A network analysis of how neonicotinoids have become embedded in New Zealand's agricultural practices

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Abstract of a thesis submitted in partial fulfilment of the requirements for the Degree of Master of Natural Resources Management and Ecological Engineering

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This thesis uses tools from within the expansive area of scholarship known as Actor-Network Theory (ANT) to describe the material relations contributing to the on-going use -or discontinuation- of neonicotinoids in NZ's agricultural practices. All though ANT is named a theory, for this thesis, it is better understood as a disparate family of material-semiotic tools, sensibilities and methods. These tools are simultaneously semiotic because they are about relations that carry meaning, and material because they are about the physical stuff caught up in those relations.

Because ANT is so expansive, I have focussed on the specific tools from within its literature that I have applied to the case-study of neonicotinoids. Therefore, I have used Callon's key principles (agnosticism, generalised symmetry and free association) to remain free of *a priori* assumptions, describing actors and controversies as they emerge from the data and to look at the importance of non-humans without bias. I have also used Bruno Latour's CSSF to identify potential interview participants and to analyse this hazardous substance/ agricultural practice controversy. Subsequently, these two tools have enabled me to make sense of how neonicotinoids are embedded -and maintained- in NZ's agricultural practices.

Interview participants were identified by utilising the CSSF as a method for following the actors, subsequently resulting in 16 semi-structured interviews being performed. A thematic analysis was initially used to order the interview data and developed some scope of the case study. This was followed consecutively by an application of the CSSF, which supported an in-depth analysis of the case study and a representation of those material relations between growers, beekeepers, seed and chemical company representatives, international markets, consumers and regulators. Subsequently, the CSSF revealed that neonicotinoids are very much embedded in the agricultural practices of the

arable sector, while they have been simultaneously removed from the agricultural practices of the apples and pears sector. Latour stresses that there is no separation between the context and the issue itself and subsequently, his CSSF brings the scientific, environmental, political and historical contexts into the material relations which the CSSF represents. Therefore, it is these material relations that I have traced and shown to contribute to the on-going use -or discontinuation- of neonicotinoids in NZ. More specifically, this thesis demonstrates how differences in the public representation of neonicotinoids and the presence, or the absence of maximum residue levels and grass grub underwrite the opposing uses of neonicotinoids in NZ.

Thus, by applying the CSSF to a case-study of neonicotinoids, this thesis demonstrates how it might be used to understand agricultural practices. Furthermore, by applying a critical lens to the CSSF, I have critiqued the way I set boundaries in this thesis, the lack of practical direction in the literature, the imposition of theoretical lexicon and the CSSF for what it missed. Subsequently, this research offers guidelines for using the CSSF to identify research participants, follow the actors and make sense of hazardous substance or agricultural practice controversies.

Keywords: Neonicotinoids, Agricultural Practices, Actor-Network Theory, Circulatory System of Scientific Facts, Arable Sector, Apples and Pears Sector, New Zealand.

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Acronyms

ACVM	Agricultural Compounds and the Veterinary Medicines Act
ANT	Actor-Network Theory
CRI	Crown Research Institute
CSSF	Circulatory System of Scientific Facts
ERMA	Environmental Risk Management Authority
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
HORTNZ	Horticulture New Zealand
HSNO	Hazardous Substances and New Organisms Act
MFE	Ministry for the Environment
MPI	Ministry for Primary Industries
MRL	Maximum Residue Level
NZEPA	New Zealand Environmental Protection Authority
NZ	New Zealand
OP	Organophosphate
p.a.	Per annum
STS	Science and Technology Studies

Chapter 1

Introduction

1.1 Background and significance

This thesis explores neonicotinoid use in New Zealand (NZ). More specifically, it explores how this class of insecticides has become - and remains - embedded in NZ's agricultural practices. Neonicotinoids are the most widely used insecticide in the world (Cressey, 2017). They resemble nicotine, and are systemic, meaning that they are taken up by the roots or leaves of a plant and translocated to all other plant parts (Clarke, 2018). Subsequently, global agricultural and chemical communities consider them to be highly effective and environmentally friendly (AGCARM, 2019; United States Environmental Protection Agency, 2019). Recently neonicotinoids have been gaining traction in the media and drawing the attention of many governments due to the potential harm they cause pollinators (Clarke, 2018). Subsequently, they are becoming restricted, even banned around the globe (Sanchez-Bayo, 2014; Magallanes, 2018). Nonetheless, NZ legislators are not following this trend and have left neonicotinoids out of their hazardous substance reassessment programme (Ardern et al., 2014; Clarke, 2018). Therefore, the primary objective of this research is to understand how neonicotinoids have become embedded -and maintained- in NZ's agricultural practices.

On the one hand, advocates state that neonicotinoids lead to economic gain, are a necessary treatment especially at the seedling stage of crop/pasture development, are highly targeted and environmentally friendly, do not harm pollinators, are already strictly regulated and ensure people have access to affordable and reliable food (AGCARM, 2013; Carrington, 2017; Chapman & Jackson, 2010; Kleinschmit & Lilliston, 2015; McSweeny, 2017; Piddock, 2018). On the other hand, critics state that neonicotinoids have adverse effects on human health, ecosystems and the environment, they cause pollinator decline and the regulation surrounding their use is outdated (Budge et al., 2015; Carrington, 2017; Hobbs, 2002; Kleinschmit & Lilliston, 2015; Ministry for the Environment, 2018; Walters, 2013). Due to the potential impacts which neonicotinoids have on food production and the environment, whether these be positive or negative, it has become a widespread debate. An important argument against the use of neonicotinoids is around the potential harm they cause honeybees and other beneficial insect populations (Ardern, 2014). In NZ, this is of great concern because apiculture contributes $5.1 billion to the economy per annum (p.a.) (Ministry for Primary Industries, 2017). This contribution is primarily associated with the benefits provided by pollination services. Additionally, a new Manuka honey industry has emerged, leading to the highest

national beehive population on record. Manuka honey exports are valued at over $329 million p.a. Subsequently, it has attracted a lot of media attention (Ministry for Primary Industries, 2017).

Bruno Latour's Circulatory System of Scientific Facts (CSSF) (1999a, pp. 98-108) has been applied to this research to facilitate an exploration of how neonicotinoids are embedded -and maintained- in NZ's agricultural practices. My research will also explore how the CSSF, a network representation, might facilitate an investigation into the relationships and interactions that surround the use of neonicotinoids in NZ. By using the CSSF, my research will show how relationships have formed and how neonicotinoids are being framed. Furthermore, this thesis explains why research opposing neonicotinoid use has been unable to remove them from NZ's agricultural practices. Subsequently, this case study has also enabled me to explore the potential of the CSSF as a suitable framework for investigating hazardous chemical controversies in the future.

1.2 Personal motivation

Both my academic and professional experiences motivated this research. Most importantly, my position at Springbank honey in Cust, NZ, drove my interest in neonicotinoids. After beginning my employment there, to support myself during my studies, I quickly became aware of several studies demonstrating the negative impacts which neonicotinoids cause honeybees. My personal experience of observing beehive deaths caused by the unlawful use of agricultural compounds (Environmental Protection Authority, 2019) intensified this interest. During the completion of this master's degree, I was lucky enough to spend some time in Austria, where I noted the ongoing European neonicotinoid debate. I was living in Austria at the time when three types of neonicotinoids were banned and therefore observed the significant bottom-up movement which drove this. Subsequently, I could not understand how neonicotinoids were still being used so extensively in NZ.

I had previously used tools from within ANT to try and understand why honeybee sites were being established on public conservation land in NZ despite a Department of Conservation recommendation not to do so (Beard, 2015). Having found some success performing this research, I decided to once again use tools from within ANT for my master's thesis. Having completed a Bachelor of Commerce (Agriculture) and having spent many years working on farms across Canterbury NZ, I have developed an interest in agricultural practices and how they are both implemented and chosen. Therefore, the main objective of this research, to understand how neonicotinoids have become embedded -and maintained- in NZ's agricultural practices, appeared to be a good fit. Initially, I wanted to know why neonicotinoids were still used in NZ. I was misled in thinking that there was a hidden corporation making sure it stayed around. Fortunately, ANT is a constructivist approach to social theory (Tonelli, Silva et al., 2010), it asks how something is made rather than why something has happened. Furthermore, Latour's CSSF (1999a) asks how science is

done. So rather than assuming neonicotinoids are embedded -and maintained- because of the actions of a particularly powerful actor, adopting a CSSF approach made me re-evaluate how they remained embedded in agricultural practice. The reader needs to keep these personal motivations in mind as they make their way through this thesis. Admittedly there are many possibilities for me to have biases, considering my previous work, employment and the fact that I have beehives. There is not much more I can do to alleviate these biases, but I hope that by being self-reflexive and acknowledging this potential for bias at the outset I am allowing the reader to draw their own informed conclusions from my research.

1.3 Methodology

The methodology of this thesis focused on the analysis of in-depth interviews with individuals from across NZ's agricultural community, a document analysis of relevant publications and reflections of my own practices. The interview participants included landowners, beekeepers, seed and chemical company reps, product group reps, regulators and researchers, while the documents primarily consisted of journal articles, regulatory material, newspaper articles, conference papers, press releases and web pages. Finding suitable interview participants and the relevant documents proved quite challenging, due to there being some secrecy around hazardous substance supply chains in NZ. Furthermore, most of the NZ media coverage referenced the same spokespeople when discussing neonicotinoids. I utilised snowball sampling, Latour's CSSF (1999a), Callon's key principles (1986) and some previous CSSF case studies at every stage of this research. It was these theoretical resources and methodologies that enabled me to collect data, be selective about what data were relevant and to then analyse it and discuss all the pertinent phenomenon.

The CSSF (1999a) is a framework used during the data collection and analysis stages of this research and it has informed agricultural practice studies before. For example, Ingram (2007) used the CSSF to highlight how the participation of scientists and the pursuit of scientific research developed several agricultural technologies. More specifically, she used the CSSF to follow the making and maintenance of three separate agricultural methods for managing soil. Fitzsimmons (2004) builds on the work of Latour to demonstrate how ecologists have vascularised their work throughout American agricultural and political communities. She explained how "ecologists made a structure of engagements for translating knowledge into practical action and political power". Warner (2008; 2016) also used Latour's tool to understand science in general, but mainly those controversies stemming from the work of Rachel Carson's Silent Spring. Latour's CSSF played a significant role in directing me where to look for interview participants. I used his loops as a way to find relevant actors and their peers. Later on, I used the CSSF to represent the data in such a way that I could highlight phenomena such as agricultural practices relational and material nature, as well as answer those research questions

presented below. I finally went on to critique the CSSF, attempting to reflect on my practices, by acknowledging the boundaries and limitations of both myself and this research.

1.4 Research objectives

The main aim of my study is to explore how neonicotinoids have become – and remain - embedded in NZ's agricultural practices. To do this, I have explored how relationships across NZ's agricultural, scientific, political and environmental communities have developed. I have also explained how the continued use of neonicotinoids is an outcome of these various relationships. Furthermore, I have discussed why the scientific knowledge that challenges the status quo, like the non-target effects of neonicotinoids, has been unsuccessful in removing them from NZ's agricultural practices. I have also been able to assess the suitability of specific tools taken from ANT literature for investigating hazardous chemical controversies in the future. Finally, I explored the idea that agri-environmental controversies are never just scientific, that policy, business and society all have a significant role to play. To achieve these objectives, I have answered the following research questions:

1. Who and what are the major actors that influence the scale and frequency of neonicotinoid use in NZ, and what have been their roles?

2. How have certain relationships been made and maintained between actors?

3. How are neonicotinoids as an agricultural practice embedded -and maintained- in NZ, and why has opposing knowledge been unsuccessful in removing it?

4. How can Latour's CSSF be used to investigate similar controversies in the future, in particular, those which involve hazardous chemicals used in NZ's agriculture?

1.5 Outline and structure

This thesis is organised into seven chapters. Chapter 1 has provided a broad overview of the controversy surrounding neonicotinoids, both on a global and domestic scale. It also provides this study's terms of reference. Chapter 2 provides a detailed account of the background information which is relevant to this case study. This includes a background investigation into the policy controlling agrichemicals, the key industry stakeholders (apiculture, agriculture and agrichemical), the international positions on neonicotinoids as well as the domestic ones. Chapter 3 provides a detailed review of Michel Callon's key ANT principles (1986) and Bruno Latour's CSSF (1999a), both scrutinising them through a literature review and considering their relevance to this case study. Chapter 4 details the specific methodology utilised during the data collection and analysis, which is followed by Chapter 5 that outlines the key findings from a series of in-depth interviews in a thematic format. Chapter 6 produces a review of the results while also discussing

some issues that occurred during the research process. Finally, Chapter 7 concludes the research by explaining what it has contributed to CSSF and hazardous substances literature.

Chapter 2

Background

2.1 Introduction

Before I can undertake an analysis of neonicotinoid use in NZ using the CSSF (1999a), it is necessary to consider the background information relevant to this case study.

Firstly, this chapter provides background information on who and what appears to be involved with neonicotinoids in NZ. These include regulators and the NZ agricultural, agrichemical and apicultural industries. There is a need to evaluate the relationships between these groups to answer the first and second research questions of this thesis.

Secondly, I will consider the role of policy in controlling agrichemical use in NZ, particularly the Hazardous Substances and New Organisms Act (HSNO) (Ministry for the Environment, 1996) and the decision-making body named the NZ Environmental Protection Authority (NZEPA). This provides some of the background information necessary for understanding the relationships between those actors which are contributing to the embedding -and maintenance- of neonicotinoids in NZ's agricultural practices.

Finally, I will discuss the changing global perspectives on neonicotinoids, which will focus on the European Union (EU) and their extensive bans on this class of insecticide (McGrath, 2014). This information is relevant to answering the third research question and understanding why knowledge opposing the use of neonicotinoids has been unsuccessful in removing it from NZ's agricultural practices.

This chapter will, therefore, demonstrate that neonicotinoids have become embedded -and maintained- in NZ's agricultural practices.

2.2 Agriculture in New Zealand

NZ split from the supercontinent Gondwana around 85 million years ago. Because of its isolation, NZ's flora and fauna have evolved unique characteristics and traits. This not only led to a lack of predatory land-dwelling species but has helped mould NZ's agricultural landscapes and practices into what they are today. The primary reason is that some endemic insect species adapted well to the modification of landscapes caused by human activities. This subsequently led to them thriving in those landscapes and now being classified as agricultural pests (Brockie, 2007; McLintock, 1966).

Since colonisation, agriculture has been the primary source of income for NZ, and there has also only been a brief period in the 1860s when agriculture did not lead NZ's export earnings (Peden, 2008; Tourism Industry Association New Zealand, 2019). There has always been large scale economic activity occurring in NZ. However, the first settlements of Māori did not practise commercial market transactions but engaged in gift-giving and barter. They lived in subsistent, self-sufficient units known as hāpu and effectively utilised what the land provided them (Haggerty and Cambell, 2008; Easton, 2010). Cultural and ideological changes meant that Māori became expert resource managers and gardeners (The Reserve Bank of New Zealand, 2007; Easton 2010) and their diet consisted of birds, seafood and gathered fern-root, as well as cultivated crops which had been imported by their Pacific ancestors (Kingi, 2008).

In 1769, two European explorers, James Cook and Jean François Marie de Surville both came to NZ. They subsequently traded cabbages, turnips, potatoes, wheat, rice, peas and pigs with the Māori tribes of Tolaga and Doubtless Bays (Kingi, 2008, 2019). It did not take long for Māori to begin trading these European crops with one another, with some records suggesting that this occurred from as early as 1803 (Kingi, 2008).

Before the establishment of an organised European settlement in NZ, there was a heavy reliance on those resources that occurred naturally. This period saw the rise of export industries reliant on seals, whales, timber and flax (Russell Stephens, 1966; Peden, 2008). After many years and the development of an organised British settlement, the industrial revolution occurred. Subsequently, large scale agricultural expansion, the replacement of sail with steam and the invention of refrigeration allowed NZ to dive into the international market (Russell Stephens, 1966).

Since the 1850s, NZ's economic backbone mostly revolved around pastoral grazing and the subsequent commodities of wool, meat and dairy (Kingi, 2019). The great pastoral era began when the first flock of Merino sheep arrived in NZ and, within 30 years, there were over 3 million. This growth continued, and by 1901 there were over 20 million Merino sheep in NZ. The vast area of 'free' land available in the South Island, which was ideal for fine-wooled sheep breeds, helped this rapid expansion. This growth subsequently led to the development of a frozen meat export industry (Russell Stephens, 1966; Peden, 2008). The tussock lands of the South Island quickly required pasture renewal which allowed for vast areas of land to be ploughed and planted with wheat crops. Thus, by the 1880s, this wheat crop made up 20% of the NZ's income (Peden, 2008). At the same time, the dairy industry began in NZ with the first factory opening in 1881, and by 1890 there was within the region of 150 butter and cheese factories in the country (Peden, 2008). Through the early 20th century pastoral based agriculture remained the biggest earner in NZ and in 1920 it contributed 91% of NZ's export earnings.

The capacity of NZ's agricultural land was reached around this time, and the large-scale use of superphosphate help facilitate continued growth (McLintock, 2019). NZ gained the title of Britain's distant stock farm following WWI, and several scientists arrived from Britain to boost the productivity of NZ's agriculture. Subsequently, this initiated the founding of the Department of Scientific and Industrial Research and Massey Agricultural College. Lincoln Agricultural College was also upgraded (Brooking, 2006). However, farms struggled to survive between the wars, and many returned to native bush, which was exacerbated by the great depression and the collapse of wartime prices (Brooking, 2006).

NZ entered its golden age of farming following WWII. There was a record number of farms, and the nation's sheep flock reached 70 million, while the cattle herd reached 8 million (Brooking, 2006). Over the same period, cereal crops remained an essential part of NZ's agriculture, and a new agricultural commodity in the form of vegetables for processing commenced in the 1980s. When Britain joined the EU, NZ's agricultural production exceeded demand, and the country faced a severe fiscal crisis. Subsequently, the NZ government implemented a serious deregulation programme which saw the removal of farm subsidies and the end of NZ's agricultural golden age (Ross, 2019).

To remain competitive in the highly subsidised markets of the EU, NZ's farmers had to diversify their production and improve the efficiency of their operations. This move towards a value-added product space, in hand with greater access to irrigation and the opening of new markets in Asia, Europe and the Middle East, resulted in a dairy boom (Brooking, 2006; Peden, 2008). Since the 1980s, there has also been a spike in NZ's horticultural production. Apple export earnings grew from $37.75 million in 1980 to over $800 million in 1995. Kiwifruit exports increased from $34.5 million in 1980 to over $540 million by 1990 and total export earnings from wine were $662.4 million in 2007 (Peden, 2008). As of 2016, 45.3% of NZ's total land area is being farmed. Between 2002 and 2016, total land area under dairy increased from 1.8 to 2.6 million hectares and subsequently, land area under sheep and beef decreased from 10.7 to 8.5 million hectares. Furthermore, the land area under grain crops increased by 101.4% over the same period (Stats NZ, 2018).

This section demonstrates that NZ has a heavy reliance on horticultural and agricultural production (McLintock, 2019). This is because of its economic benefits and the connection which much of the population has with the land. Therefore, many difficulties arise when agricultural and horticultural productivity is threatened. Nevertheless, social, political and environmental movements have had significant effects on NZ's agricultural practices. DDT was once heavily used in NZ. It was mixed with fertiliser to control endemic pasture pests. In 1989 this harmful chemical was banned in NZ on the back of Rachel Carson's Silent Spring (Wildblood-Crawford, 2006). However, as some things change, some do not. Neonicotinoids, a class of agricultural pesticides subject to substantial bans

internationally (see section 2.6), are still widely used in NZ (see section 2.7). NZ's farmers rely on neonicotinoids to protect their crops from endemic agricultural pest species at the seedling stage. Unlike DDT, there does not appear to be substantial movements backing a neonicotinoid ban (Morton, 2018; Twaddle and Sanderson, 2014).

2.3 Agrichemical industry

The agrichemical industry revolves around the importation, production and supply of those chemicals which improve agricultural production (Ministry for the Environment, 2019). Agrichemicals are managed in NZ under three acts of parliament; the Hazardous Substances and New Organisms Act (HSNO Act), the Ozone Layer Protection Act and the Agricultural Compounds and the Veterinary Medicines Act (ACVM Act) (Ministry for the Environment, 2019). There is a small number of key stakeholders in this industry, including six international brand owners that either operate within NZ or hold secured relationships with NZ based parties. They usually have teams in NZ that focus on building relationships with farmers, specialist farm retailers and service providers (Ministry for the Environment, 2019). Even more recently, these six major agrichemical companies have formed three entities. These entities now jointly control 70% of the global agrichemical and 60% of the global seed market (Crowe Horwath, 2017; Ministry for the Environment, 2019).

As well as the brand owners there are generic suppliers who have a physical company presence in NZ, source their products via imports and represent around 30% of the market. A generic agrichemical is one whose patent has run out and is now being manufactured, sold and marketed under various brand names, by multiple companies (Ministry for the Environment, 2019). The ability of these companies to produce and retail the same generic chemical under different brand names means that they are competing with one another on price alone, rather than chemical efficacy and ecotoxicity. Furthermore, modern telecommunication and social networks have enabled their sales teams, to interact frequently and directly with farmers. Farmers in NZ depend on agrichemicals for the success of their businesses, and they hold close relationships with their supplier. Typically, farmers only keep enough product on hand to maintain their farm for one year; this is likely a consequence of changing brands and the frequent release of newly improved formulations (Fitzpatrick, 2019). The combination of price competition and direct supplier to end-user relationships has meant that the generic supplier proportion of the industry is rapidly growing (Ministry for the Environment, 2019). Because of this growth, there are now anywhere between 15 and 20 generic chemical distributors in NZ who directly compete with research-based patented brands (Ministry for the Environment, 2019).

Because a number of widely used chemicals have recently come off patent, there has been a jump in the number of these generic brand options available, resulting in lower-priced compounds across NZ,

leading to higher application rates and less care taken when the applications occur (Manktelow, Stevens et al., 2005). Subsequently, agrichemical resistances have been observed across NZ (Manktelow, Stevens et al., 2005), resulting in various changes to the agricultural industry and its community. Farmers now have an increased reliance on specialist agrichemicals. There is also more public pressure to minimise application rates and several integrated pest management strategies have been developed (Martin and Workman, 1994; Science Media Centre, 2015; Bourdôt, Buddenhagen et al., 2019; Ministry for the Environment, 2019).

The Ministry for the Environment (MFE) has "not been able to identify information, collected and verified centrally, on which sectors in agriculture use agrichemicals and in what proportion" (Ministry for the Environment, 2019). Furthermore, the Environmental Protection Authority (EPA) has stated that "we really don't know what's out there" (Hancock, 2018). There are also no records of consistent data collection across the whole sector (Agrichemical Trespass Ministerial Advisory Committee, 2002; Ministry for the Environment, 2019). Because the agrichemical industry does not reveal any market share information (Ministry for the Environment, 2019), there is no way of determining the rates at which agricultural chemicals are used in NZ. This section outlines those existing relationships between the agrichemical sector, farmers, regulators, researchers, the media and more. It also indicates that further investigation of several documents and interview data will contribute to an understanding of the roles of and relationships between these individuals and organisations, and how they have contributed to the scale and frequency of neonicotinoid use in NZ. It will also help us understand how those relationships formed in the first place, and therefore suggest how neonicotinoids have been maintained and not removed from NZ's agricultural practices.

2.4 Pollinators and the apiculture industry

> *Pollination by animals is a crucial ecosystem service. It underpins New Zealand's agriculture-dependent economy yet has hitherto received little attention from a commercial perspective except where pollination clearly limits crop yield. (Newstrom-Lloyd, 2013)*

Prompted by the works of those like Rachel Carson and a growing environmental movement, the use of pesticides and herbicides is more carefully considered by bodies like the NZEPA. Along with impacts on human health, the effects of agrichemicals on other species is also considered. The effect on pollinators is particularly important as according to the Food and Agricultural Organization of the United Nations (FAO), 35% of the world's agricultural land, which supports 87 of humanities leading food crops, are reliant on some form of animal pollination (Food and Agricultural Organization of the United Nations and Republic of Slovenia Ministry of Agriculture Forestry and Food, 2018). Because pollination in NZ has historically been performed by unmanaged *Apis mellifera* hives and non-*Apis* pollinators, there has not been much research into the contribution of pollinators to NZ's economic,

social and environmental well-being (Bennett et al., 2018). Nevertheless, NZ's managed honeybee hives do provide pollination for a wide range of crops and the use of bumblebees has been gaining traction.

Furthermore, NZ has several solitary bee species and other animal pollinators which all contribute to the pollination of crops, native and non-native flora. However, NZ is yet to harness the capabilities of and manage native pollinators, so it continues to rely heavily on non-natives for pollination services (Newstrom-Lloyd, 2013). This reliance makes NZ's pollination susceptible to risks like pests, disease, pesticides and declining floral resources (Newstrom-Lloyd, 2013). All of which are known to contribute to the endangerment of vertebrate and invertebrate pollinator populations (The White House Office of the Press Secretary, 2014). The accidental importation of honeybee queens carrying the parasitic mite, *Varroa destructor,* led to the death of thousands of honeybee hives over the last two decades and the ensuing rise of apiary operational costs. This caused the number of beekeeping enterprises to drop by 50% in 8 years and the destruction of all NZ's feral hives (Ministry for Primary Industries, 2017). Following the introduction of Varroa, those beekeepers who remained were rewarded with a price jump and an increase in demand for Manuka honey. The nectar produced by the Manuka (*Leptospermum scoparium*) flower has gained a reputation as having healing properties, fetching prices of up to $300/kg (Beard, 2015). Subsequently, there is growing competition for bee sites with access to native bush and the value of NZ's honey exports reached $329 million in 2016/17 (Ministry for Primary Industries, 2017). So, despite the pressure of Varroa, NZ's apiculture industry still contributes over $5.1 billion to the economy p.a. (Ministry for Primary Industries, 2017).

