as a public health concern. This research provides further evidence that Canada is on the wrong path at the cross roads between regenerative agriculture and the status quo if the goal is to develop sustaining, equitable food systems.

This research project was undertaken with the intention to share the results with a broad audience of scholars and pulse sector participants, and to provide a text through which to compare insights with scholars outside my discipline in an effort to build on the interdisciplinary focus of my program of study.

1.5 Thesis Organization

Chapter 1 introduces the research focus and problem context, methodology, assumptions, limitations, and intended contributions of the study.

Chapter 2 provides justification for the theoretical and methodological approach to the research. Additional theoretical frameworks are introduced: IPES-Food's 8 Lock-Ins (2016); Vivero Pol's 6 Food Dimensions (2015); and Raworth's Doughnut Economics (2014). Inayatullah's Causal Layered Analysis

(CLA) provides a method of discourse analysis. The roots and key frameworks are established prior to an analysis of narratives on choice, efficiency and safety within food and agriculture disciplines.

Chapter 3 examines productivism rooted in mechanistic models and ecologism rooted in holistic models, distinguishing “food science” from “food systems” orientations within the literature and how these orientations inform the assessments and priorities of Canadian agriculture.

Chapter 4 offers an overview of what pulses need, what pulses offer, and the Canadian pulse sector to set up the case study analyzing ‘Canadian agriculture at a crossroads’.

Chapter 5 delves into the narratives of choice, efficacy and safety in Canada’s food system using Causal Layered Analysis (CLA). Interviews with food scientists inform the literature-based analysis. These narratives are discussed in the context of Canada’s pulses sector and the IPES-Food 8 lock-ins.

Chapter 6 analyses the narratives of Choice, Efficiency and Safety in Canada’s pulses sector using IPES-Food (2016) 8 Lock-Ins Framework. This chapter explores the connections between world views and food systems perspectives distinguished in Chapter 3 in order to assess drivers of Canada’s industrial pulse sector

Chapter 7 brings together the findings of the literature review and the perspectives of stakeholders to analyze sustainability claims made by Pulse Canada. A food systems approach to sustaining food systems offers a critique of the commodification issue at the heart of food systems sustainability.

Chapter 8 concludes with a summary of findings and future directions for research, along with final statements related to the research process and project.

Chapter 2. **Theory and Methods**

Theoretical roots supporting the analysis include political economy and political ecology, while frameworks informing the research include IPES-Food's 8 Lock-Ins, Raworth's Doughnut Economics, and Vivero Pol's the Six Food Dimensions Framework. Once these frameworks are outlined, section 2.3 describes the methods (2.3) for incorporating these frameworks into the research including the procedures, data presentation, and analysis. The section ends with a detailed case for choosing Inayatullah's Causal Layered Analysis (2.3.1) as the discourse analysis method applied in Chapter 5 for analysing dominant narratives on choice, efficiency and safety.

2.1 Theoretical Context: Political Economy of Food Systems

Political economy incorporates research from a variety of disciplines beyond classical economics to understand economic outcomes (Rudell et al. 2011). Outside academia, several Canadian researchers have long characterized the economic and political dimensions of food. Researchers Brewster and Cathleen Kneen began writing about the political and economic dimensions of food in the early 1970s in their independent publication the Ram's Horn. Brewster Kneen's 2002 investigation of Cargill in *The Invisible Giant* launched a public conversation on the political and economic dimensions shaping the global food system, dispelling the myth of supply and demand as the key driver of production choices on farms (Kneen 2002). Pat Mooney's research through ETC Group further details the political dimensions of food systems (ETC Group 2013), while Wayne Roberts explored the political economy of global food systems in his 2008 book, *The No-Nonsense Guide to World Food*.

More recently, a growing body of work is forming within Canadian academia addressing the political and economic dimensions of food systems, with much of that research prioritizing alternatives to industrialization at the local level (Koc et al. 2008; Levkoe et al. 2017; Rotz 2017; Whittman et al. 2012). Greater attention to researching the political and economic dimensions of food systems relative to policy, civil society, and governance mechanisms at the international level is required, given what resilience scholars describe as "wicked dilemmas" facing modern societies (Quilley et al. 1998; Clapp 2016). Such research is challenging given the inherent difficulties of complex systems analyses that require consideration of multiple competing and irreconcilable interests. For example, if analyzing Canadian export policy, does one consider it successful if those exports displace income and undermine nutrition for India's poor and hinder that nation's agenda of being food self-sufficient in pulses (Shiva 2016)? Research in food systems must weigh interests as expressed by civil society — concerned with lost biodiversity, pesticide use, and other impacts of industrialization of food systems— with those expressed by sector stakeholders and government— concerned with maintaining cheap food access, supporting industry to grow, and smooth functioning of the economy. Recently developed frameworks provide tools for examining the complex political and economic dimensions of food systems using a socio-ecological lens, and three of these are reviewed in the next section.

While research into the political economy of food systems is itself a nascent and growing field, this research is grounded in political ecology. Political ecology focuses on the intersection of political economy principles and ecologically-informed social sciences, representing an alternative to an apolitical field of ecology (Escobar 1998). Research in political ecology connects bio-physical concerns with the human power dynamics at the centre of studies in political economy (Healy et al. 2018). Raymond L. Bryant and Sinéad Bailey (1997) are credited with developing three foundational assumptions within the practice of political ecology: 1) uneven distribution of costs and benefits of changes to the environment are a result of socio-economic and political differences; 2) the unequal distribution of costs and benefits re-enforces existing inequalities and thus political ecology intersects with political economy; and 3) political implications arise in terms of the changes in power dynamics amongst stakeholders from the unequal distribution of costs and benefits (Healey et al. 2018).

This research employs several frameworks selected for their relevance to food systems sustainability questions that are not considered in conventional metrics of success employed by the agribusiness sector or the Canadian government or its provincial governments. These frameworks support content analysis that considers socio-ecological impacts of food systems choices, and are briefly described below in section 2.2.

2.2 Sustainability Frameworks critiquing Industrial Food Systems

Research shows a strong link between agriculture and climate change (Weis 2013; Shiva 2017; Rockstrom 2009; UNCTAD 2013; Raney, Steinfeld, and Skoet, 2009; Frison 2016; Barlow 2014; Collins and Lappe 2015; GRAIN 2015; Koc et al. 2008; Blay- Palmer 2017). While on one hand industrial agriculture generates a steady food supply for those able to engage it economically, it has at the same time generated intolerable negative outcomes on multiple fronts (Weis 2007; IAASTD 2009; Ikerd 2008). Using the insights of new sciences (from toxicology to neuroscience to microbiology to ecology) that have been developed since the introduction of chemicals in agriculture, scholars have documented the negative externalities and lack of sustainability built into the industrial food system (Carson 1962; Pretty 2008).

With no inherent mechanism within the dominant economy for internalizing the socio-ecological costs of industrial food systems, new frameworks have arisen. Newer metrics from "emergy" or embedded energy calculations (Agostinho 2011; Odum 1996) to Life Cycle Analysis (LCA citations; Dias paper on 5 dietary systems) expand what gets measured within the reductionist approach traditionally employed in research. New frameworks help characterize impacts of complex systems interactions like those taking place in the agrifood system, supporting researchers to more broadly evaluate impacts of the negative externalities of industrial food systems.

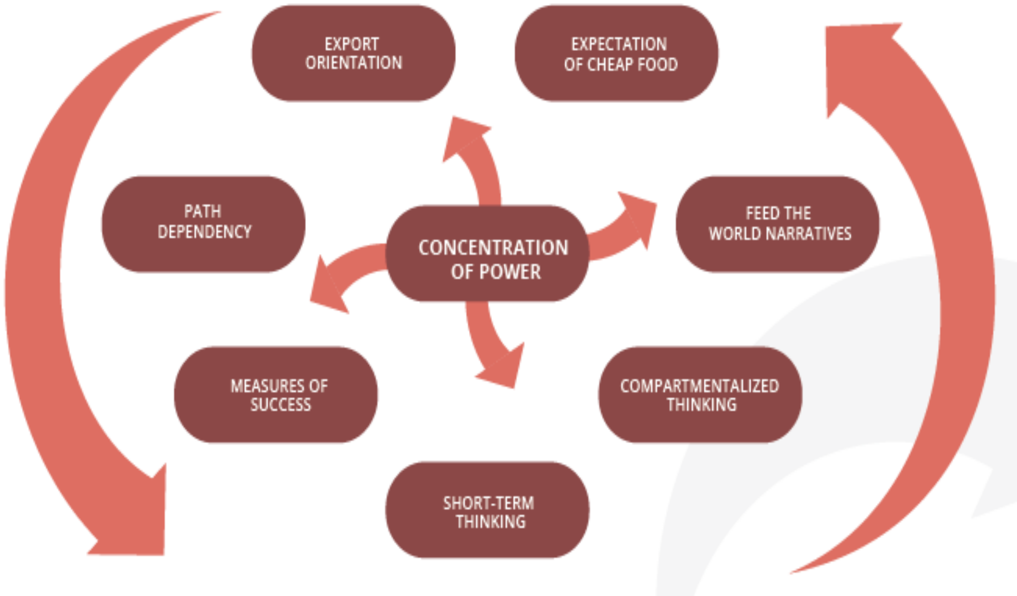
2.2.1 IPES-Food 8 Lock-Ins Framework (Frison et al. 2016)

Vicious cycles that have little to do with choice, efficiency or safety lock in industrial food systems, obscuring alternatives to commodification (Frison 2016; Rotz 2017). This research utilizes the International Panel of Experts on Sustainable Food or IPES-Food 2016 report, "From Uniformity to Diversity" (Frison 2016), as a framework for identifying and evaluating the impacts of hidden drivers on Canada's pulse sector in Chapter 6, providing the primary theoretical framework for this research.

Specialized industrial food systems are built on approaches that are "analogous to industrial processes in their scale and task segregation and seek to derive productivity gains from specialization and intensification of production" (IPES-Food, 2016:10). Specialization in this sense refers to a socio-economic paradigm focused on the efficient production of a few items or a focus on a specific stage in a production system.

Agroecological systems refer to the science of applying concepts and principles of ecology to the design and management of sustainable food systems. Elsewhere in this research the term "regenerative agriculture" is employed as an analog for agroecology. Agroecological food systems offer numerous approaches and strategies to encourage interactions and relationships between species of both commercial and non-commercial importance to the system as a whole (Gliessman 2007). Rosset expands on this definition of agroecology to ensure the socio-political dimensions of the agroecological system are captured, ending the notion of 'man' separate from 'nature' and agro-ecosystem as separate from the broader ecosystem (Rosset & Martinez-Torres 2012). Diverse agroecological food systems are built on multiple sources of production. Producers fluctuate what, where, and when foods are produced to achieve long-term soil health, healthy agro-ecosystems and sustaining livelihoods (Frison 2016).

Figure 1 IPES-Food: Eight Lock-Ins Framework



Source: (Frison et al. 2016)

IPES-Food distinguished 8 lock-ins (Fig 2.2.3) that perpetuate specialized industrial food systems despite a growing body of evidence that such systems are inherently unsustainable: path dependency; export orientation; expectation of cheap food; feed the world narratives; compartmentalized thinking; short term thinking; measures of success; and concentration of power.

Path dependency locks in Specialized Industrial Food Systems as self-perpetuating, as the demand for a return-on-investment (ROI) for large capital investments leads to making further large investments to maximize the previous ones (Frison 2016). For example, grain farmers investing in equipment to manage thousands of acres of soy will add new crops to their rotation only if the same equipment can be used.

Export orientation impacts food systems in spatially and temporally dynamic ways. These impacts affect various stakeholders, vulnerable populations, and regions differently, and can instigate fundamental shifts that alter entire economies. For example, a rise in soy exports from Brazil that results in massive rainforest loss and accompanying loss of biodiversity (IAASTD 2009; Peschard 2017).

The expectation of cheap food results in factors independent of food production creating entry points for changes in food systems. An example is the rise in demand for processed convenience foods driving varietal development research to optimize grain size and shape for various pulses to increase processing efficiency.

Industrial agriculture is also locked in place by the highly compartmentalized institutions and governance structures that govern the setting of priorities in politics, research and business. Canada's lack of a comprehensive food policy means that Canada can have a climate change priority of capping global temperature rise at 1.5 Celsius while maintaining an agricultural policy entirely reliant on fossil energy that drives temperature rise.

Short-term thinking such as shareholder expectations, election cycles, and retail imperatives produce unforgiving timeframes that push short-term solutions to the forefront and keep private and political interests invested deeply in existing systems— despite indicators that new approaches are required to existing systems – even as they generate increasing problems.

'Feed the world' narratives ignore root causes of insufficient diets: socio-political problems of poverty and access, social equity and power relations including wars, and the interconnectedness of food systems challenges. Such narratives encourage governments to focus solely on increasing production.

How we measure success drives research investment, program development and political support. For example, industrial food is locked in to yield per acre as a measure of efficiency and productivity. Approaches that maximize these will get research attention, ignoring important research or defining the terms of research into things such as resiliency, regenerative capacity, or resource efficiency.

Lastly, concentration of power serves to re-enforce all other lock-ins. Market concentration in multiple sectors shapes the food system. Seven companies control close to 100% of fertilizer sales, four companies control 90% of the global grain trade — with AGT foods controlling 40% or more of the world's lentils — and three companies corner 50% of the seed market (Chemnitz et al. 2017; Frison 2016; ETC Group 2013).

These eight lock-ins operate as mutually reinforcing feedback loops. For example, compartmentalization in agricultural research creates an environment in which scientists working on resolving aflatoxin issues privilege genetically engineering of soil microbes as a solution. Yet these scientists may have little or no training in or awareness of the roles that changes in plant communities from complex intercropped systems like grasslands to simple monocultures of a given commodity crop play in creating conditions for aflatoxins to dominate. Given the lock-ins of both export orientation and cheap food expectations further obscure solutions that question the fundamental culture are overlooked, justified by metrics developed in a compartmentalized research environment.

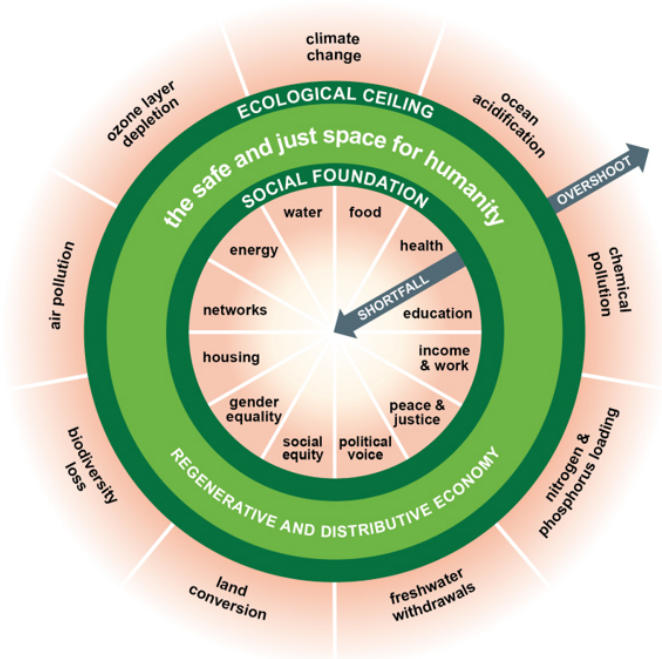
2.2.2 Raworth's Doughnut Economics (Raworth 2014)

Ecological economics seeks explicit inclusion of ethical issues that are left out of mainstream economics (Leining 2013). Doughnut Economics (Raworth 2014) is an integrative ecological economics framework that combines assessments of biophysical limits (Rockstrom et al. 2009) with identification of social foundations (Raworth 2012; UNDP 2018) that together ensure a sustaining economy. The Rockstrom Resiliency Centre developed a biophysical/technical framework of nine planetary systems boundaries to convey ecological thresholds that, if breeched, put the earth's capacity to support biological life in question. They are planetary systems in that regulate and the stability and resilience of the biosphere, and include ocean acidification, chemical pollution, nitrogen and phosphorous loading, fresh water withdrawals, land systems-change, biodiversity loss, air pollution, ozone layer depletion, and climate change (Fig. 2). Four of these— climate change, loss of biosphere integrity, land-system change, altered biogeochemical cycles (phosphorus and nitrogen) – have been transgressed in large part due to demands from industrial agriculture.

These nine boundaries are represented in Fig 2 as Ecological Ceilings. Transgression triggers non-linear, abrupt transformations on a continental or planetary scale (Rockstrom et al. 2013). Due to the interconnectedness of living systems, transgression may also trigger other boundaries to shift or be transgressed. Transgression of seven of the nine boundaries have been quantified, and humanity has already crossed four of the nine: climate change, rate of biodiversity loss, land systems change, and changes to the global nitrogen and phosphorous cycles. Industrial agriculture is implicated in all four of these transgressed boundaries (Rockstrom et al. 2013; Raworth 2014; Steffen et al., 2015). Two of the four transgressed boundaries are what scientists call 'core boundaries', meaning that significant alterations will result in the Earth being in a new state (Steffen et al., 2015)

Raworth's analysis integrates Rockstrom's framework with social foundations identified by civil society at the Rio+20 meetings— food, water, income, education, resilience, voice, jobs, energy, social equity, gender equity, and health. Within this framework, poverty is recognized as exacerbating

Figure 2 Doughnut Economics: A safe space for humanity



Source: (Raworth 2017)

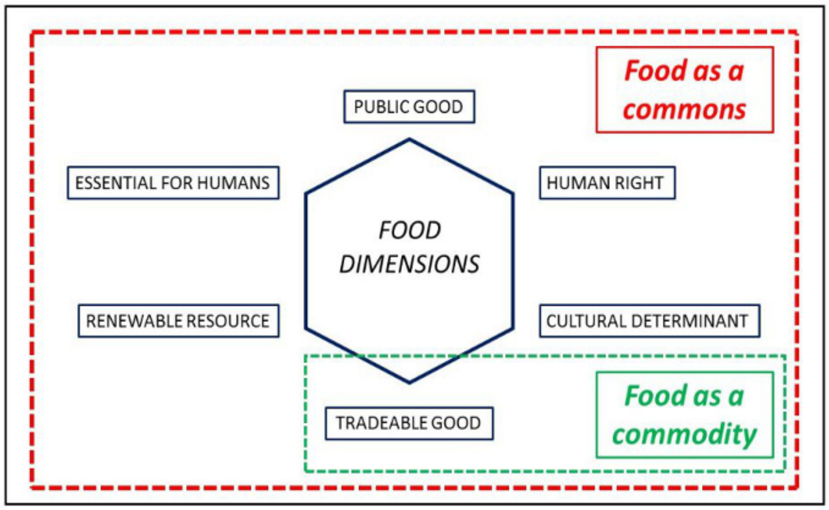
ecological stress which in turn exacerbates poverty (Raworth 2012). Poorly designed policies and interventions for moving humanity back within the planetary boundaries while ignoring social foundations can drive societies below the acceptable levels of the social foundations. Without an adequate social foundation, societies will not have the political will or resources to address the planetary boundaries. The challenge is designing policies that prioritize poverty eradication and environmental sustainability and are prioritized to bring society within the "doughnut" (Raworth 2014).

2.2.3 Food Dimensions (Vivero Pol 2015)

Valuing food exclusively as a commodity, industrial food systems have no economic mechanisms built into their structure for addressing the planetary boundaries or social foundations captured in Doughnut Economics. Without a normative shift in how we value food, adopting such an economic framework into policy decisions may prove challenging. Vivero Pol (2015) offers such a normative shift with his six food dimensions framework (Fig 2.2.5). This framework provides the foundation for assessing how we value food and govern our food systems. Vivero Pol argues that food is not only a commodity but is: essential for life; a public good; a human right; a renewable resource, and a cultural determinant.

A transition towards sustainability, in Vivero Pol's view, means adopting a 'food as a commons'

Figure 3 Six Food Dimensions



Source: (Vivero Pol 2015)

over a 'food as a commodity' narrative as normative. Recent research supports the call to create policies, incentives and other market mechanisms that acknowledge food values beyond commodification (Clapp 2018; Levkoe et al. 2017; Ikerd 2008). However, the market mechanisms that dominate this research in Canada commodify nature in ways that are simplistic and inadequate to protect further degeneration of the Earth's productive, regenerative base. Ecological paradigm thinkers reject monetizing nature and the biological systems that regulate life, arguing against commodifying ecosystems services and other values within the food system. Instead, policy makers are encouraged to move beyond commodity thinking and embrace intrinsic and multifunctional values in nature generally, and within food systems specifically (O'Neill 1997; Salleh 2017; Clapp 2017). For example, if convenience foods end generational transmission of home-based food processing knowledge, how does one put a price on lost fermentation starters, or the recipes that go with them? In this framework, all six dimensions of food are considered in food policy direction.

2.3 Methods

This research examines the socio-ecological impacts of Canada's industrial food system through a case study of the country's emerging pulses sector. My research is largely qualitative – an appropriate strategy when investigating a new field of study, or when theorizing prominent issues (Jamshed, 2014). My research analyses the characterization of industrial pulse production by proponents in Canada as 'sustainable agriculture' by testing the stated benefits of industrial production of pulses for Canada's farmers within the research framework (Chapters 4, 6 and 7); and exploring the unintended impacts of industrial food systems on the sustainability of those systems (Chapter 7). The research framework integrates IPES-Food's 8 Lock-Ins (Figure 1), Raworth's Doughnut Economics (Figure 2), and Vivero Pol's 6 Food Dimensions (Figure 3).

Data Sources

Data collection for this research began with a thorough review of relevant databases including AGRICOLA, CAB Direct, FAO, Scopus, JSTOR, and ProQuest. Texts known to be seminal research on the state of industrial agriculture were revisited in the context of Canada's pulse sector (UNCTAD, 2013; Macintyre, B., et al., 2009; Raney, Steinfeld, and Skoet, 2009; Frison et al., 2016). Searches using the terms included 'pulses', 'pulses + Canada', 'pulses + modern + agriculture', 'pulses + organic', 'pulses + intercropping', 'pulses + sustainability', 'pulses + climate change', 'pulses + nitrogen', 'pulses + GHG', 'pulses + soil', 'pulses + health', and 'pulses + processing'. Similar searches substituting 'pulses' with 'legumes', 'lentils', 'chickpeas', 'peas', 'beans' and 'fava beans', and adding ' + Canada' were conducted.

Few articles specific to Canada's pulses sector turned up across platforms, with a body of agronomic literature focused on productivity improvements within industrial systems. In the multi-disciplinary database Scopus, for example, 'Canada + lentils + sustainability' returned 20 documents – only two dealt specifically with alternative models of production, though 14 of the studies dealt with general agronomic knowledge from investigations into pests and root diseases, for example, or exploring optimum watering times. Additional sources included relevant articles, books, industry materials, and government resources. I also received recommendations from key informants for both information in the published literature, as well as for names of colleagues to approach whom they felt had information relevant to the story of Canada's pulse sector. Companies or researchers mentioned in relevant articles were also search terms to see if additional works were available. Simple searches on Google were also conducted throughout the research phase to scan for news articles on specific industry players within Canada including AGT Foods Inc., Pulse Canada, and SaskPulse.

Data was gathered through semi-structured interviews with seven key informants. Key informant interviews are an appropriate form of data collection when seeking input from experts who are most knowledgeable on a given issue (Lavarkas, 2019). The key informants were selected because they were a) speakers at the Global Pulse Confederation's Future of Food Conference in July, 2017; b) published pulse sector champions or researchers involved with agronomics, strategy development or food product development at a senior level in Canada or globally; c) participants at a senior level in the organic pulse sector; and/or d) were critical of industrial pulse production in Canada. I chose to keep the interviewees' identities confidential to give the interview participants as much latitude to speak candidly on challenging subjects. The questions were designed to be open ended and to encourage dialogue with the key informants, to reveal underlying world views, to identify opportunities within the pulse sector the food scientists I interviewed were passionate about, and to confront the controversy about reliance on chemicals at harvest.

Data Analysis

In order to contextualize the case study, I first analysed text-based local agronomic and nutritional knowledge particular to pulses, then focused my sectoral research on Canada's industrial production system to gain a general knowledge of the sector's history, structure, and trajectory. In addition to the published literature, several trade association websites and publications were examined, including SaskPulse, Pulse Canada, the American Pulse Association, the Canadians Special Crop Association, and the Government of Canada.

Next, I developed codes to categorize data according to several themes that derive from the research question. This method for data analysis was chosen given the wide variety of data forms and disciplines included in this research (Saldana 2009). Saldana recommends Descriptive Coding particularly as a first order of coding to be further analysed using content analysis – a technique preferred when engaging with published materials in the journal literature, books, and industry publications (Krippendorff, 2003). These codes were applied to the interviews and presentations as well as the text-based materials.

Descriptive codes for research regarding paradigms include "food science" relative to mechanistic views of nature and science and "food systems" relative to holistic views of nature and science (Grierson, 2009). During the research for Chapter 5's investigation of industrial food systems narratives, I coded for data invoking "choice", "efficiency", and "safety" when reviewing both industry data and the published research within industrial food systems. The eight lock-ins framework served as a source for descriptive codes when engaging the Chapter 6 investigation of choice, efficiency, and safety in Canada's pulse sector. These codes include 'cheap food', 'feed the world narratives', 'compartmentalized thinking', 'short-term thinking', 'measures of success', 'path dependency', 'export-orientation', and 'concentration of power'. Descriptive codes associated with socio-ecological indicators used in this study include 'sustainability', soil health', 'climate change', 'reduced N use', 'food security', 'water use', 'processing', 'nutrition', 'pesticide harvesting', 'seed development', and 'profitability'. Descriptive coding associated with assessing world view orientation used in this study include 'mechanistic', 'productivist', 'holistic' and 'agroecological'.

Once an initial textual analysis was undertaken, I attended the world's largest ever pulses conference to further contextualize my existing knowledge of the industrial food system in Canada with the particulars of the global pulse trade, and to identify key players in the sector in a public setting. The Global Pulse Confederation's "Pulse 2017: The Future of Food" Conference in Vancouver, July 10-13, 2017 included several sessions on global pulse production outlooks, consumer behaviour change, marketing strategies for the global pulse brand, processing developments, and the Confederation's Annual General Meeting. I also spoke with farmers, government staff, brokers, scientists, and marketers throughout the four days to gain an awareness of the global sector and Canada's place in it. Upon returning from the conference, further text-based research was conducted, using the same databases as well as University of Waterloo thesis repository and library search functions to further explore themes following the formulation of the research question.

During the final stages of research, seven experts agreed to be interviewed with interviews taking place via phone between May 1, 2018 and July 15th, 2018. Of the original fifteen, six accepted, and one recommended I speak with their colleague, who also agreed to be interviewed. One respondent refused to be interviewed and eight neglected to respond given the short timelines for the project published. These interviews provide additional context and insight to the textual analysis. Responses from the semi-structured interviews are integrated in Chapter 4. Chapter 6 uses a narrative approach to reflect on the question of pulse sector sustainability in light of food systems discourse and sustainability indicators drawing from the three frameworks and these seven interviewees.

Interviewee 1 – PhD. Nutrition, Nutrition Director, Sector Organization

Interviewee 2 – P.Ag. Agronomist, Sustainability Director, Sector Organization

Interviewee 3—Clinical Nutrition Scientist; Academia

Interviewee 4 – Food Scientist; Innovation Specialist Public-Private Partnership

Interviewee 5 – Pulse Breeder, Private Enterprise

Interviewee 6 – Genetics and Genomics, International Agency

Interviewee 7—Citizen Researcher, Non-Affiliated

A more robust dataset would have been beneficial to the replicability of the study. The data sets derived from the discourse analysis of the interviews are not statistically significant. The research was designed to build the evidence base from content analysis of the published literature and the public-facing materials of industry including the Future of Food Conference proceedings, and as such these interviews were included to provide insights from 'the ground' relative to my synthesis.

Content analysis involves "abductively inferring contextual phenomena from texts" to move an analysis outside the data, bridging the "gap between descriptive accounts of texts and what they mean, refer to, entail, provoke, or cause" (Krippendorff, 2003:85). While largely informative some content analysis in Chapter 3 employs abductive inference.

In Chapter 5, I employed a specific approach to discourse analysis called Causal Layered Analysis (2.3.1) exploring three themes -- choice, efficiency, safety-- that arose from the textual analysis regarding beliefs about the superiority of industrial food systems over other models. Analyzing discourse can also solve a very pragmatic issue associated with interdisciplinary studies and outlined in the literature regarding specialized language that becomes codified within disciplines. How an issue is framed influences how that issue is comprehended, potentially limiting the scope of possible responses to that issue (Green & Dzidic 2014). Discourse analysis can help reveal underlying assumptions connected to world views that privilege or obscure interpretations of the data are brought to the surface. Details on CLA are provided below in section 2.3.1.

Content analysis employed to bridge the data on pulse production in Canada with critiques in both the eight lock-ins framework (Chapter 6) and the Doughnut Economics framework (Chapter 7). Abductive inference was further employed when a) analyzing agronomic and trade data about industrial pulses and cross referencing it with agronomic and trade data about other industrial crops at the centre of sustainability critique; and b) investigating sustainability claims of Canada's industrial pulses strategy, paying particular attention to the central role of chemical management in the economics of Canada's pulses strategy. This chapter's analysis draws on Raworth (2017), IAASTD (2009), and Vivero Pol's 6 food dimensions framework (2015) as guiding frameworks.

My research follows a narrative approach to textual presentation of the research data. This method is supported by research concluding that ecosystems approaches for sustainability necessitate working with scenarios or narratives to depict causal loops, since reductionism's linear causality ignores the phenomena exhibited by Self Organizing, Holarchic, Open systems or SOHOs (Kay et al. 1999). Political and social dimensions of food systems, like the natural world in which they function, are shaped by causal loops. In such contexts, narratives help reveal underlying assumptions and indirect causation shaping policies and actions that further lock in industrial agriculture (Frison et al., 2016).

2.3.1 Causal Layered Analysis

How farmers and eaters think about the 'problem' of agriculture and food deeply impacts proposed solutions (Bishop et al. 2013). Discourse analysis can become a tool for societal change—where the new discourse brings into sight that which is materially experienced but invisible under the dominant paradigm. For example, the women's and LGBTQ+ movements in North America have shaped public perception by reframing language. Discourse, therefore, "provides a tangible way of influencing and even changing a whole societal structure." (MacGill 2015:56).

Table 4. An overview of Causal Layered Analysis

Source: Bishop et al. 2013:5.

Deconstruction Levels of Causal Layered Analysis

Layer	Concern/Foci
Litany	Issue presented as the uncontested truth, is superficial lacking depth, can result in a sense of helplessness or apathy
Social Causal	Issues presented in terms of systemic and/or technical explanations
Worldview/Discourse	Deeper, more complex understanding of the issue. Relates to the meaning of the issue that is constructed. Worldviews shape understanding, and by understanding a worldview, researchers are able to determine insights as to how an issue is socially constructed. Discourses express a worldview through the sorts of words, terminology or phrases that are used. There may be multiple worldviews in evident in the one data set.
Myth/Metaphor	Deep mythical stories and social/cultural archetypes, emotional experiences and responses to the issue. This is the most distal layer of analysis and is likely to require the greatest amount of analytical investment.

CLA is a discourse analysis method associated with Futures Studies — an interdisciplinary study speculating on possible, probable, and preferable futures. Futures Studies research is applied in long term policy development to better understand the second and third order effects of a given policy (Bishop et al. 2012; Inayatullah 2004) where second order and third order refer to effects spun from an initial cause that then become a cause spinning new effects. CLA can assist analysts in uncovering hidden drivers with the intent of creating transformative spaces that allow for a range of possible futures (Bishop et al. 2013; MacGill 2015). In the context of globalization, a clash of ideas, agendas, beliefs, and priorities are unavoidable. As such, scholars must engage in communication, focusing on "how relationships, identities, and tasks are in the communication" itself (Manning 2014:432).

This method provides an avenue for analyzing the ontological territories from which actors are operating as a precondition to transformative action: *"*The futurist philosophy is that by understanding the deeper more complex underpinnings of an issue, it is only then that genuine change can occur.*"* (Bishop & Dzidic 2014:15). Finding new metaphors and new narratives is identified throughout environment research as a necessary cultural transformation in the Anthropocene as the old Cartesian metaphors no longer suffice (Quilley et al. 1998; Kay et al. 1999; Salleh 2017; MacGill 2015; Raskin 2016). By treating the present as a problem, CLA helps find new metaphors that allow for envisioning other possible futures (Milojevic 2014; MacGill 2015).

As shown in more detail in Table 2.3.1, CLA consists of four layers of analysis. The first layer, the litany, states a problem that is quite visible. The litany is what the general public says about a problem. The second layer identifies social causes of the problem – the interconnections, technical explanations and social and policy analysis that play some role in shaping the narrative. The third layer is that of worldview and discourse in which shared culture, values, language, shape the narratives available: "A worldview is a coherent set of shared beliefs which provide a framework through which the systemic operates" (MacGill 2015:57), predetermining the available discourses possible in the litany and social/causal layers. The fourth layer is that of metaphors and myths, which form a firm foundation for belief systems where things are hidden or invisible. This layer involves the languages of archetypes, emotional responses, and visual images (Milojevic 2014). This fourth layer requires the analyst to elicit "the root myth or metaphor that supports the foundation of a particular litany of issues" (MacGill 2015:57).

Like a microscope's multiple lenses, CLA's layers allow for a contextualized and nested understanding of an issue with each layer's focus revealing important analysis for comprehending the possible futures in a given context. The litany is what we say, the social/causal layer is what we do, the worldview and discourses layer is what we think, and the myth and metaphor layer are who we are (Bishop et al. 2012).

In Futures Studies, the final step in CLA is to reconstruct through ascending the layers towards new possible futures considering the multiple needs uncovered and articulated in the deconstructing process (Inayatullah 1998, 2004; MacGill 2015). Solutions and conclusions that arise from research focused solely on the first two layers of analysis may re-enforce the sets of assumptions that, unchecked, will reproduce the types of issues identified in the Litany (Milojevic 2014; Inayatullah 2004). Such a reconstruction is beyond the scope of the current research.

2.4 Limitations of Methods

Analyses that highlight binaries are increasingly seen in human geography and in other disciplines as problematic. The binary framing of agriculture as at a crossroads, along with the binary framing of food science/food systems approaches, risks glossing over the multiple, conflicting priorities within either paradigm, the diverse strategies and tactics already in play, and the porousness between seemingly dichotomous on-farm systems. However, for the sake of distinguishing the ontological shift between an industrial and an agroecological approach to food systems, binaries are illustrative.

Time constraints affected the number of interviewees and available research. Accessing the 2016 Agriculture Census data was beyond the scope of this paper due to the processing times for requests. With additional time, specific inquiries would be placed with Statistics Canada to provide robust comparative data to the 2011 Pulses analysis. Industry perspectives absent from the interview process were captured during presentations at the Global Pulse Confederation's 2017 Convention in Vancouver entitled 'The Future of Food'. A detailed picture of the network of relationships horizontally and vertically amongst Canada's pulses sector was beyond the scope of this inquiry. Such an investigation would not track towards meeting the specific objectives laid out in this thesis, though such work would be an enormous contribution to the literature.

Limiting the scope of study to reflect on the dominant Canadian-based industrial agriculture meant First Nations perspectives on and approaches to food systems were not explored, nor were knowledgeable treaty people from First Nations' communities engaged in the design or delivery of this research. Acknowledging that pulses are traditional crops of the Six Nations in our region, a respectful and thorough exploration of indigenous food systems was beyond the scope of this research and will be the starting point for my PhD work researching Food Commons in Canada.

Chapter 3 **A Conceptual Divide: Food Science and Food Systems**

3.1 Introduction

A homogeneous productivist view of agriculture dominates Canadian policy and research. In the context of Canada's largely hegemonic food science paradigm, Canada has the most choice within the most efficient and safe food system in the history of humanity. Alternatives to industrialization are considered unnecessary (Prouse 2017; Bloom 2014), yet food systems research suggests that such pronouncements have led to food systems collapses in many parts of the world. Proponents of industrialization argue that choice lays in the hands of farmers and eaters. Since specialized, industrial food systems dominate, the conclusion is that they must be the best systems. Were that the case, there would be no need for this current research, nor for the global agroecology movement. While innumerable short and medium term benefits arise in specialized industrial food systems, a productivist approach fails to account for the complexities of food systems interactions, interdependences, and limitations. Clearly, agriculture is at a crossroads (Frison et al 2016).

The underlying assumptions we make are informed by how we view our place in the universe—our cosmologies. Greeks, Renaissance, Native Americans—all have cosmologies centred on a Living Earth, viewing Earth as a mother with circulatory, reproductive, elimination and respiration cycles. Yet over the past 300 years, the institutional and paradigmatic products of what is commonly called 'The Enlightenment' —western mechanistic science and industrial capitalism— have come to dominate, where society relates to the Earth as inert, dead, and manipulable (Merchant 1992:41). Researchers argue that cultural narratives of the Earth as Mother and Nurturer, as a living organism, are a constraint restricting the actions of human beings: "One does not readily slay a mother, dig into her entrails for gold, or mutilate her body." (Merchant 1992:43).

To some extent, then, the Enlightenment involved re-making the Earth-based cosmology into a mechanistic one, as inspired by Francis Bacon and his contemporaries. Bacon's conceit was the enlargement of human domain over and separate from nature (Grierson 2009; Shiva 2017). After 300 years of placing man above and separate from nature, the future of organized societies now rests on altering cosmologies to adopt an emerging scientific concept of Socioecological Systems. Socioecological Systems are human systems— or human societies— interacting with, nested in, and shaping the natural world (Constanza et al., 2007:12). Socioecological Systems require us to "re-animate" the Earth from its mechanistic allegory. Both Merchant (1992) and Constanza et al. (2011) argue that cultural traditions (steeped in "sociological civility" and presumably now lost in corporate capitalist societies) put brakes on activities that destroy our environment. While this may be true of animist cultures to some degree, another explanation may simply be that a lack of technological capacity for rapid destruction prior to the middle of the 20th century played as much a role in this "brake" function as did "cultural traditions".

Over-confident ideologies, despite being justified by some kind of scientific inquiry, still fail as evidenced by the rise and collapse of historical totalitarian systems during the last century. The current expression of corporate capitalism and the military industrial complex that supports it is one such over-confident ideology, justified by classical economics and an outdated mechanistic world view supported by reductionist applications of science (Merchant 1992; Salleh 2017). "The concept of a paradigm refers to scientific communities, shared commitments/values, and the creation of common frameworks among them based on a shared framework for addressing a problem (Kuhn 1970). Importantly, an implication of this is that "paradigms are partly social in nature" (Gaudreau 2015:32-33). Gaudreau illustrates that two paradigms can overlap, with dominant paradigms upheld by communities with shared goals and accepted truths.

Discourse analysis has another value when engaging in interdisciplinary matters like food systems. Systems thinking requires breaking down discipline-derived linguistic barriers and identifying analyses for which scholars in a shared discipline grant untested assumptions. Framing and the belief systems in which one operates implicates what constitutes 'sustainable'. For the purposes of this research, and with attention to trans-disciplinary study and increasing understanding, I will be referring to the Productivist-Extractivist Paradigm as a 'Food Science' Paradigm and to the Ecological Paradigm as a 'Food Systems' Paradigm.

3.2 Productivist Extractivist Paradigm: Food Science

The 'mechanistic', reductionist paradigm has shaped the modern world for several hundred years and remains culturally dominant despite physics leading science to adopt a 'holistic' view over the past one hundred years (Grierson, 2009:199). Shiva refers to the mechanistic paradigm that dominates today as both productivist and extractivist, as the term 'mechanistic' alone only describes the theoretical model for the physical world, ignoring the socio-ecological dimensions at work (Shiva, 2017). This research refers to the Productivist-Extractivist Paradigm - where other researchers use the terms Newtonian or mechanistic paradigm—in order to overcome a false assumption that productivism is apolitical or neutral (Shiva 2017). Industrial capitalism is legitimated by a mechanistic worldview, wherein resource economies express as productivist and extractivist. The domination of nature is the ethic of industrial capitalism. Mechanistic thinking and industrial capitalism lie at the root of the ecological crises (Merchant 1992:59). In this paradigm, only that which can be traded, commodified and taxed is of value.

Productivism is concerned with modernizing and industrializing agriculture, gaining favour during the Keynesian era of stabilization and economic intervention that began in the 1930s as a response to the Great Depression. Productivity ramping up production to stimulate economic growth (Martin, 2010). Research characterizes three major structural components of agricultural productivism: intensification, concentration, and specialization (Jay 2004:152). Extractivism is the neoliberal strategy of privatizing the export of raw materials, historically benefiting rich countries at the expense of

predominantly the Global South, particularly indigenous communities and impoverished women (Lowe et al. 1993:221). Both are expressions of mechanistic views of Nature,

In the Productivist-Extractivist Paradigm, the view is that “the current hunger and malnutrition that extends to some one billion people reflects poor policies, low productivity and low incomes. Failure to

Figure 5 Productivist-Extractivist Paradigm

Source: Author’s formulation

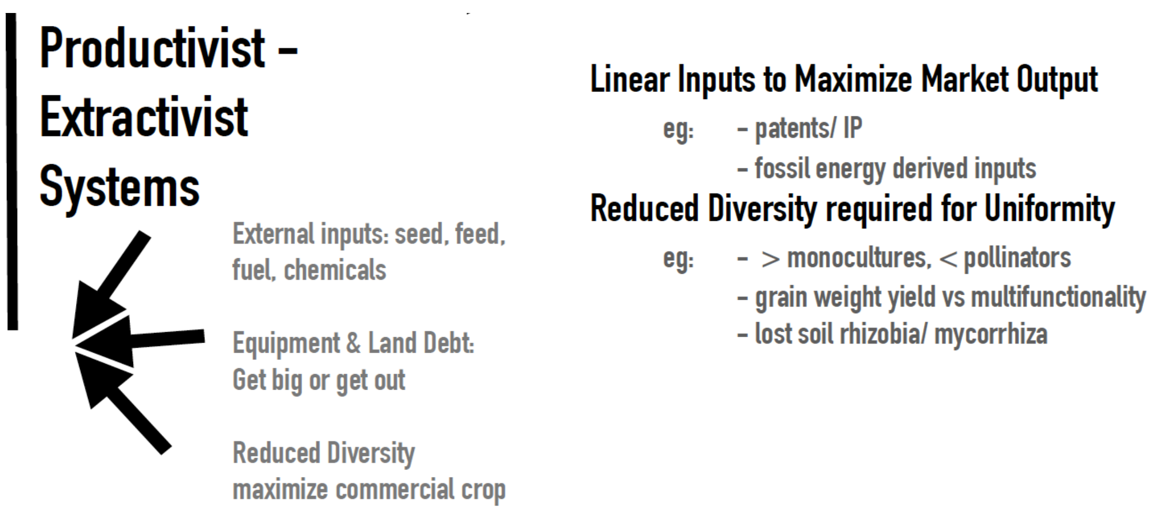


Figure 5 conceptualizes the Productivist-Extractivist Paradigm as a linear flow, input/output system in which relationships amongst elements are rarely examined beyond simple cause/effect and feedback loops are ignored. The system takes in external fossil energy-derived inputs supported by patents and Intellectual Property (IP) mechanisms and attempts to maximize output as measured by the weight of the saleable portion of the crop. Productivist-Extractivist Paradigm demands intensification and uniformity, reducing plant diversity on the farm. The ecological costs of inputs, purchased externally, are not necessarily factored into the bottom line of the business operating within this model. Productivist-Extractivist Paradigms measure yield per acre, values uniformity, emphasizes external inputs, and counts destructive activities as contributing to economy. Commodity markets deliver low margins and depend on high volume for the business case.

continue to apply new technologies to advance productivity on the farm and across the food system simply worsens every aspect of these problems, especially those forced on individuals and families who live in poverty." (Prouse 2018:14). In essence, poverty in this view is a result of a lack of productivity. On the other hand, some argue poverty is not something peasants need to be pulled out of through productivist agriculture policies, rather poverty is itself a consequence of Productivist-Extractivist policies that focus on the export of commodities (Shiva 2017; Escobar 2008).

Food science approaches are concerned with concentration, isolation, characterization, and recombination. Food scientists are engaged in extractive science, processing raw ingredients into isolated ingredients and fractions and then rebuilding foods with desired flavour and nutritional profiles. This Productivist-Extractivist Paradigm requires "extractive science and extractive technology that manipulates seeds, soils and animals so that more is extracted for the market" (Shiva 2017). A Productivist-Extractivist paradigm ignores the first law of thermodynamics: there are no free lunches in nature.

Something is given up in the ecosystem in order to produce these apparent increases in output. For example, if we want more grain, we get less straw. Because quality and diversity have been substituted with quantity and uniformity, the grain is of poorer quality and goes to animal feed. In this approach to food, the industry traders are the market, not the people (Kneen 2002; Shiva 2017). Markets were historically physical places that house comparable items in an open and tactile environment in order to obtain goods and services. Today's 'market' is a series of trading agreements predominantly amongst transnational corporations (ETC Group 2013; Shiva 2017). Productivist-Extractivist Paradigm commodifies what was once produced for nourishment (Vivero Pol 2017).

Productivity in Specialized Industrial Food Systems is a measure of output of saleable grain per paid employee (Young 2012). Intellectual Property rights and patents drive profitability in the Productivist-Extractivist Paradigm. A food science approach to food studies emerges from this paradigm. The science is reductionist: "Reductionist and statistical tools, for the sake of mathematical tractability, seek to eliminate the very complexity and uncertainty that characterize complex systems by assuming mechanistic linear causality" (McCarthy 2006:4). What emerges is a homogeneous approach to food that is characterized by food science approaches.

3.3 Ecological Paradigm: Food Systems

Scholars are challenging that homogeneity, offering a food systems/multifunctional view that reveals the ecological and human rights costs of cheap food, (Weis 2013; Winson 2013; Levkoe et al. 2017). In an Ecological Paradigm (EP), that which is in circulation provides value to nature, to the local society, and to future productive capacity. The Ecological Paradigm holds multifunctionality as the foundation of prosperity and there is no 'waste' (Raskin 2016; Wilson 2009). Circular economies drive Ecological Paradigm, both in terms of 1) investments in soils and seeds resources at the local level; and 2) financial investments in human resources for production and local markets for consumption. Those operating within an Ecological Paradigm approach biodiversity as the insurance policy against unforeseen weather, pest, disease or market failures (Holt-Giménez & Altieri 2013). Circular economies design waste out of the system—products are designed with materials reuse and recycling in mind, reducing lost embedded energy or eMergy in the system. Circular economies differentiate between durable and consumable components in product design—using as many biological ingredients that are less toxic and can more readily be returned to the biosphere directly or after several uses. Durables in this system are made of metals and plastics, also designed from the start for reuse. Devices with rapid technological changes are built for upgrade rather than disposal and replacement. Most crucially, circular economies favour renewable sources of energy to increase resilience (McDonough and Braungart, 2002). In an Ecological Paradigm, the circular economy would of necessity discourage consumption, encourage sharing over ownership, and re-introduce commons (Vivero Pol, 2017; Shiva, 2017).

In the dance between social and ecological tensions in food systems priorities, some ascribe to adhering fully to global limits: "A macro-ecological perspective on the sustainability of local systems emphasizes their interrelations with the larger systems in which they are embedded, rather than viewing these systems in isolation" (Burger et al. 2012: 3). This interdependent view in an Ecological Paradigm leads to a cooperative, circular economy that occupies Raworth's Doughnut (2017). Counter to the competitive ethic that drives modernity, researchers claim humanity must give up notions of environmental management: "We need to adjust how we live on the earth, rather than figure out how to manage the earth. Unfortunately, mastering nature is an assumption integral to capitalist modernity, so sustainable solutions will require some kind of epistemic reorientation" (McMichael 2011: 804).

Figure 7 Ecological Paradigm

Source: author's formulation

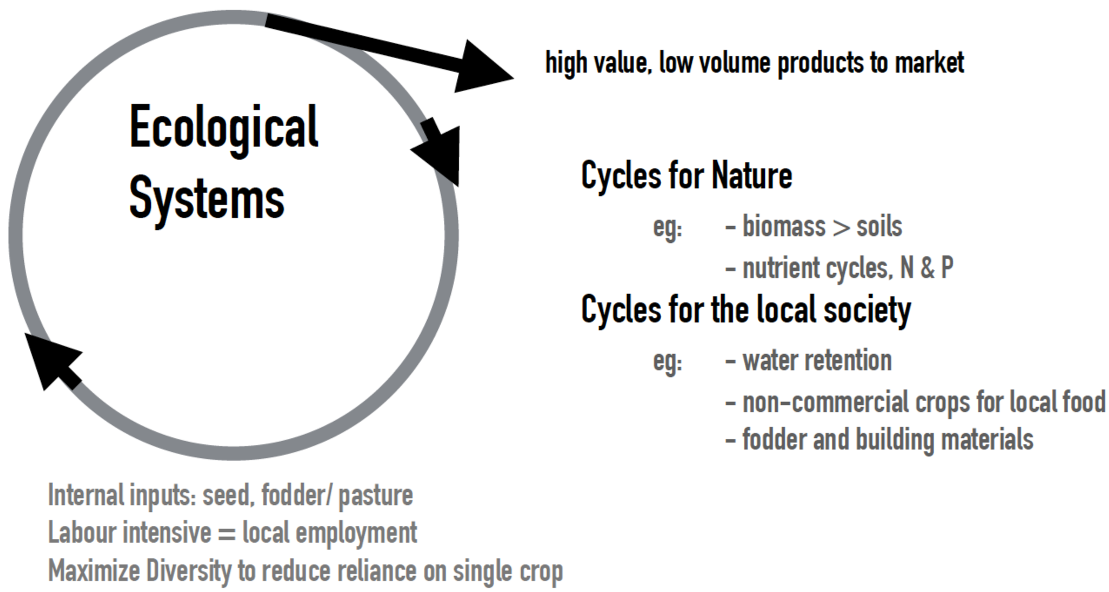


Figure 6 conceptualizes Ecological Paradigm illustrating the cyclical materials flow in food systems wherein nested and complex relationships are the basis of systems design. The system relies on internal inputs of seed, fodder and pasture and as such is self-limiting in scale. Ecological Paradigm attempts to maximize profit — the actual income from the farm after input costs are covered— rather than focus on yield of salable grain. In this paradigm, minimizing input costs by using practices that circulate resources internally, like composting and seed saving, is 'productive'. Ecological systems honour multiple valuation of food,, favouring high value finished products over low volume commodity approaches to market exchanges. Ecological Paradigm reduces consumption and humanity's current overtaxing of the earth's biocapacity (WWF 2012), By regulating the pace at which materials and labour can be dedicated to destructive and regenerative activities within a closed loop system, high value low volume strategies ensure access to resources and provision of ecosystem services for future generations.

The Ecological Paradigm is characterized by Food Systems research and considers both the ecological limits and the social requirements captured in the Doughnut Economics Framework (Fig 2.2.2). Rather than valorizing context-free yield per acre, Ecological Paradigm prioritizes nutrition per acre. Nutrition per acre considers what is spent (economically, socially and ecologically) to produce what profit (net nutrients as a measure of productivity) — as compared to the yield per acre metric which only considers commodity price (Shiva & Singh 2011). Multifunctionality and an emphasis on cycles drives decision-making, and regenerative activities are measured as contributing to the economy regardless of cash exchange.

Multifunctionality is an approach to agricultural management that reverts the trend of specialization. In a multifunctional system, livestock and grains coexist. For example, the services a lentil crop provides to the next season's wheat and the SOM the lentil plants contribute to the soil are part of the function of lentils— not just the price captured for the dried lentil grain (Renting et al. 2009). In an Ecological Paradigm, production is human food oriented, and productivity achieved within the context of a human - ecosystems health nexus. Ecologism is the philosophical and political system of thought that arises from an Ecological Paradigm, offered as a post-capitalist, post neoliberal politics (Salleh 2017; Raskin 2016).

Productivity in an Ecological Paradigm is a measure of the contribution to economics of the farm through regenerative activity. Ecological Paradigm measures nutrition per acre, values diversity, and emphasizes internal inputs. It counts regenerative activities as contributing to economy regardless of whether money is exchanged to represent that value, including maximizing employment. A food systems approach to food studies emerges from this paradigm.

3.4 Food Science and Food Systems: A Discussion of Two Research Approaches

Given the near hegemony in Canada's research community of the Productivist-Extractivist Paradigm or Food Science paradigm and with it a broad acceptance of agricultural intensification as the logical path forward, it is challenging to make the case for transformation in food systems. The outlook of Food Science arising from the Productivist-Extractivist Paradigm sees the industrial approach as a linear progression of the best and highest application of technology towards the business of 'feeding the world'. In the Food Science paradigm, food is valued strictly as a commodity. In the Food Systems paradigm, all six food dimensions as defined by Vivero Pol (2017) are given priority. The economies of each paradigm are shaped both by the world views and the corresponding data sets that are produced by the expression of the economic priorities and systems each paradigm offers.

A false dichotomy exists within a Food Science perspective between policies that support 'jobs' and ones that protect the 'environment'. Productivist-Extractivist Paradigm frames economic development and environmental conservation/restoration as competing interests. Yet Raworth's research shows that social and planetary boundaries are interdependent: "Environmental stress can exacerbate poverty, and vice versa. Policies aimed at moving back within planetary boundaries can, if poorly designed, push people further below the social foundation, and vice versa. But well-designed policies can promote both poverty eradication and environmental sustainability –- bringing humanity into the doughnut from both sides" (Raworth 2012:5). Solutions are, of necessity, multifunctional.

An ecological view of the natural world acknowledges life as nested self-organizing systems rather than separate 'biological machines' (Holling 2001; Escobar 1998) and calls for new metrics and decision tools that overcome policy silos and implement 'joined up' food policies (Levkoe et al. 2017). In a mechanistic world view of agriculture, living systems are reduced to their component parts to be understood, and are treated as both static and genetically deterministic. This belief ignores the fact that plants are self-organizing systems that learn and engage within their environment dynamically (Clayton and Davies 2006; Shiva 2017).

As opposed to a mechanistic worldview which is reductionist and linear, an ecological worldview is emergent and circular. The Ecological Paradigm holds humanity as an integral and inseparable part of the web of life in which people are co-creators with the living systems in which they exist. Food systems approaches to research engage these concepts when measuring the utility of a given intervention, policy, or product. While the mechanistic, Productivist-Extractivist Paradigm fetishizes the individual over the collective, the multifunctional, regenerative Ecological Paradigm seeks to optimize the health and well-being of the broader society (Skilbeck 2015). This socio-ecological civility is reconstructed in the Ecological Paradigm, modelled historically by traditional hunter-gatherer cultures for whom socioecological civility was, arguably, customary (Gibson 2013: 96-97).

The 'food science' paradigm is an expression of a Cartesian, mechanistic world view of nature, a narrative failing to account for the socio-ecological realities that affect food system sustainability. An analysis of the literature from food science school and the literature from the food systems school of food studies displays a discursive disconnect. These differences in core understanding of terminology and ideology are explored in Martin (2009), Rotz (2017), Vivero Pol (2017), and others. Deconstructing and re-articulating metaphors based on revealed assumptions of this hegemonic view of food and food systems is a potent way to challenge the status quo and open possibility of alternatives to it: "The way out of any double bind is to recontextualize or reframe the problem, thinking it through dialectically. This is what a paradigm shift means. By moving to another level of abstraction, the contradictory tension between two static options can be resolved" (Salleh 2017:36).

The liberal, professionalized environmental movement has not broken from the Productivist-Extractivist Paradigm, despite adopting the analysis and tactics that arise within an Ecological Paradigm. Instead of tackling consumptivism, the North American environmental movement, born out of Carson's Silent Spring call to action and exemplified by World Wildlife Fund and Sierra Club, became focused instead on creating “islands of biodiversity”, stuck in a view of nature as something to be consumed — if not for resource extraction then for human activity of some kind (Guha 2003:3).

Guha (2003) addresses two fallacies that seem to drive the dichotomous nature of the conversation amongst environmentalists in occidental countries: the romantic economist and the romantic environmentalist. These fallacious archetypes correspond to food science and food systems approaches living within Productivist-Extractivist Paradigms and Ecological Paradigms. If we just let the “free market” play out, according to the Fallacy of the Romantic Economist, globalization will result in the universalization of consumption. Such a narrative is a fallacy as there are ecological limits to a global consumer society (Guha 2003: 7). Romantic Environmentalists, on the other hand, imply that all development is a “nasty imposition on the innocent peasant and tribal, who, left to himself, would not willingly partake of enlightenment rationality, modern technology or modern consumer goods” (Guha 2003: 7). Such a narrative ignores the benefits of modernity and glosses over the impositions of pre-modernity.

The mechanistic, productivist, extractivist world view applied to natural systems trades living systems diversity for assembly line uniformity. With this orientation, timber exploitation becomes like mining, forests become non-renewable resources, forest peoples become dispensable (Shiva 1993). The analytical approach distinguishing the Productivist-Extractivist Paradigm and the Ecological Paradigm— a discourse analysis aimed at uncovering illusions of consciousness— risks the ire of Marxists for whom appeals to shift consciousness are appeals to simply interpret reality in another way. Conceiving of ideas exclusively as social constructs that have an independent existence suggests only a re-interpretation and introduction of new ideas and concepts— new phrases to replace the old ones[1]— is required to foment social change. Marx suggests that new phrases “themselves are only opposing other phrases” and those who engage in such exercises "are in no way combating the real existing world when they are merely combating the phrases of this world” (Marx 1845).