Declining biodiversity of pollinators is linked to the intensity of agricultural practices and neonicotinoids have been ascribed as one of the leading causes. Habitat loss, parasites, disease, adverse weather and poor nutrition also contribute (Godfray et al., 2014; Beston, 2017). Subsequently, there is growing concern around the impacts which neonicotinoids have on hives. This begs the question, how does the relationship between NZ's beekeepers and landowners function, particularly around the use of agricultural chemicals, like neonicotinoids, and the potential harm they cause beekeepers' hives (Ardern et al., 2014).

This summary shows the importance of pollinators to the environment, people and the economy. It also demonstrates that it would be difficult to feed the world without pollinators (Klein et al., 2007). Representatives of pollinators frame neonicotinoids as being detrimental to not just humanity but all life on earth. Likely, neonicotinoid use in NZ would not have become controversial unless for the sequence of events involving the fall and rise of NZ's honeybee population. Beekeepers are probably the first individuals to observe the misuse of neonicotinoids and any of their adverse effects

(Woodcock et al., 2017). Which raises interesting questions about the relationship between farmers and beekeepers and the role they play in embedding neonicotinoids in NZ.

2.5 Hazardous substance regulation in New Zealand

As stated in section 2.3 of this chapter, pesticides, like neonicotinoids, are managed under 3 acts of parliament (Ministry for the Environment, 2019). For this thesis, I will only go into to detail about the HSNO act as it is the primary statute for assessing and approving pesticide use in NZ. I will also outline the function of the NZEPA as the decision-making body under the HSNO Act (Lorns, 2019).

In the early 20th century regulation of hazardous substances was created through market availability (Ministry for the Environment, 2002) and in 1959, formal law was established (Agricultural Chemicals Act, 1959). The Agricultural Chemicals Board was also developed and included users and producers of chemicals appointed by the Minister of Agriculture (General Assembly of New Zealand, 1959; Magallanes, 2018). Its primary function was to ensure the wellbeing of agriculture. Compulsory registration of agrichemicals was imposed and required an application showing the effectiveness of a chemical at eliminating pests (General Assembly of New Zealand, 1959; Mann, 1972; Magallanes, 2018). This raised questions about the extent to which people and the environment were considered in applications (MacIntyre, 1989; Magallanes, 2018). Which, together with public pressure, issues in the decision-making process and a lack of understanding about the effects of pesticides led to the act and board being reviewed (MacIntyre, 1989; Magallanes, 2018). What resulted was the formation of the Pesticides Act (1979) and the Pesticides Board, which focussed more on public safety and the environment. More power was given to annul registrations, and the board included a nominee of the Minister for the Environment. For the first time, pesticide registrations could be refused because of environmental risk (General Assembly of New Zealand, 1979).

Once again, public pressure and issues with the decision-making process of the Pesticides Board led to the establishment of a new Act during the 1990s. This was the HSNO Act which focused more on risk reduction, and it remains the primary statute for approving and regulating pesticides in NZ (Ministry for the Environment, 1996; Harris et al., 2004). Its purpose is to “protect the environment, and the health and safety of people and communities, by preventing or managing the adverse effects of hazardous substances and new organisms” (Section 4). Unlike previous regulations, the HSNO Act assesses hazardous substances based on their risk characteristics and allows for public participation (Section 2).

The Environmental Risk Management Authority (ERMA) was also established during the 1990s to make decisions under the HSNO Act. In 2011 another reform meant that ERMA was replaced with the NZEPA (Ministry for the Environment, 2011, Section 7 (1) (a) and 25). Unlike the Pesticides Board,

there is not a requirement for a member of the NZEPA's decision-making board to represent environmental interests (Magallanes, 2018). When deciding on a pesticide submission, the NZEPA must consider various principles (Ministry for the Environment, 1996) which safeguard the life-supporting capacity of air, water, soil and ecosystems. They also maintain and enhance the ability of people and communities to provide their own economic social and cultural well-being (Section 5). Generally, the NZEPA approve hazardous substances if their benefits outweigh any adverse effects and vice versa (Section 29 (1) (c)). However, the NZEPA maintains total discretion over the approval of hazardous substances as long as they consider all the right factors (Section 29 (3)). Another significant regulatory body is the Ministry of Primary Industries (MPI) which holds some responsibility for enforcing the decisions made by the NZEPA. MPI began in 2012, and all the members of the NZEPA board are appointed on the recommendation of the Minister (Ministry for Primary Industries, 2019).

Following bans on three classes of neonicotinoids in Europe during 2018 (section 2.6) (Piddock, 2018), the NZEPA declared that "when new information is released, the EPA always takes a good look at the science, evaluating it to see if there is something we need to factor into our thinking here" (Environmental Protection Authority, 2018). In 2018, the NZEPA also declared to ramp up its chemical reassessment programme (Clarke, 2018). The reassessment programme was "designed to lay the foundations for a modern chemical management system; one supported by robust and up-to-date evidence and data, and which aligns with the standards, knowledge and practices recognised by our regulatory partners globally" (Environmental Protection Authority, 2018). However, neonicotinoids, along with many other controversial chemicals, were not considered for reassessment (Cressey, 2017). Therefore, under the HSNO Act, the banning of a pesticide by other countries is not grounds for reassessment (Magallanes, 2018). The NZEPA stated that neonicotinoid's exclusion was because their hazard profile and their risk to human and environmental health does not meet priority criteria (Hutching, 2018). They followed this up by saying that the use of neonicotinoids in NZ is already heavily regulated. Interestingly, the NZEPA has recently called for information on neonicotinoids to understand how they are being used in NZ (Environmental Protection Authority, 2018). This description of the HSNO decision-making process, as well as the role of the NZEPA, raises several questions about; how the NZEPA gain data for hazardous substance applications, whether they are considering the adverse effects of neonicotinoids, what the benefits are which outweigh those adverse effects and who holds relationships with the NZEPA that benefit from the use of neonicotinoids.

2.6 Neonicotinoids in Europe

Following the first application of Gaucho (a neonicotinoid) in France, some of the local beekeepers noticed that their hives were dwindling. In response, the beekeepers approached the producer of Gaucho, (Bayer CropScience) and demanded a thorough investigation into whether this neonicotinoid affected honeybees. Several studies showed no adverse effects, but others carried out by the French government and independent researchers supported the beekeepers' claims. Subsequently, in 1999 the French government imposed a ban on Gaucho (Sanchez-Bayo, 2014; Magallanes, 2018). Following this, Europe has become increasingly concerned about the effects neonicotinoids have on pollinators. So, the European Food Safety Authority reviewed neonicotinoids, and in 2013 the EU imposed partial restrictions on three classes of neonicotinoid (AGCARM, 2013; Kothage, 2018), all of which are widely used in NZ.

These restrictions have sparked a debate over whether the benefits provided by neonicotinoids outweigh their detrimental effects (Woodcock et al., 2017). A meta-analysis published in the Proceedings of the Royal Society aimed to summarise all the natural science evidence relevant to neonicotinoids and insect pollinators (Godfray et al., 2014). It concluded that there is limited information to guide policymakers (Sanchez-Bayo, 2014) and that under current management strategies, neonicotinoids are toxic to insect pollinators. There are several ways pollinators can be exposed to neonicotinoids, including plant exudates, dust from machinery, foliar sprays and contamination of soil and water (Godfray et al., 2014). Estimates of neonicotinoid traces in pollen and nectar vary, but the dust emitted from drilling machines contains high levels, and its drift has been linked to events of mass honeybee death (Bonmatin, 2015). Neonicotinoids can persist in the environment for 15-300 days, and concentrations accumulate when treated crops are grown repeatedly. They have also been observed in weeds and untreated crops grown in rotation (Godfray et al., 2014). Because of these reasons, in 2018 the EU voted to extend the restrictions already in place by altogether banning the use of 3 neonicotinoids in open fields (Greenpeace European Unit, 2018; Environmental Protection Authority, 2019b). To comprehend how neonicotinoids have been made and maintained as an agricultural practice in NZ, I must understand how this became a controversy in the first place. The above description of Europe's perspective and the development of neonicotinoids as a globally recognised debate will support the discussion of and contrast to NZ's position on neonicotinoids.

2.7 Neonicotinoids in New Zealand

Neonicotinoids have been popular since their introduction to NZ in 1992 (Mellet, 2012). They are intended for arable crops, forage brassicas and pasture grasses and as of 2011, made up 28.5% of the global insecticide market. Which is primarily due to their correlation with increasing crop yields

(Godfray et al., 2014). Neonicotinoids are known for their ability to control insects while having low toxicity to mammals (AGCARM, 2013). There are several ways neonicotinoids can be applied, including sprays, drippers, granules and pour-on (Godfray et al., 2014). However, typically, the application is via a seed treatment which allows the insecticide to be taken up in the growing plant and be present in all the plant parts, including the nectar and pollen (Simon-Delso, 2015).

It is widely publicised that neonicotinoids are an environmentally friendly crop protection method that without, certain crops would be impossible to grow in NZ (AGCARM, 2013). The removal of seed treatment varieties of neonicotinoids would likely cost the NZ economy between $800 million and $1.2 billion (AGCARM, 2018), affect the employment of 5,300 full-time workers and reduce national crop yields by one third (AGCARM, 2018). This is because 62% of seeds planted in NZ are treated with some form of neonicotinoid, and the treatments alone contribute an additional $368 million to the market value of those seeds (AGCARM, 2019b). This suggests that the economic benefits of neonicotinoids are helping to maintain them in NZ's agricultural practices. Subsequently, this opens a discussion into who is gaining those benefits. It also raises questions about how those beneficiaries are convincing the NZEPA that the benefits of neonicotinoids outweigh their detrimental effects.

Due to growing concern about the non-target effects of neonicotinoids, there have been several public calls to ban them (Clarke, 2018), but changes have not occurred. However, some retailers have decided to stop selling neonicotinoid products (Didovich, 2018), and the NZEPA has agreed to "keep an eye" on neonicotinoids (AGCARM, 2013). The NZEPA will not make regulatory changes despite their publications acknowledging neonicotinoid toxicity (Ardern et al., 2014; Clarke, 2018; Environmental Protection Authority, 2018b, 2019). The NZEPA and MPI, ensure that neonicotinoids are used in such a way that residues are minimised, and they also acknowledge a lack of NZ based studies supporting the adverse effects of neonicotinoids (Environmental Protection Authority, 2018b). The NZEPA maintains that NZ pollinators are not at risk from neonicotinoids because of tight regulations surrounding their use (Environmental Protection Authority, 2018b).

Furthermore, the Foundation for Arable Research (FAR) has stated that the risk to bees is not as significant in NZ because we do not tend to use neonicotinoids as a foliar spray (Piddock, 2018). The NZEPA also states that international attention on the effects of neonicotinoids mainly relates to colony collapse disorder (CCD), a phenomenon not recorded in NZ (AGCARM, 2013; Ardern et al., 2014). Although it is suggested that even in low concentrations neonicotinoids harm bees, the NZEPA maintains that NZ beehive problems are caused by Varroa mites (Magallanes, 2018). Nevertheless, the NZ House of Representatives has voiced concerns that the NZEPA is not assessing chemicals appropriately and is not monitoring volumes of pesticides imported or used in NZ (Ardern et al., 2014). Another concern is that the NZEPA's focus is on the use of neonicotinoids as a foliar spray,

even when most international interest is around pollinator exposure through the systemic effects of seed coatings. What this means is that seed treatment neonicotinoid applications are not controlled by any rules (Clarke, 2018). A final criticism is that the NZEPA ignores the unpredictable damage caused by neonicotinoids at population levels, the tipping points which then lead to the collapse of pollinator populations are only observable after they occur (Magallanes, 2018).

This section raises questions about the NZEPA's justification for not reassessing neonicotinoids. Is the NZEPA not considering the research which demonstrates the adverse effects of seed treatments or is there some difference between NZ's use of seed treatments and the rest of the world's?

2.8 Summary

This chapter outlined the background information needed for this thesis and provided a knowledge base for understanding Chapters 5 and 6. Thee descriptions of NZ agriculture, NZ's agrichemical industry and NZ's apicultural industry, present in this chapter, have provided me with some insight into how a point has been reached where neonicotinoids are a necessary agricultural practice in NZ. Furthermore, this chapter has provided an overview of the regulating bodies and statutes that manage neonicotinoids in NZ. Lastly, I have outlined the banning of neonicotinoids in Europe which highlights that agricultural practices are not universal. I have also described how neonicotinoids are seen and managed in NZ. The inconsistency between these cases shows how important it is to understand under what conditions an agricultural practice, thrives and dies (McNamara et al., 2004). My analysis in chapters 5 and 6, therefore, establishes how particular relationships have made and maintained this agricultural practice.

Chapter 3

Literature Review

3.1 Introduction

Actor-Network Theory (ANT) is a group of tools, sensibilities and methods of analysis which map relationships between things and concepts simultaneously and was created to understand the process of knowledge creation in the broader discipline of Science and Technology Studies (STS). ANT was developed by Michel Callon and Bruno Latour (Callon, 1986; Callon and Latour, 1981) in Paris during the 1980s. It is also often associated with John Law, who began shortly after and later collaborated with Callon (Callon & Law, 1982). Because ANT has been used to study everything from scallop fisheries (Callon, 1986) to nuclear fission (Latour, 1999a), and offers up a breadth of conceptual tools, researchers must define how they use the tools within its literature very specifically. Subsequently, I have restricted myself to a very specific and workable approach which uses a limited number of tools from the ANT literature.

Therefore, this chapter gives an overview of Latour's CSSF (1999a) and Callon's key principles (1986), the specific tools from within ANT literature used in this thesis. It also provides explanations of why these tools have been chosen and how they will be applied. Firstly, I will outline the key principles of ANT (1986) that I have used in this study. In particular, I will introduce the theoretical tools which will be utilised during Chapter 6 to explore how the relationships between human and non-human actors have made and maintained neonicotinoids in NZ's agricultural practices. More specifically this chapter introduces Bruno Latour's (1999a) circulatory system of scientific facts (CSSF), a framework which outlines five types of activities that "science studies need to describe first if it seeks to begin to understand in any sort of realistic way what a given science discipline is up to" (Latour, 1999a, p. 99). This framework guides both the data collection and analysis stages of this thesis: it will help me follow the actors and examine the differences between a network that maintains the use of neonicotinoids, and another network where neonicotinoids have been removed. I will also outline a number of criticisms and commentaries of the CSSF. This is a necessary procedure to answer my fourth research question, which aims to review the appropriateness of the CSSF for investigating hazardous chemical controversies in the future (see section 1.4). Finally, this chapter will point to some literature that makes inferences about what makes and maintains agricultural practices.

3.2 Key actor-network theory principles

ANT looks at how science and technology are made and maintained (Latour, 1987), and it directs researchers to "follow the actors" (Latour, 1993). This is a relatively simple request. However, there can be various actors involved in any network.

> *This, then, is the core of the actor-network approach: a concern with how actors and organisations mobilise, juxtapose, and hold together the bits and pieces out of which they are composed; how they are sometimes able to prevent those bits and pieces from following their own inclinations and making off; and how they manage, as a result, to conceal for a time the process of translation itself and so turn a network from a heterogeneous set of bits and pieces each with its own inclinations, into something that passes as a punctualized actor. (Law, 1992, p. 2)*

ANT allows researchers to understand how actors come together and form networks of heterogeneous material due to some aligned interest (Law, 1992). Furthermore, ANT explores how these networks are made, maintained and broken down (Tatnall and Gilding, 1999). There are three key principles to ANT, as described by Callon (1986). These principles are "agnosticism", "generalised symmetry" and "free association" (p. 196), and their purpose is to help manage an ANT analysis while surmounting other methods of sociological analysis (González, 2013). In effect, they overcome those methods which ignore the role of nature and non-human actors in a phenomenon and instead give privilege to humans and society.

The first principle "agnosticism" suggests that non-human actors make up the world in which humans survive, and so no actor should receive a privileged status given its social standing, species or even cognition (Callon, 1999; Harding, 2017). Callon describes it as "impartiality between actors engaged in controversy" (Callon, 1986, p. 196). Researchers must be impartial in their observations by systematically avoiding censoring any interpretations provided by the actors (Callon, 1986; Law, 1986, 1987). Furthermore, researchers should abandon any preconceived ideas regarding the networks makeup, causation, creation and the reliability of an actor's account (Ritzer, 2005). "Agnosticism" ensures that there is no censorship of the actors' accounts by the researcher, even if those accounts do not align with the view of the researcher. Any form of censorship will likely hinder an accurate and developed understanding of the controversy at hand. Compliance with the principle of "agnosticism" requires consideration of "the facts of Nature and the social contexts which they elaborated and shaped" (Callon, 1986, p. 221). In addition to this, it requires a faithful report of doubts about society and potential "alliances". This principle raises several questions about how I have avoided judging the positions taken by my interview participants, reducing them to a particular sociological interpretation. Furthermore, it makes me consider how I have remained impartial in my line of questioning, my selection of interview participants and my analysis of networks.

The next principle is called “generalised symmetry” (Callon, 1986, p. 196), and it describes how conflicting opinions of actors should be explained in the same neutral terms, that work in the same way for both humans and non-humans (Callon, 1986). An actor is anything that can “exert detectable influences on others” (Law, 1987, p. 132). Fundamentally, both nonhuman and human actors can take action and can also be anything or anyone (Law, 1986). Dankert (2011) reinforces this, stating that “humans first shape the buildings and then are shaped by the same buildings.” Therefore, actors should not be defined on *a priori* definitions but on what they do. Callon and Latour (1981) explain that actors are “any element which bends space around itself, makes other elements dependent upon itself and translates their will into a language of its own. An actor makes changes in the set of elements and concepts habitually used to describe the social and the natural worlds.” A researcher who is performing an analysis using tools from within ANT should, therefore not give humans priority over non-humans to take action (Law, 1992). Because of this, status, species and even cognition should not influence the notion of what defines an actor. Humans, technology, organisms, texts, buildings and objects should all be given the status of an actor within an actor-network. Therefore, compliance with the principle of “generalised symmetry” requires sticking to the same vocabulary throughout a study. Subsequently, the terms; actors, relationships and those of Latour’s CSSF (1999a), are applied without discrimination to all actors throughout this thesis (Callon, 1986, p. 221). This principle raises questions about how I have avoided using “institutional and organizational configurations to explain” the making and maintenance of agricultural practices in NZ and avoided explaining the on-going use or discontinuation of neonicotinoids as coming down to a “balance of power or to a series of conditions” (Callon, 1986, p. 222).

Lastly, there is “free association” (Callon, 1986, p. 196) which demands that potentially anticipated or pre-existing distinctions between humans and non-humans should be abandoned, like those between the social, environmental and technological (Callon, 1986). Therefore, the actors’ relationships should be allowed to fluctuate and become the focal point of the analysis. Essentially, “free association” proposes that actors on all levels and of all forms can interact and influence one another (Harman, 2014) and that nature is social through and through (Castree and MacMillan, 2001). Fundamentally, the principle of “free association” demands that researchers “follow the actors in order to identify the manner in which these define and associate the different elements by which they build and explain their world, whether it be social or natural” (Callon, 1986, p. 201). Latour (2003, p. 12) explains that the directive to follow the actors is a command to search for connections and find out how and why new relationships form. Complying with the principle of “free association” requires avoiding *a priori* categories and relationships. This allows me to follow neonicotinoids through the various relationships which make up the networks central to this thesis. It also allows me to view neonicotinoids as an object which is changing rather than locking it into a

fixed role. Furthermore, the roles of each actor and their subsequent relationships can fluctuate. Therefore, unpredictable relationships which "become visible and plausible only after the event" (Callon, 1986, p. 222) can be described and understood.

These three principles are supported by Latour (1993) when he shows how other sociological theory forms distinct categories and argues that to understand controversies, we must break down those distinctions. Like Callon (1986), Latour (1993) is arguing against *a priori* assumptions. Subsequently, ANT is not a theory of the social (Latour, 1996, p. 22), but a theory of "how to study things" (Latour, 2005, p. 142). By following these three principles this research is free of the dualities between nature, society and technology that is usually assumed. This, therefore, allows me to look at the importance of non-human actors without bias and trace the making and maintenance of an actor-network that embeds -and maintains- neonicotinoids in NZ's agricultural practices without locking actors into fixed roles or censoring their accounts.

3.3 Actor-networks and network representations

When Latour (1993) states that all classifications and categories result from rather than cause social organisation, the social organisation he is referring to are the actor-networks he attempts to describe. An actor-network is a group of actors linked together through activities, relationships and associations (Law, 1992, 2002; Latour, 1996). Callon (2012) says that everything "is an actor-network reducible neither to an actor alone nor to a network. An "actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of" (p. 93).

The process called "punctualization" is the simplification of an actor-network so that it is observable as a single actor. This actor is simple, appears only for a time and masks the networks that produce it (Law, 1992, p. 385). Once an actor-network becomes stable and punctualised, it can no longer be questioned or tested, so it forms a "black-boxed network" whose behaviour is now independent of its context (Callon & Latour, 1981, p. 285). An example of a "black-boxed network" is a modern computer. When someone uses a computer, they do not consider the complexities which are involved in its making and maintenance (Pantumsinchai, 2018). Like this, the process of "black-boxing" sees sub-networks disappear and therefore, actor-networks become actors (Van House, 2004). Subsequently, a network is a collection of black boxes which are themselves networks. Callon and Latour (1981) explain this as; "a black box contains that which no longer needs to be considered, those things whose contents become a matter of indifference" (p. 285). A punctualized actor-network can change and evolve because actors outside of the punctualized network can weaken relationships in it. Therefore, a stable, punctualised or even "black-boxed" actor-network can revert to a complex network of actors (Law, 1992).

Tools from within ANT, like the CSSF, attempt to crack open these punctualized networks that appear to be singular objects. Network representations are particularly good at revealing these networks inner workings, identifying where they might face resistance and therefore allow a researcher to describe the complex network of material relations which make them up. Law (1992) maintains that only a network which is made up of and supported by various durable material relations can be stable. Therefore, only by using a network representation like Latour's CSSF (1999a), which reveals and follows material relations, can I identify whether a network is stable and therefore describe how neonicotinoids are embedded -and maintained- in NZ's agricultural practices.

In a similar train of thought, Latour (1999a) discusses how associations or relationships between actors are continually being formed, reformed and destroyed in any given setting, which sometimes creates new actors. These new actors have different attributes from those of the original actors involved in their making (Dankert, 2011). Latour (1999a, p. 180) uses the example of a gunman to explain this idea of actor creation more clearly. The gun and the man are separate entities, but when put together they form a hybrid body, the gunman, which creates a new distinct actor that is greater than the sum of its parts. Therefore, when someone is shot, it is the relationship between the gun and the man, forming the gunman that matters. Network representations, therefore, encourage their users to look at the underlying structures of fixed concepts (Waltz, 2006, p. 23). By following the actors, a comprehensive network emerges, which would otherwise appear as an intricate group of actors with misshaped connections. Thorough research will reveal the well-established associations between actors, and only empirical evidence can be described and therefore be real.

STS researchers have repeatedly critiqued the application and description of the oxymoron "actor-network". Latour (1999b) stated that "there are four things that do not work with actor-network theory; the word actor, the word "network", the word theory and the hyphen! Four nails in the coffin" (p. 1). The first "nail" is concerned with the word "network", and Latour claims that the internet has meant that everyone now believes they know what it means. He says the typical description of a "network", "transport without deformation, an instantaneous, unmediated access to every piece of information" (p. 1), is precisely the opposite of its meaning in ANT. To Latour, the term "network" is like the term "rhizome" as used by Deleuze and Guattari (1988), it is a set of transformations. Researchers must view "networks" as a set of translations, transformations and transductions, inapprehensible to the traditional terms of sociology.

> *Being connected, being interconnected, or being heterogeneous is not enough. It all depends on the sort of action that is flowing from one to the other, hence the words "net" and "work". Really, we should say "worknet" instead of "network". It's the work, and the movement, and the flow, and the changes that should be stressed. But now we are stuck with "network"*

> *and everyone thinks we mean the World Wide Web or something like that. (Latour, 2005, p. 143)*

For a researcher to effectively perform a network analysis, like the CSSF, they must be aware of the unit of study, the network. More specifically, they must understand that network representations aim to describe how links are made and maintained and what is linked together. It is for this reason that Latour claims "worknet" would be a better description for the unit of study. Furthermore, Latour no longer feels the term "network" should be used as it does not correctly describe the translations that a researcher wants to explore.

The second "nail" refers to the word "actor" and its hyphenation with the word "network". Latour states that he always opposed the use of a hyphen as he claims it reminds the researchers of "the agency/structure cliché [of social theory]" (Latour, 1999b, p. 16). Law (1999) states that:

> *Truth and falsehood. Large and small. Agency and structure. Human and non-human. Before and after. Knowledge and power. Context and content. Materiality and sociality. Activity and passivity…all of these divides have been rubbished in work undertaken in the name of actor-network theory (p. 3)*

This relentless throwing out of the *a priori* categories is what separates network representations from other sociological approaches. Therefore, by reminding researchers of these clichés, this hyphenation of actor and network, brings them too close to those divides which they attempt to avoid.

The third "nail" considers the word theory. Latour (1999b) argues that ANT should be called "actant-rhizome ontology" (p. 19). He continues by saying that ANT was never a theory of what makes up the social, as he explains:

> *ANT was simply another way of being faithful to the insights of ethnomethodology: actors know what they do and we have to learn from them not only what they do, but how and why they do it. It is us, the social scientists, who lack knowledge of what they do, and not they who are missing the explanation of why they are unwittingly manipulated by forces exterior to themselves and known to the social scientist's powerful gaze and methods. (Latour, 1999b, p. 19).*

This thesis takes note of this critique and instead views ANT, as a crude set of methodological tools for learning from actors without imposing *a priori* definitions on their " world-building capacities" (Latour, 1999b, p. 19).

The fourth and final "nail" revisits the hyphenation between actor and network. Latour explains that most misunderstandings about ANT stem from this linking of words (1996, p. 16). He emphasises that

the hyphenation represents the debate between agency and structure, that the fathers of ANT never wanted to enter.