The exercise of discerning underlying assumptions through a paradigmatic distinction is not, as Marx warned, simply redefining reality through word play divorced of material context and the influence of external machinations. The discernments made in this study introduce material realities into decision-

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1 “It is evident that the Young Hegelians have to fight only against these illusions of consciousness. Since, according to their fantasy, the relationships of men, all their doings, their chains and their limitations are products of their consciousness, the Young Hegelians logically put to men the moral postulate of exchanging their present consciousness for human, critical or egoistic consciousness, and thus of removing their limitations” (Marx 1845)

making processes that are obscured by the lingering and dominant Productivist-Extractivist Paradigm. This engagement with phrases creates space for concepts that are material in basis but unrecognized as such under the dominant mechanistic narrative.

The 2016 International Year of Pulses campaign promoted pulses as a healthy choice. The global pulse sector launched a new marketing campaign promoting pulses as a "sustainable agriculture solution" while simultaneously doubling down on Specialized Industrial Food Systems as the dominant approach to pulse production (Bacon 2017). Yet data from new disciplines—from soil microbiology and toxicology for example—demonstrates that Specialized Industrial Food Systems are systems in crisis. Following up on a damning report from the UN Special Rapporteur on Food Security (DeShutter 2012), the federal government has recognized that policies across several ministries impact and are impacted by food and agriculture. In 2016, the Canadian Federal Government initiated a Food Policy development process, setting an intention to create a unifying policy for Canada's food system (AAFC 2018).

In the meantime, productivist-extractivist policies in siloed ministries supported by food science approaches to food and agricultural research dominate. One example is the Federal Government's five-year overarching policy framework, Growing Forward 2 (GF2). From 2013 to 2018, the federal and provincial governments subsidized more than 6,500 cost-shared projects through $147 million in GF2 funds. During the framework's development, Christie Young, Executive Director of Farm Start, critiqued the draft GF2 Framework for 1) its overt focus on yield as productivity disconnected from ecological costs of the systems used to achieve yields; 2) its lack of focus on farmer profit; and 3) collapsing the concept of innovation with high-input systems, high tech breeding systems, and IP or patentable results (Young 2012). The systems of production encouraged under such policies are incongruent with what research tells us about the hidden socio-ecological costs of industrial foods.

In economics, production and pricing ought to be related: the higher the cost to make a product, the higher the price at market. With food, we get a perversion of this basic market calculus, because the real costs of production are hidden. In the food systems literature these hidden costs are referred to as negative externalities (Weis 2013; Lappe & Collins 2015). They include: 1) the cost to ecosystems; 2) loss of farmer knowledge and farmer livelihoods; and 3) the cost to farmers (Shiva 2017).

The first hidden cost of Canada's industrial food system is to ecosystems: eutrophication, ground water and surface water degradation and toxicity, soil toxicity, lost biodiversity including pollinators and other key insect species, deforestation, and lost grasslands (Martin 2010; Rotz 2017; Clapp 2016; Weis 2007; UNCTAD 2013; Frison et al. 2016; IAASTD 2009). These systems lead to a reduction in nutrition per acre due to monocultures. Lost seed diversity is borne by future generations who have no access to previous genetic diversity created in economies that were driven by parameters other than transportability, uniformity, and early ripening (Quilley et al. 1998; Schroff & Catelini 2014). The costs of diet-related diseases, such as diabetes, are borne by Canada's public health system and those whose lives are impacted by diet-related illnesses. The second hidden cost of imposing industrial systems everywhere is a permanent loss of farmer knowledge — reflected in seeds, soils building practices and animal husbandry— and loss of farmer livelihoods — reflected in informal economies. The third hidden cost is the cost to farmers, exemplified through price manipulation from vertically integrated and ever-consolidating monopolies and cartels. Consolidated industries drive the price to the farmer down, extract value from the farmer through intellectual property payments and a treadmill of inputs, and control pricing in the market (ETC Group 2013; Shiva 2017).

The economics of the Productivist-Extractivist Paradigm insist that policies must prioritize the economy over the environment. This economic view insists that practices that toxify the farm ecosystem are, in the end, the environmentally responsible thing to do if these practices keep new farmland out of production. This argument for agricultural intensification accepts the notion of sacrifice zones as a necessary trade-off given the irreconcilability of current levels of consumption, ecosystems services needs and biodiversity priorities (Holt et al. 2016; Tilman et al. 2011**;** Kremen & Albie 2012). Yet such trade-offs ignore the long-term impacts on the regenerative capacity of food production systems.

Overwhelmingly, environment scientists are sounding alarms about our fossil energy intensive and dependent, commodity-driven, export oriented, highly processed, specialized industrial food system (UNCTAD 2013; Weis 2013). Yet Productivist-Extractivist Paradigm is the dominant framing around agriculture and food in Canada, creating a hegemony that obscures other discourses which have valid contributions to make on the question of systems sustainability. Pulses represent an opportunity to rethink Canada's industrial approach and examine the fundamental vulnerabilities and inevitable collapse of the current trajectory of industrialized food systems. Given what is known about the inability of the planet to sustain industrial food systems (Rockstrom et al. 2009; Pretty, 2008; Odum 1996; Lappe 1972; Winson 2013) alone is not driving decision-making.

A variety of drivers are influencing these directions for Canada's pulse sector. This chapter distinguished two world views connected to what scholars refer to as the Western scientific tradition categorized as favouring either food science or favouring food systems approaches to research and policy. Scientists engaged in this research might take issue with such a simplification and could rightly argue they inhabit grey areas that bridge this slow shift away from a normative mechanistic view of nature towards an ecological one.

The dominance of the productivist-extractivist world view shapes researchers' relationships to data. The distinction drawn in this section informs the case study that follows in Chapter 4 and provides a context for the discourse analysis in Chapter 5 using Causal Layered Analysis to explore the themes choice, efficiency, and safety that arise within a productivist-extractivist paradigm -- revealing what is obscured by virtue of the near epistemological hegemony within agricultural research and policy in Canada.

Chapter 4 **Agriculture at a Crossroads: Pulses as a Case Study**

IPES-Food's report, "From Uniformity to Diversity" (2016), describes agriculture as being at a crossroads with a need for humanity to choose a direction: the locked-in path of specialized industrial food systems and certain systems failure, or the difficult path of diverse, agroecological food systems fraught with socio-economic and political challenges. Pulses are at the centre of these crossroads and are garnering increasing attention from researchers involved with industrial and agroecological study (FAO 2016; Interview 1, 2, 3, 4 and 6 2018). A renewed interest in pulses culminated in 2016 being declared the UN/FAO International Year of Pulses (IYP 2016).

Little research has been conducted in Canada to evaluate the socio-ecological impacts of industrializing pulse production on a massive scale (Lappe & Collins 2015; Clapp 2016). The interdisciplinary research conducted by major agencies and think tanks over the past decade has demonstrated that industrial food systems are, by design, unsustainable (UNCTAD, 2013; Macintyre et al., 2009; Frison et al. 2016). Key works documenting the negative externalities of industrial food systems include Frances Moore Lappe's *Diet for a Small Planet* (1972) which launched the modern vegetarian movement in North America, Rockstrom's *Nine Planetary Boundaries* (2009) which draws attention to industrial agriculture's role in exceeding life-supporting ecological limits, and Weis' *Ecological Hoofprint* (2013) which details the true cost of the "meatification" of the diet. This combined body of research characterizes the ecological and social impacts of the cheap food system.

Another body of food systems sustainability literature focuses on the rise of alternative food networks (AFNs) as a response to the crises caused by specialized industrial agriculture. Valuable research in this area focuses on documenting success stories and offering case studies at the local and regional scales, while other researchers have focused on more broadly characterizing the ecological and social benefits of AFNs (Pollan 2008; Whitmann et al. 2011; Foran et al. 2014). Increasing attention is being given to analyzing barriers to transitioning from specialized industrial food systems towards diverse agroecological systems, particularly at the local level (Weiler et al. 2016; Koc et al. 2008; Levkoe et al. 2017; Rotz 2017; Martin 2011).

Claims of sustainability are becoming the cornerstone of the global industrial pulse brand following the IYP 2016 (Bacon 2017). Yet a contextualized reflection is required if such claims are to be consistent with Canada's commitments to the social foundations that provide the basis for the seventeen Sustainable Development Goals (SDGs) and the ecological imperatives outlined in Raworth (2017). In this chapter, a brief overview of what pulses need, what pulses offer, and the Canadian pulse sector at the time of the research provides the background information required to use pulses as a case study to reflect on Canada's industrial food system.

4.1 Pulse Sector Overview

Pulses are annual and perennial crops that are a subgroup of the Leguminosae family (the pea family) and are harvested solely for the edible seed portion of the plants. The Latin words puls or pultis are considered the origins of the term "pulses" which means "thick soup" (AGT 2018). Pulses refer specifically to the dried seed and are also known as grain legumes. When leguminous plants are used as fresh vegetables like green peas or green beans, they are not considered pulses. Legumes are also excluded from the "pulse" label when grown as oil-producing crops such as soybean and ground nut or peanut. Likewise, leguminous plants used for cover crop purposes such as alfalfa or clover are not considered pulses.

Eleven primary pulses — dry beans (e.g., kidney, lima, pinto, navy), dry broad beans (fava, horse), dry peas (garden), chickpeas, dry cowpeas (black-eyed pea), pigeon peas, lentils, bambara beans (groundnuts), vetches (used mainly for animal feed), lupines (used mainly for animal feed and as ornamental flowers), and minor pulses (winged bean, guar bean) — are recognized by the FAO as meeting the "pulse" definition (FAO 1994). Of these, the FAO focuses on five as the major global pulse crops— dried peas and beans (*Pisum sativum L.*), lentils (*Lens culinaris Medik.*), chickpeas (*Cicer arietinum L.*), and fava beans (*Vicia fava L.*)— due to their global trade value (FAO 2016).

While the FAO insists that all pulse species "merit research investment based on their unique importance" relative to local dietary preferences and in the context of unique local, regional and global diversification and resilience needs (FAO 1994), not all promising avenues are receiving their due research investment (GPC 2017; Interview 6 2018). In fact, until the last two decades, even these five economically significant pulse families were essentially forgotten foods— pushed to the margins of production and use by policies favouring other crops (Shiva 2016). Recent research and development attention on pulses indicates a recognition amongst policy makers that these pulse families can play an important role in the project of creating socio-ecologically just, climate adaptation- and mitigation-focused food systems, particularly for Canada's grain farmers seeking to diversify (Jason, Malone and Eathorne-Malone 2016; FAO 2016; Gan et al. 2015; Interview 5 2018).

Pulse production has been a human activity for more than 10,000 years and is ubiquitous globally, with centres of origin in Asia, Africa, and the Americas. Economically valuable crops cultivated in temperate climates, pulses have been found in archeological sites in India, Egypt, Mesopotamia, the

Americas, the Mediterranean, and Switzerland (FAO 2016; Jason, Malone and Eathorne-Malone 2016; Cassiday 2017). In Canada, split yellow and green peas, lentils, and chick peas dominate the prairies and the bulk of Canada's pulse exports. In Ontario, white beans are a major crop. Fava beans offer a great deal of potential in Canada according to Dan Jason of Salt Spring Seeds. However, Canada's pulse industry associations-- Pulses Canada and SaskPulse-- are focused on three pulses in particular: lentils, dried peas and chickpeas.

4.1.1 What Pulses Need

Like all plants, pulses require ample water, sunlight, and fertile soils with available nitrogen, phosphorus and potassium, as well as specific trace minerals to grow and thrive. Legumes are known as nitrogen fixers, meaning the plant can draw atmospheric nitrogen without needing synthetic fertilizer applications. Roughly 70 per cent or more of lentil nitrogen requirement can be achieved through nitrogen fixation of naturally occurring N in the atmosphere, and in beneficial growing conditions when inoculated with the appropriate rhizobia, with the remaining 30 percent of N needs can be derived from the soil organic matter (SOM) breaking down in soils (FAO 2016). Nitrogen fixation occurs when nodules on the plant roots interact with the rhizobia and microbiome in the soils to pull nitrogen into the plant. When synthetic nitrogen is applied, or when soil nitrogen levels reach 28-40kg/ ha, additional nitrogen has the effect of reducing nodulation and nitrogen fixation. Essentially, the plant gets "lazy" in the presence of ample available synthetic nitrogen and reduces nodule development and fixation in the presence of high nitrogen (Government of Saskatchewan 2018).

Pulses are prone to biotic and abiotic stress, and the lack of investment in seed development over the past century means that development of pest and disease resistant varieties globally has stalled (Joshi and Rao 2017:9). The global project to modernize agriculture initially left pulses out due to their lack of responsiveness to hybridization and to monoculture production. In Canada, farmers work with one cropping season; however, in regions where pulses are traditionally grown and in their centres of origin, farmers have bred pulses in the context of multiple cropping seasons. Much of the world's seed heritage in pulses predates the project of agricultural modernization and thus the bulk of local pulses are adapted to multi-season rotations and bred to be grown in mixed or multiple cropping systems rather than in monocultures (Shiva 2016; FAO 2016; Jodha & Singh 1990).

Mixed cropping or multiple cropping systems involve two or more crops grown simultaneously with either distinct row arrangements or no row arrangements (FAO 2016). The new methods of cereal production adopted in the second half of the twentieth century eliminated the use of multiple cropping despite the high productivity of such systems (UNCTAD 2013; Shiva 2016; Tillman 2011). For example, peas stand straighter and are therefore easier to harvest when grown in a mixture with triticale, oat, or barley. This intercropped mixture yields more dry matter per acre than a single pea stands or pea 'monoculture' (Oelke et al. 1991). The peas also exploit soils effectively for water and nutrients, making these available for all crops in the mixed cropping system (FAO 2016; Shiva 2016; Oelke 1997).

4.1.2 What Pulses Offer

At a time when the excesses of industrial livestock production are under fire for impacts on ecosystems health and on human health (Lappe 1968; Weis 2013; Winson 2013; IAASTD 2009; UNCTAD 2013), pulses offer a good news story. Pulses are best known as a complete vegetarian source of protein when eaten in combination with grains such as wheat, millet, rice, or buckwheat. On average, pulses contain 20-25 per cent of protein by weight, offering twice the protein available in wheat and three times the protein found in rice. In addition, pulses do not contain residual hormones and antibiotics that can be found in meat and dairy (FAO 2016; Monk et al., 2017; Rao and Joshi, 2017).

Calculations on future food requirements to meet the needs of the world's population in 2050 vary based on projected dietary preferences. One forecast for global caloric and protein requirements showed that crop demand corresponds in a linear trajectory with per capita income increases—which researchers determined was an indicator of greater livestock product consumption. Their analyses "forecast that global demand for crop calories would increase by 100% ± 11% and global demand for crop protein would increase by 110% ± 7% (mean ± SE) from 2005 to 2050" (Tilman et al. 2011). While this analysis results in a projected doubling of global crop calorie and protein demand over 2005 figures, the study forecasts figure lower than the 176% (caloric) and 238% (protein) increases that can be extrapolated from Canada's per capita demands on grains were all nations in 2050 to reach Canada's per capita levels. This study predicts 30% more crop production required than the 70% referenced by other researchers (Weis, 2013; Frison et al., 2016; Lappe and Collins, 2016), based on the researchers' emphasis on quantitative global trends in per capita crop demand connected to income-dependent dietary choices whereas the 70% figure is qualitative data based on expert opinion of national and regional demand trends (Tilman et al., 2011). The researchers also acknowledge their projections do not fully account for disruptions to global grain supplies due to a) climate breakdown or b) increasing social tensions that are predicted to accompany the more regular crop failures climate scientists are predicting.

Wide adoption of pulses as a protein substitute, however, can lead to significant reductions of our 'ecological hoofprint' (Weis 2013). Kilogram for kilogram, pulses grown in agroecological systems demand 20-40 times less fossil energy to produce than industrial-scale meat due in large part to pulses' nitrogen fixing capacity (Jason, Malone and Eathorne-Malone 2016). When comparing the ecological costs of pulse production with meat production, drastic reductions are also evident in 1) the use of water per gram of protein; 2) the use of synthetic fertilizer per gram of protein; and 3) acreage required per gram of protein (FAO 2016; McVicar 2010). Canadians have reduced demand for red meat by 25% over the past decade, while 43% of Canadians are seeking more plant-based protein in their diets. While only two percent of Canadians are vegan and six percent are vegetarian, the target market for plant-based protein includes a significant portion of Canada's population based on the above statistics (von Massow et al. 2018).

Including pulses in rotation improves the range of ecosystem services— including climate change mitigation— provided within a given farm operation (Millennium Ecosystem Assessment 2005). Planting pulses improves the depth and quality of Soil Organic Matter (SOM) and diversifies soil nutrients (Government of Saskatchewan 2018; Interview 2 2018). Fixing atmospheric nitrogen reduces the overall demand for synthetic nitrogen fertilizer, the manufacture of which uses excessive amounts of natural gas and other fossil energy sources. Nitrogen fertilizer accounts for 50% of all energy used in commercial agriculture (Woods, 2010). Pulses add an estimated five to seven million tonnes of nitrogen in over 190 million hectares of soils globally (FAO 2016). Nitrogen oxide is 300 times more potent a GHG than carbon dioxide -- intercropping pulses with cereals reduces nitrogen oxide emissions (Chandler 2013:174).

Pulses are nutrient-dense, low in calories, low in fat, and high in fibre. Micronutrients in abundance in pulse crops include folate, iron, calcium, magnesium, zinc and potassium (FAO 2016; Shiva 2016; Jason, Malone and Eathorne-Malone 2016). Children at risk of stunting from malnutrition in the first 1000 days of life are nourished by pulses, which have an array of micronutrients as well as the protein they are prized for when combined in the diet with cereal grains (Shiva 2016; FAO 2016). Pulse consumption reduces risks for several non-communicable diseases and health conditions, including diabetes, obesity, and heart disease. Pulses also play a role in developing a complex and diverse gut micro biome as the RS fibres in pulses are slow to digest and provide fuel for healthy bacteria (Bacon, 2017; Monk et al., 2017; Buttress and Stokes, 2008). Pulses, like millets and sorghum, are counted among the "forgotten foods"—foods that had no commodity value as part of the project of food systems globalization, despite having local nutritional and cultural importance (Vivero Pol 2017; Rundgren et al. 2016).

4.2 Canada’s Pulse Sector

Several trends have impacted the direction of agriculture in Canada over the past few decades, including: stagnant farm earnings, rural depopulation, consolidation, policy changes in the seed sector, reliance on intellectual property for innovation, agricultural intensification, and economic pressures (Duyek 2007; Kneen 2002; NFU 2008; Koc et al. 2008). Canada’s shrinking agricultural sector continues to struggle in once profitable crop areas, receiving an ever-smaller portion of what is spent at retail on food. Canola, wheat, corn and soy are increasingly less reliable profit centres for Canada’s farmers (Aitkens 2015).

As a result, farmers have been turning to pulses. Efforts to adapt pulse production beginning in the 1980s improved yields while ensuring new cultivars fit within the existing management regimes (from seeders to harvesting approaches), minimizing costs for innovative farmers willing to risk a new crop. Early adopters on Canada’s prairies have profited. The 2011 Census showed just over 1700 of roughly 4500 total prairie pulse growers submitted farm receipts of over $1 million (StatsCan 2016), with India as the primary customer. Total Canadian pulse production in 2017 was 7.3 million tonnes.

Global pulse production dropped significantly during the second half of the 20th century as a result of Green Revolution policies and the subsequent wide adoption of wheat, corn, rice and soybeans. Countries like India in which pulses remain a staple food needed to step up imports to meet demand (Rahman 2015; Rinku et al. 2001). Investment by Canada’s pulse sector gave Canadian producers a small advantage in both agronomic improvements and in setting up integrated value chains to meet the growing global demand for pulses, which is projected to continue to rise for decades. Projections indicate a 23% increase globally in pulse consumption, with Africa expected to experience a 50% increase in pulse consumption (Cassiday 2018, GPC 2017, PIC 2018). Pulse Canada has been working with the sector to diversify from Canada’s main buyer, India, by promoting consumption of pulses and pulse-ingredient products within the North American, European, and what economists call ‘emerging markets. The sector is betting heavily on ultra-processing to make pulse ingredients desirable to food manufacturers for ingredient substitution (PIC 2017; GPC 2017).

A few decades ago Canada didn’t register as a producer of note for pulses. In 1970, only 600 hectares of lentils were in commercial production in Saskatchewan, a province with 41% of Canada’s arable land. In just 45 years, Canada went from obscurity to the world’s leading lentil exporter, producing 1.5 million tons—600,000 tons more than India (Nedumaran et al. 2015). Early innovators saw a future for pulses in the province’s dark-brown soil zones. Three levers—profitability improvements, breeding programs, and accessible processing—helped prairie farmers capitalize on that fact, and today 97% of all of Canada’s lentil production takes place in Saskatchewan (Barr et al 2009:1).

4.2.1 Improvements in Profitability

Canada's industrial approach to pulses is being aggressively promoted globally (Shiva 2016; Ganeshaiah 2016; GPC 2017; Interview 2 2018). In the context of global trade, Canada's heavily mechanized, chemically reliant pulse production systems currently result in an economic advantage for Canada's farmers over small-scale producers reliant on farm labour and mechanical or hand cutting – in pulses called swathing (Nedumaran et al. 2015; Interview 6 2018). Chemical reliance and 'modern' breeding approaches — genetic mapping, hybridization and genetic engineering— are cultural practices aimed at adapting pulses for the industrial system. Genetic mapping "speeds up" commercial breeding based on connecting trait expression with specific genes. Lentils from seed banks and from communities around the globe are being collected through the public-private partnership between University of Saskatchewan and NRGene, a private big data firm. Led by U of S scientists Kirstin Bett and Bert Vandenberg, the $7.9-million Genome Canada-funded "Application of Genomics to Innovation in the Lentil Economy" seeks to improve yield and quality by pulling genes from wild relatives, land races, and regional varieties for breeding into commercial varieties (AG Canada 2017). Hybridization has been pursued over the past 100 years largely to push yields in various crops, despite Lewontin's claim there is no biological reason that open pollination cannot achieve similar improvements (Lewontin 2001). Hybridization ensures a level of uniformity that modern agriculture is dependent upon, but this uniformity isn't carried on in saved seeds. Hybridization also renders the farmer-- who for thousands of years saved seeds as part of agricultural practice – dependent on seed companies (Collins and Lappe 2015; Shiva 2016).

Time-consuming swathing has been replaced with direct chemical harvesting, increasing short-term profitability for prairie farmers. Swathing is a mechanical step in the harvest process using a blade (hand held or mechanical) to cut the crop when the seeds are at 50% maturity or greater, placing the crop in rows held together by interlaced straws. The remaining stubble keeps the crop from touching the earth, allowing the crop to dry down (Seymour, 2017). The registration of new fungicides, herbicides and desiccants— including the Imidazolinone family of herbicides for use during emergence, and Glyphosate-containing products for use pre-harvest— provided predictability, and uniformity. Replacing swathing with chemical direct harvesting reduces risk of yield loss associated with rainy weather that interferes with drying grain legumes to acceptable moisture levels and fungal counts. This standing dry down phase using chemical desiccants saves farmers time and reduces loss in field when compared with swathing.

Swathing requires several days of consistently dry weather, less predictable with climate breakdown. The yield is more reliable and thus more profitable (SaskPulse 2017; IPCC 2013).

4.2.2 Breeding Programs

As with Canola, Canadian farmers have both government and publicly funded university support for breeding programs aimed to address specific agro-economic issues that, prior to these investments being made, prevented the wide adoption of pulses (Kneen 1992; Pulse Canada 2018). In 1983, the five year-old Saskatchewan Pulse Producers created a research and development fund collected through automatic, mandatory fees that are based on a percentage-of-volume “tax” taken from the farmers’ income, called a check off. Agriculture and Agri-Food Canada, University of Saskatchewan (the Crop Development Centre) and the University of Guelph are responsible for the bulk of the seed development under this program (SaskPulse 2017). The check off funds are earmarked for varietal development, and seed breeding royalties are eliminated for participating farmers. These new genetics combined with reliance on pre-harvest herbicides have shifted the cost/benefit ratio at the farm level, rendering pulses competitive with other prairie crops (AGT 2018; Pulse Canada 2018). Breeding shorter varieties for Canadian production has also improved profitability by reducing losses due to lodging (bending over of stems near the ground before harvest) and by allowing farmers to employ existing equipment used for other grains (Interview 3 and 4 2018; SaskPulse 2017).

While the public-private partnership model SaskPulse initiated is an incredible example of farmer-led research, shifts over the many years since the check off was initiated are having some unintended consequences. For example, during the interviews, one interviewee mentioned the irony of Saskatchewan farmers having to sell seeds bred with their money for their advantage to competitors globally with the ‘bonus’ being the Canadian farmer isn’t paying a royalty (Interview 6 2018). While the lack of royalty payment is advantageous when competing with crop programs within the Canadian system, the advantage is minimal when competing with outside farmers who can access improved seeds funded by Canadian farmers. When viewed over the life of the program to improve lentil production in Canada, it seems we may have, as with Canola, socialized the risks and privatized the profits (Kneen 2002).

4.2.3 Processing

Whether for food, feed, pet food, or industrial uses, processing pulses is at the heart of Canada's agriculture sector growth strategy. Canada is the world leader in dry pea production, attracting investment in integrated growing and processing businesses both from domestic and foreign interests, as recent investments in processing facilities by AGT Foods and Verdient attest (AGT 2018; Cross 2017). During the ten years leading up to and including 2016, 4,922 new pulse ingredient products were released in North America. In 2016, Canada saw the release of 298 new pulse-containing products and Canada exported over $4.1 billion CAD of pulses (Zarouki 2017:1). Various experts have questioned both Canada's export strategy and industrial production models in light of socio-ecological costs at home and abroad (Clapp 2016; Levkoe et al. 2017; Frison 2016; UNCTAD 2013; Ikerd 2016). However, the pulse sector and government supporters are counting on a linear trajectory of "productivity" and on historical boom-bust cycles in commodities continuing into the next thirty or so years (AGT 2018).

Pea ingredients are increasingly popular substitutes in pet food formulations, driven by manufacturers seeking to improve their bottom lines and the marketability of their products, and pet owners seeking higher quality ingredients. Just shy of 89% of all new U.S. pet food products containing pulse ingredients were released by branded products. Pea protein, pea protein concentrate, pea fibre, and dried peas are routinely included in pet food formulations, often quite prominently (Zarouki 2017:10). This increase coincides with the processing sector's expansion of fractionation plants and milling centres.

Canada's AGT Foods has recently expanded its processing capacity by adding four new processing streams with major fractionation units coming online in 2019 and 2020 in Saskatchewan (AGT Press Release March 2018). In 2017, Roquette of France announced it would be building the world's largest pea processing facility in Portage la Prairie, Manitoba. Verdient Foods launched a sizeable organic processing facility in Vanscoy, Saskatchewan (Heppner 2017; Cross 2017).

Processing on Canada's prairies largely focuses on protein concentration, isolation, and deflavouring (Noteworthy et al. 2017: 139). From the perspective of an integrated value chain, creating uniform, flavourless ingredients that shore up profitable brands and provide multiple markets for "functional" ingredients makes incredible business sense.

Canada's AGT Foods dominates the global market in pulses, capturing 45% of the global trade in these commodities and their processed products with operations in several countries (AGT 2018). Yet in the 12-month period prior to February 2018, AGT share value had dropped 40 percent, while Vancouver-based Stat Communications data showed that by mid-February of 2018, grower bids on certain grades of large green lentils dropped 34 per cent since November of 2017 (Skerritt 2018). AGT press releases in the spring of 2018 and recent annual reports indicate AGT management feel this slump is simply a normal boom/bust commodity cycle, predicting returns to previous levels of profitability as global oversupply evens out (AGT 2018). Yet in the decade leading up to these drops in value, Canadian farmers had largely experienced year on year gains. And while it is true that Canadian commodities ride boom/bust cycles (when this research began in 2016, wheat and canola prices had dropped 33% and pulses had gained—the exact opposite scenario is seen in mid 2018, two seasons later), Canadian farmers were seeking to avoid such cycles through inclusion of pulses in rotations. Such cycles are tied to the economics of commodities generally rather than the specific commodity itself.

4.2.4 An emerging market matures

Canada has ramped up production to meet worldwide demand, yet so too has the world. In industrialized countries, 28% of cereal production is exported while 52% of pulse production is exported (Joshi and Rao 2017:12). As with soybeans, Canada's optimism and early successes in newly expanding pulse export markets must be tempered with fact that every other ministry in every other agricultural exporting nation that can grow pulses is working from the same playbook, and a global oversupply will impact small scale farmers with the highest labour costs per weight of pulses produced the most.

Outstanding questions from the literature review were addressed at the $1,500 per person Global Pulse Confederation's "Future of Food" Conference in July 2017 where the world's pulses players gathered, representing $100 billion in global pulse trade at the retail level alone (Bacon, 2017). This conference provided a stark global context for the roughly 12,000 farms—80% of which are located in Saskatchewan-- growing any scale of pulses across Canada (Statistics Canada, Census of Agriculture, 2011). Canada's pulse growers face increased competition for export markets from other countries also eyeing pulses as a key economic strategy. In addition, domestic policy changes aimed at shoring up domestic food security in pulse-eating countries like India also affect Canadian sales.

Canadian farmers enjoyed a relative boom with few contenders for markets from 2010 to 2015, and now other major producers have come on board to compete and the impact on Canadian farmers has been significant. Indian Prime Minister Modi's "Second Green Revolution" policy was launched in 2009 and aimed at expanding pulses and oilseeds acreage domestically to meet demand (Ganzel 2009; FE Bureau 2014). Pulses production in India has increased steadily and a once reliable export market for Canada's pulses has become volatile. In December of 2017, India imposed new tariffs on lentil and chickpea imports of 30% and 40% respectively (Skerritt 2018). New competition from Australia, Ethiopia and South America is adding to the pressure on Canadian exports (Penner, 2017; Nedumaran et al. 2015).

. The next chapter explores hidden assumptions about industrial food systems that mask as observation within the hegemonic food science discourse through a Causal Layered Analysis of the notions of choice, efficiency and safety in the context of Canada's food system.

Chapter 5 **Choice, Efficiency and Safety: Examining the Narratives**

Narratives within industrial food systems claiming choice, efficiency and safety are best achieved when pursuing what is described as a Specialized Industrial Food System, dominating food science research (Frison et al., 2016:11). The food science approach, as discussed in Chapter 3, arises from a Productivist-Extractivist Paradigm (Productivist-Extractivist Paradigm). Applying Causal Layered Analysis (Inayatullah 1998), I unpack specific narratives about choice, efficiency and safety drawn from statements from interviewees, the presentations during the Future of Food Conference in July 2017 and industry publications (Motes, 2017;.

These narratives obscure drivers in Canada's industrial food system. While CLA typically involves moving back up through the four layers to reconstruct new alternatives (Inayatullah 2004), the analytic method is applied in the current research to reveal hidden beliefs and assumptions in practice today that impact research and policy processes. Interviews, industry research and publications from BASF, The Global Harvest Initiative and CropLife, and speakers at the Global Pulse Confederation's "Future of Food" Conference in July 2017 in Vancouver provide the narratives on choice, efficiency and safety used in this analysis. The forecasting step within each of the three narratives would not bring value without involving a large number of stakeholders and is beyond the scope of the current research aims and resources. Discourse analysis, and not problem-solving, remains the focus of the current inquiry. The tables found in 5.1.1, 5.1.2, and 5.1.3 summarize the analysis of Productivist-Extractivist Paradigm narratives about choice, efficiency and safety.

5.1 Introduction

The dominant food system in Canada reflects a near hegemony of thought steeped in food science discourse, with industry publications reflecting a belief that industrialized food systems are "highly efficient" and "can accommodate many degrees and types of preferences and levels of purchasing power" (Motes 2010:19). Proponents of industrial agriculture operating in a Productivist-Extractivist Paradigm claim we end up with the industrial food system due to 1) farmer and consumer choice; 2) efficiency of the system; and 3) the safety such systems assure (Prouse 2018; BASF 2018; Motes 2010; Steensland & Ziegler 2017). In essence, this narrative determines the market has chosen the best possible system. However, the critical food systems literature suggests we end up with the industrial food system due to lock-ins and hidden drivers that are based in valuing food solely as a commodity at the expense of other values (Frison 2016; Vivero Pol 2017; Clapp 2016).

Industrial food systems value one food dimension (food as commodity) at the expense of other food dimensions, food as: a renewable resource; essential for life; a human right; a cultural determinant; and a public good (Vivero Pol 2017). This free market food-as-commodity narrative ignores the social needs and ecological boundaries outlined in Kate Raworth's doughnut economics (Raworth 2017), obscuring lock-ins behind rhetoric on choice, efficiency and safety. The resulting lack of visibility of negative impacts of industrialization frustrates attempts to organize a transition towards truly sustaining food systems (Frison et al. 2016).

As the Executive Director of the Organic Council of Ontario from 2009-2014, I engaged media on behalf of Ontario's one-billion-dollar organic sector, requiring a thorough and informed understanding of industrial food system proponents' responses to the rise of the organic sector to 3% of the mass food market (COTA 2014; Pries 2012). Working independently, with university researchers and in coalitions of industry, civil society, media consultants, academia and government, the author analysed and deconstructed communications from industry, academia and government to ascertain underlying values, priorities and beliefs. Critiques revealed that industry positions and narratives demonstrated shared assumptions about what constitutes choice, what makes the current approach efficient, and what constitutes safety in food systems. These narratives are reflected in industry and government reports and publications (von Massow et al. 2018; Prouse 2018; BASF 2018; GPC 2017) and are consistent with free market narratives expressed by commodity farmers and captured in food systems research (Rotz 2017; Bishop et al. 2013; Inayatullah 2017; Martin 2013).

Unpacking these dominant market narratives of choice, efficiency and safety offers insights into the assumptions that drive political and economic dimensions of Canada's food system. Following Bishop et al. (2013), the questions used for the key informant interviews correspond to one or more of the four layers within the CLA analysis. Interviewees were given opportunities in each of twelve questions to speak in terms of these three narratives of choice, efficiency and safety. Content analysis of textual sources played a central role in this CLA, scanning reports, communications, presentations, and publications. Tables summarize the analysis with a discussion of the four layers in each of the three narratives from a Productivist - Extractivist Paradigm perspective. Once the underlying assumptions of these narratives are distinguished, a short discussion of the implications for the results of this analysis provides context for the application of the eight lock-ins framework (Frison et al. 2016).

5.1.1 Choice

There exist several ways to consider the notion of choice within the current research. Primarily, this analysis addresses the Productivist-Extractivist Paradigm and food science conceptualizations of food systems choice in terms of free market dynamics and liberal societies— where farmers are free to choose how they manage their operations and consumers choose freely what they wish to see in the world by what they buy. If societies want more, or less, control over aspects of regulations they can choose this or that government. These notions are predicated on free market narratives of level playing fields, of one person one vote democracy, of meritocracy and of self-regulating supply and demand. The entire field of ecological economics— as exemplified by the works of Herman Daly, Eleanor Ostrom, Homer-Dixon, and Raworth (Daly 2004; Homer-Dixon 2008; Raworth 2017) — is a response to the lack of ecological perspectives within the classical, mechanistic approach to economics.

Researchers note that choices, while shaping our world to some degree, are also shaped by our beliefs and stories about the world. Failing to imagine another way of being is a trap of the Productivist-Extractivist Paradigm, and overcoming this trap opens up possibilities that are inaccessible when one views the world in reductionistic, disconnected terms alone. Escaping the grip of the mechanistic worldview is perhaps the major challenge in creating a sustainable world in the Anthropocene, and not the technological, economic or political challenges upon which analyses tend to focus (Skilbeck 2015).

As one can recall from Figure 4 An Overview of Causal Layered Analysis, the first layer, the litany, is the uncontested truth, at a superficial level. It reflects what people say. The litany in this case is the idea that agricultural intensification/industrial systems give consumers and farmers more choice than at any point in history (CropLife 2011). Farmers and industrial food champions have good reason to celebrate the successes of the Specialized Industrial Food Systems when the goals are to produce as many calories as the world can as quickly as the world is capable (Martin 2012). The post Great European War (2) governments seeking to avoid famine made a project of modernizing agriculture with the focus of maximizing grain output per acre, the commentary on choice at conferences, on line, and in publications repeats a common refrain that industrialization has given eaters and food providers more choice than ever in history. A class of food scholars able to study and devote time to this research exists undeniably as a direct result of industrial specialization. The modern Canadian food system creates divisions of labour such that some of the people indeed have access to levels of education and leisure of which previous generations — and much of the world— could only dream.

At the second layer of analysis, social causes, Productivist-Extractivist Paradigm voices claim industrial food systems offer the most choice, and the proof is the grocery store shelves with more access to more kinds of food throughout more of the year as a result (Bloom 2014). Yet critics point to the fallacy of choice where twelve plants and five animal species makes up 75% of the planet's diet, with rice, wheat and maize making up 60% of calories and proteins obtained from plant sources (FAO 1999).

Farmers, according to agribusiness, also have more choice than ever before and need all the tools in the toolbox available to manage their operations. In such a framing, discussions over management approaches come down to proving whether this one herbicide or that other herbicide causes this or that issue (rather than inquiring why we have unwanted weed presence). Data that supports these social causes include the range of choice in fungicide application regimes and herbicide regimes in lentils and the volume number of new pet food products using pea fractions (Zarouki 2017).

Table 1 Causal Layered Analysis: Choice

CHOICE Causal Layered Analysis	
	PEP / Food Science
LITANY: ***what people say***	More people the world over eat more and better because of modern agriculture… reflecting ingreased availability of all foods, dietary diversity" (Motes 2010:14)
SOCIAL CAUSES: systemic or technical explanations ***what people do***	Advances in food science have led to greater food choice (GHI) Data that supports these social causes include: 1) # of finished products from non North American cuisines available in grocery stores 2) # of varieties of lentils available to a Prairie farmer today vs. in 1975 3) # inputs available and apparent differentiation in varieties of commodity crops 4) Variety of specialized equipment to choose from for planting/ management/ harvest compared to previous generations
WORLD VIEW: expressed through terminology, words, phrases ***what people think***	"That lost variety couldn't compete" "Vote with your dollar" Linear language; Binary; cause/ effect Choice is within sets rather than amongst sets: 16 kinds of corn-based sugar coated extruded cereals
MYTH: socio-cultural archetypes, emotional responses, mythical stories ***what people feel***	* Antiquated artisan food has no place in the modern era (Bacon 2017) * The market is the Best Conductor (Rungren 2016) * Canadian farmers choose (Prouse 2017) ARCHETYPES: Meritocratic free markets; The Rational Actor; The Empowered Consumer; Free Will; Rugged Individual

At the world view/ discourse layer, the third in the analysis, farmers within a Productivist-Extractivist Paradigm are seen as having “more choice” in their tool kits than ever before. These choices in practice are limited to which chemical-seed combinations to use, which two to four cash crops to rotate, and when to sell a crop (Martin 2013), rather than choosing among a range of approaches to weed management, like intercropping. Choice is in practice amongst a solutions set — choosing amongst progeny of a handful of red lentil varieties grown monoculturally — rather than choices between solutions sets — choosing between monocultural red lentil production or a corn/pulse/ squash inter-cropped system as is the world view in an Ecological Paradigm (Ekin et al. 2007).

In a mechanistic world, today’s array of choice is seen in the assumed context of a linear progression from fewer choices in some previous time to more choices today than ever before. When one investigates the evidence, however, a massive loss in seed biodiversity was identified by RAFI in 1983, with the National Geographic creating an iconic graphic of the loss of some 90% of commercial seed varieties in a 100-year period (Siebert 2011). At the fourth layer of myth, food is only a commodity. The fava bean plant, for example, is like a fava bean making factory with the yield of fava beans per acre in a given season as the myth’s framing. At the level of myth, “artisan” production and “natural” selection that doesn’t involve corporate seed development and hybridization/biotechnology is “old fashioned”, antiquated, outdated, or a poor choice. In this mythology, farmers have given up pre-industrial practices (open pollination or farm-based seed saving or inter-cropping) because the latest industrial practice (genetic engineering or IP-based seed systems or mono-culturing) is better. When considering “choice” as it is mythologized in a Productivist-Extractivist Paradigm, two specific myths — meritocracy and consumer choice — are perpetuated in industrial food systems.

The Myth of Meritocracy promotes the idea that merit alone and not privilege nor structural inequities informs the choices being made. The emotional response is that science as Canada does it produces the best result and the truest result. Evidence of these myths include the adoption of the phrase ‘scientifically advanced agriculture’ in place of the shorthand ‘industrial agriculture’ (Motes 2010). Where a given system is ‘better’ that system would dominate; while the myth appears to be apolitical it can also be seen as a form of activism in support of the status quo.

The Myth of Consumer Choice arises within the dominant neoliberal economic doctrine that the market, not the public through government, is best situated to be conductor of an increasing number of areas of public life. This doctrine includes a belief that “consumers shape how production is organized" and “(where) policy-makers take a back seat.” (Rundgren 2016:9). In other words, the public votes with their dollars. Within an Ecological Paradigm, choice involves intergenerational thinking, as exemplified in Anishnaabe philosophy of considering in choice-making what the impact of an action is seven generations forward and seven generations past (Oral teachings, Willie Pine 2018). Operating in an Ecological Paradigm one considers how a choice that may benefit one individually impacts others.

5.1.2 Efficiency

What is considered 'efficient' depends largely on the goal at hand. Generally, efficiency within a given system is achieved by avoiding waste and reducing overall material and energy use per unit of benefit. In practicing environmental assessment, efficiency is meaningless as an independent objective. The efficiency requirement for sustainability is to provide a larger base for ensuring sustainable livelihoods for all while reducing threats to the long-term integrity of socio-ecological systems (Gibson 2016).

Table 2 Causal Layered Analysis: Efficiency

EFFICIENCY Causal Layered Analysis	
	PEP / Food Science
LITANY: ***what people say***	"Agrochemicals, modern genetics, modern machinery… contribute to sector efficiency and growth" (Motes 2010:18) "Goals in pulse breeding (rely on) rapid introduction of new technologies and ideas that allow us to increase/ maintain genetic and economic gains (Ta'ran et al. 2017)
SOCIAL CAUSES: systemic or technical explanations ***what people do***	"Increasing sustainability through a highly productive and efficient system that simultaneously protects the environment by means of sensitive and efficient use of natural resources" (Jeff Simons, Ely Lily, in Motes 2010:15) Data that supports these social causes include: 1) productivity data measures improved productivity via reducing # workers/ volume of food output; yield of commercial grain per acre of land cultivated 2) Uniformity reduces waste at the processing level (Bacon 2017) 3) increased sales in convenience food as proof of the inevitability of continued growth in convenience food sales (PIC 2018) 4) Economies of scale (that don't measure negative externalities)
WORLD VIEW: expressed through terminology, words, phrases ***what people think***	"skillful application of science can allow the global population to better control its own development and growth" (Motes 2010:4) "Ways to bring weeds under control: whether its the ultimate pre-seed/ pre-emergent turndown or exceptional in-crop control, you'll find solutions to keep your fields clean all season long" (BASF 2018) PHRASES: building blocks of life; Crop Protection products; comparative advantage in production; fortified with essential nutrients; modern agriculture; yield per acre; scientifically advanced farming
MYTH: socio-cultural archetypes, emotional responses, mythical stories ***what people feel***	"food production growth is no longer seen as tightly constrained even though many production resources are —fixed, or nearly so, as Malthus correctly perceived" (Motes 2010:4) ARCHETYPES: The Environmental Zealot; The White Knight; The Selfless or Benevolent Corporation; The Modern FarmerMan as Machine — Soil as Substrate — Plant as factory

Conventional efficiency initiatives demand maximum yield, economies of scale, and avoidance of duplication. Resilient efficiency initiatives demand flexibility, modularity, diversity, and avoidance of thresholds. Metrics that derive from new sciences describing interdependence, nested systems, and feedback loops are ignored in conventional efficiency initiatives, thus new metrics are required to evaluate sustainability (Gibson 2016; Vivero Pol 2017). Food science research is based on the assumption that increasing efficiency requires reducing the number of farmers producing food, and that the remaining farmers will continue to adopt 'modernizing' practices and reducing the amount of paid labour per unit of food produced. As farmers disappear, however, so too does the agri-cultural knowledge, often handed down over thousands of years of experience— a deeply inefficient exercise from the resilience perspective of food systems research.

At the layer of the Litany, the analysis reveals a near homogenous acceptance within food science research and policy that agro-chemicals, modern genetics and modern machinery are necessary to achieve efficiency and growth. Mechanization in particular has been essential in generating productivity (Motes 2010:18). Various studies and agencies forecast the need for an additional 70-100% increase in food output relative to 2009 levels (Tilman et al., 2011; Prouse, 2017; FAO 2011). Citing the dual challenges of population and economic growth, industry promotes the notion chemicals are required to close the global agricultural productivity gap (BASF 2018; Tilman et al. 2011).

Jerry Steiner, a Monsanto Executive, quoted in Motes (2010) declares, "We need to produce as much over the next 40 years as we have in the last 10,000 years, and do so on about the same amount of land" (Motes 2010). From a food science perspective, the answer is yield increases. Efficiency is seen as synonymous with industrial intensification, with a conflating of Specialized Industrial Food Systems and efficiency as a singular concept achieved in the wake of the Green Revolution, now more than 50 years old (van Zanden 1991). This conflation has been so complete that a Second Green Revolution seeking to industrialize pulses is underway in India and elsewhere (FE Bureau 2014). The litany repeated amongst those operating within a Productivist-Extractivist Paradigm— farmers, scientists, nutritionists and eaters — is that technological efficiencies within the industrial model move us steadily towards sustainability.

At the layer of social causes, efficiency is achieved by creating uniformity. Building larger systems that produce economies of scale reduces costs of final products. Because large farms produce more output per worker, the system itself is deemed efficient. Specialized Industrial Food Systems produce consumer goods that prioritize convenience and price over other values. This convenience supports societal efficiencies as fewer people are spending long periods of time engaged in food production, procurement, or preparation. As climate change is limiting the places food can grow, intensifying production is seen as the only viable way to address losses without expanding agriculture's physical footprint (Motes 2010; Steensland & Ziegler 2017).

Data that supports these social causes include 1) improved productivity achieved through reducing the number of employees per unit of food output, or per yield of commercial grain per acre of land under cultivation; 2) that uniformity reduces waste at the processing level; 3) increased sales in convenience food shown as proof of the inevitability of continued growth in convenience food sales; 4) reduction in the number of people needed to produce a given unit of food. Data left out of the Productivist-Extractivist Paradigm logic, and captured in food systems approaches, include 1) improved productivity means both more people working and measuring nutrition per acre rather than yield alone; 2) waste is measured as a feedstock for other processes — desirable or harmful— eliminating the notion that something thrown away doesn't count; and 3) the impacts of convenience foods on socio-ecological well-being.

When asked about the importance of diversity in farm ecosystems and amongst the varieties and types of pulses being grown, one food scientist interviewed responded that ecosystems diversity doesn't currently factor into crop choice and development: "Things are grown because they are going to produce more (yield per acre) in this climate, to be more pest resistant" (Interview 3 2018). This interviewee felt confident such productivism wasn't inherently problematic, as University of Saskatchewan researchers have collected lentil seed diversity from around the globe in a seed bank thus feasibly a choice can be made later to pursue development of varieties for reasons other than productivity.

At the world view/ discourse layer of analysis, the phrases in Table 5.1.4 compartmentalize, reduce and commodify food. Efficiency is understood in a linear way. 'Modern agriculture' is collapsed with innovation, ignoring the innovations within agroecology supported by the latest science, such as soil building approaches that maximize microbiotic and fungal diversity (Fox et al. 2007; Jason, Malone and Eathorne-Malone 2016). Feed the world as a phrase evokes an efficiency so vast that a select few can produce for everyone, everywhere. But who is included in these concepts of 'efficient' and who is left out? Is this system "efficient" for a cow whose rBGH injections have her sucking her own bones for vitamins to make an additional volume of milk beyond that which her highly genetically attuned body can produce without the hormone interference? (Chopra 2008).

Efficiency within a Food Science approach is being able to shuffle essential nutrients where they are needed when they are needed and in uniform products that allow recombination to pursue "optimum" nutrition — a building blocks approach. Negative externalities are not part of the efficiency equation. Only that which has a commodity value is measured— leaving unpaid labour and costs to actors outside the profit exchange in a food systems transaction off the efficiency scorecard.

This approach to efficiency oversimplifies the material flows, ignoring emergy costs. Emergy, or embedded energy, finds conceptual roots in Biology Energetics as explored by Lotka (1922), General Systems Theory as expressed by Von Berttalanffy (1968) and Odum's Systems Ecology (1983), according to Agostinho et al. (2010). Emergy measures the total energy embedded in a given product. For example, in lentil production, in addition to yield per acre and a few calculations about energy use on farm, emergy measurements would consider the energy embedded in seed development; manufacturing and delivery of synthetic fertilizers, fungicides, and herbicides; the manufacturing of equipment to plant, spray, harvest and process the crop; the mining of the materials that are used in manufacturing; soil loss; and water loss. Credit for the initial articulation of an emergy methodology goes to Odum in which emergy was proposed as a metric for systems analysis, accounting, and diagnosis. In this approach, all resource energy use is measured in solar equivalent Joules (seJ) (Odum, 1996; Agostinho, 2011). In the Productivist-Extractivist Paradigm, efficiency means a linear maximization of productivity of the sellable grain per acre, and metrics like emergy are obscured.

The myth layer of analysis holds food as only a commodity, ignoring other food valuations. Efficiency is the natural outcome of highly technical systems and non-commodity values are rendered invisible. Food is simply a series of nutrients that can be compartmentalized, separated, and reconfigured to meet human and, in particular, livestock health requirements. The recent increase in pulse products as animal feed and in pet food formulations an example of this approach in action (Interview 4 2018; Zarouki 2017). The myth requires a belief that we know the major nutrients and the minor ones, and the correct mixture of those things, disregarding any synergetic effects at the foodstuff/organism level. The central archetype is the Machine. Plants are seen as machines; human bodies are seen as machines. As such, food is seen as a series of components or "building blocks" that fuel the body-machine. Plants are seen as little factories and soil is merely a substrate to hold the plant and provide nutrients, often supplied by humans (Shiva 1993).

Food is not generally viewed as medicine in this mythology, instead medicine is seen as the expertise of chemists, not gardeners. As such, food is considered primarily for its energy-giving properties (calories) and its ability to provide three macronutrients and a handful of known micronutrients in roughly the amounts scientific inquiry has determined is needed to avoid poor health. Such a view is evidenced by what nutritional information Canada demands of food manufacturers and restaurants to provide on labels and menus. In an Ecological Paradigm, food is valued for its healing properties and avoided for its harming properties (Erasmus 1993).

Industrial food is ultimately, at the level of myth, Freedom: "the development of (the) modern food system has been a major factor in improving the standard of living enjoyed in much of the world today” (Motes 2010:16). Efficiency in food production frees up time for societies that are becoming cosmopolitan. Competition for scarce, finite resources requires greater efficiency in how we use these resources. From a food science perspective, in such a context “the only feasible approach that can permit the world to meet the competing demands it faces while more effectively dealing with its physical, economic and social constraints is through increasingly rapid innovation and productivity growth” (Motes 2010:29). Mythical stories about Specialized Industrial Food Systems efficiency focus on the superiority of modernity over Traditional Systems of Knowledge, which are considered inherently less efficient. Emotional narratives include the ideas that producing food without chemicals will kill the environment by using up more land, and that denying industrializing nations’ farmers efficient chemically reliant and biotechnology-driven agriculture is starving millions (Mote 2010; Steensland & Ziegler 2017).

5.1.3 Safety

Canada’s current regulations around food safety focus on avoiding what kills a person in three days, ignoring the health and nutritional impacts of our food system over time. Pesticide exposure levels are set based on acute poisoning and immediate death impacts, with no account for synergistic effects amongst compounds (let alone testing commercial formulations rather than simply ‘active’ ingredients) or cumulative effects of constant presence of a given chemical or set of chemicals in the diet (Leu 2014; Chopra 2008). Little has been done to investigate the impacts of processing on nutrient availability or integrity. Claims of Canada’s excellent food safety record is based on the fact we simply don’t look for chronic health impacts that arise as a direct result of industrial food systems.

The litany on safety claims “Consumers deserve the widest possible variety of safe and affordable food choices” (Motes 2010:15). The challenge is to make food both cheap and safe, and agricultural intensification and industrial food systems are widely regarded as the safest way to feed the world. The implications from a food science perspective is that food safety is concerned solely with contamination hazards, whether physical, chemical, or biological, and that these hazards in the modern food system are greatly reduced over past eras (Motes 2010:15). This view ignores diet-related chronic illness as a food safety issue on the rise today.

At the social causes layer, safety is achieved in industrial food systems through the use of the latest technologies to reduce safety hazards arising from processing and distribution-related food borne illness outbreaks (Chopra 2009). The increased movement of food around the planet and increased globalization requires standardized protocols for reducing risks. Modern technologies like pasteurization, irradiation, and chemical preservatives ensure food stays fresh longer and kills potential pathogens in food. A zero tolerance approach to hazards in food safety environments favours industrialization of primary production and processing over artisanal production, whose systems have the same safe food targets without facing similar risks (Scrinis 2007). Stainless steel, anti-microbial agents, and various chemical interventions have become standardized in an effort to fully eliminate food borne illnesses, making the cost of entry too steep for localized producers and processors to compete.

Hazard Analysis and Critical Control Points (HACCP) certification provides market-based assurances of food safety protocols being followed, and this type of Quality Assurance program (QA) fills a transnational function to meet safety standards in WTO trading partner jurisdictions (Roesel & Grace

Table 3 Causal Layered Analysis: Safety

SAFETY Causal Layered Analysis	
	PEP / Food Science
LITANY: ***what people say***	"Consumers deserve the widest possible variety of safe and affordable food choices" (Motes 2010:15)
SOCIAL CAUSES: systemic or technical explanations ***what people do***	Industrial food systems offer safety through standardization, hazard analysis (Motes 2010; Roesel & Grace 2014) Modernizing processing and production systems reduces exposure (Prouse 2017) Data that supports these social causes include: 1) # of outbreaks of food borne illnesses with immediate death/ illness 2) Studies from proponents of various food safety certification systems 3) Entire branch of Food Science investigating food safety = literature 4) Coliform counts
WORLD VIEW: expressed through terminology, words, phrases ***what people think***	"Farmers use production methods that are sustainable for the environment" (BASF 2014:8) "Better Living Through Chemistry" (Dupont 1935 Ad Campaign) Modern processes like pasteurization saves millions of lives (GHI) Pathogen = hazard regardless of context: zero tolerance for presence (Gibson 2013; Roesel & Grace 2014) Consumers trust food producers to keep the food supply safe, and they're more concerned about food contamination than about technology used on the farm (Motes 2010) Linear; Binary; cause/ effect; Uniformity above all
MYTH: socio-cultural archetypes, emotional responses, mythical stories ***what people feel***	* Traditional food is untested and unproven, whereas industrial food is rigorously tested * The Dose Makes the Poison * "Biotech food has been proven safe, denying Golden Rice to Africans meant millions went needlessly blind!" (Kennedy 2016) ARCHETYPES: The Neutral Scientist; The Backward Peasant; The Test Strip; The Trustworthy Farmer

2014). Such extra-governmental standards reinforce the food science approach to food safety and further ostracize local customs and traditions that work other logics (Goubin by 2014).

Yet this reputation for safety is not built on evidence. A meta-analysis of 171 agricultural impact assessment studies conducted between 2008 and 2016 found only 2% of papers looked at environmental impacts like biodiversity loss, global heating effects or ecosystem change. Given the role food systems intersect with several Sustainable Development Goals (SDGs), this lack of generally accepted methods for connecting research outcomes to sustainability impacts is problematic (Weißhuhn et al. 2018). It would seem that researchers are not perceiving ecological impacts of agricultural products as a safety concern.

Analyzing the World view/discourse layer, food safety in a Productivist-Extractivist Paradigm is concerned primarily with what will kill people directly and over a short period of time. A food science paradigmatic response to a food safety concern is to attempt to eliminate the hazard completely. In the industrial food system, this elimination approach results in region-wide bird culling to eliminate risk of bird flu spreading, for example (Yuan et al., 2015). Such strategies seek to eliminate the hazard rather than taking a risk assessment approach (Roesel & Grace 2014).

The linearity of the Productivist-Extractivist Paradigm world view is evidenced through a long-held approach to food safety restricted to concerns about what makes consumers sick immediately. According to Jeff Simmers of Eli Lily, consumers trust food producers to keep the food supply safe, focusing their safety concerns on food contamination and not on farm practices (Motes, 2010). Food contamination and food safety outbreaks when they do occur in Canada's food system are far reaching due to mass distribution and are accepted as the occasional price of generally a safer supply of food. Trust is afforded to scientists and to farmers by society, who see these professions as benevolent and altruistic while at the same time society trusts government to provide rigorous approvals processes. This trust is known as 'social license' (Arnott & Savage 2015).