Regardless of this, Latour expresses a need to "not abandon the creature to its fate but continue all the way in developing its strange potential" (1999, p. 24). Because I am attempting to find out if the CSSF (Latour, 1999a), a network representation, is useful in understanding how agricultural practices are made and maintained, I have followed Latour's direction to continue developing its strange potential. I will, therefore, continue to use the phrase "actor-network theory" and its parts throughout this thesis. More specifically, I will use Callon's key principles (1986) and Latour's CSSF (1999a) to understand how neonicotinoids have become embedded –and remain – in NZ's agricultural practices.

3.4 The circulatory system of scientific facts

Research provides a representation of reality, which enables critical reflections of that representation and specific choices about its form (Gad and Jensen, 2010). Subsequently, scholars have continuously experimented with different representations of actor-networks. Often a single image is central to a network analysis, as is the case with this thesis. Therefore, what follows is an overview of the specific network representation used in this thesis, a review of its previous case study applications and an indication of how it has been used as a research methodology here.

I have applied, explored and critiqued Latour's (1999a) CSSF. The CSSF discourages researchers from assuming a phenomenon is down to a particularly powerful actor and instead encourages researchers to focus on tracing the material-semiotic relations between actors in a network. These relations "are simultaneously semiotic (because they are relational, and/or they carry meanings) and material (because they are about the physical stuff caught up and shaped in those relations)" (Law, 2019, p. 1). So rather than assuming neonicotinoids are embedded -and maintained- because of the actions of a particularly powerful actor, adopting a CSSF approach made me re-evaluate how they became and remained embedded in agricultural practices. The CSSF approach subsequently encouraged me to explore the material relations developed between various actors who are all interested in neonicotinoids. The CSSF (Latour, 1999a) thus became a useful tool for me from the outset.

The CSSF is a visual representation of an actor-network, and its foundational purpose is to show how all scientific facts (controversial or not) can be kept alive (Tabak, 2015). Latour's CSSF shows the outcome of any scientific research as a result of five interrelated types of activity, each of which involves several actors (Latour, 1999a, p. 99). It describes how scientific facts can exist, remain stable and survive (p. 99). Latour introduces the CSSF during his book titled: *Pandora's Hope: Essays on the*

reality of science (Latour, 1999a). Not only has this visual representation of an actor-network (Fig. 1) directed me to more actors, their roles and power dynamics, but it will also highlight the kinds of actors that participate in this network and the network constructing activities which each actor undertakes (Warner, 2008).

Latour's CSSF describes

> *five types of activities that science studies needs to describe first if it seeks to begin to understand in any sort of realistic way what a given science discipline is up to: instruments, colleagues, allies, public and finally what I call links or knots (Latour, 1999a, p. 99).*

Figure 1 The circulatory system of scientific facts, sourced from (Latour, 1999a).

Although the CSSF diagram contains very little detail, it is far from being a simple depiction of network activities. The first loop is called "mobilization of the world", and it is about how actors convert the object of their study into discourse. It also describes how non-humans are progressively loaded into discourse and includes the expeditions, surveys, instruments and equipment that are used in scientific research. It also consists of the sites where all this equipment is assembled, such as laboratories, museums and databases (Latour, 1999a, p. 101). The second activity is "autonomization", which describes the construction of scientific professions, disciplines and institutions that support and contribute to research as colleagues (p. 102). The third activity is called "alliances", and it describes a further group of actors from outside the scientific community that must also support a programme of research, such as politicians, industrialists and the military. It

considers the enrolment of groups and individuals that would typically remain outside of the discourse and is about creating “alliances” through worked persuasion and liaison (p. 103). The fourth loop, known as “public representation”, describes the creation and upkeep of relations with the outside world, that of reporters, pundits and the layperson. It considers the role of the public (p. 105). Finally, the scientific content is depicted as the last activity called “links and knots”. This name was given by Latour to avoid the historical baggage that comes with the phrase “conceptual concept” (p. 106). The “links and knots” tie all the other loops together but cannot exist in isolation from them, serving as the conceptual “heart” of the network.

3.4.1 Agricultural practices and case study applications of the CSSF

In some circumstances, the CSSF has already been applied to case-studies which investigate, the making, maintenance and removal of agricultural practices (Ingram, 2007; Warner 2016). Therefore, this section analyses and synthesises a variety of works which look at how agricultural practices, as well as disciplines, are made and maintained from a CSSF perspective and the perspective of other social science methods. I have subsequently drawn a number of conclusions about what the CSSF offers studies which look at how agricultural practices are made and maintained, and therefore what the CSSF offers this research.

Overview of previous research that has studied agricultural practices

To understand what the CSSF offers research which looks at the making and maintenance of agricultural practices it is essential to highlight the conclusions that other social science methods make about agricultural practices. Agricultural practice literature often focusses on how individual motivations and benefits affect the adoption of new and innovative agricultural practices (Bangura1983; Lalani et al., 2016; McManus & Powe, 2007; Pannell, 2008;). Another common trend is to look at how the individual and situational characteristics of farms and farmers affect the maintenance of agricultural practices (Rogers & Shoemaker 1971; Waters et al., 2009).

In a study that looked at why farmers are using conservation practices, Lalani et al. (2016) found that the usefulness of conservation agriculture to the farmer and the farmers perceived importance of this practice was the most reliable indicator for a farmer’s intention to use conservation agriculture on their farm. Similarly, when farmers perceive that an agricultural practice is viable on their farms (Bangura, 1983), or is better than the method or agricultural practice it supersedes (Rogers & Shoemaker, 1971; Giera et al., 2006; McManus & Powe, 2007) they are more likely to adopt alternative and novel agricultural practices. Economic reward has also been another research interest of social scientists investigating the making and maintenance of agricultural practices. Lalani et al. (2016) found that short term yield and a higher return on investment was a crucial driver in the adoption and maintenance of conservation agriculture practices.

The personal and family circumstances of a farmer are commonly considered to be a significant driver in the behavioural decisions of farmers, and therefore their intention to adopt agricultural practices. Bangura (1983) suggested that the individual goals of farmers had the most significant impact on their adoption of innovative agricultural practices. This work also suggested that those farmers with higher aspirations were more likely to adopt new and recommended agricultural practices. Those farmers who were motivated by; the recognition they would gain from adopting the agricultural practices and the perceived goals they would attain, were again more motivated to adopt the innovative agricultural practices. Similarly, some studies suggest that because farming is not just a job, but a lifestyle, farmers carefully consider the uptake of an agricultural practice because of the way it might affect their land and the environment (Vanclay, 2004; Ahnström et al., 2008). This suggests that what might be suitable for one farmer is not necessarily suitable for all farmers.

Giera et al. (2006) and Lalani et al. (2016) come to similar conclusions about what factors cause the making and maintenance of agricultural practices. They ultimately suggest that a farmers perception of the relative advantage or "the balance of benefits" (Lalani et al., 2016, p. 89) which an agricultural practice provides is what determines its adoption and therefore its maintenance.

These studies reveal that a farmer's decisions to adopt agricultural practices comes down to the self-motivated intrinsic and extrinsic rewards which that adoption might offer. Therefore, each of these studies have a very individualistic understanding of what makes and maintains agricultural practices; they each suggest it comes down to the individual farmer. This raises questions about what previous research that has studied agricultural practices miss. Firstly, they tend to have a bias towards the individual because they suggest the adoption of an agricultural practice can be solely explained by the individuals motivations, actions and interests. In doing this, they neglect the relevance that other factors can have on the making and maintenance of agricultural practices. They also tend to rely on experimental approaches for data collection, which limits their ability to assess the messy social complexity of a phenomenon. Furthermore, these studies view adoption as a onetime event, which is not affected by previous interactions, they state that any change comes down to individual choices. So, although the findings of these studies are valuable to understanding the decision-making practices of farmers, they do not pay attention to the material-semiotic relations which contribute to an agricultural practice being made and maintained. This, in turn, undermines an understanding of the making and maintenance of agricultural practice. Subsequently, it raises several questions about what the CSSF (Latour, 1999a) can offer studies of agricultural practices and whether it is suitable for acting as a sensitising device to examine the making and maintenance of neonicotinoids in NZ's agricultural practices. Therefore, what follows is a synthesis of those case-study applications of the CSSF which have an agricultural, scientific and disciplinary focus.

Case study applications of the CSSF

Unlike the above studies of agricultural practices, the CSSF encourages researchers to follow the actors and look at how material relationships are contributing to the making and maintenance of a phenomenon. Therefore, to argue the case for the use of Latour's CSSF (1999a) in this thesis, what follows discusses five studies that use this network representation to demonstrate how agricultural practices, professions and scientific projects are made and maintained through a series of material relations.

The significant works which I have reviewed are Fitzsimmons (2004), Ingram (2007), Edwards (2014) and Warner (2008, 2016). Ingram (2007), who studies three alternative methods for improving soil fertility, and Warner (2016), who studies how the work of Rachel Carson reduced the use of agricultural chemicals, are considered for their application of the CSSF to agricultural practice case studies. Edwards (2014) who investigates the development of a genetically modified tearless onion is considered for her application of the CSSF to a NZ setting. Finally, Fitzsimmons (2004), who studies the vascularization of ecology in the USA, and Warner (2008), who studies the vascularization of agroecological principles, are considered because they step away from analysing a single project and apply the CSSF to broader disciplines.

All these studies are concerned with the activities of human and non-human actors to interest one another and translate each other's interests. Moreover, each of them uses the CSSF to emphasise the dynamic relationships which contribute to the making and maintenance of a scientific research project (Edwards, 2014), a scientific discipline (Fitzsimmons, 2004; Warner, 2008) or an agricultural practice (Ingram, 2007; Warner, 2016). Ingram builds on this by saying that the CSSF emphasises the dynamic relationships that exist with material nature, the strategies which scientists use to mould their ideas and the alliances they develop to convince others of their research (p. 300). Subsequently, the ways which actors engage material nature, create scientific facts and enrol a wide range of audiences, can become very clear (p. 309). Edwards similarly uses the CSSF to highlight the relevance of each relationship to the integrity of the circulatory system. Furthermore, Fitzsimmons (2004) uses the CSSF to examine who and what ecologists engage with, revealing that ecologists are "actively, transmitting and circulating the arguments of their community" (p. 36). Thus, allowing her to demonstrate how ecologists made a "structure of engagements for translating knowledge into practical action and political power" (p. 36). Each of these studies subsequently highlighted the versatility of the CSSF (Latour, 1999a) as a methodological tool which makes sense of the relational nature of various phenomenon. Therefore, not only does the CSSF present itself as a useful tool for making sense of how neonicotinoids are made and maintained in NZ's agricultural practices, but it offers a different way of explaining the adoption of agricultural practices which the previous literature, described above, has not considered.

Edwards (2014) demonstrates that the CSSF can be used to "convey the distribution of interests that can be coordinated to perform a fractionally coherent object" (p. 147) and to "provide a detailed account of how each actor is joined together through the circulation of various intermediaries" (p. 146). Callon describes intermediaries as "anything passing between actors that defines the relationship between them" (1991, p. 134). Although none of the other case studies highlight the presence of intermediaries, I have utilised them to try and make sense of the relationships that are maintaining neonicotinoids as an agricultural practice in NZ. It is all well and good to say that a relationship exists, but it is difficult to make inferences about that relationship unless you understand how it functions, or understand what resources each actor is trading in order to interest one another in the relationship and their individual goals. Therefore, I have referred to this transfer of intermediaries as "material relations" throughout this thesis. Furthermore, it is these intermediaries that I identified while using the CSSF in the data collection of my thesis (e.g. crop protection programmes and critical use cases), and which have then directed me to the actors taking part in their trade.

Warner (2016) utilises the CSSF to analyse scientist's engagement with the world outside of the "cloistered laboratory" (Warner, 2016, p. 30). Edwards (2014) similarly details the involvement of various actors who "extend beyond the walls of the laboratory to include a heterogeneous mixture that breaks down the divides between science, society, and nature" (p. 120). While Ingram argues that actor-networks concerned with soil fertility management rely on the development of scientific knowledge to gain legitimacy with farmers, consumers, policymakers and others (p. 299). Furthermore, Warner (2008) describes how agroecology cannot be made or maintained in California without the association between various different actors who exist both inside and outside, the laboratory and the field. All of these studies suggest that looking beyond the boundaries of the laboratory or a particular community can provide new light to understand the making and maintenance of scientific facts or agricultural practices. Once again, this is something which other methodologies for studying the adoption, making and maintenance of agricultural practices do not consider but which the CSSF offers. Thus, by following in the footsteps of these CSSF researchers and looking beyond the individual decisions of farmers, this thesis will potentially offer a new direction and considerations for researchers who want to investigate hazardous substance or agricultural practice controversies in the future.

These previous case studies have each used Latour's loops to help them make sense of a phenomenon and identify those actors who are involved. "Mobilization of the world" (Latour, 1999a, p. 99) is the tools and sites which scientists use (Fitzsimmons, 2004), or in other words the process by which humans investigate natural phenomena and subsequently forge social behaviour (Warner, 2016). Warner (2016) uses this loop to demonstrate how Rachel Carson joined farmers in the field

armed with scientific methods, devices and statistics to illustrate the ecological degradation caused by agrichemicals (Warner, 2016, p. 31). "Autonomization" (Latour, 1999a, p. 102) describes the development of institutional structures and their activities (Fitzsimmons, 2004, p. 37), the relationship between extensionists and agricultural scientists (Warner, 2008, p. 772), or the importance of peer validation (Warner, 2016). Warner (2016) emphasises that without the approval of these peers "resources dry up, disciplines wither, and lines of scientific investigation fail" (Warner, 2016, p. 32)."Alliances" (Latour, 1999a, p. 103) describes governmental as well as non-governmental organisations (Fitzsimmons, 2004, p. 40), grower organisations (Warner, 2008) and those patrons who put scientific knowledge to practical use. Warner 2016 states that "knowledge contained by the academy is feeble compared to that put into economic action" (Warner, 2016, p. 32) and therefore, he emphasises that this loop moves in more than one direction because industry asks scientists for help and scientists need to convince industry of the commercial potential of their research(p. 32). "Public representation" (Latour, 1999a, p. 105) is the representation of ecology as that discipline who speaks for the laypeople and the millions of non-humans which humans share the environment with (Fitzsimmons, 2004, p. 40) or how environmental agencies represent agricultural pollution to the public, while also representing the public in the agricultural industry (Warner, 2008). These case studies which have previously used the CSSF as a way of representing, analysing and finding a network have not given away many of the practicalities involved in using this model. However, their descriptions of each loop gave me some indication of what to look for when applying this model to NZ's neonicotinoid use (see sections 3.2.4 and 4.2.2).

Warner (2016) brings forth considerations about how the circulation of scientific knowledge demonstrating the detrimental effects of agricultural chemicals can catalyse change in on the ground practices. This raises questions about the third research question of this thesis: How are neonicotinoids as an agricultural practice embedded and maintained in NZ, and why has opposing knowledge been unsuccessful in removing it? Warner's (2016) application of the CSSF revealed how Rachel Carson was able to vascularize the knowledge from her scientific discovery to the public, which meant that the public began working on behalf of nature. Subsequently, Carson also circulated knowledge from the public, back to the field, which reduced the use of agricultural chemicals (p. 32) and strengthened the network. Warner (2016) continued by insisting that even when the public's view of agricultural practices is distorted from the truth, they have a say in how agricultural practices are done. Warner (2016) further shows that Rachel Carson's critics could not disrupt the network destabilizing her research because she had vascularized her scientific discoveries to the public. Therefore, in terms of this thesis, the CSSF encourages me to take a closer look at how neonicotinoid proponents have vascularized the benefits of neonicotinoids to the public and powerful allies,

thereby strengthening the network and preventing the scientific research opposing the use of neonicotinoids from disrupting the network.

Warner (2016) also gives insight into how a slight change in one of Latour's loops (Fig. 1) can circulate through all the other loops, moulding the network into something different. Similarly, Edwards (2014) found that the tearless onion project failed because an attempt to move the onions out of the laboratory brought anti-GMO spokespeople into the network, subsequently destabilizing the network stopping the life-support of the project. Furthermore, Warner (2008) shed light on how the CSSF (Latour, 1999a) is a useful tool for understanding how knowledge interventions can stimulate activity in multiple loops of a network. He states that "well-designed interventions ripple through multiple loops, and successful partnerships have devised strategies that echo through all of them" (Warner, 2008, p. 772). Warner explains that any new knowledge which stimulates economic activity will strengthen the network (2008, p. 772). These works highlight the CSSF's ability to pinpoint where a change in the network occurred and therefore describe how that affected all the other loops. This subsequently reinforces Latour's statement that "each of these five activities is as important as the others, and each feeds back into itself and into the other four" (1999a, p. 99). Moreover, these works have encouraged me to pay particular attention to those relationships or partnerships which design strategies to influence other parts of the network, to gain their support for neonicotinoids and therefore strengthen the network which maintains neonicotinoids.

Edwards (2014) demonstrates how the CSSF can be applied to present-day environmental issues. She uses the CSSF to represent and study an environmental controversy while it was ongoing, which enabled Edwards (2014) to interpret the outcomes of the GMO onion project. Similarly, the CSSF allowed Warner (2008) to interpret the trajectory of change within the Californian public extension programme during a period of flux, created by pressure to reduce agricultures environmental impacts, which subsequently forced additional actors into the network (p. 771). Both Edwards (2014) and Warner (2008) were able to follow the actors as they built relationships with one another, negotiated and moved "interessement devices". Other studies portray the adoption of agricultural practices as a one-time event. Studies which use the CSSF, on the other hand, can investigate a phenomenon as it changes and transforms. By facilitating Latour's directive to follow the actors, the CSSF allows actors to fluctuate and enables researchers to consider how the historical setting and present-day changes can impact a network. This comes back to the CSSF's ability to show how a change in one part of the network can flow through all the other loops. If something changes in the present because the researcher has highlighted the material relations and the vascularization of the object, it becomes easy to make inferences about how that change will affect the other loops and therefore the outcome of the network. The ability to trace actors and the object, as they fluctuate, is vital to this thesis because neonicotinoids are still used in NZ.

Ingram (2007) explains how the three methods for improving soil fertility and therefore the three networks she studied each involved various actors. She then highlights that in every case these actors were brought together due to their shared belief that agricultural science needed to do a better job at working with nature. The CSSF similarly allowed Edwards (2014) to show how a variety of actors not typically connected have come together because of their shared interest in the GMO onions project. While for Warner (2008) it is the principles from the science of agroecology and for Fitzsimmons (2004) it is the scientific centrality of ecology, great social significance and urgency which bring together various actors into a stable network. These studies have shown that a variety of things make up the pumping heart, or the "links and knots", of a network. Subsequently, they shed light on how the CSSF can be used to examine how a variety of actors, with different political and ethical attitudes, can be joined together in a coherent network of material relationships around an object which they are either directly or indirectly interested in. This has significant implications on this thesis because unlike the other sociological methods usually associated with studies of agricultural practices, the CSSF can facilitate a study of an object by following that object through a network of relationships. This, in turn, uncovers actors and research participants which other sampling methods would not have identified and allows researchers to observe how an object is being framed and translated in a broader variety of material relationships.

Both Ingram (2007 and Warner (2016) have strictly adhered to Latour's original description of the CSSF (1999a). Both place the researcher or research team in a central role who mobilise the world, form a scientific profession, build alliances and convince the public of their research. In the case of Ingram (2007), this resulted in the success of an agricultural practice, while Warner (2016) described how Rachel Carson was able to change an agricultural practice. In both these applications, the construction or reduction of an agricultural practice is described as a scientific endeavour, which highlights the potential for an agricultural practice to be made and maintained because the scientific research concerned with its performance has gained legitimacy with colleagues, influential groups and the public. They both highlight that the participation of scientists and the pursuit of scientific research has led to a range of agricultural technologies and changing agricultural practices. This raises questions for this research about whether the making and maintenance of neonicotinoids is solely a scientific enterprise. Therefore by using the CSSF, this research looks at whether things like political, ethical, environmental and scientific settings inform the network and motivate the relationships of each actor.

Warner (2008) and Fitzsimmons (2004) step away from studying a specific instance of scientific research and show that the CSSF is a useful tool for studying broader case studies. Therefore, rather than representing how a researcher builds relationships to make and maintain their project as scientific fact, here the CSSF is used to describe how various actors have become interested in the

disciplines of ecology (Fitzsimmons, 2004) and agroecology (Warner, 2008). They also show how the material-semiotic relations of actors contribute to a stable network. This bodes well for this thesis because both these works have shed light on how the CSSF can be used to investigate more than just small one-off projects as described by Edwards (2014).

All these works (Fitzsimmons, 2004; Ingram, 2007; Edwards, 2014: Warner, 2008, 2016) highlight the benefits of the CSSF and are useful for identifying that the CSSF (Latour, 1999a) can enhance an understanding of how agricultural practices are made and maintained, by bringing forward its relational nature. They highlight that the making and maintenance of agricultural practice cannot be fully understood by solely looking at individual farmer decision-making practices. Furthermore, these studies which use the CSSF also provide insight into the role of various actors in the making and maintenance of agricultural practices and use the CSSF to understand controversies by describing the network as it appears. However, these works raise serious questions about how the CSSF can be implemented as a practical methodology for identifying actors, following these actors and analysing interview as well as documentary data. Therefore Chapter 4 highlights the practicalities that I employed while using the CSSF (Latour, 1999a) as a research methodology.

3.5 Limitations of the key principles of ANT and the CSSF

So far this chapter has explained why Callon's key principles (1986) and Latour's CSSF (1999a) might be useful for understanding how neonicotinoids are embedded -and maintained- in NZ's agricultural practices. However, it is essential to highlight the main criticisms of these tools to understand what they fail to achieve. Therefore, this section introduces three criticisms of Callon's key principles and Latour's CSSF.

The first criticism raised by Harding (1992, 1998, 2008), Bloor (1999) and Restivo (2010), argues that Callon's principle of "agnosticism" ignores social demographics and power structures like racism and patriarchy. However, "agnosticism" does not encourage researchers to ignore these structures outright; it merely removes any *a priori* relevance they have (Dankert, 2011). Instead, it encourages researchers to find out about power structures through the course of the research. Ingram (2007) also critiques Latour's CSSF (1999a) for its failure to deal with these relations of power and social hierarchies. She goes on to state that even though Latour claims to put the political back into the laboratory, he does not relate his ideas to the influential fields of academic study that focus on patterns of power and dominance (Ingram, 2007, p. 301). Ingram also disagrees with Latour's notion that the success of a network can be caused equally by a well-designed strategy of the actors or by being in the right place at the right time (p. 302).

The next criticism is of Callon's "generalised symmetry" principle (1986). Whittle and Spicer (2008) have heavily critiqued this assertion that a non-human can be an actor. They argue that this removes the pivotal role of humans and also state that this idea runs the "risk of displacing the defining human characteristics of the polis as a space of meaningful, purposeful, self-aware and non-repetitive action" (p. 620). Whittle and Spicer (2008) argue that the political action of humans is non-routine, which stands in contrast to those routine actions of non-humans. They continue by stating that "generalised symmetry" degrades an understanding of action "by obscuring the fact that it is only through the intervention of humans that agency—and thus political transformation of social arrangements—can occur" (pp. 620-621). Callon and Latour (1981) response to this is that whatever unit of discourse is used "is no way limited to 'human'" (pp. 301-302). Therefore, this symmetrical point of view is supposed to overcome that exact over-emphasis on humans agency which other sociological approaches have.

In response to these critiques, the research discussed in this thesis adopts a stance which acknowledges these social hierarchies exist but allows them to reveal themselves through the analysis of empirical evidence. By using the CSSF (Latour, 1999a) to find interview participants, follow the actors and analyse the material relations which make up the network which embeds -and maintains- neonicotinoids in NZ's agricultural practices, I have ensured that the *a priori* relevance of social hierarchies and priority to humans are removed. However, by presenting the conflicting viewpoints of all the actors and quoting the exact words of the interview respondents, limiting my biased commentary, I have still identified the power relations and social hierarchies as they have emerged from the data. Furthermore, by adopting the principle of "generalized symmetry" as an analytical stance and not an ethical position (Law, 1992) and therefore explaining the interview participants views in the abstract and neutral terms of Callon's key principles (1986) and Latour's CSSF (1999a) I have been able to describe the key role which non-humans play in the embedding -and maintenance- of neonicotinoids in NZ's agricultural practices.

A final criticism of Callon's key principles (1986), and network representations like the CSSF (Latour, 1999a) is regarding the reflexive approach. Murdoch (2001) argues that the "theoretical lexicon" (Whittle and Spicer, 2008, p. 620), which these tools impose does not match the accounts or language that the interview participants and therefore the actors would use themselves. Whittle and Spicer (2008) similarly argue that researchers, who use these tools, believe that they offer "a 'superior' or 'expert' view implying that the explanations of members are either 'naïve' or 'wrong'" (p. 618). They suggest that users of network representations need to hold "a more rigorous commitment to reflexivity" and "treat all accounts as in principle equal, including the one produced by the analyst" (p. 618). Whittle and Spicer (2008) also suggest paying close attention when using Callon's four-stage model (1986) to study anything other than Scallop fishing in St Brieuc Bay. They

argue that the “un-reflexive application of the four-stage model to other settings belies a positivistic attempt to verify the universality of Callon’s original account” (Whittle & Spicer, 2008, p. 618). They are arguing that when applying this model unreflexively to new case studies, the researcher is merely reducing their research to a “series of deductible tests that confirm or refute the four-stage model of translation” (p. 618). They go on to suggest that the model should be used by the researcher as a concept to understand complex situations, without losing track of the empirical complexity of each case. Although I am not using Callon’s model (1986) in this thesis, this criticism can likely translate to any network representation. Therefore, it raises questions about how I might have changed the data when making it fit the CSSF (Latour, 1999a).

I have continued to acknowledge these criticisms throughout this thesis attempting to be self-reflexive along the way, in the hope that this might alleviate some of the issues which arise from using Latour’s CSSF (1999a) and Callon’s key principles (1986). These criticisms will be revisited in Chapter 6 to discuss how they shaped this research and how I was able to overcome issues which arose from the methods chosen in this thesis.