When it comes to safety beyond contamination, the industry describes farmers as using production methods that are safe for the environment (BASF 2014:8). Social license in this regard extends a belief that Canada's regulators would not permit approval of products that were harmful to the environment. Agronomist and founder of University of Guelph's Organic Farming program, Dr. Anne Clark, described the pesticide safety worldview at an organic sector keynote address. As a budding undergraduate, Clark was shocked to learn there was not a standardized, government-led process. Instead, she learned, the process involves a non-standardized, opaque administrative review of research conducted by applicant companies and protected from independent scientific scrutiny (Clark 2012).

Analyzing the myth layer, economies of scale are believed to produce the safest food available (Roesel & Grace 2014). At the root of the Productivist-Extractivist Paradigm and Food Science approach to safety and food systems is the foundational narrative of industrial capitalism: domination over nature (Merchant 1992; Shiva 1993, 2010). Food science narratives invoke war mythos, such as the "War on bugs" and the "War on Weeds" found in the writings of agronomists (Clark 2012). In the Productivist-Extractivist Paradigm, nature is to be controlled, and is seen as an enemy. Such a view arises from defining 'man' as separate from and above nature (Merchant 1993; Salleh 2017). In the Productivist-Extractivist Paradigm, nature is to be controlled, and is seen as an enemy. The war on nature myth is evident in the language of agribusiness advertising: "Weeds grow aggressively by nature, taking away water, nutrients and sunlight that your lentils would otherwise need. Because lentils are a relatively non-competitive crop, effective weed control using multiple modes of action becomes important during the critical period for weed control" (BASF website 2018).

Narratives that rise from this myth that humanity can dominate nature include linear causality, exemplified with the adage 'the dose makes the poison', and linear progress, exemplified by the argument that processed, modern methods of food production and processing are rigorously tested while traditional food production and processing are untested and unproven. In an Ecological Paradigm, a foundational myth is the Earth as Mother. One does not rip open, poison, or destroy one's mother (LaDuke 2005).

Discussion

When examined more closely, assertions that choice, efficiency, and safety narratives at the heart of industrial food systems are based on assumptions about the nature of the relationship between humans and nature. This disconnect is demonstrated through industrial agriculture's war on weeds, endless rapid growth for prosperity orientation, and false sense of choice in the marketplace.

Researchers offer hypotheses on the disengagement with the results from inter- and transdisciplinary research on food systems sustainability within entire pockets of food systems related disciplines. Scientific ignorance is hypothesized as a root cause in the disconnect between information from the environmental and health sciences critical of industrial food systems, and the research priorities of scholars operating within the hegemonic food science paradigm. Research points to three kinds of scientific ignorance: 1) ignorance as a default state or inherent condition; 2) ignorance as a lost realm or selective choice; and 3) ignorance as a strategic ploy or active construct. Choices a researcher makes regarding metrics and standards, strategies and methods, the types of information to share, who to interview, and a host of other considerations "can selectively influence the contours of scientific knowledge" (Elliott 2012:346). In this conceptualization, what is known, what is known about what both is known and not known, and what is not known aren't just matters of "science", but of whose science for what reasons. Further research regarding the connections between levels and locations of scientific ignorance on the one hand, and underlying productivist-extractivist world view acceptance or rejection on the other hand would enhance this discussion, however is beyond the scope of this project.

Elliott (2012) uses the example of the IAASTD Report "Agriculture at a Crossroads" (Macintyre et al., 2009) as a case study to investigate the phenomena of selective scientific ignorance. IAASTD's report conclusively demonstrates the instability of the industrial food system and calls on researchers to engage in critical work to decouple agriculture from fossil energy. In the case study, conclusions in the IAASTD report regarding the need to shift agricultural research away from industrial systems continue to be ignored by the dominant agricultural research community. While ignorance of a subject matter may be obvious, "it may be much less clear that, say, the metrics or questions emphasized in a particular domain are hiding important forms of information that would be valuable to obtain" particularly when a company or think tank "merely designed its studies in ways that reduced the likelihood of uncovering harmful effects" (Elliott, 2012:342).

The IPES-Food report *From Uniformity to Diversity* (Frison et al. 2016) picks up on the IAASTD's crossroads imagery, declaring humanity is at a fork in the road and must actively choose between Specialized Industrial Food Systems and Diverse Agroecological Food Systems. Recognizing the binary narratives constructed within this research simplifies the situation and itself obscures "wicked dilemmas" surrounding policy options, visible and obscured. Such simplifications are utilized as a narrative tool to examine fundamental shifts (Quilley et al. 1998), or what McMichael calls "epistemic reorientations" (McMichael 2011).

Contrary to the Productivist-Extractivist Paradigm, Ecological Paradigms have long existed. The human experience of the Earth as a living body forms the basis of the medieval organic metaphor of nature, itself stemming "from the Great Chain of Being, which had originated with the Greeks and had been transmitted to medieval writers who adapted it to their own cosmology" (Grierson, 2009:201). World views impact what evidence is considered and what evidence is ignored. If it is not choice, efficiency and safety driving industrial food systems to dominate, then what drivers are shaping food systems in this way? The next chapter synthesizes these critiques of the narratives of choice, efficiency and safety within Canada's industrial food system in the context of the 8 Lock-Ins Framework (Frison et al. 2016) using Canada's emerging pushes sector as a case study.

Chapter 6 **Choice, Efficiency and Safety in Canada's Pulse Sector: The 8 Lock-Ins**

Underlying assumptions within industrial food systems research shapes the narratives on choice, efficiency, and safety in Canada's food system, dispelling the notion that the industrial food system is the result of free market forces and 'rational actors' within it. Just as food systems researchers have been gaining ground with policy makers to address the negative externalities of Specialized Industrial Food Systems and inviting sober second thought about the costs of cheap food, industry groups are funding research questioning the conclusions of food systems research. Industry-sponsored research in nutrition, according to researcher Marion Nestle, is an exercise in marketing to sell products. In the sugary drink research, health effects were indicated in 90% of independently funded studies, while remarkably, 90% of studies funded by the industry show none (Nestle 2013).

As learned through the tobacco science debate and climate change debate, industry is aware they need only create doubt and confusion, not prove the safety or sustainability of their products and approaches (Oreskes 2011). In a 2008 Journal of American Medical Association article, an Orwellian-named industry front group, The Centre for Consumer Freedom, states that their strategy "is to shoot the messenger. We've got to attack [activists'] credibility as spokespersons" calling Nestle on their website "one of the country's most hysterical anti-food fanatics." (Voiland and Haupt 2012).

The resulting lack of clarity about impacts of industrialization frustrates attempts to organize a transition towards truly sustaining food systems (Frison et al. 2016). Food systems researchers identify several political and economic 'lock-ins' perpetuating industrial food systems (Frison et al. 2016; Rotz 2017). Overcoming the inertia arising from what Brewster Kneen describes as "a pissing match of science" (Kneen 2015) requires a complexity vs reductionist approach to understanding food systems. The current chapter examines how lock-ins drive industrialization within Canada's food system using pulses as a case study. These lock-ins obscure alternatives to Specialized Industrial Food Systems—Diverse, Agroecological Food Systems (Frison et al. 2016). The IPES-Food 8 Lock-Ins Framework (Fig 2.2.3) is used to analyze the narratives of choice, efficiency and safety as they apply to Canada's industrial pulse sector.

6.1 Lock In 1: Path Dependency

Industrial agriculture is a self-reinforcing feedback loop of investments in the costly-to-obtain skills, training, equipment, land, inputs, and networks required to achieve scale. Given the need for a return on those investments, farmers are unlikely to fundamentally shift modes of production, particularly if specialization involved scaling up operations. Specialization of the sort practiced in Canada—particularly on Canada's prairies— acts as a feedback loop that may require large-scale operations focusing on specialized equipment or inputs in order to achieve a large enough production base, preventing farmers from engaging in anything but highly specialized industrial production (Frison et al., 2016). For example, in Canada's pulses sector, it took two actions – agronomic improvements to allow pulse cultivation with current soybean equipment and chemical harvesting break throughs to eliminate a mechanized step – to spur adoption of pulse production allowing farmers to maintain the same equipment and agronomic regimes used in other grain production. As a result, "Farmers are effectively locked into this pathway, even as the negative outcomes of industrial agriculture start to multiply, and even as the quest to recoup those investments in the face of narrow profit margins requires them to continually intensify their production" (Frison et al., 2016:46). Scale and mechanization act as feedback loops on the system. Altering the industrial farming path is costly.

This type of path dependency connects to the myth of choice within the Productivist-Extractivist Paradigm. Pulses present an opportunity to shift towards truly sustaining practices. The FAO and researchers outside the agricultural industrial complex demonstrate that pulses' benefits are optimized in mixed cropping or intercropping scenarios. Pulse variety can enhance ecological and dietary diversity. However, given the deep debt load most farmers carry for land and equipment, adoption of new crops is restricted by what equipment and management approaches a given farm business has already invested in, as those investments must be fully utilized to make economic sense of the original purchase or lease. Path dependency prevents low-tech innovations from even being evaluated, let alone adopted.

Pulse researcher Lana Shaw began experimenting with intercropping using flax and chickpea in 2013 began working backwards from the equipment and land ROI farmers require and develop sustainability-driven pulse crops that don't require straying far from the dependent path. Increasing crop diversity in a profitable manner while reducing synthetic N use and pesticides are important steps in the direction of sustainability—which for Shaw begins with economic viability of farm activity. As such, the researcher uses current equipment as a boundary in her study design (Guenther 2018).

Mono cropping is an example of path dependent technology. Shaw guesses that Saskatchewan farmers grew 20,000 - 25,000 intercropped hectares in 2017. Despite the benefits and the fact that intercropping researchers are committed to herbicide tolerance in all intercropped pulses as well as the grains or oilseeds with which they are planted, Shaw has only been able to secure $80,000 from SaskPulse's check off program for seed breeding and has had to turn to crowd funding to keep her research going (Guenther 2018).

The Productivist-Extractivist Paradigm as characterized by food science approaches uncritically posits that consumers have the power of choice and exercise that power to shape farmer choices (Motes, 2010; Prouse, 2017), yet this narrative has little historical or contemporary foundation. Canada's pulse sector discusses the future of food as if consumers are in the driver's seat, ignoring the role food manufacturers play in creating consumer demand. Pulse Canada's Gordon Bacon insists that ingredient substitution in existing processed foods is the forward path for pulses (Bacon 2017).

Technical innovation itself is pathway dependent. The economics of the Productivist-Extractivist Paradigm demand continual growth, reliant on continual technological innovation to create new value and increase the GDP. Canada takes a one size fits all approach to food safety regulations, which also results in path dependency. Regulations focus on eliminating hazards rather than assessing risk, privileging businesses with access to capital to meet the food safety regulations designed to address the types of issues that arise in the largest, fastest production facilities. Such prescriptive approaches can be deeply costly to processors, squeezing out small and mid-size players for whom meeting regulations designed to keep massive processing facilities safe is cost prohibitive (Gibson 2012). As Canadians are exposed to fewer and fewer products produced outside of Big Food, the sense arises that corporate food must be safer than artisan food due to its ubiquitous availability. The cost of meeting regulations designed for high volume, high risk settings favours those with volume squeezing out mid-size and small processors.

6.2 Lock In 2: Export Orientation

Canada's pulse sector is ambitiously export-oriented, as reflected in federal policy for several years. Export orientation reinforces concentration of power, as consolidation along the value chain as well as across subsectors increases the power of given corporate clusters, who then influence policy to favour their business models. In Canada, vertically integrated pulse giant AGT Foods handles up to 45% of the world's lentil crop in a contemporary year, equivalent to 90% of Canada's entire lentil crop (AGT 2018; Ta'ran et al. 2017). Agribusiness claims that the agricultural sector is "expected to share its productivity with the world", particularly through making cheap food and aid programs available to newly industrializing nations (Motes 2010:17). Which also reinforces the "feed the world" lock-in.

Canada's use of chemical harvesting renders the local Indian farmers' crops slightly more costly than Canadian crops to produce and get to market, as the Indian farmer expends 50% of their crop value in labour (Pengali 2012). Relying on Canadian lentils and yellow or green split peas — which are not traditionally a part of the Indian diet and are lower in available protein and micronutrients than traditional varieties— has meant India's largely vegetarian population is importing malnutrition. For example, yellow split peas have 10 g of protein per 100 g whereas yellow moong dal has 14 g per 100 g resulting in a drastic drop in protein content in the diet (Shiva 2016).

Export orientation limits choice, counter to the narratives explored in Chapter 5, because it privileges scale, uniformity, and distributability. Such a focus encourages growing commodities that can be processed to last longer, such as grains, over fresh foods. In the pulse sector, specific fractions of peas and fava beans are becoming highly valued for processed foods (Zarouki 2017), encouraging a breeding path dependency that is focusing efforts on uniformity over nutritional diversity.

Despite the immediate and important issue of dealing with acute food shortages, an export policy orientation works counter to broader societal goals. For example, Canada has signed on to the Sustainable Development Goals (SDGs) and exporting pulses to India may seem like a step toward addressing hunger. However, Indian farmers are left holding pulses when Canadian farmers' slightly cheaper imports are purchased with Indian tax payer dollars, causing further poverty and discouraging planting of pulse acres. In this regard, Canada's policy works counter to the SDGs which aim to reduce poverty amongst India's poor.

Export markets remain unpredictable and Canada's advantage in industrial pulse production may be short-lived. With Prime Minister Narenda Modi implementing a Second Green Revolution focusing on pulses since 2011, Canadian farmers felt the inevitable burst of the export bubble (Singh et al. 2016). Canada's number 1 and 2 markets for red lentils, India and Turkey, were in trouble mid-2018. India slapped tariffs on chickpeas and lentils, while Turkey purchased a greater portion of lentils from Kazakhstan — a cheaper production regime (Pratt 2018). Not only are importing countries stepping up domestic production, so too are other exporting nations including Ethiopia, south American countries, and Myanmar (Penner 2017). Once these countries fully adopt the chemical harvesting techniques ubiquitous in Canada, Canadian farmers' price advantage will shrink and likely disappear, as it has with soybeans and other commodities.

6.3 Lock In 3: Expectation of Cheap Food

Cheap food being made available through the trade-offs of industrialization "increases the capacity of any population to invest in more productive work, education, economic development and cultural activities" (Motes 2010:14) and results in "improved quality of life and living standards" (Motes

2010:16). While reducing Canada's agricultural sector to 2% of the population has undoubtedly allowed the 98% of the remaining population to shift from a rural agrarian to a more cosmopolitan society in a few decades, this "efficiency narrative" ignores the socio-ecological costs of cheap food when assessing the benefits of industrialization. This narrative makes the assumption that farm work is inherently undesirable, ignoring the reality that what we value and do not value impact the toil involved with farming today. Food consumption is a requirement of every citizen, and as such every person relies on their own labour or the labour of others to eat. With a different economic arrangement and values structure for food, growing food can be enjoyable and health-giving, as well as sustaining ecologically and economically. Toil is a result of food commodification, not an inherent condition of farming (Jason, Malone and Eathorne-Malone 2016; Vivero Pol 2017).

Expectation of cheap food, like production path dependency, is so locked in to the food science approach to research that it is a parameter of agronomic and food processing research (Ta'ran 2017). The Global Harvest Initiative claims the balance must be struck between food being affordable and sustaining. In the U.S., 80% of farmers agreed or strongly agreed with the narrative that "producing sufficient amounts of food requires the use of pesticides" (BASF 2014:11). The implication of the statement is that without pesticides, farmers believe we couldn't produce enough food cheaply. Only 41% of American consumers shared this view, yet consumer behaviour would appear locked in to the expectation of cheap food.

Research shows consumers state they support food values beyond price sensitivity, while their actual purchase behaviour shows that beyond a minor price premium, most consumers won't allow other values to over-ride price -- the growth of the organic sector is a promising reversal of this lock-in, however organic shoppers still exhibit price sensitivity (Frostling-Henningsson 2014). Perhaps this disconnect in what customers *say* and what they actually *do* when shopping for food informs the farmers' thinking when it comes to the question of whether they think consumers care about sustainability in agriculture. Only 27% of U.S. farmers believe this is true, whereas 79% of American consumers agree with this statement (BASF 2014). Even when aware of and sharing science-based concerns about pesticides, consumers are locked in to the expectation of cheap food.

Safety narratives obscure cheap food expectation as a lock in, with consumers prioritizing concerns over food contamination as a safety issue, and not prioritizing safety concerns about use of "technology" on the farm. Affordability is a pressing human concern: "For this reason, consumers from all classes and geographies — from those who can afford organic foods to those who struggle to maintain a diet that sustains them — must be allowed to choose from an abundance of safe, nutritious and, most importantly, inexpensive food options." (Motes 2010:15). Notice the framing being about all classes having access to inexpensive food, rather than addressing poverty. We get the answers to the questions we ask, and as such "how do we feed the world" — a production question— gets a productivist answer. A systems question — "how do we end hunger" — gets an ecological response.

Cheap food is the financial driver for some of the planet's largest corporations. Ultra-processing, where food ingredients are broken down further into fractions, and complicated chemistry experiments are engaged to make palatable the slurries and powders that have been clumped together like food building blocks. Cheap food makes food manufacturers a lot of money, as uniform, fractionated ingredients can be purchased relatively inexpensively and shipped anywhere and anytime. One food scientist interviewed for this research candidly acknowledged that while it is obviously much better to eat a whole lentil, in capitalist economies we make money by partitioning: "Value added —which I think is a bit of a misnomer— is what works" to make money, and therefore fractionation, ingredient substitution, and use as filler will be pursued by industry (Interview 6 2018). Since almost all pulses R&D work in Canada is done as a public-private partnership, what is profitable to industry stakeholders who in a position to invest now will drive the research in directions that maintain profit centres for those investors.

6.4 Lock In 4: Compartmentalized Thinking

Compartmentalization is the organizing principle of Productivist-Extractivist Paradigm. Research, policy and farm sector institutions collectively reinforce compartmentalization (Frison et al. 2016:52). The emergence of Canada as a top global pulse producer and exporter was only possible once key agronomic factors in pulse production were overcome through a combination of technology, scale, and negatively externalizing aspects of the production model. Food science approaches to research played a key role in this process. Concepts of plant and soil health and fertility arose like gospel from the Green Revolution era privilege: 1) input-intensive High Yielding Varieties (often hybridized, usually water-hungry, nutrient needy and perfect season requiring); 2) uniformity over diversity; 3) single solutions over localized ones; 4) commodity crop development over minor crop development; and 5) technological innovation over social innovation (Frison et al. 2016:51). Pulses offer an opportunity to re-engage a more cyclical, ecological approach to food production that is obscured by compartmentalized approaches to assessing agricultural policy, practices, or priorities.

Pulses research is compartmentalized in the food sciences approach. In a Productivist-Extractivist Paradigm, yield is valued above all other measures based on a mechanistic, linear understand of what is efficient. Measuring yield per acre compartmentalizes the productivity questions to the lentil grain alone, ignoring the potential contributions pulses are making to nitrogen in the soils and thus to the Soil Organic Matter (SOM).

The research and training centres themselves lock in Specialized Industrial Food Systems, blocking systems approaches from gaining ground. Agricultural colleges have become a place where interaction amongst the disciplines is uncommon. As a result, mainstream research and teaching centres "have evolved with little attention to the complex interactions between the natural environment and human society that underpin food systems (Francis et al., 2003)" evidenced by "the large number of academics focus their research on the industrial model of agriculture (Francis et al., 2004)" (Frison et al. 2016:52).

Food scientists approach food as reducible to component parts which can be measured, synthesized, and re-assembled without significant loss of integrity or quality. In this manner, food can be reconstructed to have desirable nutritional profiles. Such compartmentalized, assembly line thinking ignores synergies within whole foods or food combinations that can minimize the effects of anti-nutrients and make desired nutrients bioavailable (Scrinis 2007; Powar 1998). This Productivist-Extractivist Paradigm approach to food is known as "nutritionism" and is an example of the compartmentalized thinking that is a key driver in Canada's food system (Scrinis 2007). This reassembly is packaged as 'choice', yet it is a choice amongst a wide variety of essentially the same ingredients in various recombinations — think the chips or soda aisle of any major grocery store in a major Canadian city's suburbs— reinforcing the Productivist-Extractivist Paradigm narrative (Pollan 2008).

According to agribusiness, many of those whose research enumerates the harms and identifies the instabilities and injustices of industrial agriculture, "no longer feel the need to debate, but simply declare their opposition to factory farms or industrial agriculture without definition or justification—and, especially without discussion of the practicality or the economic or social cost of the changes proposed" (Motes 2010:17). Demanding to set the terms of the debate is a tactic activist and lay scholar Brewster Kneen warned about in his book Farmageddon (1998). Kneen suggests compartmentalizing the economic and social cost of addressing a broken food system is akin to resisting action on climate change because of 'jobs'. It is rarely "practical" to undo socio-ecological injustices and calls to focus on social and economic costs of changing the food system ignore the costs of doing nothing different (Lappe & Collins 2015). This locks in the Specialized Industrial Food Systems as any answer that involves re-organizing the economics of food systems.

Within a productivist-extractivist paradigm, biotechnology is seen as efficient. For example, one of the benefits of chemical harvesting in pulses is it reduces or eliminates non-commodity seeds that end up affecting the purity of the harvest, offering what industry calls 'clean grain'. At the layer of myth, as discussed in Fig 2.2.x, the Productivist-Extractivist Paradigm's war on nature cannot tolerate any species but the commercial species, lest the nutrients and water used by non-commercial plants in a field are robbing the farmer of potential grain weight. What gets measured when determining efficient in this example matters a great deal. This isolation of clean grain for market access favours uniformity over other values. What are the inefficiencies of pursuing clean fields in terms of soils health management protocols that were followed in order to obtain clean grain? What were the costs in terms of pollinator habitat? What unknown soil microbiological synergy functions do certain non-commodity species contribute to the health and well-being of soils and therefore to the commercial crop?

6.5 Lock In 5: Short Term Thinking

Farmer Chris Boettcher runs a six-year rotation on his family's 300 acre biodynamic farm, yet federal agricultural policy and programs run in five year increments, and many project cycles last one to two years (Boettcher 2012). Private interests run on quarterly profit reports while governments seek results from investments in R&D that are immediate, measurable and announce-able. Corporations prioritizing short-term economic returns are unlikely to invest in long term transformations from practices that are generating profits today. "Politicians seeking re-election are unlikely to espouse policies whose rewards will not materialize within the same electoral cycle" (Frison et al. 2016:53). In Canada's pulse sector, this orientation fails to prioritize intergenerational and long-term environmental concerns about the safety of 'crop protection' products and mutagenesis breeding. Data is often gathered over very short periods of time, with small sample sizes, or with controls that lack rigour or are not performed in field conditions under multiple production regimes, due to the extreme expense of such undertakings (Leu 2014).

Short term thinking leads to premature declarations of success. The Green Revolution of the 1950s — 1980s was declared a success (van Zanden 1991) and that thinking persists despite evidence on the ground that the agricultural miracle is short-lived. Adopting water-loving, synthetically fertilized and pesticide-protected High Yielding Varieties post WW II in India and elsewhere has long term implications, such as SOM depletion, lost seed varieties (and therefore lost genetic capacity to adapt to climate chaos), and lost farmer knowledge and skills such as seed breeding. And while the successes of the 'agricultural modernisation' project of Norman Borlaug and his contemporaries have been mythologized, the destruction of peasant agriculture and agroecological systems in the wake of the rapid industrialization is challenged in the manner climate deniers and tobacco scientists aimed to cast doubt on the evidence, cementing inaction (Oreskes 2011).

Adding additional crops with the same herbicide tolerances is the epitome of short term thinking. With no new classes of pesticides in the R&D pipeline, herbicide overuse is leading to several economic problems for farmers who can no longer rely on a single action application (Hursh 2018). Lentil farmers are now regularly tank-mixing multiple pesticides and making several passes in a season (BASF website 2018).

One major failure of the Productivist-Extractivist Paradigm is to recognize explicitly that food is political (Clapp 2016; Escobar 1998), and as such it is subject to the short-term thinking of election cycles and policy windows (Frison et al. 2016). The myth arising from the Productivist-Extractivist Paradigm is that the market is the Best Conductor (Rungren 2016), obscuring the role of corporations and government policy in incentivizing certain behaviours. The result is the belief that consumers 'choose' the Lentil Chip as a way of making snacking healthier. Given the prevalence of Nutritionism within food science-based research, nutrition claims of adding pulse ingredients are suspect, as the nutrition information used to market pulses is largely gathered from studying whole, traditionally prepared pulses from various nutritionally dense local seeds (Interview 6 2018). This data is then adjusted mathematically to reflect the portion contained of a given processed pulse ingredient, flour or slurry.

In the food science paradigm, nutrients and components of food are no different than building blocks that can be taken apart, snapped back together, and maintain their properties. Thus, these milled, fractionated products of pulses are assumed in a food science paradigm to offer the same nutritional benefits as the traditional preparations of whole pulses. In this context, short term thinking leads to the use of pulse fractions to move a snack item, like corn chips, from classification as junk food due to empty calories to classification as a health food due to added protein and fibre. These reformulations of nutrient devoid snacks into healthier choices gives manufacturers access to school children. The pulse sector feels this strategy of ingredient substitution will make people more comfortable with pulse ingredients given complaints about beany flavours, texture, and the time required to prepare whole pulses (Bacon 2017). And yet the investments in these short-term substitutions serve to reinforce the industrial model of production rather than open space in the food system for a kind of whole foods oriented pulse consumption and minimal processing that food scientists indicated in interviews is the nutritionally preferred (Interview 6 2018; Interview 1 2018).

When considering the narrative of safety, Canada's pulse sector is locked in to short-term thinking. Food borne illnesses that affect people acutely are the primary concern of food science research, rather than dietary impacts that create chronic health issues that, along with acute exposures, concern food systems analysis. While manufacturers have been quick to jump on "allergen-free" labels for pulse products in response to the consumers seeking to avoid soy products and wheat products, such claims are perhaps premature. Allergic reactions to lentils and lupines overlap peanut allergies have been reported, and favism is a hemolytic response to eating fava beans, the result of a genetic disorder affecting some

400 million people (Cassiday 2018). Not restricted to medically necessary avoidance of irritants and known allergens, free from labels appeal to generally health conscious North American consumers with sales up in Canada 4.8% and in the US by 7.9% between 2011 and 2016. (Zarouki 2017:6-7). Given the ubiquitous nature of soy and wheat ingredients, allergic responses and dietary sensitivity to these ingredients are more visible. As currently pulse protein consumption in North America is low, the incidence of allergenicity is low. Once North Americans begin consuming these proteins more regularly, allergic responses could climb and those companies positioning themselves as "allergen free" could have a branding problem.

6.6 Lock In 6: 'Feed the World' Narrative

Feed the World narratives of the modern era made their way into public policy, with the U.S. Department of Agriculture (USDA) in 1963 declaring the long term betterment of the Nation relied on product specialization, maximizing productivity and resource allocation towards highest profitability (Ikerd 2010). When Specialized Industrial Food Systems proponents invoke a "Feed the World" narrative and claim Specialized Industrial Food Systems are the only possible way to achieve said goal, the understanding of food security is "limited to delivering sufficient net calories at the global level" (Frison et al. 2016:54). In the USA, 79% of farmers surveyed and 75% of consumers surveyed agreed or strongly agreed that one of the biggest challenges for farmers is to feed the growing world population. In India 96% of farmers and 88% of consumers agreed or strongly agreed (BASF 2014:10).

Across economies, in industrialized and industrializing nations, the "Feed the World" narrative has locked in industrialization, preventing the investigation by those who hold power into the efficiency of small scale, decentralized, agroecological, localized food systems to feed the world. Path dependency plays a strong role in this regard, and complete reliance within Canada's Specialized Industrial Food Systems on chemicals, large acreages, expensive equipment, and high input techniques leaves farmers and consumers alike with no visible option. The "feed the world" narrative is highly vulnerable to any pillar of the Specialized Industrial Food Systems production system having its social license revoked through changes in social priorities or ecological realities affecting food production and processing.

Increasing awareness of and action on pesticide impacts are threatening the pillar of chemical reliance. In the summer of 2018, a major glyphosate trial took place in the USA with a lower court judgement determining that the $289 million payout to an herbicide applicator with Non-Hodgkin's Lymphoma opening the floodgates for additional litigation to begin (Gillam 2018). However, glyphosate containing products make up 500mL of every litre of pesticides used in Ontario and is ubiquitously used in Canada's pulse production (Kelly 2013). The question of glyphosate safety and pulse production is addressed in detail in Chapter 7.3.

When export-oriented Canada directs economic growth strategy on continued growth into India's staple food market, the strategy depends on Indian farmers not getting engaged domestically and falling short each year. And for small price differences, India's hand harvested pulses — potentially grown from many varieties that suit the local conditions, traditions and nutritional requirements— could be addressing SDGs through agroecology (Vivero Pol & Schuftan 2016). The multi-functionality of 1 and 2 hectare farms across India working with diverse mixtures with pulses on their plots could be producing 2.5x the nutrition per acre over the monocultures of soy or corn (Shiva and Singh 2014). The export pulses from Canada impede the growth of the domestic pulse market in India.