3.6 Summary

ANT offers a wide range of theoretical and methodological tools that can be used across a variety of different social science disciplines to study various controversial phenomena. However, to understand how neonicotinoids have become embedded -and maintained- in NZ’s agricultural practices, I have limited the tools which I will apply in this thesis. Therefore, this literature review has introduced the tools from within ANT which are used in this thesis.

Network analysis and more specifically, Bruno Latour’s CSSF (1999a) are central to the study of neonicotinoids in Chapter 6. Latour intended the CSSF for the analysis of those mechanisms which make and maintain scientific facts within and outside conventional academic disciplines (Ingram, 2007). Moreover, it is a methodological tool for analysing how scientists engage with the social world outside of the cloistered laboratory (Warner, 2016). However, this thesis somewhat steps away from the study of how scientific research is made and maintained. Instead, it investigates how an agricultural practice can become embedded, even when the scientific consensus surrounding neonicotinoids is still up for debate (McGrath, 2014). I will use the CSSF to identify key documents and actors interested in neonicotinoids, follow the present-day material-semiotic relations of those actors and therefore represent and describe how neonicotinoids have been made and maintained in NZ’s agricultural practices.

A series of case studies have informed this introduction to Latour’s CSSF (1999a). Each of them adopts this network representation to make sense of the material relations that make up a network.

Furthermore, this thesis draws on those case-studies to make inferences about how neonicotinoids have become embedded -and maintained- in NZ's agricultural practices.

Alongside the CSSF (Latour, 1999a), I will attempt to adhere to the key principles of ANT, described by Callon (1986). "Generalised symmetry", "agnosticism", and "free association" not only ensure that the network representation is a more honest reflection of reality, but they help me minimise my biases throughout all stages of this thesis.

This chapter also highlights criticisms of these tools which I have considered while performing this research. Primarily these criticisms have encouraged me to be self-reflexive at every stage of this research, acknowledging where my methods, my chosen theoretical tools and my affiliations might introduce bias, giving an unfair reflection of reality. Furthermore, these criticisms have encouraged me to take care when adhering to Callon's key principles (1986).

Finally, this literature review considers nine papers which explain the making and maintenance of agricultural practices as coming down to the motivations, principles and actions of individuals. These will be considered alongside my discussion to highlight what the CSSF (1999a) and the Callon's key principles (1986) taught me about agricultural practices.

The following chapter describes the methodological aspects of using this approach. It introduces the case-study methodology commonly associated with the CSSF and outlines the specific applications of the CSSF applied during the data collection and analysis stages of this thesis. It also describes how the CSSF is used to represent the neonicotinoid network.

Chapter 4

Methodology

4.1 Introduction

The previous chapter introduced Callon's key principles (1986) and Latour's CSSF (1999a) as the tools which are used to make sense of how neonicotinoids have become embedded -and maintained- in NZ's agricultural practices. These tools, particularly Latour's CSSF (1999a), have helped inform and perform the process of data collection in this research.

Therefore this chapter will continue to describe the role of the CSSF in following the actors during this thesis. It will begin by discussing the case study methodology commonly associated with ANT. Then It will define and describe the exact methods of data collection used in this thesis. At the same time, I will discuss how I went about finding potential interview participants, how I accounted for ethical considerations, how I convinced participants to partake in the research and how I attempted to ensure that the interview data reflected reality. Lastly, this chapter introduced how I made sense of, organised and presented the data.

Researchers need to acknowledge how they shape the research process and its outputs (Palagnas et al., 2017). Furthermore, researchers need to recognise their "personal and methodological concerns" (p. 426) and their own "contributions to the construction of meanings and of lived experiences throughout the research process" (p. 426). By doing this and realising how one influences, acts upon and informs the very studies they engage in, a researcher not only honours those involved in the research but enhances the theory building and the research quality (Palagnas et al., 2017). Therefore throughout this chapter, I have attempted to be self-reflexive, by discussing where my interests, academics and career have introduced biases into this research. Predominantly this comes down to my work as a beekeeper, my pre-existing relationships with some interview participants, my time spent in Europe and my motivations for doing this research in the first place.

4.2 Case study

A common approach to social science research is the use of case studies. The meaning of the word "case" varies drastically, from an individual to a complex series of relationships (Marby, 2008). Bromley (1986) described case study research as beginning with the desire to derive an up-close or in-depth understanding of a single or a small number of cases set in real-world contexts. This comprehensive approach aims to produce an invaluable understanding of those cases, hopefully substantiating a better, or new understanding of real-world behaviour and its meaning.

Similar to how the nature of the "case" can vary, the methodology which informs case study research is also not clear. Hammersley and Gomm (2008) suggest that the term "case study" overlaps with other research methods, such as ethnography, participant observation, fieldwork, qualitative research and life history. Case study research typically wants to discuss a broad range of contextual and other conditions related to the case. Subsequently, to fulfil case study research, the relevant data needs to come from multiple sources of evidence. By doing this, "case study research goes beyond the study of isolated variables" (Yin, 2014, p. 4) and describes how the context and other complex conditions relating to a central phenomenon are necessary for understanding it.

Yin (2014) describes three situations where case study methods can be applied. Firstly, to answer the projects research question (Shavelson and Towne, 2002). Case study methods are relevant to descriptive research questions, they ask what is happening or what has happened, and explanatory ones, they ask how or why something has happened (Yin, 2014, p. 5). This thesis asks "how" neonicotinoids have become embedded in NZ's agricultural practices. Secondly, case study methods favour the collection of data in natural settings, which is stressed by their emphasis on studying phenomena in their real-world context (p. 4). By performing some original fieldwork and interviewing participants concerned with the use of neonicotinoids in NZ, I gained a better understanding of the actors, their relationships and the phenomenon at hand, compared to if I had relied on a questionnaire or another instrument. The last situation is that case study methods can be used in evaluations (Yin, 1992, 1994, 1997; U.S. Government accountability office, 1990). This research project fits this criterion because it could be labelled as an evaluation of NZ's neonicotinoid use.

Yin (2014) emphasises that case study research methods "can cover the entire range of situations, from initial exploration to the completion of full and final authoritative studies, without calling on any other methods" (p. 6). A common concern with case study methods is a lack of trust in the procedures of case study researchers. This lack of confidence often stems from exposure to case studies where the material was altered to demonstrate a particular point more effectively (Gavin, 2003; Ellet, 2007). However, this alteration also happens in experiments (Rosenthal, 1966), questionnaires (Sudman and Burns, 1982) and historical research (Gottschalk, 1968). However, case study research is repeatedly criticised because these biases occur frequently and the method is youthful. Subsequently, researchers using case study methods must pay even more attention to the potential for bias to enter their research. Furthermore, case studies, like experiments, are "generalisable to theoretical propositions and not to populations or universes." (Yin 2014, p. 15). Fortunately, this inability to generalise is not an issue when using the CSSF because it does not produce grand narratives; instead it describes how a scientific fact or agricultural practice is made and maintained (Latour, 1999a, p. 99).

Case studies are “important elements in the epistemic landscape of STS” (Beaulieu, Scharrnhorst, & Wouters, 2007, p. 673) because “the discipline of STS works through case studies” (Law, 2008b, p.2). Moreover, case study methodology is the standard approach for research utilising network representations like the CSSF, and has been applied to everything from a bicycle (Bijker, 1995), nuclear fission (Latour, 1991) accounting management (Elsayad, 2016) and agricultural practices (Ingram, 2007; Warner, 2016). Case studies are a suitable methodology for CSSF research because it allows researchers to describe exemplary, historical and contemporary, moments and episodes. Therefore the reader can learn about the theory, the essential features of an argument and the historical cases or the contemporary controversies, through instances rather than in abstract (Law, 2008c, p. 6). Furthermore, case studies allow researchers to find out what “theories mean in practice, and about where they apply” (Law, 2008c, p. 7). Subsequently, researchers add to their ideas and build their arguments through case studies (Law, 2008c, p.6). For example, Latour (1988) uses the pasteurisation of French agriculture to argue how scientific facts circulate through laboratories into other sites. Case study methodologies are also relevant to research with an agricultural focus. Ingram (2007) used three cases of alternative soil management, to argue that a variety of different languages, frameworks and technologies are required to convince farmers to go back to nature. Thus case study methodologies appear to be a good fit for this thesis which focusses on how neonicotinoids are embedded -and maintained- in NZ’s agricultural practices.

4.2.1 Case study methods

Yin (2014) discusses the six most common sources of evidence used in case study research; document analysis, archival records, interviews, direct observations, participant observation and physical artefacts. Yin emphasises that no case study method has a complete advantage over all the others. Instead, each has its comparative strengths and weaknesses. Yin (2014) also highlights that using multiple sources of evidence is vital for dealing with issues of data validity and reliability. Yin et al. (1985) found that case studies using many sources of evidence were rated higher in terms of quality and reliability than those relying on isolated evidence. Moreover, multiple sources of evidence allow the researcher to address a much broader context, which an isolated source might not identify. Additionally, this enables a researcher’s lines of inquiry to converge, whereby the intersection can calculate the precise location of an object (Yin, 2014, p. 120). Subsequently, multiple sources of information make case study findings more accurate and convincing.

I chose to use interviews and document analysis over the other four sources mentioned by Yin (2014). This is because they are the sources, I am most familiar with, and they offer many strengths for this thesis. Firstly, the document analysis is predominantly used alongside the CSSF (Latour, 1999a) to identify and follow potential interview participants. I chose document analysis because

publicly available documents are easily accessed, they can be reviewed repeatedly, they are not created as a result of this case study, they provide broad coverage of the controversy, and they offer physical linkages which can be followed to identify actors interested in NZ's neonicotinoid use.

Interviews were chosen because they focus on the controversy, they provide novel conclusions about the research, and they allow me to engage with the actors I am trying to describe. I did not utilise physical artefacts or archival records because they were not readily available and I was limited in the time I had with the participants. Lastly and although participant observations are considered a cornerstone method of ANT, I did not utilise them here. Participant observation in ANT studies involves extended periods of fieldwork, the learning of a new language and ultimately becoming integrated into the community, like how Latour (1999a) spent an extended period in the Amazon observing an expedition with the aim of collecting and reporting its soils. Eventually this should allow the researcher to become an insider and be treated as such allowing their research to be based off pure observation. The controversial nature of this research topic, the time limitations of a one year master's thesis and the requirement of my chosen method which meant I had to interview many individuals from the entire network being observed meant that participant observation was not only impractical but it was simply not feasible. In simple terms I did not have the time to perform participant observation up to a standard which would have provided me with sufficient data to draw a good picture of those relationships that make up the neonicotinoid network. Therefore, what follows is a brief description of my chosen methods, and section 4.2.2 will detail how I applied these methods to this thesis.

Interviews

Interviews are the primary method for data collection in this thesis, as they are consistent with its interpretive nature (Creswell, 2007). Interviews allow researchers to understand actors' viewpoints (Clarke and Dawson, 1999) and give a "voice to common people, allowing them to freely present their life situations in their own words" (Kvale, 2009, p. 481). Although interviews take many forms, they all involve a consistent line of questioning. Because qualitative interview techniques view participants as "meaning makers" (Warren, 2002), in-depth interviews aim to provide participants with an opportunity to speak. The researcher's job is to allow "the interview subject to talk a lot– openly, trustfully, honestly, clearly, and freely – about what the researcher is interested in" (Alvesson, 2003, p. 17). In-depth interviews allowed me to capture the respondents' points of view without pre-determining their options through *a priori* questionnaires (Patton, 2001).

Effective in-depth interviews ask "how" questions and not "why" questions because they are non-threatening and friendly (Becker, 1998; Yin, 2014). "Why" questions can create defensiveness in the participants and "how" questions are the preferred method of addressing "why" questions in an

actual conversation (Yin, 2014). In-depth interviews are relatively easy to perform and do not require much of the participants time (Yin, 2014; Cloke, 2004). On the other hand, they demand a large investment of time on the part of the researcher. Because they encourage participants to speak freely, in-depth interviews often reveal novel information. Therefore, researchers must prepare for this with follow up questions to discover even more new data (Mabry, 2008).

There are two problems with in-depth interviews that researchers using this methodology should take into consideration. Firstly, they should maintain a level of reflexivity. Researchers must be aware of their involvement in the interview process (Bryman and Cassell, 2006; Pessoa et al., 2019) as they can easily impose their view on the respondent. This can occur through body language, terminology or by asking a question that offers insight into the rest of the interview schedule (Alvesson, 2003). Secondly, interview responses should not be taken as the truth (Randall & Pheonix, 2009, p. 125). Researchers must understand that "stories are told in particular situations to particular listeners for particular reasons" (p. 126) and "stories – not 'facts' and not mere 'information' – are ultimately what we are hearing in a qualitative interview" (p. 126). Essentially interview participants may want to portray themselves as something they are not and in a more favourable light (Alvesson, 2003).

To prevent these problems from occurring in my research, I exercised more caution when analysing my interview data, I built a rapport with the participants to gain data that more accurately reflected reality (Alvesson, 2003), I showed each respondent a level of respect which demonstrated that their responses were essential to my case study (Patton, 2001) and finally I never took for granted an interview participants answer in the first instance. Further detail of the practicalities involved in performing these interviews are presented in section 4.2.2.

Document analysis

The primary use of a document analysis is to "corroborate and augment evidence from other sources" (Yin, 2014, p. 107). They also can be gathered from a wide range of sources which have become easily accessible since the development of the internet although the sheer amount of data available can itself be problematic. Nonetheless, the document analysis does not play a central role in the data collection of this thesis. Instead, it has been used to make inferences which act as clues for further investigation (Yin, 2014, p. 107). More specifically, I have performed a document analysis in conjunction with Latour's CSSF (1999a) at the outset of this thesis, to identify potential interview participants (see section 4.2.2). Documents have also helped me verify spelling, titles and names.

By utilising a document analysis in this way, I have also been able to overcome some problems with case studies' reliance on documents. The first problem is the idea that researchers mistakenly assume all documents tell the truth (Yin, 2014, p. 108) One must also remain aware that documents can not only store information but build the heterogenous networks being studied (Prior, 2008).

They are active parts of the subject, event or case being studied and can eventually remove the need of someone to convey instructions (Cambell, 2004; Prior, 2008). Therefore, a researcher utilising documents must be attentive to the context in which they were written. Subsequently, by using the CSSF (1999a) to identify and follow the actors involved in the making and maintenance of agricultural practices in NZ, I am actively seeking to identify the intended purpose and audience of each document identifying not only how the document is used but also how it was made. Therefore, I can act as a vicarious observer, analysing documents as communications between actors, where one is attempting to achieve some objective. Yin (2014) states that "by constantly trying to identify these objectives, you are less likely to be misled by documentary evidence and more likely to be correctly critical in interpreting the contents of such evidence" (p. 108). Another problem with documents is that researchers can quickly become lost in reviewing the available material. Therefore, they must design strategies to deal with all the information they inevitably come across. Once again by using the CSSF, I have not only created a strategy to deal with all the information, but I have also inadvertently gone along with Hinchcliffe's solution (2001, p. 6) to follow the "controversies, arguments and debates through the empirical materials".

4.2.2 Methods of data collection used in this study

This section describes the research process and provides an overview of this thesis. It focuses on how I selected participants, how I performed the interviews, and how I accounted for ethical issues. This section predominantly discusses the interviews as they are the primary source of data collection, while a document analysis was used in conjunction with Latour's CSSF (1999a) to select research participants and to provide some background information at the outset.

Selecting research participants

This section describes how I chose research participants at the outset of this project. Firstly, I have attempted to adhere to Palaganas's (2017, p. 426) comment that researchers "need to acknowledge that indeed it is impossible to remain "outside of" one's study topic while conducting research." Therefore, I hope that by being self-reflexive and acknowledging where I have biases, I am making the findings of this thesis more credible. It is essential to recognise that I did not attempt to select participants randomly. At every point of the research process, I likely had some effect on the data, but it was at the beginning where I had the most impact. Since 2016, I have supported myself by working as a beekeeper, and it was because of this that I became interested in neonicotinoids. Because I experienced beehive deaths caused by the unlawful use of pesticides, because I own my own beehives and because I spent a significant amount of time in Europe while three types of neonicotinoids were being banned (see section 2.6), I have become an advocate for changing agricultural practices in NZ. Therefore, it is hard to deny that I am biased.

To identify potential interview participants and therefore follow neonicotinoids, I utilised Latour's CSSF (1999a) in conjunction with a document analysis. Publicly available documents regarding the sale of neonicotinoids, agri-seeds and pest monitoring services were vital in finding research participants. However, other materials including press releases, newspaper articles, company websites and public submissions on planned regulatory changes were also useful. The CSSF helped me follow the movements of human and non-human actors through their translation operations and material relations. While performing a document analysis, I utilised Latour's CSSF to direct my attention to those actors who are interested in NZ's neonicotinoid use. It also expanded my horizons to include actors whom I would have missed if I had solely relied on other sampling methods, such as snowball sampling. Latour's CSSF not only enabled me to expand my horizons but filter through a large number of actors indicated in the documents, focussing my attention on the most influential ones. The CSSF (Latour, 1999a) identifies five loops to pay attention to and urges for a close analysis of the networks that develop when experts, things, colleagues and laypeople interact. Thus, I attempted to apply the CSSF to the documents and find those actors and relationships Latour describes. One thing I noticed was that Latour's loops often directed me to the same actors, which was beneficial to my project because it again reduced the number of potential interview participants and suggested that some actors and some relationships were more significant than others.

Firstly, I tried to identify how neonicotinoid proponents have used instruments and loaded their arguments with non-humans. I also considered the chain of circulating documents, equipment, plants and places that uphold the vitality of neonicotinoids. Or, what Latour describes as "mobilization of the world" (Latour, 1999a). In doing this, I looked at actors like international chemical companies, NZ seed and chemical companies and products groups who were circulating these documents. The documents included press releases, media interviews, public submissions on planned regulatory changes, crop protection programmes, maximum residue levels and much more. And they were subsequently mobilised to the media, landowners, the NZEPA as well as one another.

Similarly, Latour's "autonomization" loop helped direct me to those actors considered agricultural practice experts. I identified fact sheets and pest control programmes written for growers and found the actors producing these documents and using them as intermediaries in their relationships. Those actors included organisations such as AGCARM, FAR, apples and pears NZ, Horticulture NZ (HortNZ), international chemical companies and NZ seed and chemical retailers. Latour's suggestion (1999a, p. 102) that experts are made through the convergence of numerous individuals who are all convinced of scientific research encouraged me to delve deeper into the relationships which have created these experts. By utilising snowball sampling, I was able to identify the other actors in the "autonomization" loop of each network (Chapter 6).

Next, I used Latour's "alliances" loop (1999a, p. 103) to identify the diverse actors involved in the making and maintenance of neonicotinoids. This directed me to look at their regulatory management, and I became aware of the neonicotinoid call for information made by the NZEPA (Environmental Protection Authority, 2018b). I also became aware of a list of priority chemicals whose regulation is out of date. The NZEPA constructed this list, yet it did not contain many of NZ's most controversial chemicals, including neonicotinoids (Hutching, 2018). By continuing to follow neonicotinoids, I was able to identify actors making submissions to preserve this chemical. I continued to follow the directive of the "alliances" loop and discovered a NZ house of representatives document (Ardern, 2014), which discussed neonicotinoids and the relationship between beekeepers and landowners.

I also utilised Latour's "public representation" (1999a, p. 105) during the document analysis, which describes how the benefits of neonicotinoids are popularised through the media and other publications. It's also about how people's everyday practice, system of beliefs and opinions are affecting agricultural practices. Subsequently, I looked at how some members of the public are becoming interested in neonicotinoids. I was also able to identify the global trend away from neonicotinoid use, and I began to consider the impact this would have on the production of NZ's exports. Sure enough, by following neonicotinoids and their bans in Europe, I highlighted the preferences of international markets for and against neonicotinoids. Subsequently, this guided me to look for those actors holding direct relationships with these markets.

As well as using Latour's CSSF (1999a) and a document analysis, I also drew on my pre-existing relationships to identify potential interview participants. Before embarking on this research project, I had pre-existing relationships with beekeepers and growers who deal with neonicotinoids in NZ. I chose to perform interviews with them and engaged a level of snowball sampling during those interviews. Snowball sampling is "a technique for gathering research subjects through the identification of an initial subject who is used to provide the names of other actors" (Lewis-Beck, 2004, p. 2). I utilised snowball sampling to continue following the actors. Essentially, during each interview, I paid particular attention to the people, organisations, regulating bodies and non-humans that the participants mentioned. I also invited each interview participant the opportunity to identify individuals who they believed would offer new data and be interested in this research. Often the individuals identified through snowball sampling, were colleagues, friends and relatives of those individuals I had already interviewed.

Interview schedules

Before conducting the face to face interviews, interview schedules were written up (appendix A.1) and approved by the Lincoln University Human Ethics Committee (see appendix A.3). I used five

different interview schedules. One which contained eight questions that were presented to all the participants and then a separate one for growers, regulators/product group representatives, seed and chemical company representatives and beekeepers. All the questions were open-ended to encourage the participants to tell their own stories. The interview schedules held the interviews focus on critical areas of interest. But some flexibility was allowed to let the participants speak about any new information which I had not yet come across, or which they found particularly important. Furthermore, this allowed me to use follow up questions where needed, mainly to understand those interesting and relevant points that an interview participant may have otherwise quickly passed over.

Conducting interviews

I conducted sixteen interviews with participants from NZ's arable sector as well as NZ's apples and pears sector between June and September of 2019. To improve anonymity and protect their identity, I collated participants data depending on their similarities. I interviewed three Canterbury-based arable farmers, here referred to as "Arable Grower" and they had a range of different farm sizes and crops. Each had a different approach to arable production, but they all supplied the same NZ based seed and chemical companies. I also interviewed two horticultural growers, here referred to here as "Fresh Product Grower", who grew various crops and had a variety of different business sizes. They came from across NZ and produced for both the domestic and export markets. The growers of different products in NZ often pay levies to corresponding product groups. These groups often lobby the NZEPA to keep chemistries within NZ, due to their perceived critical use. They also offer market access and crop protection services for growers. Subsequently, I interviewed three representatives from a number of these product groups, referred to here as "Product Group Representative". I also interviewed one "Researcher" with a background in wild pollinators, honeybees, seed production and chemical efficacy and represented a public research institute. Two representatives of NZ's regulatory groups charged with the assessment, reassessment and regulation of hazardous substances were also interviewed, and they are referred to here as "Regulator". Lastly, three representatives from NZ based seed growing organisations as well as seed and chemical retailers were interviewed, and I refer to them as "Seed and Chemical Company Representative". These individuals ranged from the technical field reps, company directors and crop monitoring coordinators.

The Participants' details came from publicly available records, like MPI's "listed beekeepers" (Ministry for Primary Industries, 2020), and the interviews were done face to face when possible, with three conducted over the phone. Before doing an interview, I contacted the participant via the phone introducing the study and inviting them to participate in an interview. If they verbally accept this invitation, I then forwarded an email that reintroduced the research and again asked them to join. This email (appendix A.5) contained a research information sheet (appendix A.2),

which explained the project in further detail, outlined the participants' involvement and included the measures taken to secure their anonymity and reduce personal risk. This email also invited participants to determine a suitable date and time which their interview could take place and assured them of their right to withdraw from the research. It also emphasised that participants' data would be treated in confidence and kept private. A set of open-ended questions guided the interviews which followed a semi-structured procedure to allow the interviewees to tell their own story and answer in their own words. All the interviews took place at the participants' workplaces accept for those conducted via telephone. After a personal introduction, I briefly described the purpose of the research and how their contribution would add to the final results. I then gave each of them another resource information sheet to look over and a confidentiality agreement to sign (see appendix A.5). To build some rapport before formally beginning the interview, I spoke to each participant about my interests in their work. Usually, this involved discussing my experience working and studying in NZ's agricultural industry. As agreed in the Lincoln University Human Ethics Committee approval (see appendix A.3), I spoke to each participant about the voluntary nature of the interviews and reinforced that they could withdraw at any stage.

Furthermore, issues about confidentiality and anonymity were addressed in the research information sheet and again on the consent form. In all cases, the interviews were less than one hour, they were recorded with each participant's consent, and each was later transcribed verbatim. As I gained a better understanding of how to draw out interesting information from the participants, I began to be more relaxed and followed the interview schedules more loosely, relying heavily on my ability to ask follow-up questions to gather information. This procedure was effective in getting participants to talk extensively about their activities and relationships, which was consistent with the concerns of this thesis. The interviews were particularly good at capturing the flavour of the participants material relationships, how they use intermediaries, and how they translate meaning.

Loose conversational style interviews can often stray away from their core focus (Guest, 1995, p. 137). Fortunately, I was able to refer back to the interview schedule, which served as a constant guide. However, I did find that when an interview was straying away, the most novel and interesting information emerged. Although each interview focussed on the same or similar schedules, they were all different. Some individuals had a heightened understanding of neonicotinoids technical use while others seemed very knowledgeable about the material relationships I am attempting to describe. In some cases, participants avoided discussing particular relationships presumably because of how it might reflect on them. While others, to my surprise, were very open about relationships that I thought would be highly sensitive. I sought to continue discussions about the relationships I had not heard about previously and decided to stop interviewing participants when I was able to answer my

research questions and was not hearing anything new. On completion of each interview, I emailed the participant thanking them for their time.

4.3 Organising the data

This section describes how I organised and interpreted the wealth of empirical data collected from the 16 in-depth interviews mentioned above. There is no clear direction or outline of how to arrange interview data in a case study, nor is there any direction given in the previous iterations of the CSSF (see section 3.4.1). Therefore a thematic analysis was applied to the interview data so that I could make sense of the wealth of information, present it in such a way that readers would get the most out of it and organise it so that I could then discuss it in terms of Latour's CSSF (Chapter 6). Furthermore, Braun and Clarke (2007) state that thematic analysis is the "foundational method for qualitative analysis" (p. 78). If anything, I chose this approach because I began to notice that several specific issues, themes, relationships and individuals were dominating the responses of interview participants from different actor groups.

Thematic analysis is among a cluster of qualitative methods which focus on identifying patterned meaning across a dataset. There are many different types of thematic analysis, but they all involve the process of carefully reading and re-reading the data to identify, analyse and interpret patterns (Braun and Clarke, 2006; Rice and Ezzy, 1999). However, different versions of thematic analysis vary considerably as their underlying philosophy and procedures for producing those themes vary. Braun and Clarke (2006) discuss there being two significant types of thematic analysis present in the literature. The more inductive approach, which is driven by the current data and the more deductive approach which is driven by assumptions of previous theories. Here, the inductive approach was adopted. I paid little or no attention to those issues or themes highlighted in previous research and have instead focussed on the themes dominating the raw data.

Because there are no qualitative studies which look at neonicotinoids as an agricultural practice in NZ, this approach was the obvious choice. The inductive approach is "a process of coding the data without trying to fit it into a pre-existing coding frame" (Braun and Clarke, 2006, p. 83). Therefore, the research findings will emerge from the themes, which are the most dominant in the raw data (Thomas, 2006, p. 238). This approach has allowed for themes to emerge from the data and allowed me to present the results in such a way that the CSSF (Latour, 1999a) can be used to make sense of it. It is important to note that Braun and Clarke (2006) described a six-step process to use when performing a thematic analysis. I have not adhered to this process, but I did utilise some procedures to identify key themes. The initial step of any qualitative analysis is the process of reading and re-reading the transcripts, thus becoming familiar with the information. During this step, I noted down my early impressions. This step began before any interviews took place, during the initial

investigations of documentary evidence and continued as the interviews were undertaken and transcribed. After completing the interview transcriptions, some reading and re-reading allowed me to gain an overarching sense of the data. While doing this, I continued to note points relevant to understanding the embedding of neonicotinoids in NZ and more specifically, those material relationships frequently mentioned by interview participants.

Because I was concerned with discrete connections, material relations and the activities of those actors involved in the embedding of neonicotinoids in NZ, I did not use traditional coding techniques. Instead, you could say I performed open-coding because I did not have any pre-set codes, and I ended up with loose themes. A theme is "a pattern that captures something significant or interesting about the data and/or research question" (Maguire and Delahunt, 2017, p. 3356) and there are no rules about what makes a theme (Braun and Clarke, 2006). By looking back and forth between the data and the loops of Latour's CSSF (1999a), I sought out and developed potential themes based on the participants material relationships. These are: NZ is a small market for agricultural chemicals, Not enough tools in the toolbox, Market pressure, A disconnect between landowners and farming, Grass Grub and the Relationship between beekeepers and farmers. To illustrate these themes, quotations were extracted from the interviews and are presented in the following chapter.

To further address the research questions of this thesis and organise the data I utilised Latour's CSSF (1999a) as a methodology for identifying key documents and actors, representing the network, analysing the relationships which have made and maintained neonicotinoids as an agricultural practice in NZ and organising the empirical data. In other words, I used Latour's framework to follow the actors.

Hacking (1991) highlights that when looking at diagrams, we should ask if it aims to convey information or convince us that it is not to be challenged. Therefore, the CSSF (1999) should not be applied uncritically. Subsequently, I have tested this network representation in Chapter 6, adapting it for this thesis, while highlighting its benefits and shortcomings for understanding hazardous substance controversies.

As a thematic analysis is used to organise the data into themes based on interview participants material relationships, Latour's CSSF (1999a) is used to further refine the data. Where the thematic analysis has highlighted important relationships the CSSF is used to make sense of those relationships. Latour's five loops (1999a) directed my attention to a broader array of actors interested in neonicotinoids in NZ than other qualitative methods in the social sciences (such as snowball sampling) would have done. It has also allowed me to filter through the large number of actors present in the documents, focussing my attention on those that fit Latour's framework (1999a) and are involved in the vascularization of neonicotinoids in NZ. The CSSF has made me view

neonicotinoid use as an outcome of the interactions between the other loops (p. 108). This meant that once I identified initial actors I was directed to other actors relevant to this case-study by tracing their movements through material relations and translation operations. I did this rather than assuming the embedding and maintenance of neonicotinoids was down to a particularly powerful actor or the science alone.

These loops shape each other and are all equally important to the network (Latour, 1999a, p. 99) and, therefore, the making and maintenance of neonicotinoids as an agricultural practice in NZ. They also feedback onto themselves as well as all the others, forming interactive loops of material-semiotic relations (Latour, 1999a, p. 99). While the conceptual heart of any circulatory system is visible to the outside world, the rest of it remains hidden from view. Therefore, the CSSF helps to break open the neonicotinoid network, trace the relationships which make it up and therefore describe how neonicotinoids are embedded -and maintained- in NZ's agricultural practices.

4.4 Summary

This chapter has introduced the research design, data collection and analysis methods used to answer the research questions of this thesis. This thesis being a case study of neonicotinoids as an agricultural practice in NZ.

This research mainly uses data from 16 in-depth interviews performed with beekeepers, growers, regulators, seed and chemical company representatives, grower group representatives and researchers who are involved in NZ's arable sector as well as NZ's apples and pears sector. A variety of documents were utilised in conjunction with Latour's CSSF (1999a) to follow the actors, identify potential interview participants, decide whom to talk to, represent the network and analyse the relationships which have made and maintained neonicotinoids as an agricultural practice in NZ. Or in other words this methodology chapter has outlined how I followed the actors. These documents also played a small role in verifying some of that data collected through the in-depth interviews. I also drew on my personal relationships and implemented some snowball sampling techniques to continue to follow the actors and identify any further interview participants.

This chapter has also outlined how I utilised a thematic analysis to organise, make sense of and present my interview data. By merely reading, re-reading and referring to the material-relations, or loops which Latour points to in his CSSF (1999a), six themes emerged from the wealth of interview data I collected. Therefore the following chapter presents this thematic analysis of the interview data and draws on direct quotations to make inferences which act as clues for further investigation in Chapter 6.

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Chapter 5

Results

5.1 Introduction

This chapter provides an overview of the findings of this research, which are derived from the 16 in-depth interviews introduced in Chapter 4. The interview participants are all involved in NZ's agricultural industry and are similarly all interested in neonicotinoids. The interviewees include beekeepers, arable growers, fresh product growers, seed and chemical company representatives, researchers, regulators and product group representatives. The ultimate goal of the fieldwork was to examine the use of neonicotinoids in NZ's agricultural industry and uncover those relationships which contribute to its continued use. As explained in Chapter 4, I used the loops from within Latour's CSSF (1999a) to help me find interview participants and then identify the actors and relationships most commonly referred to during the interviews. This chapter will illustrate how it is these same actors and relationships which are subsequently embedding -and maintaining- neonicotinoids in NZ's agricultural practices.

This chapter addresses the first question: Who and what are the major actors that influence the scale and frequency of neonicotinoid use in NZ, and what have been their roles? This is achieved by introducing those actors concerned with neonicotinoids and describing their relationships with the object of this study, and with one another. Subsequently, this chapter addresses the second question: How have certain relationships been made and maintained between actors? It is divided into six themes which have helped to organise my data. Each theme is based on interesting and common conversation topics that emerged during the interviews. This approach to organising my data also has the added benefit of allowing me to hone in on the interesting and more prominent actors and relationships contributing to the making and maintenance of neonicotinoids in NZ.

5.2 Emergent themes

The following themes have emerged from the interviews performed. Although each theme is generally associated with a question asked through the interviews, this is not strictly the case. Furthermore, these themes are organised according to their connection with each other. They are:

1. New Zealand is a small market for agricultural chemicals
2. Not enough tools in the toolbox
3. Market pressure
4. A disconnect between landowners and farming
5. Grass Grub
6. Relationship between beekeepers and farmers

5.2.1 Theme 1: New Zealand is a small market for agricultural chemicals

A persistent pattern throughout the interview process was the mention of NZs size as a market on a global scale. This pattern was frequently mentioned in regard to the availability of agricultural chemicals for NZ's primary producing sectors.

> *But we're a small country, we've got four and a half million people. We're trying to play on a global Marketplace. You know we're never going to be able to get everything. Right? (Product Group Representative 1)*

For new chemistries or new methods of application to be imported, sold and used in NZ, it must first be approved by the NZEPA under the HSNO act. It is also the responsibility of the applicant to provide all the relevant information, e.g. environmental toxicity studies, to the NZEPA and cover the costs of the application process. Several participants reported that it is multinational crop protection companies, like Bayer or Syngenta, who usually apply for hazardous substance approval in NZ.

> *In terms of things like new actives [chemistries]. I think recently I guess the big players are people like Bayer, Dow [chemical company], BASF, Syngenta those are kind of the big chemical companies. They tend to have someone who will manage the kind of regulatory activities in New Zealand. (Regulator 1)*

Participants relayed that there are high costs associated with applying for new chemistry approval in NZ and that it is a prolonged process.

> *The highest kind of fee for the most in-depth assessment that we do is something like $25,000. (Regulator 1)*

> *I think we aim to recover something like about 10 to 12 per cent. Of costs through application fees something like that. (Regulator 1)*

> *The pipeline for you know registration can be three to five years in terms of Trials and registration data packages getting together and then being assessed. (Regulator 2)*

Horticulture in NZ is based on crops considered minor internationally, and our agricultural commodities similarly represent a fraction of total global production. When international crop protection organisations are making decisions about where to and what to invest in they take into account volumes of sales, transport and regulatory barriers. Subsequently, this results in very few situations where they are applying for new chemical registrations in NZ.

> *So because it's a high cost but small market, the economies of scale just don't work and bear in mind that a lot of products are quite crop-specific. So if you had something that was particularly good for onions or carrots, but only one of those crops and that market isn't sufficiently big enough to justify the importation of that product from a supplier's point of view. Yeah,*

> *so there's a lot of commercial restrictions anyway. (Product Group Representative 2)*

The cost associated with the NZEPA applications process, together with the NZ market representing a fraction of those organisations' global sales means that they are not interested in paying for the new chemistries to be tested and then introduced to NZ.

> *The players are only getting bigger, and they are not interested in spending $150,000 on a product before they can even sell a little bit unless they know that the market is there for it. (Arable Grower 1)*

The economic incentive for those companies to introduce new products to NZ is not there and therefore the availability of crop-specific, pest-specific and softer chemistries is much less than elsewhere in the world. The following comments provide some examples:

> *So there's a registration process which is quite tedious, and it's quite expensive as well. So a lot of the chemical companies see New Zealand as a small market. So to register that particular chemical in New Zealand actually costs quite a bit of money and quite a bit of effort and the return on investment as far as they're concerned is probably not that big. So, we miss out on a lot of chemicals that are actually available overseas but not available here. (Fresh Product Grower 2)*

Several underlying ideas have come through from such comments. Firstly that multinational crop protection companies are uninterested in replacing a product if the return on investment is not there. As explained above, this is generally due to the small size of NZ's market and the high cost of the application process. However, they are also uninterested in introducing new chemistries to markets where alternative chemicals that have the same or similar efficacy already exist.

> *If they sell product A and it sells but product B is better but gives them a similar margin, why would we replace it? What's the interest? (Arable Grower 1)*

Furthermore, when registering an agricultural chemical, the methods of application and the crops to which it will be applied must be outlined in detail. Subsequently, when a crop is lacking in hectarage, it is unlikely that a multinational crop protection company will register a chemical for it because the application costs likely outweigh the return they gain from chemical sales.

> *Crop protection companies tend to register on, you know, larger crops with a higher return that will use more product. So, you know, they'll always register on wheat, barley and pip fruit and kiwifruit and potatoes and onions, but they sort of don't because the return on investment is not there, you know, register a claim for leeks or for leafy vegetables or for asparagus or for, you know, clean greenhouse tomatoes because simply the number hectares aren't there and there's not that drive, so it's very difficult for those growers to access new chemistry. (Regulator 2)*

Lastly, those organisations who bear the cost of registering a new product or method in NZ, have not been guaranteed a competitive advantage over other agricultural chemical suppliers. Essentially, the HSNO and ACVM Acts (see section 2.3), protect confidential information given in support of applications for five years. HortNZ outlined that this period of data protection is not long enough to provide the registering organisation with a sufficient economic incentive to register new products across a wide range of crops (Ministry for Primary Industries, 2012; Chapman, 2016). Currently, generic companies can copy the product label and undercut the registrant once the data protection period ends. Subsequently, the registrants often do not have enough time to ensure a return on investment before this happens.

In some cases, the registrant is unable to recoup the costs associated with the NZEPA registration process (Chapman, 2016, p. 4). Furthermore, NZ's data protection regime is not currently in line with our major trading partners (Ministry for Primary Industries, 2012, p. 8). Subsequently, multinational crop protection companies are more likely to invest in countries where the volume of sales is higher, the logistical costs are lower, and the regulatory barriers are either not there or not significant. HortNZ says that there is a need to amend laws to increase data protection. They claim that this will mean that "companies will be more willing to register compounds for smaller crops which currently do not provide a return on investment for the registration process" (Chapman, 2016, p. 4).

So what does this mean for neonicotinoids? Well, because of the registration process and the lack of incentives for multinational crop protection organisations to register new chemistries in NZ, there remains a lack of more modern, softer alternatives across the industry. Growers, product group representatives and regulators all refer to this as there not being enough tools in the toolbox.

5.2.2 Theme 2: Not enough tools in the toolbox

One of the most dominant patterns throughout this research was that the participants all believed that there was a lack of agricultural chemicals available in NZ or, not enough tools in the toolbox.

> *I think our belief is that we need all the tools in the toolbox and the ones we've got we need to use responsibly. (Arable Grower 2)*

It was also clear that growers blamed the NZEPA, the regulatory body charged with assessing and reviewing hazardous substances, for the lack of tools available.

> *Chemicals are constantly being dropped from the list but not many, there's not many new chemistries, nothing much being added on. (Fresh Product Grower 2)*

> *You need more tools you need more chemicals because at the moment, you know like there are quite a few chemicals that we can only use it once or twice right, you know, you know that you can't keep using it because*

> *otherwise, it builds up resistance, so you need different chemistry throughout the year. So you need to, so you need more chemicals. (Fresh Product Grower 2)*

> *I mean ultimately they are always reviewing chemicals and taking them away from us. (Arable Grower 3)*

The majority of individuals understood that there is a need for chemicals like neonicotinoids in NZ, mainly when there are no alternatives readily available, or when the available options are much worse for the environment and human health. Many also expressed how paramount a situation is where particular chemicals are taken away, particularly for smaller product groups who do not have the means to find alternatives.

> *You know horticulture is a shitty thing and if you've got one particular beast that you can only control with a particular chemical, and you're told that you can't use it. It can be a stressful situation, so especially for smaller growers that don't have the, you know the resources to be able to try and find alternative products so it can be a really big thing. (Product Group Representative 1)*

Throughout the interviews, participants consistently mentioned that there is room to get rid of some chemicals and, particularly from the growers that they would like to use softer options and non-chemical alternatives. However, it is made very clear from the following comment that this is only true when they do not face any personal risk.

> *Would like to use more environmentally friendly/biological/whatever products. The problem is it's really hard to make ends meet on a farm. That you can't have too many cock-ups, nature will provide cock-ups for you. So you got to get everything right. Yeah. And so the last thing you want to be doing is creating a cock-up yourself that wasn't needed to by not using a product that can give you some reliability. (Arable Grower 3)*

In some cases where there are little or no alternatives, the growers and their representatives will put forward a case to the NZEPA that claims a particular chemical is of critical use. As explained below, a critical use chemical is necessary for the viability of a specific crop, and this can come down to a lack of alternatives.

> *Yeah, that's an unfortunate situation in New Zealand that we're trying to. I say we, the product groups of New Zealand are trying to work with the EPA and help them to understand that, if they wanted to do a reassessment program if there was plenty of other alternatives and options in the toolbox then that would great, we wouldn't need to defend. We could say actually we have ten other alternatives and actually that products not being used and in some cases, that's what we did. That's what growers did say but for a number of chemistries a number of actives you know they were critical use because there was just no alternative. (Product Group Representative 3)*

The NZEPA was consistently blamed by participants, for the lack of alternative pest controls available in NZ. It was expressed that the government did not care about, or consider the implications that removing and not replacing chemistries would have on NZs primary industry.

> *Governments will just say you can't use it. Not really understanding the absolute consequence. It might seem good on paper, but the reality will not be good because you'll have such devastation in terms of crops. (Product Group Representative 2)*

A consequence of this lack of tools in the toolbox, resulting from NZ's small agricultural chemical market and its slow regulatory system (see section 5.2.1), is that growers are calling for improved research into alternatives.

> *Yeah, and like I say research should be going in to let's give us some other alternatives that will be reliable and actually work because I think you'll probably find that a lot of farmers would like that and I'd fall in this category. (Arable Grower 3)*

Growers have explained that the lack of alternatives is an industry issue and that the introduction of new chemistries should be demand-driven and not left up to chemical companies and the NZEPA.

> *So in many ways in that sense. Instead of chemical companies driving new products into the market introduction could be should be demand-driven. And it's actually the users. But were not organised. Could have a body that requests introduction for the bringing in of products. (Arable Grower 1)*

They appear to be tired of waiting for international chemical companies to introduce alternative crop protection methods, which may or may not be useful for NZ's specific purposes. Ironically, those product groups, to which growers pay a levy in exchange for research and marketing, admit that they are not very good at finding new chemicals or biocontrol agents.

> *I think we're probably not that good or EPA is not that good, and the MPI aren't that good. At promoting or investigating and researching alternative products. (Product Group Representative 1)*

Many interviewees agreed that NZ's agricultural communities are "putting the blinkers on" (Arable Grower 1), outwardly ignoring or lacking the foresight to see how global trends and market pressure might affect the future use of those chemicals available today. Furthermore, many agreed that "necessity is the mother of invention" (Product Group Representative 1) when it comes to changing agricultural practices and particularly crop protection methods.

> *Until there's somebody who tells you, you just absolutely can't do something. Then you don't look for another alternative. (Product Group Representative 1)*

However, this was not unanimous. Some interviewees insisted that it is NZ's agricultural industry leading the charge, in terms of seeking new and reliable alternatives.

> *They have been successful at getting a PGP [Primary Growth Partnership] project, which is 26 million over seven years and the whole basis of that is to be proactive about the long-term use of agri-compounds and how we can diminish the use. (Product Group Representative 2)*

One interviewee had an interesting take on why chemistries are not being replaced at the same rate as they are being removed. They explained that modern agricultural chemicals are formulated and trialled in such a way that there are significant costs and long periods involved. This means that to find a softer compound with equal or better efficacy on a target species is very difficult, let alone replacing a broad-spectrum chemical which is efficacious on many target species.

> *Yeah, so I mean, of course, you know there's always research just saying you know, what's bad so, over time, you know more and more those harsher ones, you know like DDT and so on are gone and but they're not be replaced at the same rate. A lot of new chemistry nowadays are quite targeted. So it's quite hard to find something specific that actually targets a particular pest. (Fresh Product Grower 2)*

Another consequence of this theme is the proliferation of the off-label use of chemicals in smaller crops. As shown in the following quotations, due to the cost of registration, many products in New Zealand do not carry label claims for all the crops they are used on, therefore for smaller crops (by value and area), chemicals must be used off-label. Essentially smaller crops in NZ do not have many if any, on-label tools in their toolbox. Subsequently, they rely on off-label use, which is where a registered chemical is used in a manner that is not specified on the product label.

> *Well, there's less available here. What's helping the industry here is this. It's not a loophole it's a thing in legislation that you can actually use them on minor crops because we know that if it's not usable on cereals the chances of getting in here is absolutely zilch. So you've got too actually, you're using chemicals for the seed production of vegetables but off-label because there's not a big enough market to actually justify the companies registering it. Long may it last because otherwise, we won't have any chemicals. (Arable Grower 2)*

Those growers using chemicals off-label do not have access to label directions and NZ good agricultural practice (NZ GAP) advice, and therefore, the off-label use of agricultural chemicals ultimately leads to misuse (Chapman, 2016, p. 4).

> *Let's say a mass of bees are killed somewhere, and it's proven that it's because of neonicotinoids it's more likely if not a hundred per cent because of a misuse of products in an off-label situation than because of an on-label use. (Arable Grower 1)*

> *One reason why chemicals are misused in New Zealand is that the portfolio available is relatively narrow; it's very expensive to register a chemical [for smaller crops]. (Arable Grower 1)*

Another consequence of the lack of tools in the toolbox is that growers of more diminutive crops and their subsequent product groups, fight to keep those broad-spectrum chemistries, like neonicotinoids, which they already have access to. This fight is likely exacerbated by the fact that several NZ and offshore customers do not accept products if off-label compounds have been used in its production (Chapman, 2016, p. 4).

> *Yea so I help them [growers] with that [protecting available chemistries] as well and put the benefit case forward to EPA about critical uses. Yes, of course, there's a need because otherwise, they have nothing else. (Product Group representative 3)*

> *These benefit cases usually present information regarding the crop protection services which a chemical provides growers and the current lack of alternatives. When performing a reassessment of a hazardous substance, the NZEPA will compare these benefit cases with any Ecotoxicity data and environmental risk information they have access to. (Regulator 1).*

Interestingly the beekeepers interviewed believed that it did not matter what crop protection method was the usual agricultural practice as they all serve the same purpose, to kill insects.

> *If it's an organic that kills insects, it's still the same end product for us. You're still killing insects. (Beekeeper 1)*

> *Because the problem is, if you get rid of neonicotinoids, what are you going to replace them with? I'm more scared of what you're going to replace them with. (Beekeeper 2)*

Because of NZs small size as an agricultural chemical market, the small size of its agricultural production and its slow hazardous substance assessment process (theme 1) there are not many tools in the growers' toolboxes of crop protection methods (theme 2). This lack of tools is exacerbated by the governments and some product groups inadequate research of alternatives and inability to foresee market trends. Growers and their representatives are therefore made to fight to keep what broad-spectrum chemicals, like neonicotinoids, they already have available to them. Interestingly in a situation where new chemicals were regularly introduced to NZ, it is unlikely that agricultural practices would change.

> *We're unique in that we export for those crops that do export into the different markets and often, you'll be aware, often we have to meet some niche requirements in terms of MRLs [Maximum Residue Levels] to access those markets and so as well as that, you know if there's not a, if there's a new product, a new chemistry and there's not a global MRL set. You know, you just can't use it you are reliant on that older chemistry if there's an MRL*

and it controls the pest and disease so you can continue to produce. (Regulator 2)

Therefore, as theme 1, New Zealand is a small market for agricultural chemicals, related to this theme, not enough tools in the toolbox, this theme relates to the next, pressure from domestic and international markets.

5.2.3 Theme 3: Market pressure

Ultimately, NZ's primary sectors are answerable to the consumer. Consumer movements focussed on environmental and human health issues are leading to more stringent environmental standards and an industry-wide shift towards strategies that link environmental performance with consumer expectations (Dalziel et al., 2018).

> *Consumers globally are demanding higher standards for building trust that food is safe, healthy and good to eat, including requirements for stronger systems of food fraud detection and food traceability, and that production systems meet ethical expectations for responsible innovation, including high animal welfare (Dalziel et al., 2018).*

There was an acknowledgement amongst the interviewees of their role in the agricultural supply chain. Each of them recognized that they were responding to the action of an international market.

> *So we'll look at the chemical attributes of each different chemical and then we'll test that against regulatory requirements or regulatory concerns in terms of Market access getting into countries primarily around MRLs, or maximum residue levels, so we as growers we need to achieve MRL levels under a regulatory approach but our growers who've actually got relationships through marketing and sales with customers quite often. A lot of our customers have a lot lower MRL levels than the regulatory requirements. (Product Group Representative 1)*

> *But then ultimately at the end of the day even though we are right at the bottom of the chain and we're just producing, you know wheat and barley that's made into beer or whatever. We still are answerable to the consumers to a certain extent. (Arable Grower 3)*

Interestingly, the things which each international market acts through appears to change depending on the agricultural commodity which they are demanding and on the NZ based agricultural sector they are demanding it from. To this end, two different stories have emerged from the interview data, which demonstrate how the presence and absence of maximum residue levels (MRLs) are resulting in very different outcomes in terms of agricultural practices. The first story features those participants involved in the production, marketing, sale and regulation of apples and pears. Here, consumers do not want toxic chemicals, like neonicotinoids, used in the production of their fruit.

> *A lot of our markets particularly, UK and Europe. Have been going through that transition process away from certain types of chemistry. And in Europe,*

> *in particular, the neonicotinoids are not favoured by many of our customers in those regions. So growers [in NZ] have tended to move away from them and look for alternative options. (Product Group Representative 1)*
>
> *I guess the other one would be a lot of our exporters who are looking to move product into market to customers where there's not a huge fondness for neonicotinoids. So that's probably the big ones as well. (Product Group Representative 1)*

This consumer demand is turned into action through MRLs of chemicals allowed on fresh products. Essentially, domestic and international markets are demanding that regulatory and self-imposed MRL standards are met. MRLs are "the highest acceptable level of a specific agricultural chemical residue (including veterinary medicines) allowed in food" (Ministry for Primary Industries, 2019) and are set by international and domestic regulators as well as supermarkets and individual customers. The following quotations, therefore, demonstrate that MRLs are often determining NZ's agricultural practices.