6.7 Lock In 7: Measures of Success

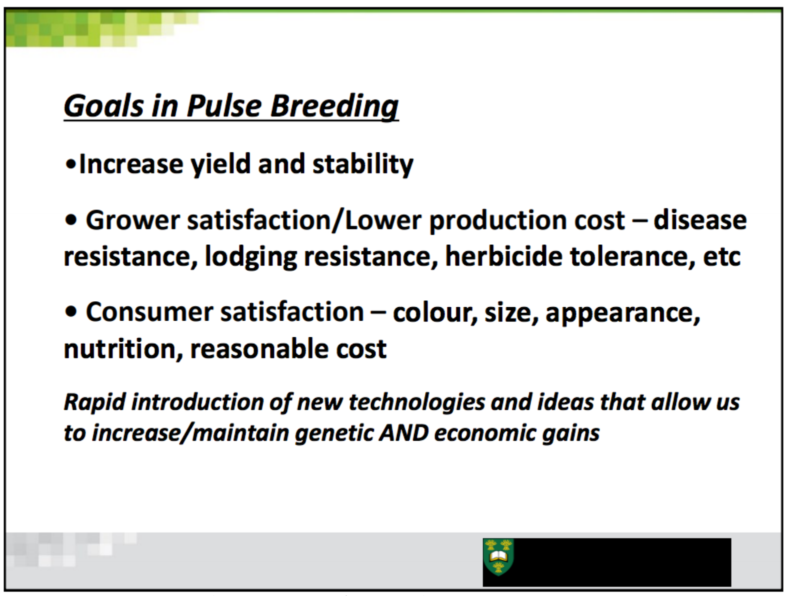
What we choose to measure shapes our perspectives. It would be impossible to measure all the possible interactions, shifts or alterations of every intervention committed on food producing ecosystems. Complexity theorists draw boundaries around a system that are artificial but that without which, no meaningful conversation about how to engage the challenge could be had (Kay 1999). The goal of current reductionist science is to create a replicable study in isolating various components to determine a cause and effect relationship. The linearity of the Productivist-Extractivist Paradigm oversimplifies and obscures complex interactions and indirect benefits when seeking metrics for success. For example, if simply seeking the maximum possible yield per acre from a fava bean crop is the measure of success, then intercropping will be determined to be less efficient. However, if considering the water use, reduced weed pressures, SOM building and atmospheric N provided from intercropping fava and barley, success would mean intercropping (Martin and Snayden 1985).

Metrics and benchmarks for success in agriculture provide feedback on the benefits of a given intervention or strategy. Performance indicators — what is chosen for measurement — impacts development program design, funding, government policy and research agendas: "Which indicators are used is therefore crucial" (Frison et al. 2016:56).

In Canada's pulse breeding program, success is measured by largely productivist metrics (Fig 6.8): a) increasing yield and stability; b) grower satisfaction through successful harvest and lower production costs — defined within the program as improving disease resistance, lodging resistance, herbicide tolerance; c) consumer satisfaction — defined as various quality characteristics, plus reasonable price; and d) rapid introduction of novel approaches and technologies is necessary to maintain and hopefully increase both economic and genetic gains (Ta'ran et al. 2017). These goals do not explicitly include ecological sustainability as an outcome.

How data is measured and what baselines are adopted, not just for assessing success but for basic characterizations, impacts how society perceives issues and thus the range of choices actually available as policy levers to affect outcomes. Beliefs that technology, innovation and science are necessarily modern and linearly progressive ignore the innovations arising through application of local and indigenous knowledge of people around the globe: "current academic understandings of innovation dynamics tends to have bias towards technical systems, rather than

Figure 8 Success in CDC Breeding Programs



Source: (Ta'ran et al. 2017)

on innovations that address social-ecological feedbacks, and support the stewardship of ecosystem services)." (Galaz 2012: 84)

Lastly, food science approaches ignore metrics that address non-commodity valuations of food, yet indicators for these other food dimensions show multifunctional benefits. For example, if valuing food as a cultural determinant, losing fermented foods from the cultural diet along with the recipes and skills to make these foods is an enormous cost to pay for the convenience of mass packaged food when those recipes provide key health benefits to gut micro biome (Katz 2014).

6.8 Lock In 8: Concentration of Power

Concentration of power, the eighth and central lock-in plays a pivotal role in the framework. While the other lock-ins interact and inform each other, power concentration is at the centre (Fig 1), and acts on and with all the other lock-ins. “the centrality of chemical fertilizer, pesticide and input-responsive seeds in industrial systems allows value to accrue to a handful of dominant agribusiness firms in these highly concentrated sectors” (Frison et al. 2016:57). Such concentration of power is evident in Canada’s fast emerging pulses sector. While the sector has many small and medium sized players, the bulk of the business belongs to a handful of astute and expansion-minded entrepreneurs, with AGT Food Ingredients Inc. controlling more than half of the global lentils trade alone (AGT 2018; Penner 2017; PIC 2018).

Feed the world narratives of expansionist businesses feed consolidation: “The drumbeats of alarm about our ability to “feed the world” have only taken us further down the well-travelled road where raising production is the ultimate goal and doing so through the expansion of industrial high-input monoculture farming is the preferred means to get there. And it is along that road where a shrinking number of increasingly powerful corporations dominate global markets and public policy.” (Wise 2015:12). Mergers between input suppliers over the past four years – including the merger between multi-sectoral behemoth Bayer and Monsanto – has only exacerbated this situation. Today a small number of private investment houses are themselves consolidating among the MNCs they hold in stock portfolios (Clapp and Isakson 2018).

Consolidation amongst multinational corporations (MNCs) drives what is presented within the range of farmer choice and consumer choice. The marketing and distribution of ready-to-eat snacks and empty calorie convenience foods across the industrializing world over the past forty years is literally changing the diets of entire countries. Consolidation is driving choice, with the 50 largest food corporations around the globe accounting for fully 50% of all food sales. And while pulse advocates are confident that innovation in ingredients will cultivate new players (Interview 4 2018), it is in fact the biggest corporations who are recording the strongest growth (Zarouki 2017).

6.9 Vertical and Horizontal Integration: Protein Industries Canada Supercluster

The sector’s capacity to organize has resulted in the 150-member Protein Industries Canada (PIC) successfully bidding for at least $150M in matching federal “supercluster” funds — a job creation strategy. Superclusters are "dense areas of business activity where many of the middle-class jobs of today and tomorrow are created” which "attract large and small companies that collaborate with universities, colleges and not-for-profit organizations to turn ideas into solutions that can be brought to market" (Government of Canada 2018). Concentration of power, the eight lock-in, is at the centre of such a consortium, with only the largest players capable of raising these kinds of matching dollars, a path dependency-reinforcing policy approach.

In the case of PIC, a consortium of 120 businesses, a handful of academic institutions and interested groups across Alberta, Saskatchewan and Manitoba will work together to capitalize on opportunities for plant-based proteins. Key partners include: AGT Food and Ingredients Inc., ADM, Cargill, Dow Agrisciences, Dupont Health and Nutrition, G3 Canada Ltd., Global Transportation Hub, Greystone Managed Investments Inc., Louis Dreyfus Company Canada, Maple Leaf Foods, Parmalat Canada, Parish and Heimbecker Ltd., Roquette Agrifood Canada, Verdient Foods Canada, and Warburton Foods Ltd (PIC 2018). Many of these firms are vertically and horizontally integrated and share licensing agreements amongst themselves (Chemnitz et al. 2017). And while one food scientist interviewed for this research felt optimistc that small and medium sized enterprises have the flexibility to capitalize on new opportunities setting themselves up to be “the next Kraft”, this myth of secession does not seem to be playing out as food businesses continue to consolidate globally (Clapp 2016).

Plant-based protein is a $13 billion market world-wide, of which Canada currently has a minimal share. PIC was formed to increase Canada’s global market share of the novel proteins, fractions, ingredients, and technologies arising in Canada’s pulses sector. PIC is pursuing growth in three areas — manufacturing of crop-proteins, crop fractions, and natural food ingredients; ingredient applications; and bulk exports to diversified, high value markets (PIC 2018). PIC is aiming to be the second globally for total agricultural exports and fifth globally in terms of agri-food exports specifically, which PIC estimates to mean an additional $30 billion in business for companies operating in Canada (PIC 2018). For PIC, doubling down on industrialization and intensification is the path forward for agriculture and food in Canada, obscuring solutions that focus on horizontal knowledge building over value chain approaches that serve industry (Frison et al. 2016:51).

Industry stakeholders —who’ve become fewer and fewer in number — are ever more vulnerable to shocks both ecological and economic. The demands of uniformity put pressures on farmers and on ecosystems whose capacity to support a diversity of biotic life requires adhering to planetary boundaries (Raworth 2017; Rockstrom et al. 2009), regardless of the opportunity to replace corn flour with pea flour in single use bag snacks. While some small and medium size enterprises will undoubtedly benefit from PIC investments and the public dollars matching these, PIC’s focus on fractionation and ingredient substitution favours the large, consolidated multinational corporations at the helm.

Superclusters create some opportunities for smaller players, but as discussed in 6.1 Path Dependency, the larger players whose investments take the $150M invested federally and turn that into a projected $700M in business to Canada (PIC 2018). “Once the power structure becomes distorted giving pre-imminence to one sector of the society, there is a tendency for those in power to use their greater power to maintain the distorted metaphors for their own benefit, thus forming a positive feedback loop (Heylighen & Joslyn, 2001) increasing inequality (Piketty, 2014)” (MacGill 2015:62). These distortions within industrial food systems are evident in the red barn and overalls branding multinational agribusiness corporations engage. Researchers can remove these distortions and the cognitive barriers inhibiting acceptance of critical new data and perspectives by distinguishing the underlying assumptions about what constitutes choice, efficiency, and safety. These distinctions can alter how 1) policy makers view choice in food systems; 2) efficiency metrics are determined and utilized; and 3) society approaches the concept of food safety.

6.10 Commodification and the Value of Food

At the centre of this world view lays the construct of commodity. When we see food simply as a commodity, we ignore its role in societal well-being. In Canada, food and agriculture are currently managed as an economic portfolio and fall under the jurisdiction of trade ministries rather than health or environment. The federal government is currently developing a Food Policy for Canada with a stated objective of overcoming this siloed approach to food, however the Conference Board of Canada and the various industry groups representing specialized industrial food systems interests maintain the current export-driven, industry focus of Canada’s food policy ought to remain central in the new food policy (Bloom 2014).

Plants viewed as weeds in an industrial food system may be viewed as a meal supplement in an agroecological food system. Weeds — or the less politically charged term non-commercial plants — present in a field provide: 1) food and medicines for the farm families working the fields; 2) fodder and medicines for their animals; and 3) habitat for the numerous food chain members that provide ecosystems services in support of healthy crop returns for the farmer. The intercropped approach provides nitrogen support for the wheat crop, which in turn provides water for the legume, while both benefit from disease and pest pressure relief associated with polycultures (Ghaley et al. 2005). However farmers are rewarded financially solely on the quantity and quality of their pulse crop in the context of prices negotiated on the same basis with every other pulse growing region. While the commodity may bring in some cash for the farmer, the costs associated with inputs for this style of farming and the lost productivity of locally important weed species are left out of the equation when industrialists promote the benefits of high input agriculture (Shiva 2010; Salleh 2017).

The metric associated with this commodified view is ‘yield per acre’, yet the concept of “calories in: calories out” eludes the conversation. Organic farmer Tony McQuail first drew this missing math to my attention at a farmers’ meeting in 2006, during the formation of the Organic Council of Ontario. He suggested that when we measure the calories required to produce food and the actual calories of food produced, low input organic systems were in fact more efficient that high input, chemically dependent industrial systems (McQuail 2006). Yet too often, the yield measure takes the arbitrary concept of a single season’s production as the comparison, ignoring the impacts of the previous season’s choices on outcomes. Even Pulse Canada’s 10 Year Pulses Strategy strongly recommends abandoning this way of viewing “efficiency”, encouraging farmers to consider multiple seasons when evaluating success, as pulses provide benefits down the road to subsequent crops (GPC 2017).

Shifting from yield per acre towards a health and wealth per acre indicator puts people at the centre of the food system (Levkoe et al. 2017). In its inception in 1946, the World Health Organization defined health as a state of complete physical, mental, and social well-being and not just the absence of diseases or infirmity. A newer definition includes the ability to lead a socially and economically productive life. Singh and Shiva expand on this WHO definition, acknowledging health is also: 1) a fundamental human right; 2) the essence of productive life; 3) intersectoral; 4) an integral part of development; 5) central to the concept of quality of life; 6) involves individuals, state, and international responsibility; 7) a major social investment; and 8) a worldwide social goal (Singh and Shiva 2011). These dimensions of health are reflected in Vivero Pol’s 6 Food Dimensions Framework and are intimately tied to food systems whether we hold those systems accountable for impacts or not.

Commodification hides the social costs of lost diversity. Prior to the Green Revolution, Indians typically consumed roughly 20 different kinds of pulses in the diet throughout the year, whereas today a typical Indian diet may consist of three or four different pulses. The impact is a reduction in nutritional diversity, with various micronutrient deficiencies exacerbated as a result (Shiva 2016; Pingali 2012). Since the introduction of industrial approaches to agriculture and the rise of seed companies at the turn of the last century, the world has lost over 90 percent of our previous commercial seed diversity (National Geographic 1998).

While production choices in the field are impacting ecological diversity, value-added processes are affecting nutrient diversity. Ultra-processing affects dietary diversity by fractionating whole foods that are likely to have synergistic effects into what scientists believe to be their functional parts. Functionality refers to functions within the food processing system, such as viscosity, or gelling capacity, as well as to functions as nutrients in the body. Interviewee 6 expressed deep concerns about the tendency within the food science paradigm to simply calculate nutrient content as a math problem when engaging in this type of processing. How these nutrients behave when separated from the whole bean or grain, heat treated, or otherwise processed is poorly understood, as such inquiries are expensive and time consuming to undertake (Global Pulse Confederation 2017).

Because we govern food only as a commodity, regulations affecting food production tend to consider a narrow set of economic sector issues, rendering the impacts of food production models on ecological and human health as outside the area of concern for agricultural policy. In so doing, multiple food values (Fig 3) are obscured. This reduction of multiple food dimensions to one --commodity – is at the root of the failure of the global food system (Kotagama et al., 2008-09; Magdoff & Tokar, 2010; Zerbe, 2009). Moreover, market rules not only put prices to goods but in doing so markets corrupt their original nature (Sandel, 2012). The commodification of food crowds out non-market values worth caring about" (Vivero Pol 2016: 6).

When one takes an Ecological Systems view or a Food Systems view as it is described for the purposes of this research— one sees food beyond commodity. The notion that an engaged, awake and aware eater can then simply band together with other engaged eaters with whom to shape the food system in a classic supply-demand fashion, while helpful for inspiring action on food system problems, cannot alone turn society from the industrial food system trajectory. There are hidden drivers that restrict the effectiveness of simple vote with dollars campaigns to affect widespread change.

Concentration of power in the form of consolidation challenges the notion of voting with one's dollars. Only ten food and beverage firms control an estimated 28 % of the global market. In 1992, the top five US supermarket chains held less than 20 % of the market, and twenty years later, the four largest retailers sold more than 50 % of the groceries nationally (Rundgren 2014). Yet issue articulation is not enough to foment effective global governance response: "increased salience of an issue is not enough to trigger international action but needs to be combined with institutional mechanisms that enhance the credibility and legitimacy of the information produced" (Galaz 2012: 82).

According to the dominant discourse within Canada — framed within a productivist-extractivist paradigm as characterized by food science perspectives — Canadian farmers and eaters have the most choice within the most efficient and safest food system the world has seen. Such a perspective requires that the food science — oriented analyst be either ignorant or unwilling to engage the socio-ecological costs of industrial production and policy. Those production approaches and policies are developed using a food science lens, obscuring socio-ecological costs as well as hidden drivers within the political and economic landscapes that perpetuate the lock-ins.

This research has distinguished the narratives about “choice”, “efficiency”, and “safety” as less influential on the direction of Canada’s food systems in the face of these 8 lock-ins that drive industrialization. The pulse sector claims that Specialized Industrial Food Systems can be made sustainable by adding pulses to rotations and to the diet without addressing the underlying systems of production. These claims are evaluated in Chapter 7, and alternatives to the status quo are introduced.

Chapter 7 **Taking the pulse of Canada's industrial food system**

7.1 Introduction

Industrial food systems successfully produce cheap calories through economies of scale, reinforcing a homogeneous food science and a productivist-extractivist view of food and agriculture. This Productivist-Extractivist Paradigm obscures the role of industrial systems in creating multiple socio-ecological pressures, including climate change, nutritional deficiencies, and water insecurity. The industrial food system has been well documented as fundamentally unsustainable economically, ecologically, and socially (UNCTAD 2013; IAASTD 2009; Frison 2016; IPES-Food 2017). Industrial food systems are increasingly vulnerable to climate and social shocks. Canada has pinned much of its agricultural hopes on the once lowly pulses to achieve sustainability goals.

7.2 Sustainability Concepts

Discussions of 'sustainability' are centuries old, and are challenged by loose definitions that, through ambiguity, render invisible the tensions between irreconcilable, competing interests. Generally, sustainability in the modern era is a vague and malleable concept. Sustainability may be a critique of socio-economic behaviour, a critique of inequity, a critique of ecological behaviour or a representation of alternatives to destructive behaviour. Over the first two centuries of industrialization such critiques and representations arise in the writings of Karl Marx, Marry Wollstonecraft, John Muir, William Blake, and Rachel Carson among others (Gibson 2016). In this chapter, sustainability claims central to Pulse Canada's marketing message are examined in the context of Raworth's Doughnut Economics (Fig. 2) and the IPES-Food 8 Lock-Ins Framework (Fig. 1).

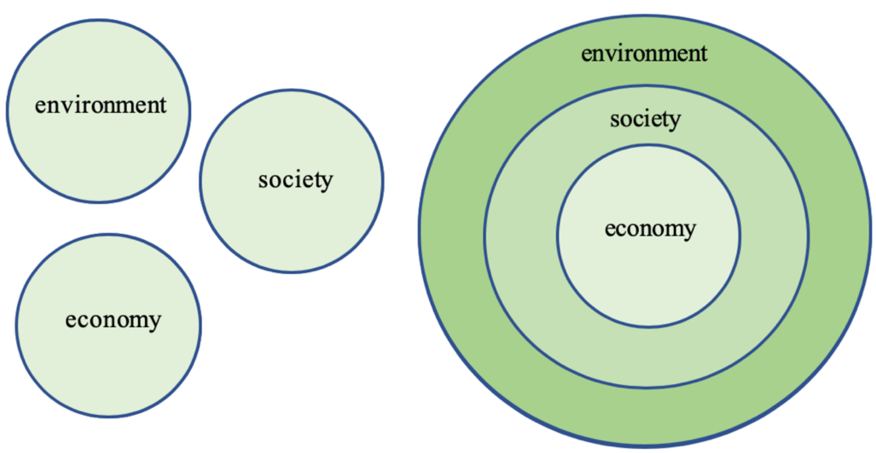
The modern concept of 'sustainable development' was introduced at the UN Stockholm Summit in 1972, where "the importance of environmental management and the use of environmental assessment as a management tool" was debated on the global stage for the first time (Saadatian et al. 2012:313). The Stockholm Summit also introduced other new terminology— 'environment and development', 'development without destruction', and 'environmentally sound development'. By 1987 these terms and the possibilities they represented for the economy had lost favour. The "Our Common Ground" report solidified the UN's approach to "sustainable development" — defined as meeting the needs of the present without compromising future generations' ability to meet their own needs (Brundtland 1987:54)—linking the project of sustainability to a growth economy organized around the accumulation of capital.

Some researchers conclude that the concept of sustainable development to be oxymoronic, as cosmopolitanism as it is practiced in industrial capitalist economies is unsustainable.by any measure (Pepper 1996). For example, each year the city imports "ever larger quantities of energy and materials to support its lifestyle and economy. Collectively, such activities, replicated thousands of times across the globe, are transforming the biosphere" (Burger et al. 2012: 4). Research shows that in 2012 alone, the biocapacity equivalent of 1.6 earths was consumed in terms of both natural resources and ecosystems services for humanity. Exceeding biocapacity equivalent means destroying forests at rates faster than they can regenerate or putting more GHGs into the atmosphere than can be absorbed by the planet's carbon sinks (WWF 2016:20).

7.2.1 Weak and Strong Sustainability

More charitable critiques of Brundtland and the capitalist project of Sustainable Development offer a weak / strong sustainability analysis to categorize the various 'three pillars of sustainability' models used in sustainability assessments. Weak sustainability allows for the productivist-extractivist narrative regarding choice to create the illusion that sometimes we can just prioritize economics without consideration of either society or ecology (Gibson, 2016a). What is relevant in the figure for the current research analysis is that the equal but separated focus on the three pillars — economy, environment, and social —demonstrates weak sustainability, on the left. In this model, the three pillars are

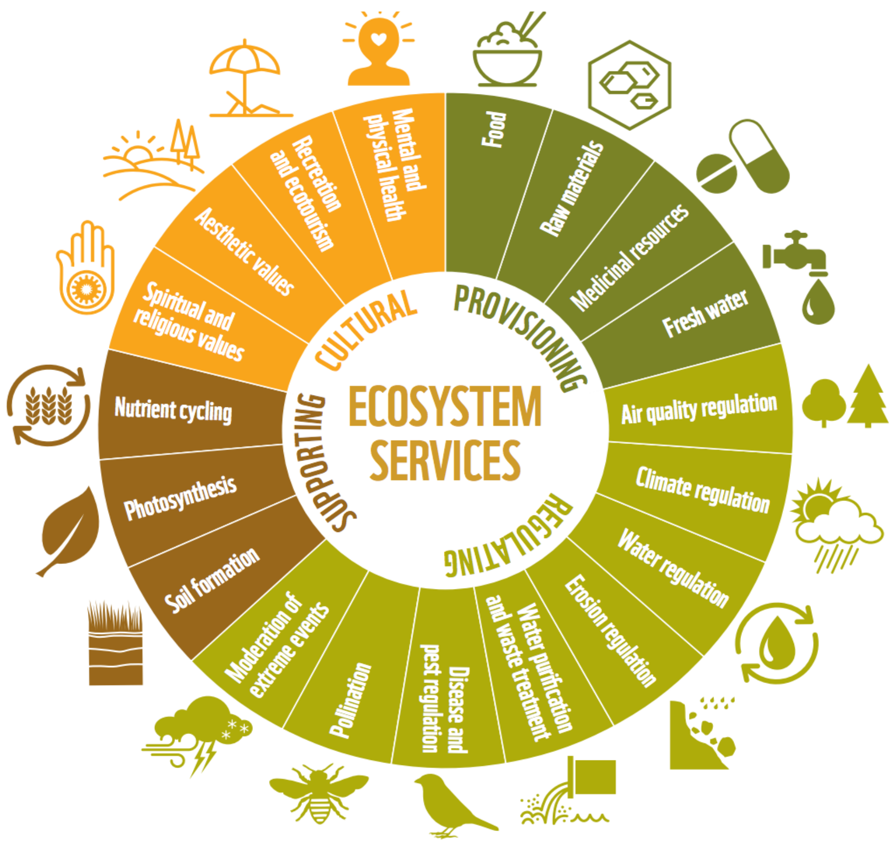
Figure 8. Weak vs Strong Sustainability.



Sources: Yaylaci & Duzgen, 2016; Gibson, 2016a compartmentalized (Lock In 4) and assessed in isolation, whereas strong sustainability is achieved when economic and social sustainability are nested within a robust ecological pillar. In the far right model, Raworth's Doughnut Economics finds a complimentary heuristic in that the economic sphere is nested within the social sphere, indicating that whatever economic activities occur in a sustaining system necessarily occur in the context of social sustainability (Fig. 8). Figure 8 is a simplification of complexities in socio-ecological systems that must be considered. The fifth lock-in, Short Term Thinking, favours weak sustainability solutions over strong sustainability ones as the difficult choices that require consideration of multiple and cascading impacts from choices that don't nest our demands of the natural world in which we are an intrinsic part within the planetary boundaries or ecological ceilings.

Sustainability claims within industrial food systems invoke Lock in 7, Measures of Success.

Figure 9 Ecosystem Services.



(Source WWF 2016:13)

Negative externalities are left off the balance sheet, yet disrupt the provision of ecosystems services. Ecosystems Services (Fig 9) refer to essential biological services upon which humanity relies and that are provided freely by nature— pollination, water purification, and soil carbon sequestration are examples. Underlying biodiversity is crucial to the maintenance of these ecosystems services, without which life for humanity would be impossible (Kremin & Miles 2012). Ecosystems services are conceptual descriptions of the deeply complex webs of nested interactions and networks within and amongst SOHOs — Self Organizing Holarchic Open Systems (Kay 1999).

Raworth's Doughnut Economics Framework (Fig. 2) ecological ceilings are deeply informed by research on ecosystems services. Reductionism and mechanistic modelling inherent in food science approaches, while providing important data about specific interactions, obscure ecosystems services and the connections and interactions within and amongst SOHOs as those interactions are not part of the observation. The Millennium Ecosystem Assessment (2005) seeks to popularize the understanding that what is done on the farm in terms of maintaining and expanding biodiversity above and below the soils has a direct impact on the ability of the planet to provide these ecosystems services into the future.

Fig. 9 is derived from the Millennium Ecosystem Assessment (2005) and illustrated by the World Wildlife Fund (2016). This figure outlines four groupings of ecosystems services and their economic dimensions. Provisioning services represent the material accumulations or products obtained from ecosystems and are the primary concern of agriculture. Regulating services are benefits obtained from earth systems processes corresponding roughly with Rockstrom's Nine Planetary Boundaries (Rockstrom et al. 2009) as captured in Raworth's Doughnut Economics (Fig 2.).

Agricultural activities deeply affect and are affected by regulating and provisioning services. Support services account for all other components that are necessary for all other ecosystems services, and activities on a farm deeply impact these supporting services. Cultural services are the non-monetary services societies derive from ecosystems, the most difficult to resolve within Specialized Industrial Food Systems (WWF 2016:13).

7.3 Sustainability Claims and Canada's Pulses Sector

For Canada's grain farmers, pulses in crop rotations mitigate some of the worst of the industrial food systems' on farm ecological impacts while providing some ecological benefits on farm and beyond. Pulse Canada is promoting pulses as an unqualified sustainable agriculture story based on these benefits with no discussion of the costs of chemical reliance. Pulse Canada and the membership are rightly proud of the improvements being made on farms across the Prairies. Pulse production offers improvements in terms of both a) the reduced ecological footprint of pulse production over business-as-usual cropping of canola, wheat, and corn; and b) a transition away from meat-heavy diets towards plant protein-based diets. In just 20 years, Canada has risen from a non-player in pulses to the leading exporter of lentils and yellow peas in the world (AGT 2018) and Canadian farmers are justifiably proud to be a part of the pulse resurgence. Pulses have been proposed as a promising remedy to much of what is broken in industrial food systems.