> *For our guys, our volume we're about 85 per cent export and our main markets at the moment are the States, Asia, UK and Europe. I find UK and Europe is by far the most stringent in terms of customer requirements driven by the likes of the larger Supermarket chains, like Aldi and that sort of stuff and the UK Marks and Spencer and stuff like that have had high requirements for a long time. We're finding now that other markets, particularly in Asia, are starting to pick up those MRLs as well. So that's becoming our main driver really, so we find that we have different market requirements for different companies and different countries, but also different companies within countries. We have growers that are growing for particular markets, and that might be based around varieties or sizes, and then they'll have Agri-chemical MRLs by country by grower, by customer, so it's all driven around that. (Product Group Representative 1)*
>
> *So, for instance, things like there are certain fungicides and insecticides the regulatory levels might be at such a level but our customers will actually they'll actually require 0 MRL levels altogether. (Product Group Representative 1)*
>
> *Yeah, then obviously the retailer part is undertaken by the retailers because as far as they're concerned, they want to manage and control their own process. Yeah and interestingly enough when you take the hundreds of thousands of tons of product and I'm talking fresh every year we would get probably I'm just saying probably because it's roundabout half a dozen and no more than 10 situations where it would be over the MRL level but bear in mind the MRL level is so much lower than the global level. (Product Group Representative 2)*

This results in an interesting dilemma for the apples and pears sector where:

> *Consumers are saying we want fresh fruit and vegetables every day on our shelves, but we don't want you to use chemicals. We're restricting the use of water and it's becoming strangled from a regulatory point of view. But the*

> *same consumer's saying oh but I want fresh fruit and vegetables every day so. That's the dilemma we have as an industry. (Product Group Representative 2)*

> *When you're relying on 100% of your consumables based on the vagaries of weather and disease and pest then that becomes a lot more complex. So that's why the market has become what it has from an Agri compound point of view for suppliers and growers. But the industry has taken a very proactive view in saying 'well despite that. Long term we have to find how we can use softer options or BCAs [bio control agents] or other options' and that's been driven by industry, not the government. (Product Group Representative 2)*

Thus, the apples and pears sector no longer applies neonicotinoids to their orchards. Furthermore, Apples and Pears NZ no longer put neonicotinoids in their crop protection programmes because consumers do not want neonicotinoids or other harmful compounds on their fresh products. Subsequently, the high-value markets which this sector exports to, turns this consumer demand into action through stricter MRLs and in some cases, zero-tolerance standards. Essentially, NZ fresh product growers must comply with MRL regulations to gain market access, which often ends up meaning they cannot use chemicals like neonicotinoids.

The second story revolves around the arable sector, and like the apples and pears sector, arable growers, product groups, regulators and exporters are all responding to consumer expectations and the subsequent markets they enact.

> *So our customers drive a lot of what we do, were very, especially in particularly one company, so it's very. Europe drives, what's happening in government, regulatory based in Europe drives a lot of what we do. (Seed and Chemical Company Representative 3)*

> *It's not just our government that regulates. We're mainly an export company so, what's happening with the European Union has a huge effect to play with also what happens here. (Seed and Chemical Company Representative 3)*

However, this story is vastly different when compared to the first one because MRLs are absent from seed production in NZ.

> *As I say, a lot of our stuff's not food grade, so we don't operate within an, within generally the label grade rules if that makes sense. (Seed and Chemical Company Representative 3)*

MRLs do not exist in the arable sector because the majority of the product is not food grade. In the apples and pears sector, the product being scrutinised with MRL regulation is from the generation which the final consumer eats. Whereas the arable sector is "actually one generation of seed away from the consumer because we produce seed" (Arable Grower 2).

So, rather than the consumers demanding less or no chemicals be used, which is then turned into action by the international markets via MRLs. In the arable sector, consumers expect high yielding and high-quality crops, which is then turned into action by offering more money to those who meet these expectations.

> *They'll breed a new stock a new line, and they'll send it to New Zealand to be grown out. They might only get 50 kilos out of a glass house that they've grown over there then they send that here, and we can multiply that 50 kilos into you know five-ton for them and then keep doing that. So that's because we can grow stuff so clean because we're free of um weeds and other types of grasses and that side of things so that's why it appeals for companies to pay a bit extra because we're probably the dearest country to grow stuff in compared to other places around the world, but it's because we can produce, purity levels that are a hundred per cent. (Seed and Chemical Company Representative 1)*

It is the NZ based seed companies who hold relationships with both the international market and the NZ growers. It is also these seed companies who subsequently translate the markets action to the NZ growers via irrigation, fertiliser and crop protection programmes. As explained below, NZ based seed companies gain the contracts of the international seed market not only because NZ has access to land and water, is free from pests and weeds and has a longitude perfect for northern hemisphere offseason seed production, but because NZ has access to agricultural chemicals banned elsewhere.

> *A lot of why we get a lot off those European seed production is because we have, dare I say it, more relaxed rules [hazardous substance regulations]. For instance, keeping our carrot seed crop alive for 15 months can become an issue, Europe with more regulations and limited chemistries available, things become harder. (Seed and Chemical Company Representative 3)*

The above quotations describe the relationship which exists between international seed companies, NZ seed and chemical companies and then NZ arable growers. Essentially an international seed company will send a NZ based seed company a small amount of new hybrid seed to be multiplied and grown out in NZ, e.g. turn 50 kilograms into 5 tonnes. NZ is chosen for several reasons including access to water, high yields, freedom from pests and weeds, a longitude perfect for northern hemisphere offseason seed production and availability of specific agricultural chemicals, like neonicotinoids. The international seed company expects that the resulting crop will be of very high quality, free of impurities and have a high yield. To ensure this occurs the NZ seed company, who is charged with finding the farmers and land to multiply the seed, design irrigation, fertiliser and crop protection programmes. These programmes are written and performed in such a way that they minimise the vagaries of growing outdoors. The following quotation explains the importance of agricultural chemicals in guaranteeing market access and maintaining the relationship with international seed companies.

> *Ah if they banned all chemical, we'll be devastated. You wouldn't be able to produce what like we're producing. Ah most of our stuffs going to export so you just wouldn't be able to produce it to send it anywhere because it would be full of weeds to start with so that's the first thing will be thrown out, and you wouldn't be able to get, grow it with you know the fungicide side of things, the insecticides it just wouldn't work. (Seed and Chemical Company Representative 1)*

This relationship between international seed companies and NZ seed companies, as well as the expectations of purity and yield, will likely mean that neonicotinoids remain a central part of NZs arable crop protection programmes. Furthermore, it has already resulted in some interviewees struggling to purchase seed which has not been treated with neonicotinoids.

> *Often I ring up asking for just the seed without the insecticide, and I can't have it. It's like you must have that, and then it's another six or seven hundred dollars a ton. So it's another major cost so instead of being a thousand dollars a tonne it's like 15, 1600 dollars a tonne. So it's like half as much again for the insecticide. You don't really want. Particularly in springtime on crops like so that's a bugbear I find I don't like being. The end of the day. We're a consumer and where else does the customer get told no, this is what you'll have. (Arable Grower 3)*

It is fascinating that NZ's arable sector is not subject to the same amount of scrutiny as the apples and pears sector. Where in the apples and pears sector, the presence of MRLs has meant neonicotinoids are no longer used, in the arable sector the absence of MRLs is helping to embed neonicotinoids as an agricultural practice.

The arable sector has an additional generation between the use of neonicotinoids and the end consumer, so the demands of those consumers and the global trends around neonicotinoids are not being turned into action through MRLs. Instead, those consumers purchasing the generation of seed produced in NZ are having their demands of high purity and yield turned into action. This is then being translated by NZ seed and chemical companies as irrigation, fertiliser and crop protection programmes, which aim to minimise the risk of any crop failure.

These NZ seed and chemical companies manage the seed multiplication process from start to finish, allowing for minimal input from the growers whose land is being used. Subsequently, the mounting pressure from international and domestic markets (Theme 3) is driving the disconnect between landowners and agricultural practices in the arable sector (Theme 4).

5.2.4 Theme 4: Disconnect between landowners and agricultural practices

> *Let's be honest like farming now. We are accountable to the consumer way more than what we used to be and people now have the ability to see things right or wrong very easily. And so yeah, I think somehow we've got to,*

> *and you know the same old Story the gap between the urban and the rural is getting wider. (Arable Grower 3)*

As above, many interviewees highlighted both the growing accountability of farmers to the end consumer and the ever-increasing urban-rural divide. However, the interviews often focussed on a lesser-known and much more exciting theme. This theme is the idea that there is a growing disconnect between NZ landowners and the agricultural practices occurring on their property. As seen in the following quotation, this disconnect is created in situations where landowners are not involved in the day to day decision making and farming duties.

> *I mean, we've got a neighbour we do harvest for, and he does absolutely nothing. He owns no machinery, relies entirely on reps and does what he's told to a certain extent. (Arable Grower 3)*

This disconnect was highlighted in the interviews by the relationships between landowners, seed company reps and contractors.

> *Well some seed reps basically write up the recommendations to apply the chemical and then give that to a contractor, the contractor then comes and does it, and the guy who owns a place hardly has any input at all. (Arable Grower 3)*

It was particularly apparent in the arable sector, explicitly surrounding the multiplication of hybrid seeds. Some interviewees even went as far as to suggest that "as far as the country goes there will be more relying on reps, than probably doing it themselves" (Arable Grower 3). This reliance on reps suggests that increasingly growers are relying on the representatives of various organisations to decide, direct and perform the daily farming practices on their property.

> *So we go out find the ground um, get the growers to sign contracts to grow the crop and we manage it from start to finish. (Seed and Chemical Company Representative 1)*

As shown in the following quotations the practices which growers are increasingly reliant on reps for include the application of agricultural compounds, irrigation, planting and harvesting.

> *So we're mainly on spray and fertiliser and also the likes of cutting times, harvest times and all that sort of thing. (Seed and Chemical Company Representative 1)*

Several ideas stemming from this theme reinforce why particular agrichemicals, including seed treatment neonicotinoids, are being used in NZ. It was suggested that at times the reps are there to "pedal their chemicals" (Arable Grower 3) and they aren't giving good advice to the farmers.

> *They pedal already treated seed like that and I know from my time in the seed company that they make a good margin on it, but it's almost like they do that to say, oh then you don't have to worry about grub or aphids well*

that's not the case like you've still got to monitor it anyway. (Arable Grower 3)

The problem is too, and I've been in this game, and the seed companies make a truckload out of selling it, so they put it on because they want to sell it. (Arable Grower 3)

Many participants have also suggested that reps recommendations are not always well informed. This can be due to many reasons, but the most apparent one was that the reps are not always experienced enough to be making informed crop protection decisions. As explained below, this comes down to a high staff turnover rate, a lack of technical knowledge and experience.

Often reps for the seed companies come from a family farm and end up going back to the family farm. So the reality is, is that they do turn over. That's just the nature of the beast. I mean, look at me. I was one, I was an agronomist, and then I came and went in a couple of years. (Arable Grower 3)

I think many of them are just nut cases they don't, they are not sufficiently trained. There are very good men that know their products, but people are more hired because of their skill to get along with a wide variety of people instead of because of their knowledge. (Arable Grower 1)

This begs the questions why are there even reps at all and if they are not making informed decisions based on experience and technical knowledge, are they merely salesmen? Interestingly one participant explained that one of NZ's leading agricultural service companies no longer has field reps.

They've just come through a big thing where they don't have field reps anymore. The woman decided that they're a waste of time. They're just out drinking coffee all day, you know paying reps x amount of money to go and deliver products or chemicals wasn't cost-effective. So she got rid of them all. (Fresh Product Grower 1)

This, supported by the following quotations, also suggests that reps are not making crop protection decisions based on field observations. Essentially, they are not designing crop protection programmes and making decisions about when to spray based on active and in-depth crop monitoring.

So it's not until they actually, something happens to them when they think oh crop monitoring, crop monitoring you know. But until something destroys one of their paddocks, that's when they think right we've got to get crop monitoring. Yes do something about this, and it's also good for the rep to see that too because yea they think wow crop monitoring, because they were just looking at the paddock, but they wouldn't have been doing the job that we do, yea and now they see that within our business what good it does. But it just takes something like that [crop failure] to wake them up and realise that yea, the value of our service. (Seed and Chemical Company Representative 2)

It was suggested that in cases when crop monitoring did occur, farmers were finding that they were frequently applying agricultural chemicals to crops that did not require it.

> *I have a particular grower that when we started [crop monitoring] he actually saved money on sprays because the TPP [tomato potato psyllid] wasn't there, he was just spraying every 10 days regardless. That's what the rep said, spray every 10 days. And then he saw the value with what we were doing that there was no TPP out there or no aphids out there at that time, why am I wasting this money on spraying. (Seed and Chemical Company Representative 2)*

The above quotations discuss a crop monitoring service offered by another one of NZ's largest seed, chemical and agricultural service companies. It was implied that even though this service is available, it is hard to get farmers on board. The lack of farmer engagement with this program is not due to the value which it provides farmers, but the relationships that exist within this agricultural service company, the relationship that farmers have with the rep and the disconnect which landowners have with farming practices. Subsequently, despite the existence of a good crop monitoring programme that reduces chemical usage and saves land-owners money, agricultural chemicals like neonicotinoids are still used.

It is easy to refer back to theme 3 (pressure from international and domestic markets) in a situation where a landowner is disconnected from the daily agricultural practices occurring on their property. Because, as shown in the following quotation, the NZ seed company reps are basing their decisions on the expectations of their international customers.

> *It's been relayed to me that the overseas companies said they do not want the excuse of the weather or anything as to why there's not a crop. (Arable Grower 2)*

This results in the NZ seed company rep doing everything in their power to control the vagaries of growing outdoors, which might impact the yield and purity of a crop.

> *There's a big disconnect of that actually coming in hitting it with. If there was an aphid there. They'll kill it. Hmm. Okay. Yeah, that's the whole attitude if there's a bit of fungus. They'll kill it. (Arable Grower 2)*

> *Normal practice is the company rep comes in and says you've got to spray this tomorrow and they just blindly do it. (Arable Grower 2)*

What results from this relationship between the NZ seed rep and the international customer is that the NZ seed rep becomes unwilling to give up decision-making responsibilities to the landowner. During this research, a seed company rep was asked about their relationships with farmers. They subsequently described an example where a farmer was involved in the decision-making process.

> *For instance, we're running some trial at the moment where the farmer is heavily involved in suggesting treatments so I would say our relationship is very good with landowners. (Seed and Chemical Company Representative 3)*

The rep then went onto explain that grower and landowner involvement in the decision-making process "doesn't happen very often" (Seed and Chemical Company Representative 3). Not only are the seed and chemical company reps unwilling to give up control to the landowner, but often the landowner is not knowledgeable enough or too busy to be making the crop protection decisions.

> *I think a lot of other farmers will just. The company rep will just say this and do that, and they have always sprayed an aphicide on the wheat in September or August or something. I'll just do it. It's just part of their spraying of weeds spray I'll put it on. Yeah, there's no, no thought about anything else. There might before, but often farmers might not have the knowledge or the do. You know, they focus on other things. (Arable Grower 2)*

> *Well, most of the information comes from the rep. Farmers are often following what they're told. They don't really know anything they go well the label says this, and they don't actually know. Their depth of knowledge is really low. Not all farmers. I've got some farmers who are amazing, but let's be honest they're probably the 1-2% the rest of them know basically nothing. They rely heavily on the rep whatever the rep says they do, or the firm they're growing for. Who normally says get the chemical rep in. (Beekeeper 2)*

Another idea that stems from this theme and likely contributes to the embedding of neonicotinoids also relates to theme 3. Due to the expectations of their customers to receive a pure and high yielding crop, the NZ seed company reps are hesitant to try new or alternative crop protection methods. The following quotation explains that seed company reps are primarily focussed on the success of a crop, which ultimately means that they rely on the older chemistries, like neonicotinoids, that they know will work.

> *Their [seed reps] emphasis is on focused on the one crop they're dealing with, and they've got to actually get a crop out of it at the other end. They're not. They are more cautious about trying new stuff most of my discussion about using chemicals is with reps saying 'just use it, you just put an OP [organophosphate] or something like that on' and it's because they know it works. But they don't actually understand the implications, and they generally have got a very closed mind. (Arable Farmer 2)*

So NZ seed and chemical company reps are translating international markets to growers in such a way that neonicotinoids are made out to be necessary to both ensure crop yield and market access. This has meant that neonicotinoids are heavily embedded in NZ's arable sector mainly due to it being those seed and chemical companies who both supply the seed to the grower for multiplication and hold the relationship with the international customer. This allows those reps to control the process

of multiplying a seed crop from start to finish and therefore, the growers or the landowners themselves are disconnected from the daily farming practices occurring on their farm.

5.2.5 Theme 5: Grass Grub

Particular chemicals are necessary for the types of agricultural systems being implemented in NZ, and this can vary depending on the industry. Interestingly, one of the regulators interviewed stated that the difference between NZ, Europe and North America in terms of neonicotinoid regulation comes down to their different agricultural landscapes.

> *It's difficult to end, also we've got quite a different agricultural landscape. The majority of like, you know, we've got small amounts of crops, cereals and vegetable crops and then we've got a huge area of pasture and we're using neonicotinoids on pasture, but obviously not the whole, we don't grow pasture for the whole area every year. It's like just small patches where there's pasture renewal or changing use to pasture so and that compared with say the US or Europe where they're growing lots of cereal crops lots of maize and corn and using maize as an animal feed. And they plant those every year, the seed treatment. Well, they have been until recently. So yeah, it's quite a different kind of yep quite different quantities being used in different ways. (Regulator 1)*

As well as the pastoral nature of NZ's agricultural landscape, some agricultural pests which make up this landscape are also acting to make NZ different in terms of neonicotinoid use. Throughout this research, there was a constant mention of an endemic beetle species or pasture pest, known as grass grub (Costelytra zealandica). This inconspicuous insect was often at the centre of conversations when discussing the use of neonicotinoids in the arable sector. Grass grub appears to be the driving force behind the use of neonicotinoids in the arable and pastoral sectors. Arable growers plant neonicotinoid-treated seeds "as a tool for grass grub control in establishing grass and cereals"(Arable Grower 2) and "also as an aphid control in early establishment" (Arable Grower 3).

There is one alternative chemical grass grub control currently available in NZ. It is a highly potent organophosphate (OP) called diazinon. Interviewees described it as the only way to protect their crops from grass grub during early establishment besides neonicotinoids.

> *So 90 per cent of that stuff [seeds] will be treated [neonicotinoids], yea and if not they'll be drilling diazinon or something like that. (Seed and Chemical Company Representative 1)*

All though neonicotinoids are the more widely used method for controlling grass grub, diazinon offers a safety net for growers. However, in 2012 the NZEPA reassessed diazinon determining that it would be banned. After considering several benefit cases like those described in theme 2, the NZEPA implemented a 15-year extension on diazinon use to help landowners control grass grub. This extension was to enable industry to find another crop protection method besides neonicotinoids and

diazinon. However, there has not been a push for people to look for an alternative (Product Group Representative 3). Many participants expressed that neonicotinoids, as a seed treatment, is the most environmentally friendly way to combat grass grub. Furthermore, they explained that the compounding effects of pest pressure from grass grub, the toxicity of diazinon, and it coming to an end, means that they have no option but to rely on neonicotinoids.

> *We have very lacking in company apart from liquid diazinon sprayed on top, which is horrible for the environment kills all the worms. And that one's just about come to an end anyway. There's no get out of jails. And so if you don't get it right up front, you're cooked, and then there's sweet all you can do about it. Hence the reliance on the seed treatments. (Arable Grower 3)*

> *Thanks to the use of very low rates of neonicotinoids we've reduced volumes of organophosphates massively and the neonicotinoids have only had an impact on sucking insects, where the organophosphates they kill everything. They kill the worms, the slugs. They would give birds a headache if I sprayed over that crop. (Arable Grower 1)*

> *Well, when they came on it was a game-changer compare it to before that, you had to use an organophosphate or some granule or something like that to mix with the product which was a lot worse for your health and the environment than a little bit on the seed. (Arable Farmer 2)*

Furthermore, neonicotinoids have been described as more cost-effective, less labour intensive and practical than the alternatives.

> *And the other benefit for us is. I know today that if we apply this product, I don't have to look at the crop every two days to see if there is an insect Invasion coming. (Arable Grower 1)*

> *If you want to produce it economically, without it, the cost would be really, really high. So like nowadays we just can't pay, can't afford to pay people to go in there and weed things by hand. Yeah and with pest and disease. Even if you were to send people in there you couldn't possibly kind of like, you know, pick billions of or millions of aphids off the veggies. (Fresh Product Grower 2)*

Even those interviewees who were considered the most prominent opponents to neonicotinoids by the others agreed with its use.

> *Neonicotinoids are an awesome chemical for a farmer. They are just great, you can apply it to your seed and you can have a product that keeps your plants safe for very low costs, the farmers would say that and the chemical companies would say that they're great for the environment. Because the amount of spraying is less, which in truth I would be inclined to agree with them. (Beekeeper 2)*

There are non-chemical alternatives available to treat grass grub. However, like diazinon, they are incredibly destructive and much worse for the environment than a seed treatment neonicotinoid. As

explained below, farmers can perform intensive cultivation to kill grass grub. Not only is this option not a guaranteed fix, but it destroys the soil structure, resulting in several flow-on effects.

> *Actually, it might be worse for the environment because if you, for argument's sake, now you're doing minimum cultivation or direct drilling of autumn cereals. You need something down there to control the grass grub and the slugs. The only other alternative is intensive cultivation to actually destroy the grass grub. Yeah, so that's not going to be as good for the environment but even that is no guarantee. (Arable Farmer 3)*

Although interviewees continually expressed their desire to move away from these destructive agricultural practices, particularly those which harm beneficial insects, they do not have any other option. Ultimately this comes down to the fear of catastrophic crop failure.

> *It's not cheap putting all this seed down and to have it all blown out by grub. And then it's just like you've got to re-drill it and then you've lost it, you know the yield on a crop and then like feed and a pasture situation like it's so. For years we've tipped phorate, you know horrible stuff organophosphates down the spout around here well dad has and then to a lesser extent I have because of the fear of Grub. Because you get out there you dig with your spade and I've done it. Dads done it. You dig all your spades across the paddocks and you find none. So sweet I won't put any stink down and then you get hammered and you do it the other way, where you find heaps and so you put it down but then who knows they might have come and gone and you would have been okay, it's it can be hit and miss with just finding the little suckers. And so the problem is once they're in and your crops in there's not a lot you can do about it so it's the fear of well, it's like what do I do? (Arable Grower 3)*

Furthermore, several participants expressed that even if they were to stop using neonicotinoids, they would end up treating their crop with some other insecticide.

> *So, you know, it's like everything in agriculture, sort of. Often what the pure science says is not really what happens in reality, and there's always give and take. So if you did drop that [neonicotinoids] out and you look after your soil by not putting that on well you're throwing on an extra insecticide on top anyway, so, you know. Yes, you've got to weigh it up in terms of what you want to, what you're trying to achieve, I suppose. (Arable Grower 3)*

There are many reasons why neonicotinoids are embedded in NZ agricultural practices. One of the most interesting was described by Product Group Representative 3. They explained that not only do grass grub help embed neonicotinoids because they are a significant pest, but also because they are an endemic species. What this means is that places, where neonicotinoids have been banned and restricted, are not exposed to the same pest pressure and limited crop protection methods that NZ agriculture endures. Furthermore, those international crop protection companies charged with the

task of introducing new chemistries are unlikely to formulate a chemical that is specially efficacious for grass grub.

> *Grass grub is endemic to New Zealand and not really a problem overseas so there's not a lot of global companies working on controlling grass grub. (Product Group Representative 3)*

This is because NZ only represents a fraction of their global sales (theme 1), grass grub only exists in NZ, there is already a working alternative (neonicotinoids), and chemical discovery is very complicated.

> *The Bayer's and BASF's of the world they won't make a chemistry for grass grub they just discover molecules and then see what they might be efficacious on. So it's a little bit difficult. Yeah. (Product Group Representative 3)*

Grass grub control brings to light the idea that necessity is the mother of invention, as presented in theme 2. The quotation below describes how there is not a drive from within the industry to seek out other options that deal with grass grub, despite one of the two available options being phased out.

> *Growers are saying to me know that actually, you know it's not too many seasons away. Before diazinon's gone what have we got coming up and as you'll be aware the pipeline for you know registration can be three to five years in terms of trials and registration data packages getting together and then being assessed so there's not a lot coming through and if there was they would be saying you know that's fine we've been given a long phase-out but ever since 2013 there hasn't been a push to. Ask people to look for chemistry but I mean, I don't know if you talk to anyone in Discovery, but it's quite a complicated process and it's also very expensive. (Product Group Representative 3)*

Essentially neonicotinoids are used in NZ for the early growth stage control of grass grub and aphids. The necessity of this early stage protection, the dominant pastoral landscape and the small amounts of pasture renewal and therefore treated seeds planted each year, means that neonicotinoids, as a seed treatment, will likely remain a part of NZ's agricultural practices. Furthermore, as explained in theme two, this section again demonstrates that there are not enough tools in the toolbox. There are only two easy to use and readily available options for dealing with grass grub in NZ, and one of them will be banned as of 2028. Rather than searching for a replacement, those relationships serving to cement neonicotinoids in NZ are further strengthening around their shared goal to hold on to this agricultural practice.

5.2.6 Theme 6: Relationship between beekeepers and landowners

A NZ House of Representatives document, discussing the health of bees, described how the relationship between beekeepers and landowners is very sensitive. It went on to explain that the

relationship is so sensitive that beekeepers are unwilling to complain if and when they suffer from the use of insecticides (Ardern et al., 2014). It suggested that beekeepers rely on the goodwill of landowners and are unlikely to put that under threat. The document also indicated that the NZEPA and the government cannot move on anything legislatively and cannot monitor the use of pesticides without complaints. This means that any potential reassessment of neonicotinoids will only occur if beekeepers record and complain about any beehive or pollinator losses caused by neonicotinoids in NZ.

My research has revealed that beekeepers are not merely not complaining, it also shows that it is nearly impossible for them to prove who and with what has affected their hives and that their complaints are often being ignored. The first of many reasons as to why beekeepers aren't complaining or their complaints are being ignored is that there is usually only "verbal contracts" (Arable Grower 1) held between landowners and beekeepers. However, this was not always the case; often, there is excellent relationships and formal contracts between beekeepers and landowner.

> *Um, what we have in our contract we talk about not, it's a signed agreement don't use spray without talking to us. Generally, if we're going out into north Canterbury here that's a pretty intensively sprayed area, to be honest. So we always go, I always talk through what you use generally, what are your top 8 products, generally, 8 will cover it. And then we talk about what we need to know when we, you have like we basically have a rule that says tell us whenever you're gonna spray and I'll say yea sweet or I'll say give me a day I need to get our gear out of there. (Beekeeper 1)*

> *The ones that have to pay compensation, make sure their spray contractor calls us beforehand to give us notice to move. They're not very good at it, they normally do it as an afterthought. So one time there we had just moved the hives in and the contractor called us saying that he was going to spray tomorrow. And were going you, you can't spray tomorrow we've just moved in 200 beehives, how the, we can't move them now, why didn't you ring us last week. Oh, we forgot to get around to talking to you, were required to talk to you before we spray, and I went well you can't spray until all the hives have moved. (Beekeeper 2)*

In one situation a beekeeper described the formal contracts as only being in place to protect the landowner from being sued by the beekeeper if they were to kill or harm the beehives.

> *On another couple of the farms, the farmer has it the other way around. So the contact is done very much to protect him from us suing him for chemical poisoning. (Beekeeper 2)*

Beekeepers are willing to sign such contracts due to the value of the Manuka honey which that bee site might yield (see Chapter 2 for more detail) and because they make a lot of money selling pollinators to crop farmers (Arable Grower 3). Following on from this beekeepers are unlikely to complain at the risk of losing those valuable sites. As one beekeeper explained

> *It's against the law for them to poison the bees, they're not legally allowed to, but I have lost bee sites for complaining that they've poisoned the bees. (Beekeeper 2)*

In contrast to the NZ House of Representatives document, this thesis research revealed multiple situations where beekeepers have complained about their beehives being harmed or killed. However, complaining does not always result in compensations for the beekeeper. Another reason why the NZ House of Representatives has not come across any complaints about beehive poisonings is that, as revealed by one beekeeper, no one is listening to those complaints.

> *The problem is that federated farmers, they can't do anything. There's no one out there. Unless you, you can ring Ecan and try and get Environment Canterbury or one of the local regional councils in. It's quite difficult, they as a rule. A lot of the people there are pro-farmer, 'they need to do this for their business.' (Beekeeper 2)*

Another problem proposed by the beekeepers interviewed was that even if they did complain, it is challenging to prove who killed or poisoned their hives. Which, not only comes down to the ability of bees to travel long distances to forage crops but also agricultural chemicals ability to drift.

> *One down the road from us where three different farmers' paddocks were sprayed. There were 70 hives on the block, the hives were either dead or nearly dead. But we didn't know which of the farmers and their contactor had sprayed the chemical that killed the hives. We're pretty sure it was the same contractor that sprayed all the paddocks, we assume it was the paddock that the hives were in got sprayed and we reckon the drift killed them. But you could easily argue that it was the neighbour's paddock that was the killer. So, therefore, who pays compensation? And we just bore the loss of the 70 beehives. (Beekeeper 2)*

As suggested in the following quotation, it is incredibly difficult for a beekeeper to prove, or even understand what is killing or affecting their hives. Furthermore, even if a beekeeper were to undergo the rigorous testing necessary to determine what agricultural chemicals were affecting their bees, there would still be a "problem with cost" (Beekeeper 2).

> *The problem with agricultural chemicals is that you don't know unless you're doing testing, you often don't know if you've got a problem. So you will see colonies with issues and you don't actually know why they've got those issues. And you can say, oh they've got a failing queen or they've just got, you don't know whether the queens got a pesticide issue. Unless you're testing the wax and testing the honey and testing the, doing the involved testing regularly, you won't actually know what's causing it. (Beekeeper 2)*

The above comments not only outline issues surrounding the protection of beekeepers from chemical poisoning, but they demonstrate a number of problems which arise when attempting to restrict the use of chemicals like neonicotinoids. Essentially beekeepers are more likely to bear the hive losses than go through the complicated and expensive process of proving particular chemical

and applicator killed their hives. Subsequently, there is a lack of complaints, and those complaints that do occur are ignored or disputed. A lack of complaints, regulators ignoring complaints and beekeepers inability to prove who and what poisoned their hives is inhibiting the reassessment of neonicotinoids. Which is subsequently preventing the NZEPA from justifying any restrictions on their use.

5.3 Summary

This chapter described the accounts of arable growers, fresh product growers, beekeepers, regulators, seed and chemical company representatives, product group representatives and researchers. Six themes were highlighted including NZ's small market for agricultural chemicals, not enough tools in the toolbox, market pressure, the disconnect between landowners and farming, grass grub and the relationship between beekeepers and landowners.

More specifically, theme 1 discussed the common notion that in NZ, the availability of agricultural chemicals is controlled by the NZEPA. It went onto demonstrate that a slow registration process and a lack of incentives for multinational crop protection companies to register chemistries in NZ is causing the lack of alternatives.

Theme 2 also starts by demonstrating the blame put on the NZEPA, but it also suggests that a lack of industry foresight is also responsible for the lack of neonicotinoid alternatives. It goes on to discuss how this encourages growers and their representatives to fight to keep those crop protection methods they have available.

Theme 3 discussed how consumer pressure is determining agricultural practices in NZ. More specifically, it demonstrated how consumers expectations and the way those expectations are being turned into action can vary depending on the agricultural sector. Furthermore, it showed how the presence and absence of MRLs have resulted in the removal of neonicotinoids in one and the maintenance of neonicotinoids in another of NZ's agricultural sectors.

Theme 4 illustrated the growing disconnect between arable growers and the daily farming practices occurring on their land. More specifically, it suggested that those reps taking over the crop management decisions are not well enough informed or sufficiently trained to be making good crop protection decisions. Subsequently, they rely on what they know works and therefore help to embed neonicotinoids in NZ agricultural practices.

Theme 5 introduced the concept that grass grub is the main reason why neonicotinoids are necessary to NZ. It went on to explain that the presence of this endemic species is a major difference between NZ's use of neonicotinoids and the rest of the worlds. It also suggested that NZs pastoral landscape

and low levels of pasture renewal means that it cannot be compared to Europe and the USA in terms of neonicotinoid use.

Finally, theme 6 explained why beekeepers do not complain when their hives are poisoned and why if they do complain, they are not being heard. It also suggested that a lack of complaints will mean that the NZEPA cannot justify restrictions on neonicotinoid use.

The next chapter provides a discussion around how particular relationships present in these themes have led to neonicotinoids becoming embedded in NZ's arable sector, while simultaneously being removed from the apples and pears sector. It will also show how a strict application of Bruno Latour's Circulatory System of Scientific Facts (1999a) only revealed half the story. Subsequently, it will go on to demonstrate why deviations from this framework were necessary to reflect the data better. By pairing this framework with the interview data, the next chapter will show how neonicotinoids as an agricultural practice is the sum of those relationships described above.

Chapter 6

Discussion

6.1 Introduction

The main aim of this research is to understand how neonicotinoids are embedded -and remain- in NZ's agricultural practices. By pairing the interview data presented in Chapter 5 with Latour's CSSF (1999a) and Callon's key principles (1986) of "generalised symmetry", "agnosticism" and "free association", this chapter will show how the use of neonicotinoids, as an agricultural practice, is the result of various material relationships. This chapter also uses these tools to describe the inner workings of NZs agrichemical market and agricultural community.

As explained in section 4.3 I did not initially assess my results using the CSSF because the thematic analysis was a good way of making sense of the data for myself. Also by presenting the conflicting viewpoints of all the actors and quoting the exact words of the interview respondents, I have limited my biased commentary, identified the power relations and social hierarchies as they have emerged from the data and therefore combatted some of the limitations of the CSSF (Latour, 1999a) and Callon's key principles (1986) described in section 3.5. I have not strictly abandoned the thematic framework presented in Chapter 5. Instead, I have followed Warner (2008, 2016), Edwards (2014), Ingram (2007) and Fitzsimmons (2004) and have framed those themes, or the key relationships they revealed, through the CSSF lens. In doing this, I have also contributed to answering the fourth research question of this thesis: How can Latour's CSSF be used to investigate similar controversies in the future, in particular, those which involve hazardous chemicals used in NZ agriculture?

Practically, this chapter utilises Latour's CSSF (1999a) to represent the data outlined in Chapter 5, catalysing an understanding of those actors influencing the scale and frequency of neonicotinoid use in NZ and the relationships existing between them. This framework has encouraged me to follow neonicotinoids as they are created by the interdependent relationships existing between those actors described in the previous chapter. Subsequently, this chapter will address the first two research questions presented in Chapter 1:

1. Who and what are the major actors that influence the scale and frequency of neonicotinoid use in NZ, and what have been their roles?

2. How have certain relationships formed between actors?

Not only will this chapter bring together the different accounts presented in Chapter 5, but it will ask if the CSSF (1999) has offered a useful way of extracting critical narratives about neonicotinoids from the data. Subsequently, it will address the third research question presented in Chapter 1:

3. How are neonicotinoids as an agricultural practice embedded -and maintained- in NZ, and why has opposing knowledge been unsuccessful in removing it?

This chapter has revealed how knowledge opposing the use of neonicotinoids has contributed to it being removed from NZ's apples and pears sector and it has also tried to make sense of why it has not done the same in the arable sector. Finally, this chapter will bring together the key content of previous chapters, discussing the strengths and weaknesses of the CSSF (1999a) and considering how it has allowed for a useful understanding of neonicotinoids. This will subsequently help to answer the final question:

4. How can Latour's CSSF be used to investigate similar controversies in the future, in particular, those which involve hazardous chemicals used in NZ's agriculture?

6.2 The arable sector, the stable network

The interviews outlined in Chapter 5 revealed that neonicotinoids are used as an agricultural practice across NZ's agricultural industry. However, it also revealed that how they are used depends on the commodity being supplied and the agricultural sector itself. What follows is an analysis of that data using Latour's CSSF (1999a) to demonstrate how neonicotinoids are embedded in the agricultural or farming practices of NZ's arable sector.

Autonomization

Latour's loop called "autonomization" refers to how a "discipline, a profession, a clique or an invisible college becomes independent and forms its own criteria of evaluation and relevance" (Latour, 1999a, p. 102). Essentially this loop illustrates how an area of expertise has been created around neonicotinoids. In terms of NZ's arable sector, this clique, college or area of expertise is made up of those actors who are convinced of neonicotinoids importance for growing high-value export quality seeds, it therefore closely resembles the market pressure theme but it also draws on data from theme 1, 2 and 4 of the results chapter. My data is useful for understanding how neonicotinoids have been made and maintained in NZ's arable sector, and therefore this loop includes the relationships between arable growers, NZ seed and chemical companies and international seed markets. It is important to note that this area of expertise has not been built through these actors coming together and learning about neonicotinoids. Rather, their relationships and this area of expertise rely on the trade of material things and the translation of interests. I will refer to this area of expertise as the

arable profession because it is made up of intercommunicating groups and individuals who are working to produce high yielding and pure seed crops.

Many other relationships likely exist that are not discussed here. However, for the purpose of this research, I have focussed my analysis on the three-way relationship between arable growers, NZ based seed and chemical companies and international seed companies. This will also enable me to demonstrate how this profession is contributing to neonicotinoid use in NZ's arable sector and is simultaneously a consequence of this use.

As outlined in section 5.2.3 NZ's arable sector exports the majority of its products overseas, particularly to Europe. More specifically international seed companies are interested in multiplying hybrid seeds and want to ensure the subsequent crops are high yielding and 100% pure. Therefore, they deploy the multiplication of these hybrid seed crops to NZ. To gain access to land, resources and growers, these international seed companies must form relationships with NZ based seed and chemical companies who almost act as a middleman between the international company and the arable grower. To this end, the international seed companies mobilise various intermediaries by which it can act upon NZ based seed and chemical companies. These include a higher payment for the NZ based seed and chemical company compared to if they had the crop multiplied elsewhere in the world and a set of standards about quality and yield (see section 5.2.3 and 5.2.4). Essentially these international companies have outlined expectations of yield and purity. They do not want the seed cross-pollinated, biosecurity dictates it cannot be contaminated with weeds and "they do not want the excuse of the weather or anything as to why there's not a crop" (Arable Grower 2). The NZ based seed and chemical companies are not passive in this relationship. They interest the international companies with NZ's longitude which is perfect for seed production during the European off-season (Scottville Farm, 2017), access to water, good farming practices and NZ's more relaxed rules when it comes to some substances deemed hazardous elsewhere (section 5.2.3 and 5.2.4). Presumably, both actors have various representatives who engage in face to face meetings with one another to align their interests and strengthen this relationship.

The negotiations between International seed companies and NZ based seed and chemical companies are translated into the farming practices of NZ's arable growers. The NZ based seed and chemical companies mobilise intermediaries which serve to influence the farming practices of NZ's arable growers and subsequently align the interest of all those actors in this "autonomization" loop. These intermediaries include fertiliser, irrigation and crop protection programmes which serve to ensure that those yield and purity expectations set by the international companies are met (see section 5.2.3). They further interest the arable growers with payment for multiplying the seed and market access. To secure their position and gain the contract to multiply the seed NZ arable growers have to

mobilise intermediaries of their own to interest the NZ based seed and chemical companies. These are often simply a commitment to follow those crop management plans set out by the NZ based seed and chemical company. Furthermore, they use programs such as Agworld to confirm they have performed crop treatments, irrigation and fertiliser applications as directed.

Getting back to the core tenant of this thesis, the crop protection plans mobilised to and followed by arable growers always contain the treatment of seeds with neonicotinoids. Due to the lack of alternatives for neonicotinoids (see section 5.2.2), the prevalence of grass grub (section 5.2.5) and NZ seed and chemical company reps reliance on older chemistries (see section 5.2.4), NZ based seed and chemical companies translate the expectations of international seed companies as; 'to minimise the vagaries of growing outdoors you must use neonicotinoids'. Subsequently, the security of arable growers' contracts with a NZ seed and chemical company and even their ability to buy seed is dependent on the use of neonicotinoids as a seed treatment (see section 5.2.4).

Alliances

Latour's loop called "alliances" describes how various actors who are generally not interested in the object of the network are captivated by it (see section 3.6). Or as Latour illustrates "the military must be made interested in physics, industrialists in chemistry, kings in cartography, teachers in educational theory, congressmen in political science" (Latour, 1999a, p. 103).

In the case of NZ's arable sector, this loop represents how a diverse array of powerful actors are involved in the successful production of high yielding and 100% pure hybrid seed crops. More specifically, it explains how the NZEPA and beekeepers are involved in embedding neonicotinoids in the farming practices of the arable sector, therefore it draws on data from theme 1 and theme 4 of the results chapter. Essentially high yielding and pure hybrid seed crops cannot be grown without the use of neonicotinoids, but the arable profession cannot use neonicotinoids unless these diverse actors become interested in them. This loop, therefore, demonstrates how those actors (the NZEPA and beekeepers) become interested in neonicotinoids. Unlike the above loop which discussed a three-way relationship and the formation of an invisible college, the "alliances" loop discusses two separate relationships which have formed between actors within the arable profession and actors that are "rich and well-endowed" (Latour, 1999a, p. 104).

The first relationship is between the NZEPA, arable product groups and arable growers. Essentially this relationship describes the activities that result from there not being enough tools in the toolbox (see section 5.2.2) for NZ's arable growers to protect their crops from pest species such as grass grub (see section 5.2.5). Once again, this relationship relies on the trade of resources; product groups primarily function as a representative body of NZ's various agricultural sectors. They collect levies from growers based on yield, land area or at a fixed rate and in return, growers receive marketing,

research and development as well as some practical support. In terms of this loop, arable product groups also provide lobbying of the government and its agencies.

The NZEPA made a call for information regarding the use of neonicotinoids in NZ during August 2018. This was the first step in assessing whether this group of agricultural chemicals needed to undergo a reassessment. NZ grower groups were able to convince the NZEPA that neonicotinoids are essential for the success of key export crops, particularly those smaller crops which do not have access to a wide range of alternative crop protection methods (section 5.2.2). Therefore, by mobilising intermediaries in the form of critical use cases to the NZEPA, product groups interested this powerful actor in neonicotinoids. NZ grower groups have been able to create a strong "alliance" with the NZEPA, linking their interests (keeping tools in the toolbox) to the interests of the public and the NZEPA. Not only is the NZEPA convinced of neonicotinoids importance to NZ's agricultural production, but they are also convinced that biodiversity declines are not caused by neonicotinoids. This is because, as suggested in section 5.2.5, the pastorally dominant landscape of NZ is different from those in Europe and North America. The NZEPA is not passive in this alliance. But rather than it being about what resources they trade, here it is about what they do not trade. They have not changed neonicotinoid regulations, and therefore, the actions of grower groups and growers have not changed. This alliance, built by product groups, has resulted in the authoritative acceptance of neonicotinoids as a safe, highly targeted and essential agricultural chemical by the NZEPA.

Another "alliance" which is informal, but still significant to this case study is that which exists between arable growers (landowners) and beekeepers (see section 5.2.6). Essentially landowners need to convince beekeepers of their agricultural practices. This is because the NZ House of Representatives can only move on neonicotinoid regulations and keep accurate hazardous substance records with complaints (see section 5.2.6). The relationship between landowners and beekeepers is very sensitive and highly valuable to both parties. Landowners mobilise intermediaries including formal contracts which offer beekeepers compensation if their hives are poisoned, access to stances of highly valued Manuka and a fee for pollination services (see section 5.2.6). These intermediaries serve to convince beekeepers of their agricultural practices. Beekeepers are not passive in this relationship. Rather they mobilise intermediaries of their own to influence the activities of the landowners/arable growers. They similarly mobilise contracts which protect their hives from being poisoned and pay landowners for access to honey-producing flora. This subsequently strengthens their "alliance" and when contractually obligated, landowners inform beekeepers of when they are using hazardous substances (see section 5.2.6).

Due to the growth of NZ's honeybee population and the Manuka honey market (see section 2.4), those beekeepers with access to Manuka are unlikely to complain even in cases where their hives

have been poisoned, this is due to the risk it poses their income. Returning to the core tenant of this thesis, landowners and beekeepers will sometimes negotiate about the agricultural practices being used. Understanding that neonicotinoids are necessary for crop protection and seeing as there is no NZ based evidence suggesting they harm honeybees, beekeepers are often relieved if neonicotinoids are used, particularly when they are being used in place of another chemical (see section 5.2.2).

Public representation

The next loop of Latour's framework, "public representation", considers how people's everyday practice, system of beliefs and opinions are affecting how science is done, or in the case of this research how an agricultural practice is done (Latour, 1999a, p. 105). For example, Latour illustrates that "a major part of advanced research in molecular biology in France … depends on a private charity's annual telethon to combat muscular dystrophy. Every argument for or against genetic determinism will feedback into this funding" (Latour, 1999a, p. 106). Because NZ's arable growers are "one generation of seed away from the consumer" (Arable Grower 2), or the public which this loop describes, there is much less accountability than Latour may have anticipated when he initially described this loop. Nevertheless, this loop represents how consumer demands are shaping the agricultural practices occurring on NZ arable farms and it therefore draws on the data of Theme 3.

Consumers are demanding fresh produce on their shelves every day, even if it is out of season and even in places where that product might not grow (see section 5.2.3). One could argue that this helps drive the demand for NZ grown hybrid seeds and the resulting use of neonicotinoids. As demonstrated in section 5.2.3, this demand for fresh produce has shaped the market into "what it has from an Agri compound point of view for suppliers and growers" (Product Group Representative 2). So, as the public is becoming more and more interested in gaining access to fresh food every day, they are subsequently and inadvertently embedding the use of hazardous substances like neonicotinoids in NZ's arable sector. It is the relationship which international seed companies have with this public, the consumer, and the subsequent generational gap which means that there is no drive to get rid of agricultural chemicals as there is in the apples and pears sector (see section 6.3). One arable grower (Arable Grower 2) explained that it is the next generation who are growing vegetables from NZ grown seeds who have to respond to market demands around hazardous substance use.

Consumer demand for clean and high yielding seeds out of season is also a part of this loop. Here a relationship exists between the users of NZ grown hybrid seeds and international seed companies. This once again relies on the trade of resources. The international consumer or those vegetable growers mentioned in the paragraph above are demanding high-quality vegetable seeds which express certain traits and are free of weeds, pests and diseases. Simply enough the consumers

interest the international seed companies with payment and those companies provide the consumers with the seed, which is of high-quality, expresses the desired traits and is free of weeds, pests and diseases. This allows both actors to fulfil their respective goals that neither can achieve alone. Profit for the international seed company and vegetable seeds for the consumers.

Mobilization of the world

The next loop of Latour's CSSF is "mobilization of the world". As explained in Chapter 3, it describes all the means by which non-humans are progressively loaded into discourse (Latour, 1999a, p. 99). When used to study how science is done, this loop deals with the instruments, equipment, expeditions, surveys and sites involved in scientific research (Latour, 1999a, pp. 100-101).

Given this thesis is not concerned with how science is done but with how an agricultural practice is done, "mobilization of the world" is a matter of how things and non-humans are of moving towards the world, making it mobile, bringing it to the site of controversy, keeping it engaged and making it available for arguments. Essentially it is about how non-humans are connecting the sites of this controversy, for example, the hybrid seeds have become a commodity that connects something as big as the international commodity market to something as small as a farmer's paddock. It is also about how these things are being mobilised and made available for arguments. For example, "An ecologist whom nobody used to take seriously can now intervene in a debate with beautiful satellite photographs that allow her, without budging from a Paris laboratory, to observe the advance of the forest in Boa Vista" (Latour, 1999a, p. 101). Although this section draws on data from all the themes in Chapter 5, it is particularly reliant on the Grass Grub theme.

As the ecologist loaded satellite photographs into her discourse about the Boa Vista, arable product groups have loaded grass grub into their defence of neonicotinoids. If grass grubs were not present in NZ's agricultural landscape, there would be no basis for the neonicotinoid critical use cases put forward to the NZEPA and these actors would, therefore, be unable to fight for what they have got (see section 5.2.2). This pasture pest is made to move in the critical use cases and the supporting documentation supplied by product groups to the NZEPA opposing neonicotinoid reassessment and supporting its initial registration (see section 5.2.2). So through the mobilization of pasture pests like grass grub, we can see how the offices of the NZEPA are linked to the day-to-day practices occurring in a South Canterbury field.

As grass grub was mobilised to connect sites and load reality to claims about neonicotinoids, the 100% pure seed crops demanded by international seed companies have become a commodity that serves to connect arable fields with the international seed market. Essentially international seed companies will not deploy seed production to NZ without a guarantee of purity and yield. Subsequently, NZ based seed and chemical companies translate this demand and load their

arguments with seed treatment neonicotinoids. They both mobilise these treated seeds in the form of crop protection plans to landowners, arguing it is the only way they can gain market access (see section 5.3.3). Simultaneously NZ seed and chemical companies are mobilizing the treated seeds to the international seed companies arguing that they are utilizing these crop protection methods as a way of minimising the risk of losing a crop to the vagaries of growing outdoors, therefore guaranteeing a pure high yielding seed crop. The mobilization of treated seeds has been so successful that arable growers struggle to buy any seed which is untreated (Arable Grower 3). This mobilization of neonicotinoid-treated seeds subsequently strengthens the relationships in the arable profession and further embeds neonicotinoids in the farming practices of NZ's arable sector.

Honeybees are progressively loaded into the discourse of many actors throughout this network. More specifically product groups mobilise the lack of complaints regarding honeybee deaths associated with neonicotinoids in NZ and similarly the lack of cases of CCD (see section 2.7), in those critical use cases put forward to the NZEPA. When the call for information on neonicotinoids went out in 2018, these product groups, mobilised this non-human along with grass grub to defend neonicotinoids (see section 5.2.2) and subsequently help embed -and maintain- them in the farming practices of NZ's arable sector. In a similar way, landowners have mobilised this lack of complaints, cases of bee deaths and cases of CCD to strengthen their "alliance" with beekeepers.

Links and knots

Latour (1999a) calls the fifth and final loop of the CSSF "links and knots". This is done to avoid the historical baggage associated with the term conceptual content. This central loop is not "a pit inside the soft flesh of a peach" (p. 106), but it is "a very tight knot at the centre of a net" (p.106). In Latour's world of studying scientific practices, this loop is the scientific content that ties all the loops together, but which cannot exist in isolation from them, serving as the conceptual heart of the network. Without this loop, the others would die, but this would happen just as quickly if any of the other loops were amputated (p. 107).

In terms of this case study, the NZ arable sector and an investigation into how neonicotinoids have become embedded in NZ's agricultural practices, the "links and knots" are neonicotinoids. Neonicotinoids are everywhere in the network but at the same time nowhere. No single part of this network can be used to explain the use of neonicotinoids in NZ's arable sector because it is distributed throughout the entire network. In terms of NZ's arable sector, the network itself and therefore, the "links and knots" are stabilised because of the action and interaction present in the four other loops. This will be explained in more detail below.

Similar to how a "concept does not become scientific because it is farther removed from the rest of what it holds, but because it is more intensely connected to a much larger repertoire of resources"

(Latour, 1999a, p. 108), agricultural practices become embedded because they are more intensely connected to more things, sites and actors. The "links and knots" described in this case study is exactly that agricultural practice which churns, steers, moves and connects the rest of the world of data, colleagues, allies and spectators.

The arable sectors blood flow

The CSSF (Latour, 1999a) suggested that five activities, which have simultaneously been performed and worked, have embedded neonicotinoids in the agricultural practices of NZ's arable sector. These five activities or loops have described the key relationships, connections, things and sites that have been made and maintained in the on-going use of neonicotinoids. Due to the interconnection of actors, things and sites described above, they are all necessary for the overall stability of the arable sectors network. If any of the loops were broken, the blood flow of the entire network would stop. Therefore, it is no individual actor or relationship but all of those described above which have made and maintained and therefore embedded neonicotinoids in NZs arable sector. These loops or activities are the creation of neonicotinoids as an agricultural practice (links and knots), the making of things, documents, sites and other non-humans available for arguments about neonicotinoids (mobilization of the world), the forming of an arable profession who share the same goal of producing high yielding pure seed crops and see neonicotinoids as one of the methods for achieving this (autonomization), making "alliances" with important and powerful actors outside of the arable profession to support neonicotinoids or at the very least not oppose their use (alliances) and aligning the arable sectors agricultural practices with the demands of consumers (public representation).