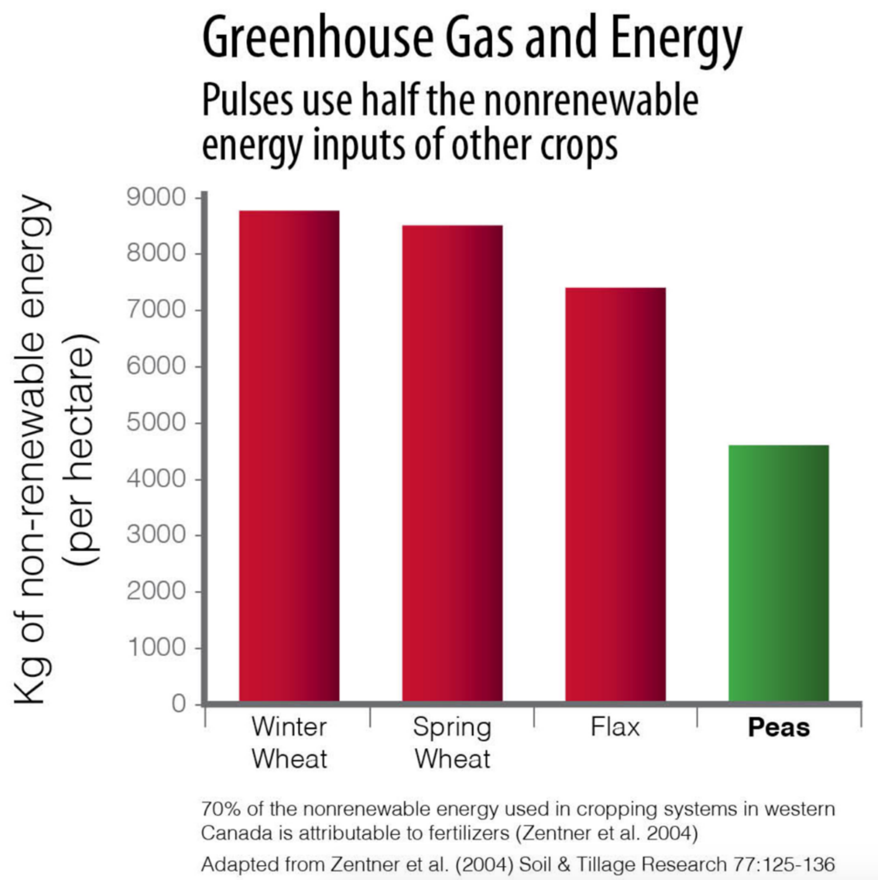
Tackling what Rotz describes as the "wicked problems" of socio-political and economic sustainability in the context of alternatives to industrial food systems is beyond the scope of this analysis (Rotz 2017). This analysis focuses exclusively on two environmental sustainability claims regarding production choices. This choice was made simple by the fact that if production is not ecologically sustainable, it is not sustainable. The Productivist-Extractivist Paradigm prioritizes economics over ecological sustainability, with the trade-offs and tensions already locked in through cheap food expectations and export orientation (Frison et al. 2016). In the end, as the Doughnut Economics Framework (Fig. 2) illustrates, both social foundations (economics) and ecological ceilings must be respected. This research momentarily suspends the economic sustainability question in order to examine the integrity of ecological and health sustainability claims the industrial pulse sector is making based on a review of production systems alone. As Herman Daly says, "The economy is a wholly owned subsidiary of the environment, not the reverse" (Clark 2007:19). Currently economics takes a default priority where the choice is between economic and ecological health.

The adoption of pulses in Canada by over 4500 farmers and a meteoric rise from lentil obscurity to the world's leading exporter in twenty years is in large part a result of chemically supported no-till practices allowing ever larger land masses to be chemically rather than mechanically 'managed' by a single company or farm family (Bekkering 2014). Pulse Canada has crafted two sustainability claims for industrial pulse production: Low Carbon Footprint and Improves Soil Health.

7.3.1 Low Carbon Footprint Claim

The major sustainability claim for the pulses sector is the low carbon footprint of pulse production. Industrial agriculture's GHG output is large in part due to excessive energy consumed in manufacturing synthetic inputs -- nitrogen fertilizer in particular. Greenhouse Gases (GHGs) – carbon dioxide, methane, nitrous oxide, and fluorinated gases-- are gases that trap heat in the atmosphere. The higher the concentration of gas particles in the atmosphere, the greater the greenhouse effect. While this process is necessary to keep the planet warm enough for biological life, anthropogenic activity since the industrial revolution has intensified the release of GHGs, amplifying the warming effect and causing feedback loops that weaken biological resilience (Government of Canada 2017). The main sources for on farm contributions to GHG emissions are: a) through release of enteric gases in livestock; b) manure left in fields; c) synthetic fertilizers; d) rice patty decomposition; e) manure management; and f) burning of Savannahs (FAO 2014).

Figure 10 GHG and Energy Use in Peas: 2004 Data



Source: Pulse Canada Website adapted from Zentner et al. (2004)

The focus on "low carbon" fails to tell the whole story on pulses and climate change. Greenhouse Gases (GHG) are thusly named as they 'trap' heat —like a greenhouse— by absorption of infrared light. Carbon dioxide is the predominant GHG in the Earth's atmosphere today at over 400ppm (IPCC 2013), however carbon dioxide is not the only GHG implicated in Canada's industrial food system. Denis Tremorin of Pulse Canada said that "we are learning from a GHG perspective, the footprint for pulses is even lower than with today's assumptions, maybe 1/2 the footprint to the point of harvest" (Correspondence with the author May 29, 2018).

Indeed, nuances in research are demonstrating previous IPCC estimates of crop residue levels exaggerated their contribution — adding to the good news story of Canada's ascendant pulse sector (Stagnari et al. 2017). Switching from animal to plant protein sources dramatically reduces methane and nitrous oxide emissions connected with feed production and livestock rearing. Methane (NH_4) is 34 times more potent than CO_2 over a 100-year time scale at trapping heat, and N_2O is 300 times more potent (IPCC 2013).

Not All Nitrogen is created equal

Adding pulses in rotation offers some nitrogen benefit to subsequent crops. In a Productivist-Extractivist Paradigm, a molecule is a molecule and a chemical is a chemical— parts can be fractionated, synthesized and shipped around. Yet the source of nitrogen seems to play a huge role in the behaviour of that N in the soil. Dr. Richard Farrell, Associate Professor in the University of Saskatchewan's (U of S) Department of Soil Science, has been running a multi-year investigation of nitrogen fixation and nitrous oxide emissions (N_2O) from various sources in agricultural systems. Preliminary findings suggest that below-ground N was important for soil food web processes, and that pulses overall contributed far less to N_2O emissions than previous methods of calculating had implied. "When you add (synthetic) fertilizer in" said Dr. Farrell, "90 per cent or so of total emission is fertilizer induced. It is clear that pulse residues are not the equivalent of fertilizer." (SaskPulse 2017). If this preliminary work proves repeatable, the "low carbon" claim is an evidence-based claim regarding N fertilizer use.

Since pulses work with soil microbiota to fix atmospheric nitrogen, farmers need to add little or no synthetic nitrogen fertilizer when cultivating pulses (Pulse Canada 2018). Canada's farmers could have a significant downward pressure on Canada's per capita GHG emissions by adopting pulses widely (Bacon, 2017). Pulse Canada has adopted the language of the two-degree diet to promote the low carbon benefit. The two-degree diet's adherents make a commitment to a reduction in global warming impacts through rejection of energy intensive and livestock-based diets and adoption of simplified, plant-based foods in the diet (Kramer et al. 2017). Research conducted before wide scale chemical harvesting of pulses was normalized shows that non-renewable resource use in pulses is half that of other grains (Fig. 10). Enteric gas reductions – which account for 40% of on-farm GHG emissions-- due to fewer livestock if pulse protein replaces meat and dairy further improve the sustainability of pulse cultivation and consumption (FAO 2014).

If direct-feeding crops to people rather than feeding crops to livestock, net reductions in the ecological footprint of Canadian agriculture are possible. The sector is positioning Canadian pulses to replace less nutritious and more water-hungry feed grains for the livestock sector (Bacon 2017). The ecological benefits of pulses do not stop with GHG reductions. One kilogram of cooked beef requires ten times the volume of water than a kilogram of dal to produce, and dried pulses can be stored over long periods with no refrigeration and no spoilage, further reducing the embedded energy per kilogram of table-ready pulses (FAO 2016). In addition to the low carbon claim, Pulse Canada announced a marketing strategy to popularize the soil health benefits of pulse cultivation.

While the sector is delivering on lower carbon emission relative to the previous practice farmers who've adopted pulses into their rotations relative to previous synthetic N use, the low carbon claim is an example of weak sustainability. The pulse sector in Canada relies on off farm inputs starting with phosphorous, which as discussed earlier in the paper is one of the four ecological ceilings or planetary boundaries humanity has transgressed (Raworth 2017; Rockstrom 2016). Researchers suggest we will exhaust known global phosphorous reserves within decades—and while the estimate of reserves varies from 30 to 300 years, what remains is of lesser quality and will, like oil, cost more to extract and refine for use (Cordell and White 2011).

7.3.2 Improved Soil Health Claim

Pulse Canada also highlights the role pulses play in improving soil health. The various decomposing materials and root exudates pulses produce feed soil micro-organisms and help build SOM. Pulses improve biodiversity in soils, which in turn makes more of the soil nutrition bioavailable to the plants (Singh 2018). The improved diversity of beneficial organisms serves to crowd out harmful bacteria and fungi. Despite pulses' preference for and performance in mixed cropping systems, rotations that include pulses as a stand-alone crop still offers improvements to soils on Canada's farms over the dominant practice within industrial agriculture. When claiming "improved" as a measure of success, one must ask "improved" as compared to what? Canada's pulse sector's improvements are measured against a system that has until recent years treated soils as a substrate. Improved in this research is in reference to industry standards for corn, soy, canola and wheat production.

Improving SOM has a number of sustainability benefits, particularly in the context of shifting and unpredictable rain patterns (Engel Di Mauro 2014). Soils with high SOM are better able to absorb more rain at once, as well as to hold water in suspension during drought. Soils with high SOM have reduced run-off, thus reduced erosion, and are better aerated. Soils with high SOM also have better Cation

Exchange Capacity, and are better able to hold and thus deliver minerals to plants. Clay soils are improved dramatically over time with increased SOM levels, as the stickiness of the clay is reduced, and surface compaction is lessened such that seeding in high SOM soils is more successful (Stagnari et al. 2017; Engel Di Mauro 2014; Ingham 2018).

While planting and growing pulses brings benefits to farm country as compared to typical grain production, reliance on the same system of thousands of acres of genetically identical plants based on chemical or mined fertilizers and pesticides may be undermining soil biodiversity. In 2015, FAO hosted the International Year of Soil during which experts raised an alarm about industrial agriculture's approach to soils management. Studies show insecticides are negatively impacting soil microorganisms (Mubarak et al., 2015:60). There have been no comprehensive cross regional studies investigating multiple trophic levels and quantifying pesticides effects on soil organisms. Researchers suggest such studies need to evaluate indirect effect of pesticides and explore whether changes in plant diversity due to fewer and fewer non-commercial species growing in fields in this herbicide era may cause indirect effects of pesticide use (Mubarak et al. 2015:62). Based on this analysis, sustainability claims regarding soil health also exhibit weak sustainability.

7.4 Sustainability Challenges for Canada's Industrial Pulse Sector: The War on Weeds

When agronomists promote the notion of a 'clear field', every plant that is not the commercially important plant in the field is viewed as an invader. Yet "weeds are inextricably products of ecology and psychology" and therefore "weed problems are best addressed by considering all aspects of the agro-ecosystems that produce them and the culture that informs how people farm and think" (Zimdahl 2010:189). Near hegemony in weed science has left agroecological management systems under-explored and under-served in weed management development (Zindahl 2010; Leu 2014; UNCTAD 2013; FAO 2009). This lack of development in non-chemical management has left Canadian farmers in a precarious position. As herbicide tolerance builds in weed populations, no new classes of pesticides are coming to market anytime soon. A second issue is the over-reliance on pesticides and herbicides is decimating insect populations around the globe (Ceballos et al. 2015).

The wide spread use of pesticides in food, forestry, and risk management scenarios is a result of those approaches getting results. When presented with immediate issues such as feeding nine billion by protecting harvests, the general reaction is to stick with a path that has by some metrics been a huge success, preventing losses in the millions of lives annually. Freeing labour from primary food production through adoption of chemical agriculture has allowed for further stratification and privatization in industrializing societies (Mahmood et al. 2014; Motes 2010), evidenced by the degree of cosmopolitanism today unknowable to their great grand-parents' generation in the mid 20th Century, when 60% of Canadians lived rurally. (Basavarajappa & Ram 2017).

Pesticide use has, among other direct and indirect benefits: 1) protected against invasive plant and insect species, and minimized deaths from insect vector diseases such as malaria; 2) reduced insect spreading contamination of known carcinogens and immune system compromisers like aflatoxin; and 3) resulted in yield gains of 10-20% globally (Mahmood 2014).Given these benefits of chemical management in prairie agriculture over the past few decades, the pulse sector in Canada has widely adopted the same pesticide regimes that corn, soy, wheat and canola producers have come to rely upon (Bacon 2018; Interviewee 2 2018; BASF 2018).

Despite the fact that pulse sectors in Canada and the USA rely heavily on agri-chemicals – from fungicides to insecticides to chemical pre-harvest. Almost all pulse acres using Glyphosate-based herbicides (GlyBH) and desiccants rather than mechanical swathing to begin the separating and drying processes, the two countries are embarking on a new campaign marketing specialized industrial pulse production as sustainable. And while the agronomic improvements pulses bring to a farm are numerous, many of these improvements are met with trade-offs when pulses are grown in the chemical systems favoured on Canada's prairies.

7.4.1 Glyphosate

Of particular concern at the outset of this research was the reliance within Canada's pulse sector on the herbicide glyphosate as a pre-harvest aid. Glyphosate (N-(phosphonomethyl) glycine) is a post-emergence, non-selective, foliar herbicide used ubiquitously in agriculture (Okada et al. 2016). In Ontario, more than half of all pesticides used by volume are GlyBH (Kelly 2015). Glyphosate-based herbicides (GlyBH) are used pre-harvest in pulse production to stress the plant, effectively killing it, bringing pods to a more even maturity and initiating what farmers call "dry down". These processes were traditionally done by cutting the plant and allowing the pods to dry in the field before gathering in a two-step process called swathin2011). For farmers, this chemical pre-harvesting process provides insurance against weather and saves time, as the herbicide begins the drying process (no need to wait for or rely on the sun and risk rain), and improves maturation uniformity, effectively increasing yields by reducing loss. The introduction of and wide adoption of glyphosate tolerant crops raises concerns amongst researchers about non-target effects on soil microbial communities and the potential for GlyBH to negatively impact soil functions, plant health and crop productivity

Glyphosate and Soil Health

The controversy surrounding glyphosate-based herbicides (GlyBH) has largely focused on cancer since the IARC monograph was released in late 2018. While this work is important, GlyBH presents a number of soil health concerns. Despite a reputation for non-accumulation, GlyBH is found to strongly absorbed in all soils in a recent study, moving quickly through soils and remaining largely in the top 5cm of the soils (Okada et al. 2016). Wide adoption of glyphosate tolerant crops—and of glyphosate use pre-harvest in pulses-- raises concerns amongst researchers about impacts on soil microbial communities and the potential for GlyBH to negatively impact soil functions, plant health and crop productivity. The research into the long-term effects of GlyBH use is inadequate (Molli et al., 2016; Leu 2014)). Lock-in #1 Path Dependency, and lock-in #5 Compartmentalized Thinking, both play a role in what determining what gets studied and what does not get studied. As the soil microbiome is only beginning to be characterized and understood,

Another study compared rhizosphere soil samples from glyphosate treated and untreated rhizoboxes in a greenhouse over four growing periods. Researchers found the relative abundance of Acidobacteria – some members of which are involved in biogeochemical processes-- decreased in response to glyphosate exposure. Reductions in the prevalence of certain Acidobacteria in soils may result in reduced nutrition of the rhizosphere (Molli et al., 2016).

In the first 50 years of its use, over 1.6 billion kilograms of active glyphosate ingredient were used in the US alone— 19% of the global 8.6 billion kilograms used over the same period. With the introduction of GlyBH tolerance traits gaining popularity since GE registrations began in 1996, GlyBH use has jumped close to 15 fold (Benbrook 2016). For Canadian farmers seeking to diversify from GlyBH-tolerant corn and soy into pulses, reliance on the same GlyBH products at harvest that are used ubiquitously during the growing season for corn and soy exacerbates an already untenable situation of overuse: “Frankly, glyphosate is over-used and carelessly applied all too often because it’s comparatively cheap” (Hursh 2018). Under pressure to meet the expectations of cheap food, lock-in #

The biological reality of GlyBH overuse is that it effectively speeds up the process of weed species’ developing herbicide resistance resulting in the economic reality of rising input costs as more and more chemistry is needed to prop up this model of agriculture, some human health and ecosystems health concerns about GlyBH cannot be ignored.

Glyphosate and Human Health

Glyphosate has a reputation in the food science paradigm as being benign to human health and less harmful to the environment as compared to herbicides it replaces. This belief centres on the fact that glyphosate acts on the shikimic acid pathway to inhibit a key plant enzyme-- 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS)—that governs essential metabolic processes in plants, fungi, and some bacteria. As humans and other vertebrates do not possess this pathway in their cell structures, assumptions have been made by regulators and scientists nullifying the risk of exposure to mammals (Meyers et al 2016). However a wave of research over the past ten years calls this assumption into question, showing a variety of mechanisms by which GlyBH can harm mammals (Martini et al. 2016; IARC 2015; Meyers et al, 2016).

Studies have indicated a variety of potential adverse effects through disruption of endocrine-mediated metabolic processes and development processes due to GlyBH exposure – from breast cancer cell growth (Thongprakaisang et al. 2013) to reproductive issues (Romano et al. 2012) to endocrine cell toxicity (Gasnier et al. 2009). Studies examining the chronic toxicity of glyphosate, its metabolites and its commercial formulations (GlyBH) suggest effects below daily exposure levels set by regulators could be toxic, and that toxicity is increased with the presence of adjuvants—which are currently excluded from scrutiny by regulators as only so-called active ingredients require assessment (Leu 2015). Several studies suggest hepatorenal damage is induced through exposure to low doses of GlyBH falling within various regulators' acceptable exposure ranges (Larsen et al. 2014; Mesnage et al. 2015; Seralini et al. 2014).

In 2015, the World Health Organization's IARC declared glyphosate a probable carcinogen (Class 2A), and researchers in Europe, North America, Sri Lanka, Nicaragua and Argentina have connected glyphosate and its commercial formulations to myriad other health crises including chronic kidney disease (IARC 2015; Zhang et al. 2016; Pandey & Rudraiah 2015). Human health concerns have been raised in the U.S. courts, after successful trials in France. These trials, along with the release of secret documents by French journalists, showed the manipulation of science and of regulators in regard to glyphosate registration and documented orchestrated personal attacks on scientists at the IARC who had, in 2015, declared glyphosate a probable carcinogen (IARC 2015). In one U.S. case, groundskeeper Dewayne Johnson was initially awarded $289 million U.S. in damages due to Monsanto's failure to disclose concerns raised in their own studies about the potential carcinogenic nature of their signature glyphosate-containing herbicide, RoundUp. Monsanto (now Bayer) at time of publication was appealing this ruling (Baum et al. 2018).

Given the lack of research into these and other basic questions, scientists operating from a food systems perspective argue that scientists and regulators should be revisiting the perceived

Figure 11 Bioamplification of Pesticides in the Environment

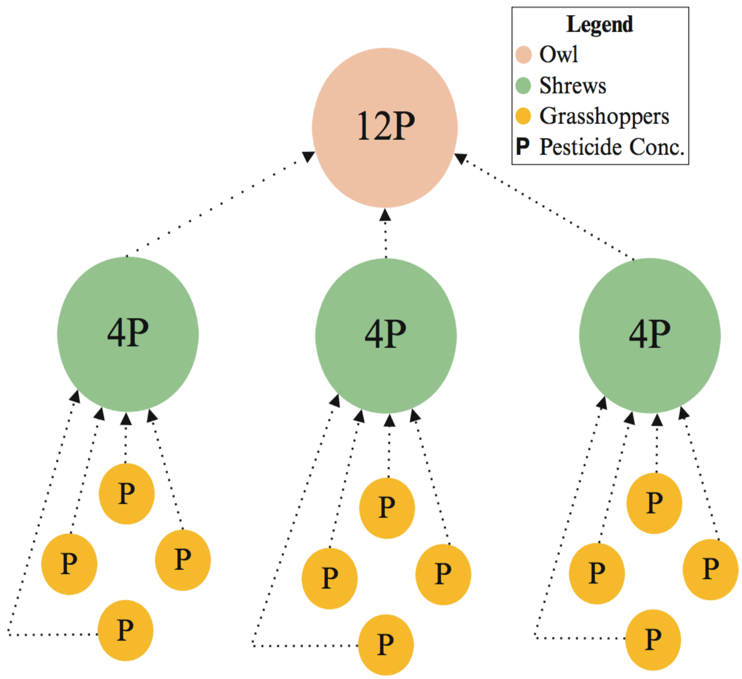


Fig 11 *shows the bioamplification of pesticide impacts in ecosystems. Research into effects on aquatic organisms carry a lot of meaning, as aquatic systems are important components in food chains. Studies for pesticide approvals are not required to consider the bioamplification impacts (Leu 2014).*

Source: (Mahmood et al. 2016:260)

neurodevelopmental, reproductive, and transgenerational effects of GlyBH in light of the mounting evidence (Mesnage et al. 2015).

Glyphosate and Ecosystems Health

Mahmoud et al. (2016) conduct a thorough review of the effects of pesticides on ecosystems, finding studies showing: lethal and sub-lethal effects on non-target plants and insects, even at low doses; drifting of volatilized herbicides injures area trees and shrubs; and increased susceptibility to disease in non-target plants (Fig.11). GlyBH use in particular is associated with reduced seed quality (Mahmood et al. 2016:252). Saskpulse warns against retaining seeds 'pre-harvested' with GlyBH and planting those seeds out the following season as germination rates will be compromised (Saskpulse 2017).

Glyphosate and its commercial formulations' impacts on the soil micro biome and rhizosphere are poorly understood, and have not been adequately studied. Rather than engage in deeply important and long-from-complete soil food web characterizations and discovery science, Productivist-Extractivist Paradigm logics demand that the latest advantages in the war on bugs and the war on weeds be commercialized. Bayer initiated a microbiology wing several years ago, and other seed/chemical giants are eagerly 'targeting' improvements in biological agents (anon 2017:61).

Research on the soils health implications for GlyBH and metabolites have shown mixed results, with some showing no negative impacts on the soil microorganisms studied, and others showing impacts on population composition and health (SOIL Association 2016). The use of multiple chemicals in tank mixes or separately but overlapping with other chemical applications in a given season is ubiquitous across crop types today (Watson 2018). Compartmentalization, the 4th lock in, ensures that each crop variety is registered as if it were the only game in town. Cumulative and synergistic impacts are not required investigations as part of that registration process (Leu 2014; Chopra 2008

Pesticides and the crops that rely upon them require ideal growing conditions to perform. Climate change is shifting rain and temperature patterns, with increased scope and intensity of droughts in many parts of the world, including in Canada's pulse producing prairie regions (IPCC 2013; 2018). Dry weather year on year creates serious problems for farmers now accustomed to using pesticides and fungicides multiple times throughout the season. Pesticides rely on the perfect amount of moisture for action. Dry weather impedes that action, and the breakdown of the previous year's residues are compromised by the lack of rain (Smith 2018). In a dry year pesticides may also move differently though the dry soils, affecting roots and ground water. Dry weather also favours the class of weeds known as C4; thistle, pigweed, and other plants known to be expanding in herbicide tolerance and causing fresh issues for Canada's farmers (Smith 2018:37). In this scenario, a vicious cycle has been engaged. When one sets out to achieve a clear field, one has created an open niche which aggressive and invasive species — plants, bacteria, birds, and so on — will fill (Smith 2018; Leu 2015).

In the interviews with food scientists, the question about glyphosate harvesting and sustainability of this model was a challenging one for all key informants: "Sustainability of glyphosate means different things for different people" suggesting that "whatever it takes to increase the (production) area is ok, I can see reason for glyphosate harvesting" (Interview 2 2018). This scientist indicated the biggest concern for farmers regarding GlyBH use is closed export markets as a result of residuals detected, adding "there are multiple agronomic approaches" available beyond reliance on glyphosate. Yet the mainstream agricultural press in Canada in light of the court case south of the border are beginning to question the value of pre-harvest use, now "so common in some areas that tiny amounts of glyphosate might be measurable even in crops that weren't sprayed." (Hursh 2018). The recognition of the potential market restrictions on farmers who did not choose GlyBH pitting neighbour against neighbour is a wakeup call to industry.

7.4.2 Imidazolinone: Clearfield Herbicides

The Crop Development Centre— an agricultural institution— is a publicly funded institution that engages research based on private funding for public private partnerships (PPP). As such, CDC could see the public interest benefits to exploring the full potential for pulses to reduce reliance on mined fertilizers, toxic 'crop protection' products, irrigation and extreme processing. Instead, the CDC has committed that every new lentil variety be 'pre-bred' with imidazolinone tolerance, achieved through chemical or radiation mutagenesis (Ta'ran et al. 2017).

Imidazolinone is the active ingredient in BASF's ClearfieldTM technology. Since 2014, every new lentil variety developed through the Crop Development Centre at University of Saskatchewan has had tolerance to imidazolinone bred into the variety (Ta'ran et al. 2017). This means that every single farmer growing lentils of any kind arising from this 'publicly funded with private partnership' breeding system can no longer save seeds without ongoing relationships with BASF (BASF 2018). The same is true for white-flowered fava bean varieties with low vicine/convicine released from 2017 onward. This ownership of the seed through chemical breeding is the ultimate consolidation of power.

Information on the effects of this class of pesticides is sparse. A search of Agricola — the USDA database— for imidazolinone turned up six references, only one of which was investigating ecological impacts. A search for the specific pesticides turned up three results for imazapic, four for imazethapyr, five for imazaquin, three for imazapic, and one for imazamox. In Agris— the FAO database— of the seventy-five references found for imidazolinone the majority were studies testing action alone or in combination with other chemicals. Of 43 studies involving the search term imazapic, two looked at leaching potential, one study investigated potential effects from imazapic used in combination with insecticides, three explored water quality an herbicide run off, and one study investigated herbicide tolerance in weed species. A search for imazaquin turned up 11 studies concerned with mobility and persistence of imazaquin in soils and aquatic environments.

Milanova and Grogorov (1996) demonstrated that in heavy rains, imazaquin is mobile up to 60 cm in soils. Silva et al. (2009) examined surface run-off of a variety of pesticides under heavy use in Brazilian agriculture in a number of locations, and found imazethapyr present in every location. Kramer et al. (2009) show persistence in soils of imazethapyr in subsequent crop seasons, and leaching up to 20 cm.

The imidazolinone family works by inhibiting acetolactate synthase (ALS), starving plants by blocking this important enzyme and disrupting the biosynthesis of isoleucine, leucine, and valine — branch-chained amino acids (UCalifornia 2018). These herbicides are so powerful and persistent they can impact plants at levels below any standard testing protocols and in subsequent seasons. This family of pesticides is also known to impact bacteria, fungi, yeasts, and algae. Standard chemical detection methods are incapable of detecting these potent chemicals at the low levels at which they affect plants. ALS inhibitors have a single mode of action and linger in the ecosystem, thus target weeds quickly develop herbicide resistance (Whitcomb 1999). One possible reason, then, to ensure all lentils are pre-bred with tolerance to the imidazolinone family is the pragmatism of persistence of these pesticides in soils for multiple years.

7.5 Discussion

Ecological implications of industrial pulse production weigh on the evaluation of sustainability. With the globalized Specialized Industrial Food Systems dominating Canadian agriculture, the economy has no mechanism to account for burdens on ecosystems services, whether provisioning, supporting, cultural, or regulating. Comprehensive meta analyses conducted over the past decade identify and describe externalities of chemical reliant farming systems that remain problematic for industrial pulse production, even with the reduced synthetic nitrogen use experienced on chemical farms that include pulses in rotations versus farms that do not. These negative externalities include but are not limited to: ground water and soils pollution from pesticide use; destruction of fossil water stores; disruption of soil carbon cycles and soil nutrient cycles; biodiversity loss above and below ground; compaction of soils; eutrophication; and bio-accumulation of poisons in the food chain (IAASTD, 2009; UNCTAD, 2013; Frison et al. 2016). These externalities throw humanity outside of the safe zone for humanity between social foundations and ecological ceilings.

Three specific areas of concern arise from this research which Canada's industrial pulse sector must resolve in order to reliably produce food into the future and to honour Pulse Canada's sustainability claims: 1) sector reliance on petrochemicals and mined inputs for primary production; 2) sector reliance on energy use in globalized value chains; and 3) industrial production systems are vulnerable to social and climate shocks. Even if we suspend the impacts on humans and our ecosystem partners momentarily, petrochemical reliance and energy use alone undermine Canada's industrial pulse sector's claims of sustainability if considering economic and resource sustainability.

1) reliance on petrochemicals and mined inputs for primary production undermines sustainability claims

Regardless of the climate impacts and health impacts from use, fossil energy is a finite resource, and accessing the petrochemicals from which fertilizers and pesticides are derived is expected to become increasingly costly as peak oil changes the economics of petrochemical utility. Energy use to produce synthetic Nitrogen will become increasingly costly. Hydraulic fracturing — fracking— is a mining system for the natural gas used in manufacturing N fertilizer. Fracking uses an enormous amount of fresh water to literally fracture rocks underground to release stored natural gas. I addition to unsustainable use of and poisoning of the planet's dwindling fresh water supply, fracking is implicated in seismic activity and illnesses in communities that are nearby (Nikiforuk 2015).

The IPCC predictions for climate chaos are reason enough to inspire a shift from reliance on GHG-inducing petrochemical reliant inputs on ecological grounds alone. The fact that the input materials themselves are expected to climb in cost as the cheap sources of fossil energy upon which industrial food systems are predicated become more scarce and therefore more expensive over the decades. Reliance on dwindling sources of fossil energy for agricultural inputs is both an economically and a materially unsustainable approach to food production will drive food prices upwards, as will dwindling phosphorous and potash supplies. Proponents of industrial food systems suggest the ecological and social trade-offs that come with industrial production are out outweighed by global access to cheap, abundant food (Prouse 2017). When costs for obtaining the petrochemicals and mined inputs skyrocket, the benefit of cheap food evapourates.

2) Energy use in globalized value chains undermines sustainability claim

With Canada investing heavily in pulse processing – most recently through the PIC $150M protein cluster-- increasingly pulse ingredients are meeting a similar fate as corn and soy— as an additive or ingredient substitute for animals rather than as a whole food for people (Zarouki 2017). Processing beyond the basic steps of dehulling and splitting pulses provides two benefits. First, it provides flexibility to ship shelf-stable ingredients anywhere for multiple end users. Second, it increases profits for snack companies eager to improve the questionable nutritional profiles of much of what they sell (Rundell 2015; Lappe & Colllins 2015; Scrinis 2008; Bacon 2017).

While the good news story of pulses' nutritional contributions continues to unfold, the ability to derive those benefits from fractions, isolated proteins, and re-introduced fibres is difficult to quantify and has not been proven by food scientists. Simply extrapolating the data developed from research on whole foods and traditional preparations onto these new fractions is inadequate, but practiced broadly within the

Productivist-Extractivist Paradigm that dominates food research in Canada. Fractionation concentrates proteins and starches, and so by a yield metric, processing increases nutrition of the finished powders when compared to whole milled pulses. Yet how such processes are affecting bioavailability and quality of overall nutrition and synergies – in particular the presence of micronutrients and enzymes and their interactions -- is simply not getting the research attention it deserves. Such research is costly, and results are challenging to characterize (Interview 1 and Interview 2, 2018). Given the dominance of Nutritionism within the Productivist-Extractivist Paradigm, the focus remains on single macronutrients while giving scant attention to the synergies within whole foods (Interview 6 2018).

The energy costs of such systems are more readily quantifiable, however. A proposed pea fractionation plant in Montana running at half capacity year round would use roughly 3.4 M litres of water, 39,500 cu metres of natural gas, 40,000 kWh and 180,000 kg of steam to process 150,000 kg a day of dried peas to produce $3 million in revenue from fractionated protein and starch sales. That's 3.4 million litres of water each and every day (Doney & Scalper 2016:22-27). These ingredients are all destined for further processing into packaged consumer products, using even more energy and water. Further energy is used for transportation to and from the fractionation plant, from the manufacturer to distribution networks and finally to the store and purchase by the consumer.

And while synthetic N reduction in conventional systems that adopt pulses in rotation for the pulse crop itself and for the crop that follows in rotation is welcome, synthetic N remains a key component for the majority of Canadian farms which are not organically managed yet include pulses in rotation. Research determined energy use in an organic legume system was 32% less than the energy use in a conventional legume system, attributable to the organic nutrient sourcing over synthetic nutrients – in particular Nitrogen (Pimentel et al. 2005:575).

3) Industrial production systems are vulnerable to climate and social shocks

This notion that industrial food systems must continue because the social and economic upheavals of abandoning the path dependency of industrial food systems seem too costly conveniently ignores the reality that the price of inaction is also too costly. Under climate breakdown scenarios, catastrophic crop failures are predicted to increase in scope and frequency, particularly in traditional pulse growing regions (Lin et al. 2008). Reliance on uniformity over diversity is a poor strategy in a shifting climate (Frison et al. 2016). The ongoing assault on diversity above and below ground is perhaps the major weakness in Specialized Industrial Food Systems: "Maintaining healthy levels of biodiversity is the best way to help species and ecosystems cope with the stresses that will come from a changing climate"

(Kenney et al. 2011: 5). Yet Specialized Industrial Food Systems continue to privilege uniformity over diversity.

The industrial food system may be efficient at moving food products around the globe in a seemingly stable climate thanks to consolidation, but climate breakdown is increasing weather disruptions, adding new levels of unpredictability to the just-in-time supply chain industrial food systems rely on for generating profits, and millions of people are at risk of being cut off from food supplies as centralized distribution systems face these climate disruption challenges.

Industrial food systems are also vulnerable to social shocks, including the breakdown of the liberal democracies in Britain, the USA, France, and elsewhere create conditions for economic and political upheaval. The rate of societal breakdown is seemingly accelerating since the birth of the WTO, exacerbated by the growing climate refugee crises and rising frequency of super storms.

Regenerative agriculture presents opportunities to protect against some of these climate shocks. Soil structure on organic farms is better able to deal with fluctuations in rain and the soil building practices that lead to this improved soil structure ensure the right soil conditions for pulses. Organic agriculture builds diversity into the cropping system, providing income for farmers should the season be a bad year for any one particular crop. Additionally, reliance on petrochemicals within organic systems when measured to the farm gate is drastically reduced over chemical systems, providing long term strategies for producing food after peak oil (Lynch et al. 2011).

One key informant sees opportunities for entrepreneurs to enter the organic food sector through pulses: "(Canada is) in a better position than others to produce organic, we have an environment adapted to those crops… farmers who I never thought would be making this shift over to organic are doing it, the economics are better over the long term, though it is not for everyone (given the) substantial risk". This key informant suggests that organic pea processing in particular has the ability to rival conventional production (Interview 2 2018).

Critics of organic agriculture as it is practiced commercially in Canada suggest commercial organic practices are simply slowing down but not avoiding food systems collapse, as commercial organic producers still mine soil, rely on external inputs, rely on annual crops, and typically avoid intercropping (Stoddart 2014). As long as the economics of food production are aligned with the neoliberal food regime demanding uniformity at all costs, producing food in ecologically responsible ways will lose out to producing food in short-term economically viable ways (Vivero Pol 2017). As author and activist Frances Moore Lappe has said repeatedly, we are having a crisis of democracy, where corporate interests have captured our regulatory environments, and the interests of shareholders are placed ahead of the interests of people and planet (Lappe & Collins 2015). Such an analysis suggests that efforts to tweak the dominant paradigm — whether by pricing ecosystems services, adding certifications or other user-pay models — will fall short as they ignore the political ecology of food. Raworth's Doughnut Economics Framework calls for a new economic mindset.

Clearly in such contexts, business as usual is not a choice we have the luxury to make if we wish to see a future in which social and ecological justice as indicated through frameworks like Doughnut Economics (Fig. 2) and the Sustainable Development Goals.

Radical Responses vs. Incrementalism

The evidence considered in this study suggests that radical rather than incremental responses are required to transform food systems. Previous movements have campaigned on single issues, like banning a specific pesticide, without addressing the conditions that lead to the issue, like commodification of food or crowded conditions or destroyed ecosystems. Taking the example of the strategy to seek bans on a single pesticide -- or any specific agricultural chemical or chemical family for that matter—will in of itself have little impact on reducing overall chemical reliance. It may be a fruitless approach as more than likely another version of a similar compound awaits approvals, or manufacturers will reformulate, and the struggle begins again.

BASF's web-based lentil crop management guide (BASF 2018) provides an example of the ineffectiveness of attempting to address the issues of industrialization in agriculture simply one chemical at a time. The reliance from pre-emergence to harvest on a number of chemicals ensures that any single pesticide removed will simply be replaced with another chemical. Maybe it isn't the seed coat containing fungicide that causes ecological and human health issues, nor the pre-emergent herbicide, the emergent fungicide, the post emergence herbicide or the pre-harvest herbicide. Maybe it's not any number of other pre-harvest aids, including desiccants such as diquat. If our reductionism cannot ascertain the exact cause, however, enough doubt remains that the product stays in circulation. Yet absence of evidence is not evidence of absence (Altman & Bland 1995).

In the pre-industrial era pulses were bred and grown in mixed stands with grains like wheat or corn. Their macrobiotic and fungal communities co-evolved. Prior to the Green Revolution, pulses and cereal grains were synergistic in traditional mixed and intercropped systems — from the Milpa to the Three Sisters to India's agroecology. Varieties of cereal grains and pulses had been bred for the complexity, protection and mutuality of the intercropped landscapes in traditional pulse growing areas (Pretty et al. 2002; Mt. Pleasant 2017; Jason, Malone and Eathorne-Malone 2016). When the Green Revolution pulled wheat out of the intercropped systems to maximize yield output, the synergies of pulse-cereal communities were lost, and biotic stress-sensitive pulses simply could not stand on their own.

Unknown and possibly permanent changes to the soil food web as a result of this 'break up' of plant communities may be impacting the nutritional quality and the resilience of pulses in agricultural systems. It is a radical change to re-introduce the kinds of cropping systems that Lana Shaw is developing with flax-chickpea mixed plots, yet applied incrementally, in that Shaw isn't requiring her farmers to forgo all chemical use but rather adopting the new practice into the existing system.

Skeptics who feel the research is still too inconclusive to assess ecosystems and human health risks cannot ignore the market risks for crops with high chemical residue levels in markets that have different attitudes about chemical risk. Residue levels can be partially addressed through fractionation and processing. While this may reduce exposure to pesticide residues in finished food products, it doesn't put the life force back in the seeds. Saskatchewan's agronomists advise farmers who use GlyBH as a pre-harvest aid not to save seeds for planting in the subsequent years, as GlyBH may affect seedling development and play havoc with germination rates (SaskPulse 2017). The nutrition that gives the seed energy to become a plant is the same nutrition humans eat the seed or grain to gain. Using GlyBH reduces the vigor of seeds – and thus reduces the utility for human and animal consumption. In cultures with over-consumption of calories, a slight reduction in nutrient value or nutrient availability can be made up with additional eating. In India—Canada's number one lentil and yellow pea destination—a reduction of even 5 or 10% in nutrient availability per calorie of food consumed is the difference between health and sickness for millions of food insecure Indians. In such a scenario, exporting seeds that lack vigour is exporting malnutrition (Shiva 2016).

Radical means root – and the call from IPES-Food, UNCTAD and others to radically reframe the food system to operate within the safe space for humanity (Raworth 2017). Canada's public breeding program is focused on chemical management, ignoring the agronomics of pulses discussed earlier in this study and the synergies of mixed cropping that negate the need for heavy chemical use. Canada's deep investment in Specialized Industrial Food Systems bends the agronomics of plant life to the economics of industrial production and the lock-ins of Cheap Food and Export Orientation (Frison et al. 2016). Given the new science on soil microbiodiversity and soil food web, breeding programs need to reconsider the root assumptions of how we breed plants for sustaining systems and not industrial ones.

The diversity and function of organisms within the vast soil food web are only just beginning to be characterized and much discovery work remains (Ingham 2018). As current detection and testing methodology fails to capture chemical presence at biologically active amounts, Specialized Industrial Food Systems reliance on pesticides may be permanently altering the very ecosystems services that have allowed humanity to thrive in domesticated ecosystems. The new soils science calls on all parties to re-evaluate the tradeoffs being made in order to refine Specialized Industrial Food Systems cropping methods — from breeding through harvest and processing.

Crisis of Democracy

Canada is vulnerable to social shocks associated with policy changes that could soon reduce or eliminate access to glyphosate and other pesticides. Democracy and Sustainability are not accidentally connected-- both are emancipating forces that seek to undo the self-reinforcing concentration of power, freeing forests and waters from the exploitation of those in power (Bhaskar 2009).

Former food systems analyst Frances Moore Lappe has spent the better part of the last decade turning her attention towards the democracy movement. After decades of seeking policies to encourage regenerative agriculture, climate-friendly diets, and food justice, Lappe realized that as long as money and not citizen's voices chooses political leadership no amount of civic effort to fix the food system will materialize (Lappe and Eichen 2018). As with the IPES-Food lock-ins framework, concentration of power renders the system socially unsustainable. "It is a grassroots "movement of movements" enabling Americans committed to the broadest array of issues to also work on the root crisis — democracy itself, the mother of all issues. And, in just the past few years, though largely invisible, this movement is succeeding in a range of reforms for inclusion and accountability" (Lappe 2018).

A lack of democracy is at the root of the issue for many thinkers who've produced a large body of work devoted to re-invigorating democracy as a means to these ends (Raskin 2016; Berkes, 1999; LaDuke 2005; Salleh 2017). In the short term, food systems advocates have the opportunity to develop positive feedback loops: "government regulations and tax initiatives can be designed to force producers to include social and ecological costs in commodity prices, thereby helping consumers to exercise informed personal choice." (Gibson 2013: 97-98). This research suggests without an economic change, food systems sustainability is unattainable. The opportunity lies with generating the political will to decouple food from the vagaries of market economics — despite the enormity of the task, transforming food systems from industrial to agroecological is a moral imperative (Ikerd 2016).

Epistemic Reorientation: food systems beyond commodification

Lock-ins have ensured that the economic sustainability of MNCs driving the food agenda over-rides all other sustainability concerns. As long as food is valued strictly as a commodity, the logic of commodity markets will result in similar institutions and structures regardless of the market-based approaches taken to address the worst excesses of chemical food production. Integral to the capitalist project is an assumption that our challenge is learning how to manage the earth, when we working on the project of how we ought to live on earth: "mastering nature is an (increasingly discredited) assumption integral to capitalist modernity, so sustainable solutions will require some kind of epistemic reorientation." (McMichael 2011: 804).

Chemical dependency in agriculture comes about not through choice, efficiency, or safety, but through the dominance of global capitalism that commodifies food and labour. Productivist-Extractivist Paradigm solutions are to remove labour from the farm, yet this research has illustrated the sustainability concerns that are irreconcilable given the state of deterioration of the globe's ecosystems services and their vulnerability to further climate or social shocks.

Even within conventional institutions, researchers are seeking to address planetary boundaries and see pulses as playing a central role: "Consumption drives the whole system, sustainability needs to be considered as well as health and economics… how do we measure these things from a food system level in a meaningful and real way?" (Interview 2 2018).

Endeavouring to unlock the food system means decoupling food from the whims of the Productivist-Extractivist Paradigm market economy, and embracing new ways to engage in food provisioning within an Ecological Paradigm food commons. It means recognizing and honouring other food dimensions through new relationships and systems that see food as a public good (Ikerd 2016; Vivero Pol 2015). The scale and weight of the challenge to induce a meaningful transition in the face of increasing climate chaos is enormous. Without a critical mass of policy makers, researchers and civil society actors in agreement that the ecological costs of business as usual — even with the significant improvements pulses offer to industrial food systems — are too risky to ignore, we leave the situation ever more precarious for the next generation and their children. It is hoped the evidence presented in this research inspires reflection, acceptance, and engagement in this central challenge of the Anthropocene.

Chapter 8. Conclusion

8.1 Summary of Research

This research questioned the assumptions underwriting the discursive environment dominated by food science perspectives in Canada's food and agriculture research. The story of Canada's emergent industrial pulse sector provided a back drop to analyze hidden political and economic drivers in agri-foods systems that undermine a shift towards diverse agroecological systems.

This study provided a synthesis of local agronomic and nutritional knowledge particular to pulses. Pulses are helping specialized industrial food systems participants to dramatically decrease the negative impacts of livestock agriculture, in particular on global warming. Adding pulses to the diet and reducing reliance on meat and dairy has measurable climate change mitigation effects while providing improved nutrition per acre over the status quo. Much of what makes pulses desirable from an agronomic sustainability perspective is undermined when pulses are industrialized and grown in chemical-dependent systems. This critique is obscured, however, by a dominant narrative with underlying assumptions about agriculture.

This dominant narrative is the product of a Productivist-Extractivist Paradigm characterized by a reductionist, food science orientation to food and agricultural issues. In a Productivist-Extractivist Paradigm, all values food represents outside of commodity are obscured. Distinguishing an emerging Ecological Paradigm as characterized by food systems research reveals what is obscured, contextualizing the criticisms of a food system that for decades has been hailed an unequivocal success. Sustainability claims made about industrial agriculture ignore underlying issues with reliance of that system on petrochemicals, mined inputs, and excessive fossil energy.

In an Ecological Paradigm — where systems complexity and new sciences including ecology, toxicology, and microbiology inform priorities— food is valued as a tradable good, a human right, essential for life, a renewable resource, a cultural determinant, and a public good (Vivero Pol 2015). Such a system moves from envisioning and therefore managing food as a commodity to envisioning and managing food as a commons.

A case study was conducted reviewing hidden drivers in Canada's pulses sector, using the IPES-Food 8 Lock-Ins Framework. This research showed total hegemony in public research of lentil breeding, as all future varieties arising from the SaskPulse/Crop Development Centre (USask) are destined to be pre-bred with tolerance to an herbicide (imidazolinone), a trait that is a product of mutagenesis. In such an environment, pathways of deep agroecology are not only obscured but excluded.

Canada's pulse sector is deeply reliant on chemical management approaches, and in this context sustainability claims were examined, focusing on Pulse Canada's promotion of pulses' low carbon footprints and soil building capacities, which demonstrate improvements over industrial systems that do not include pulses in the rotation that are at best weak sustainability. The central role of glyphosate in the economics of Canada's pulses strategy was examined in light of recent court cases involving glyphosate and a wave of research over the past five years showing human and ecosystem health concerns related to the use of glyphosate. Canada's pulse sector is vulnerable to both ecological shocks associated with industrial production and to social shocks associated with climate unrest and policy changes that could soon reduce or eliminate access to glyphosate and other pesticides. Options for further research that reconnects the economic sustainability conversation with this ecological sustainability analysis are discussed below, along with other avenues for research and public policy.

8.2 Opportunities

Pulses represent an untapped pathway addressing several externalities of the industrial food system while providing plant-based nutrition to billions. Rising interest in plant-based diets in North America for both population and ecological health combined with falling profits in the dominant commodity markets has in recent years led Canada's policy makers and agricultural organizations to turn their attention to pulses. In under two decades, Canada has gone from a non-player to the one of the world's largest exporters of pulses, with 40% of Canadian-grown lentils crops sold in 2016 to India alone and Canadian company AGT Food Ingredients Inc. controlling over half of the world's lentil trade. Turning that momentum from this current incremental trajectory towards a transformational trajectory seems daunting. Scholars identify agronomic reasons pulses were left out of the original Green Revolution. Pulses are poor candidates agronomically for production within industrial monocultural systems. Pulses traditionally are grown in mixed stands – such as was the method the Iroquois employed in the Three Sisters mixed planting system of squash, corn and beans (pulses). Much of the agronomic promise of pulses are simply not accessible when pulses are grown and processed using industrial methods. By forcing pulses to conform to the economics of the industrial production model Canada's pulses sector is missing out on an opportunity to work with pulses as a transition crop toward a truly regenerative agriculture, and may be setting the sector up for serious failures. Given the context of unavoidable catastrophic climate breakdown (IPCC 2018), it is imperative that scholars turn attention to confronting the elephant in the room that is globalized corporate capitalism. The neoliberal regime that has dominated economies and politics for four decades can no longer be left unchecked.

8.3 Tensions and Future Directions for Research

While the sustainability issues raised in this research are of extreme concern, tomorrow close to seven billion people will want to eat. Tensions between reforming and tinkering with Specialized Industrial Food Systems in place on the one hand, and engaging in transformation towards Diverse, Agroecological Systems on the other, force those who engage in the debate to make enormous trade-offs. The fact is that agroecology is not a profit generating approach to food systems and therefore has little currency on the global political agenda.

A real problem in our industrial agriculture is that farmers don't get paid for ecosystems services. When we value only commodity at the expense of all other food values and we invest public funds into agriculture, we are directly paying farmers to do things counter to our collective interests.

Guha calls out the anti-globalization movement for romanticizing pre-modernity: “it is equally a fallacy that ecosystem people want to remain as they are, that they do not want to enhance their own resource consumption.” (Guha 2003: 7). Yet I have participated in forums around the world and trainings in Agroecology and have heard directly from “ecosystems people” that they reject assumptions of what modern people consider the good life. This particular conversation is perhaps the most challenging raised by this research: development for whom, by whom? To what extent? Who decides?

While this research was nested in the assumption that Canadian policy makers are interested in balancing the various domestic and international commitments we have made, it is clear from industry publications that such a desire is not shared. India for decades has needed to address pulse production and engage domestic farmers in returning the soil health benefits that the Green Revolution robbed the country of in favour of chemical dependency. For Pulse Canada, “lending to the current problem (of tariffs on Canadian imports) is the fact that India’s domestic pulse production has seen higher-than-usual volume for the last two seasons, meaning the country was less reliant on Canadian exports.” (Seiferling 2018)

Ultimately the “wicked dilemma” of modernity vs sustainability arises. Technological cleverness cannot possibly substitute for the complexity and diversity of the biosphere and our interdependence with the broader, non-human world of which we are an intrinsic part within the timelines we have for action.

GPC's 10 Year Research Strategy (2017) lays out an agroecological pathway for industrializing economies, yet forgoes applying that advice and lessons for sunsetting industrial economies. While such explorations create strong tensions between long term transition strategies and the immediate needs of billions of eaters, encouraging Canadian researchers to review the benefits of the agroecological approaches should be encouraged as a strategy for Canadian farms. Research on alternative food systems, relational values in Nature, and transitions to food commons is building internationally. Explorations in post-capitalist forms of governance and rights of nature frameworks across the global north and global south provide fertile grounds for challenging the status quo and inspiring transitions to diverse, agroecological food systems:

Recognizing the devastating impact that industrial agriculture has on socio-ecological systems, it is important to envision an ideal world; however, in achieving this, the movement should not undercut the realities of the challenges that farmers compete with in pursuit of a sustainable livelihood. Aside from Raworth's characterization, other avenues of inquiry in the broad field of an interdisciplinary ecological economics. While this paper calls for a radical re-orientation of the economy in the direction of food commons, other researchers provide roadmaps for transition that address the concerns inevitably and rightly raised by Canada's food producers: how does one practically transition an entire economy?

Gaps exist in imagining and testing employable alternatives resulting in post neo-liberal food regimes. Further research on Canada's pulses sector following the diverse economies framework, as an example, could fill a gap in the literature investigating pathways for alternative systems to cohabitate within current systems. (Mann, 2016:106). Frameworks for transitioning from industrial food systems to, as IPES-Food recommends, diverse agroecological food systems, in the Canadian context will have to resolve the deep hegemony in research and policy that drives Canada's brand of export agriculture (Frison et al., 2016). Further research to analyse producer-consumer linkages that implement socio-ecological indicators such as those found in the food dimensions (Fig. 3) and doughnut economics (Fig. 2) frameworks could provide a pathway to implementing a food as commons rather than a food as commodity approach. A major gap in this research is the context of Canada's treaty obligations and the impacts of industrial food systems on indigenous food sovereignty.

Both the late Dr. Shiv Chopra and lay intellectual Brewster Kneen agreed that developing relationships between farmers and consumers' groups in Canada and in the country's export destinations can reduce reliance on the neoliberal food regime. Trading pulses directly amongst consumers' and farmers' co-operatives that support trading in high quality, fair priced goods could reduce the volatility of increasing financialization (Clapp and Isakson 2018) and support decision-making on a wider set of values than the commodity price. Further research exploring transition pathways for food commons to support diverse, agroecological food systems that are accountable to Canada's unique treaty obligations and Canada's obligations under United Nations Declaration on the Rights of Indigenous Peoples.

Appendix A
Interview Questions

My interviews are targeted to specific players within the pulses value chain in Canada. I have developed a short list of specific individuals whose perspectives I want to gather, and will use the snowball method in asking the interviewees whom else I ought to approach to interview to get a fuller perspective. My short list includes 2 organic and 2 conventional farmers, a lentil breeder, a chickpea breeder, an organic seed breeder, an Agriculture Canada scientist who has published extensively about pulse agronomics, two people engaged in grain trading, a processor, 2 people in industry trade association leadership, a nutrition researcher, and a researcher in India with extensive experience growing and breeding pulses in an agroecological setting. Each interview will be scheduled for one hour, with the intention that we can finish the set of questions in 30 minutes and allow for dialogue. My interviews will follow a conversational style, with 12 general questions. Given that each key informant has specialized knowledge relative to my study, the questions will be a launch point for deeper exploration about each informant's perspectives:

1. Can you tell me a little bit about your operation/research/ brokerage business/organization?

2. How long have you been working with pulse/the pulse sector, and what drew you into this work? Can you describe the range of pulses you grow/handle/ conduct research/etc.? (different families, varieties within families, etc.)

3. What opportunities do you think pulses present for farmers?

4. What issues or concerns about Canada's food system do you think can be addressed through increasing pulse (production/processing/ consumption)?

5. I am curious about how consolidation in both agriculture in general and in the pulses sector in particular is shaping the industry. By consolidation, I am referring to mergers, buy outs, and vertical integration. A current example is the proposed Bayer-Monsanto merger. What are your thoughts on this?

6. follow up question if appropriate:
New financial instruments bring investment but also more complexity to the agriculture and food sectors. Can you characterize what you feel are the impacts of changing financial regulations over investment and trading in new financial products for agricultural commodities and processed products on the way the pulses sector has developed in Canada?

7. Last year was the International Year of Pulses (IYP2016): what messaging from last year's efforts to publicize pulses benefits do you think is most important?

8. SETTING UP THE QUESTION:
In 2017 at the Global Pulse Conference, organizers announced that the new marketing for pulses would focus on "sustainability". "Sustainability" is a bit of a moving target. The definition that I am working with is what we call "living within the donut". That is, we must meet the minimal needs of our societies, which you can see here on the inner ring of this diagram, without exceeding the ecological ceilings — which you can see on the outer ring.

[I will show the interviewee Kate Raworth's "Donut Economics" model with social foundations and ecological ceilings]

Is there something in this model for sustainability that you feel you disagree with strongly?

CLARIFYING DISCUSSION: I will ask to follow up questions depending on the responses from the Interviewees, such as: If this model or aspects of this model don't work for you/resonate, can you suggest an alternate definition of "sustainability"?

QUESTION: Now that we have an understanding of what “sustainability” means to you, what does “sustainability” mean to you in the context of pulses production and consumption? What areas of pulse production do you think need to change, if any, in order to move us towards “live within the donut”, or moving us in the direction of meeting this definition of sustainability?

10. As you are aware, glyphosate is widely used in Canada as a pre-harvest aid for pulses. Can you discuss the implications for sustainability claims being made by the pulses sector?

11. Pulses, as you know, are not a complete protein, and are eaten in combination with other grains and in a wide diversity (peas, chickpeas, beans, lentils, fava, and others — along with diversity within these families, e.g. red lentils, French lentils, beluga lentils). Seed savers I work with in India tell me that the typical Indian diet traditionally include a large amount of diversity of pulses, usually around 20 different varieties. What are your opinions on the importance biodiversity in regard to both pulse types and varieties within those types, and how is this reflected or not reflected in the development of Canada’s pulse sector?

12. The rising organic market and increasing vegetarianism/reduced meat in diets are responses to what food systems analyst like myself call “externalities” of the current food system: over-use of water, increased scale leading to lost biodiversity, reliance on chemical fertilizers and pesticides, increased processed foods in the diet, and greater “food miles”. What do you see for the future of organic pulse production in Canada?

Appendix B Industry Perspective on Consumer Choice

A View from Industry—Consumer Choice and the Importance of Modern Agriculture

1. The global food industry needs technology. Without advancements in agricultural technology, humanity would likely not have progressed through the 20th century without major famines or devastating food wars. Will we be able to say the same thing at the end of this century, given that a food crisis is already here? I believe the answer is yes, because I concur with the U.N. that 70 percent of this food must come from the use of new and existing technologies and methods. And these technologies and methods must have no negative impact on the environment, animal welfare or food safety.

2. Consumers deserve the widest possible variety of safe and affordable food choices. In general, consumers trust food producers to keep the food supply safe, and they're more concerned about food contamination than about technology used on the farm. Instead, one of the most pressing human concerns about food is affordability. For this reason, consumers from all classes and geographies — from those who can afford organic foods to those who struggle to maintain a diet that sustains them — must be allowed to choose from an abundance of safe, nutritious and, most importantly, inexpensive food options.

3. The food production system can mitigate the food economics challenge and achieve an ultimate win. Facing a global food crisis, the world is at risk through the midpoint of this century. We already see the signs: our population consumed more grain than we produced during seven of the last eight years. The good news: an ultimate win is still possible. What will it look like? Five key achievements will mark its success:

- Improving the affordability of food by using new and existing technologies and optimal productivity practices.
- Increasing the food supply by instituting a vastly improved degree of cooperation across the entire global food chain.
- Ensuring food safety with a combination of technology and high quality standards and systems, coupled with a greater measure of worldwide collaboration.
- Increasing sustainability through a highly productive and efficient system that simultaneously protects the environment by means of sensitive and efficient use of natural resources.
- Producing more biofuels to reduce dependence on fossil fuels while creating no negative effect on global food supplies.

— Jeff Simmons, President of Elanco Animal Health, the animal health division of Eli Lilly and Company in Motes, 2010.

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