I have used Latour's model to interpret the use of neonicotinoids in NZ's arable sector. Seeds and other arable crops have been grown in NZ since the early days of European settlement (see Chapter 2), but more recently arable growers have collaborated with product groups as well as NZ seed and chemical companies to capture European off-season production. Furthermore, since the introduction of the HSNO ACT, the subsequent establishment of the NZEPA and the systematic reassessment of older hazardous substances, these actors have had to engage with additional actors to develop new and maintain existing farming practices. Furthermore, the growing social expectation of reduced hazardous substance use in food production has forced additional actors (consumers and the public) to participate in the network. Lastly, the death of all unmanaged honeybee hives in NZ and the subsequent re-birth of the apiculture industry (see section 2.4) has forced beekeepers to participate in the making and maintenance of agricultural practices.

What I have described above are the key components of the arable sectors network representation which illustrate the activities of human and non-human actors as a kind of blood-flow which sustains the life of neonicotinoids as an agricultural practice. This approach is a communicative understanding

of the maintenance of neonicotinoids as an agricultural practice in NZ's arable sector, which emphasizes the presence of dynamic relationships with material nature. The circulation of each loop is dependent on that of all the other loops. Therefore, the blood flow of this network is what maintains neonicotinoids as an agricultural practice. How much neonicotinoids are used, therefore, how embedded they are is proportional to the speed of this blood flow.

To study "mobilization of the world" is to study the logistics that are so indispensable to the logics of agricultural practices. Subsequently, to study the logistics of neonicotinoids in NZ's arable sector required not only the study of the things which neonicotinoids combat, support and potentially harm (grass grub, clean high yielding crops, honeybees), but the places which these things are found, translated and made available for arguments (international markets, farmers' fields, NZEPA offices). This research revealed that the high yielding and 100% pure seed crops are loaded into discourse to strengthen the three-way relationship between arable growers, NZ seed and chemical companies and international seed companies. Furthermore, the seed coating neonicotinoids, as a method of meeting international seed company expectations, are also loaded into the discourse between these three actors. Subsequently strengthening the arable profession and speeding up the circulation of the "autonomization" loop.

NZ seed and chemical companies have mobilised neonicotinoid seed coatings in the form of crop protection programmes convincing arable growers that neonicotinoids are the only method of ensuring market access as well as protecting their crops from pest pressure during early establishment. This also strengthens the NZ seed and chemical companies argument that international seed companies do not want any excuses as to why there is no crop. Similarly, the NZ seed and chemical companies mobilise the treated seeds to the international seed companies to demonstrate that everything is being done to minimise the potential of crop failure and loss, therefore convincing the international seed companies to both pay a higher rate than if the seed was grown elsewhere in the world and to continue having their seed multiplied in NZ. What this demonstrates is that the circulation within the "mobilization of the world" loop is dependent on the circulation of the "autonomization" loop. Therefore, if actors within the arable profession fail to translate their interests and the interests of others in any of the other loops, the whole network would collapse. For example, if the NZ based seed and chemical companies failed to translate the interests of international seed companies, high yielding and pure seed crops in the European offseason, to NZ arable farmers' interests, follow these crop management programmes and you will gain market access, the whole network would fail. The goal to produce high yielding and 100% pure arable crops is one of the most powerful accelerators of this circulatory system. It was frequently the primary trigger for neonicotinoid use in this sector, and it forms "the seeds of all relationships amongst" the arable profession (Latour, 1999a, p. 103).

By aligning their interests with those of beekeepers, the arable profession can form "alliances" with them. Landowners (arable growers) mobilise non-humans such as access to manuka and contracts which demonstrate that they will inform the beekeeper of when they are applying chemicals. Furthermore, in direct relation to neonicotinoid use, the arable profession mobilises government and historical data which suggest that no honeybees have died in NZ as a result of neonicotinoid use and the commonly associated bee disorder (CCD) has also never occurred in NZ. By mobilising these non-humans the landowners form an "alliance" with beekeepers who subsequently support, or at the very least do not directly oppose neonicotinoid use in the arable sector. This informal "alliance" can become so strong that in many cases even if beehives are poisoned the beekeeper will simply bear the hive losses. Essentially the value of the non-humans being mobilised, access to Manuka and pollination contracts, is so great that beekeepers are unwilling to threaten their circulation by complaining.

If the interests of the landowners were not translated to those of beekeepers and subsequently these non-humans were not mobilised, socialised and loaded into the negotiations between the landowners and beekeepers, it is likely that at times where beehives are poisoned the beekeeper would be more inclined to complain. As explained in section 5.2.6, if there were more complaints, the NZ government would be able to accurately measure hazardous substance use and would be able to justify further regulation or even bans on neonicotinoids. Furthermore, product groups would be unable to mobilise the lack of bee deaths associated with neonicotinoids in their critical use cases sent to the NZEPA. This is just one example of how a change in one relationship or one loop being cut off would result in the breakdown of all the other loops and therefore, the entire network. Subsequently, the circulation of access to Manuka, contracts and the aforementioned records concerned with bee deaths, are speeding up the circulation of the "alliances" loop. This, in turn, accelerates the circulation of all the other loops and further embeds neonicotinoids in the agricultural practices of NZ's arable sector.

By aligning their interests with the NZEPA's the arable professions can form a strong "alliance" with the regulatory body charged with registering and reassessing hazardous substances in NZ. They have achieved this and strengthened the "alliance" by mobilising non-humans like grass grub, honeybees and the seed coating neonicotinoids in the form of critical use cases for neonicotinoids. The arable profession has been able to form an "alliance" with the NZEPA who are now convinced that seed coating neonicotinoids are highly targeted, environmentally friendly, are the best way to combat the endemic pest grass grub in terms of efficiency and environmental impact and are not linked to any cases of bee death in NZ. This strong "alliance" demonstrates the blood flow between the "mobilization of the world", "autonomization" and "alliances" loops, as well as the "links and knots" or the neonicotinoids that tie them all together into a coherent network. If one of those non-humans

was not circulated to the NZEPA or was cut out of the network, the entire system which embeds neonicotinoids in NZ's arable farming practices would likely collapse. For example, if those levy based product groups which represent arable growers at the regulatory level, did not mobilise seed coating neonicotinoids in their critical use cases to the NZEPA demonstrating that they are the only safe option for combatting grass grub, the NZEPA would likely be more inclined to reassess and further regulate neonicotinoids. As Latour expresses "each of the five activities is as important as the others, and each feeds back into itself and into the four others" (Latour 1999a, p. 99). Therefore, without allies no neonicotinoids and no agricultural practice for combatting grass grub; therefore, no proof to build an arable profession, and no hybrid seed production in NZ. Or in simpler terms, without the "alliance" of the NZEPA neonicotinoids would be more heavily regulated or even banned in NZ. Subsequently, the arable profession would not be able to grow 100% pure high yielding seed crops, and arable farmers would have to revert to using other hazardous substances to deal with pest pressure. This would simultaneously contribute to increased cases of beehive deaths, consumer demands would no longer be met, and neonicotinoids would ultimately die in this agricultural sector.

Public concern over the quality, accessibility and traceability of their food likely impacts regulatory decision made about hazardous substance applications and regulatory controls around food safety. However, as explained throughout this thesis, there is a generational gap between arable production occurring in NZ and the end consumers, or the public interested in those agricultural practices contributing to the production of their food. Nevertheless, public demands internationally and particularly those in Europe are helping to define the object of this network. It is defining the agricultural practices occurring in NZ's arable sector. Similar to how finding solutions for public concern is a major motive for the activities of academic communities, meeting consumer demands is a major motive of agricultural ones. For example, there is a growing demand, from consumers, to have fresh food available all year round, which has led to the globalization of food production. As explained in Chapter 2, this export of agricultural commodities has long been a part of NZ's supply chain. Thus, one could argue that NZ's arable production is answerable to the concerns of international publics. It is international seed companies who translate the interests of their publics, fresh produce every day even out of season, into their own interests, gaining a 100% pure and high yielding seed crop out of season. It is here that the arable profession becomes concerned with public demands, and therefore the "public representation" loop is connected to the "autonomization" loop. Subsequently, this public demand is strengthening neonicotinoid use in NZ's arable sector. As with the previous blood flow between loops, if the international seed companies did not translate the interests of their consumers, the entire network would fail.

Another public, whose impact on NZ's arable sector's neonicotinoid use is likely more difficult to disprove, are the users of that seed grown by NZ arable growers. These are those fresh product

growers situated internationally who purchase the NZ grown hybrid seeds from international seed companies. As discussed in the "public representation" section, they demand high yielding high-quality seeds which express certain traits and are free from pests, weeds and diseases. Here the arable profession becomes concerned with public demands, the international seed companies translate these demands to the NZ based seed companies and subsequently the arable growers. Like above, if this translation did not occur, or there was not the same scrutiny around the quality of seeds, neonicotinoids may not be embedded in NZ's agricultural practices because the international seed companies might simply contract their seed production to a different country where it is a lot cheaper. Or if seed production remained in NZ, but international seed companies' expectations were different, NZ seed and chemical companies would similarly have different translations and may no longer mobilise seed treatment neonicotinoids to arable growers, and arable growers might be able to gain market access without the assurance that they have used neonicotinoids.

The "links and knots" of the model described above are directly moved by the four other loops, but at the same time, the "links and knots" are what "keeps them [the other loops] altogether, what strengthens their cohesion, what accelerates their circulation" (Latour, 1999a, p. 108). So essentially as Latour puts it "we have followed the veins and arteries and arrive now inevitably at the pumping heart" (Latour, 1999a, p. 106). This heart is both hard to study and hard to define as it is a very tight knot at the centre of a net which must hold many diverse resources together. If circulation stops in only one loop, the circulation of the whole model will stop because each loop is connected to each of the other four loops. Therefore, each of the activities, things, places and relationships described above are directly connected to the "links and knots" of this model. In the case of NZ's arable sectors and its use of neonicotinoids, the "links and knots" is the strong and heavily embedded agricultural practice of using neonicotinoids. This is linked to the "autonomization" loop as it is the arable profession or actors within it who are directly applying the neonicotinoid to seeds and then planting those treated seeds. This link between these two loops is so strong the "links and knots" might appear independent from the other loops. However, any change to the other loops can change the circulation between the "links and knots" and the "autonomization" loop. For example, an increase in consumer demand for transparency through more generations of food production, or an NZEPA reassessment of neonicotinoids would directly stop this circulation, NZ seed and chemical companies would no longer include neonicotinoids in their crop management plans, and therefore arable farmers would not use it anymore. However, as it goes, neonicotinoids are heavily embedded -and maintained- in NZ's arable sector.

6.3 The apples and pears sector, the destabilized network

This research revealed a second network that was not anticipated at the outset. While following the actors using Latour's CSSF (1999a) I was pointed towards the relationship between growers and grower groups and it was through interviews with these actors, particularly the grower groups that this loop emerged. Because my research began as an investigation of NZ's agricultural industry as a whole, I thought it was a good idea to interview actors who were involved in the production of various agricultural commodities. Therefore, I reached out to grower group representatives from not only the arable sector but also NZ's apples and pears sector. It was during interviews with these individuals that it emerged that while in the arable industry neonicotinoids are heavily embedded in crop management practices, that is not the case for the apples and pears sector. What follows is an analysis of the apples and pears sector using Latour's CSSF (1999a) that subsequently reveals the discontinuation of neonicotinoids rather than its on-going use observed in the arable sector.

Autonomization

Once again, this loop refers to how a "discipline, a profession, a clique or an invisible college becomes independent and forms its own criteria of evaluation and relevance" (Latour, 1999a, p. 102). But unlike the previous network here this invisible college is made up of fresh product growers, apples and pears NZ and domestic as well as international supermarkets. This invisible college is made up of those actors interested in the production of high yielding and high-quality fruit crops.

A fruit crop is subject to a different level of scrutiny and undergoes different tests depending on which supermarket is buying the product. This scrutiny normally includes various quality assurance tests, including checking the size, quality and ripeness of the fruit as well as testing the levels of chemical residues that are on it. The relationships in this loop are built on the exchange of resources. The supermarkets circulate quality standards to apples and pears NZ, who in return, connect the supermarkets to NZ growers. In exchange for a levy paid by growers, apples and pears NZ exchange crop protection plans which ensure residue levels are met, marketing services, industry representation and market access. Having been put in contact with the domestic and or international supermarkets growers send produce to the supermarkets in exchange for payment, under the condition that those quality assurance standards mobilised by the supermarkets are met. All going well resources and negotiations circulate through this loop and subsequently strong relationships and the apples and pears profession is made and maintained.

Alliances

This loop bears the most similarity to that described in the arable sector. It is again made up of two separate "alliances" in which an exchange of resources effectively interests powerful and well-endowed actors. Here only one actor has changed, and that is simply due to the agricultural sector

which this network represents. Instead of an arable product group, this loop now describes apples and pears NZ. Functionally this loop has not changed, the action or the circulation of this loop is virtually identical to that described in the arable sector. As above it considers the relationships between product groups and the NZEPA as well as landowners and beekeepers. Once again, it represents the action of the invisible college to interest powerful actors in their farming practices.

The first “alliance” exists between the NZEPA and apples and pears NZ. Once again, this relationship relies on the trade of resources, apples and pears NZ mobilise critical use cases for particular agricultural chemicals or crop protection methods to the NZEPA, and in exchange, the NZEPA may tighten regulation or allow there continued use under current regulation. As described in the arable sector, in terms of neonicotinoids, the NZEPA is convinced of its necessity to produce smaller crops, and because of the money, it generates for NZ.

The second “alliance” is that between landowners and beekeepers, once again this “alliance” relies on the transfer of pollination services from the beekeeper in exchange for finances and sometimes access to honey-producing stances of native bush. It is still an informal “alliance” where landowners must convince beekeepers of their farming practices, particularly those with the potential to harm beehives (see section 5.2.6). Landowners (fresh product growers) in the apples and pears sector, like those in the arable sector, generally mobilise contracts which offer beekeepers compensation if their beehives are poisoned and a reasonable warning time before they spray. Furthermore, landowners might mobilise access to stances of highly valued Manuka (see section 5.2.6). These intermediaries serve to convince beekeepers of the agricultural practices occurring in the orchards. Beekeepers are not passive in this relationship they also circulate resources to influence those agricultural practices, including contracts which protect their hives from being poisoned, pollination services and in some cases where bee sites yield Manuka honey, a fee for leasing that site. Like in the arable sector, in the unlikely case where a beekeeper's hives are poisoned, they are unlikely to complain due to the risk which this may pose their income. That income being those finances they earn from either the pollination services they provide or the Manuka honey they produce. Essentially this “alliance” is strengthened, and beekeepers are convinced of the farming practices because of the finances they earn, and the risk which complaining about the practices might cause their business.

Public representation

In this “public representation” loop, we can see some of the most significant differences between the arable sector and the apples and pears sector. Where consumer demand in the arable sector helped drive the use of hazardous substances like neonicotinoids in farming practices, here it is doing the opposite. There is no generational gap between the fresh product growers and the consumers like there was in the arable sector. The apples and pears sector is producing fresh products going directly

to supermarkets around the world for immediate consumption. As before consumers are demanding fresh produce on their shelves every day. However, due to global trends (see section 2.6), these same consumers are becoming more and more conscious of what is going into the production of their food. Subsequently, consumer demand is now having a large effect on those agricultural practices occurring in a farmer's field or a grower's orchard. As explained in section 5.2.3, many of NZ's high-value apple and pear export markets have been going through a transition process away from certain chemicals, neonicotinoids being one of the most controversial of these. So a growing consumer awareness of the practices contributing to the production of their food, a demand for a more transparent supply chain and stigmas around particular chemicals, particularly in regions of the world which have previously banned their use, are influencing the agricultural practices occurring in NZ's apples and pears sector.

There is a relationship here which again relies on the transfer of resources. International consumers of NZ's apples and pears are exchanging payment to supermarkets, and in return, they are receiving and expecting fresh fruit, which is free from agricultural chemicals all year round. Essentially this consumer demand for fewer chemicals is being circulated through all the loops of the network. This circulation and the effect which this is having on the ultimate use of neonicotinoids in NZ's apples and pears sector will be explained below.

Mobilization of the world

There are a number of differences between this loop and that one described in the arable sector. Grass grub is not present in this network; however, other insect pests, like aphids, are and are likely the reason why neonicotinoids have been used in apple and pear orchards in the past. A significant difference is that these insect pests do not come with the same inability to treat and lack of alternatives that have been a problem for grass grub control. Another significant difference is the presence of seed treatments, due to the nature of the orchard industry neonicotinoids or similar insecticides are applied as a spray or soil drench. This means that the apples and pears sector cannot benefit from the low eco-toxicity levels that seed treatment neonicotinoids exhibit. Although I could likely go on and on about the different things and sites being mobilised in the apples and pears sector compared to the arable sector, there are just two interesting things which significantly impact the circulation of this network and the discontinuation of neonicotinoids in the apples and pears sector.

These things are honeybees and maximum residue levels (MRLs). Although honeybees are mobilised in the arable sector, they are mobilised here in a different loop of the network representation and to a much different effect. More specifically, the mobilization of honeybees by consumers are leading to the mobilization of MRLs by supermarkets which is subsequently impacting the way in which neonicotinoids are being used in the apples and pears sector.

So as economists spit out reliable data thanks to a new survey (Latour, 1999a, p. 101), consumers of NZs apples and pears, particularly those in Europe can now demand lower use of agricultural compounds in the production of their food, thanks to regulatory changes, transparency of supply chains and consumer trends. More specifically and getting back to the core tenant of this thesis, European consumers are able to mobilise the regulatory changes around neonicotinoid use in Europe and the effects which neonicotinoids have been shown to have on honeybees (see section 2.6) to demand that neonicotinoids be removed from the production of their food. Immediately this brings together multiple sites of this controversy, the consumer's home and the supermarket. Immediately this demand, these regulatory changes, the effects on honeybees and global trends are translated by international supermarkets into a form which renders itself immediately useful in arguments with the apples and pears profession. This form is MRLs or the maximum levels of chemicals allowed on fresh products by supermarkets. Consumers of NZ's apples and pears and therefore international supermarkets do not favour neonicotinoids. Therefore, they implement a zero-neonicotinoid residue level to influence the agricultural practices occurring in NZ's apple and pear orchards (see section 5.2). Essentially if NZ's apples and pears do not meet the quality assurance standards implemented by the international and domestic supermarkets, they will not be accepted. How this mobilization of MRLs circulates through the "autonomization" loop and then the rest of the network will be discussed below.

Links and knots

Once again the "links and knots" draw our attention to what is ordering, managing and collecting together the world described in the other four loops of the network, that world composed of "data, colleagues, allies and spectators" (Latour, 1999a, p. 108). Like in the arable sector, the "links and knots" of the apples and pears sector are neonicotinoids as an agricultural practice. What has been demonstrated is that the area which manages, propagates, determines and implements neonicotinoids as an agricultural practice is much larger and more heterogeneous than one would initially recognize. Farming practices are not simply a determinant of farmer preferences, market pressure, or legislation. This Latourian representation of the machinations which deliver and determine neonicotinoid use in NZ's apples and pears sector suggests that it depends on the continued formation of a collective. This collective which links together various sites, from farmers' fields to a European household or a French supermarket to the offices of apples and pears NZ etc. Furthermore, this collective is dependent on the trade of resources, the translation of interests and the strengthening of relationships.

The apple and pear sector's blood flow

As explained in the blood flow of the arable sector, a slight change in any of the loops would stop the blood flow of the network and virtually kill neonicotinoids as an agricultural practice. So, while

neonicotinoids as an agricultural practice are very much embedded -and maintained- in the arable sector, it has been removed from NZ's apples and pears sector. This is due to differences in key relationships, actors, things and sites. This section describes those differences which have stopped the blood flow of the apples and pears sector, which subsequently lead to the removal of neonicotinoids as an agricultural practice.

The circulatory system of scientific facts suggested that five activities, which have simultaneously been performed and worked, have embedded and maintained neonicotinoids in NZ's arable sector, while slight differences to them have led to neonicotinoids being removed from NZ's apples and pears sector. In both networks these activities are; the creation of neonicotinoids as an agricultural practice (links and knots); the making of things, documents, sites and other non-humans available for arguments about neonicotinoids (mobilization of the world); the forming of an invisible college who all share the same goal (autonomization); making "alliances" with important and powerful actors (alliances); and aligning the agricultural practices with the demands of consumers (public representation). Unlike the arable sector, neonicotinoids have not become embedded here, suggesting that some part of the network has not worked in harmony with the rest of it. Instead, it has disrupted or changed the blood flow, which was maintaining neonicotinoids.

Although it is not normal to follow the blood flow of a Latourian network by beginning at the "public representation", for the purpose of demonstrating how neonicotinoids have been removed from the apples and pears sector this is a suitable place to begin. In interviews with members from both sectors (Chapter 5), it was very apparent that both arable and fresh product growers are answerable to the demands of the consumer. As explained in the blood flow of the arable sector, a generational separation and a translation of consumer demands by international seed companies contributed to the circulation of specific interests which led to the embedding of neonicotinoids. On the other hand, the apples and pears sector has no generational gap, and the demands of the consumer are slightly different. Rather than just demanding fresh food on their shelves every day, consumers of NZ apples and pears want to know what practices are contributing to the production of their food. Moreover, they want to make sure that chemicals which they are concerned about and are banned where they live are not being used in the production of the food which they eat. Just like how members of the arable profession translated the demands of their consumer and aligned their interests to meet those demands, the apples and pears profession has done the same. This is because meeting consumer demands is a major concern of agricultural communities. What results from this is a connection between two sites of this network. Supermarkets are directly connected to the consumer, through the transfer of resources, consumers give payment in the form of money to supermarkets and receive fresh products which are free from unwanted agricultural chemicals, like neonicotinoids, in return. As stated earlier, it is the supermarkets which translate this demand, fresh

products free of neonicotinoids, into something which is understandable and aligns with the interests of the apples and pears profession, that interest being market access and sale of product. What this demonstrates is that changes in the interests of the public have changed the way the "public representation" loop is acted out: a lack of generational gap and the interest of the public in consuming food free of agricultural chemicals, particularly neonicotinoids, alters the role of the market (here the supermarket, in the arable sector the international seed market/companies).

If we continue to follow how this different consumer demand moves through the network, altering it and stopping the neonicotinoid blood flow as it goes, we next come across the international and domestic supermarkets and how they translate this demand. In order to meet those demands of their consumers and maintain the supply chain of NZ apples and pears, those supermarkets which are a part of the apples and pears profession make these demands mobile by converting them into MRLs. These MRLs are immediately useful in arguments with their colleagues or those other actors in the "autonomization" loop (Latour, 1999a, p. 101). As stated, earlier supermarkets like to control their own regulation and quality assurance programs by implementing strict standards which products must meet. These standards act as an industry-standard which individual producers must meet if they wish to gain market access and sell their product. So, the question of what agricultural practices should be used in the production of apples and pears is not just a focus of fresh product growers and apples and pears NZ but a focus of supermarket quality assurance standards that pay close attention to consumer demands. The mobilization of MRLs are likely the most significant difference between the two networks, and if I was to pinpoint the cause of neonicotinoid removal in the apples and pears sector, I would say it was here.

The mobilisation of MRLs by supermarkets are serving to directly destabilise neonicotinoids. From this point, the entire network begins to break down and the circulation of relationships, things and sites that embed neonicotinoids halts. Instead, what circulates through the "autonomization" loop is quite the opposite. If for no reason other than to maintain market access, apples and pears NZ has translated these MRLs into the crop protection plans and advice which they issue growers. Simply they remove neonicotinoids from the crop protection plans, introducing an alternative and advising growers about changes in supermarket regulation and consumer demand. Apple and pear growers have responded to this by doing exactly as advised, removing neonicotinoids from their crop protection programmes and implementing the recommended alternative. Essentially fresh product growers have "tended to move away from them [neonicotinoids] and look for alternatives" (Product Group Representative 1). Therefore, the differences in consumer demand and the subsequent mobilization of MRLs has led to the removal of neonicotinoids in NZ's apples and pears industry. Even though this was a minor change in the "public representation" loop of the network, it rippled through the "autonomization" and "mobilization of the world" loops.

There is not much more to say about the removal of neonicotinoids in NZs apples and pears sector. The pumping heart at the centre of this network, or the "links and knots" tying it all together, has changed because the blood-flow no longer circulates, neonicotinoids no longer circulate. I will explain how these changes circulate through the remainder of the network all though it seems impractical and irrelevant to do so. It is unlikely that this would change the "alliance" between landowners and beekeepers at all because as explained by one beekeeper it does not matter what insecticide a landowner is using "it's still the same end-product for us. You're still killing insects" (Beekeeper 1). Furthermore, this relationship was never dependant on the specific use of an agricultural chemical. Instead, all that mattered, for both parties, was an exchange of resources and hopefully some level of protection for the bees. But the removal of neonicotinoids will not affect the price of Manuka honey, the cost of pollination or the sensitivity of this relationship, so beekeepers still will not complain because of any potential risk of losing their income. There is potential for the removal of neonicotinoids to trigger some complaints, but complaints about another chemical. Because beekeepers or at least those interviewed as a part of this thesis are more scared about what you would replace neonicotinoids with than the neonicotinoids themselves (see section 5.3.6).

In terms of the "alliance" which apples and pears NZ hold with the NZEPA, one could speculate that if there is any future call for information about neonicotinoids or a future reassessment of this class of insecticides, the lack of benefit and critical use cases from this highly valuable sector might contribute to their eventual banning. What I am suggesting here is that in the past this sector would have put forward benefit cases to defend neonicotinoids, but since they no longer use them and it has effectively been removed from agricultural practices, it is unlikely that apples and pears NZ would invest resources into helping defend a compound which they do not use, and which their consumers do not want used. It is more likely that their defence and commitment might relocate to another chemical. It is likely that the relationship between these two actors remains, but no longer to embed neonicotinoids. This is because there remains the issue of there not being enough tools in the toolbox (see section 5.2.2).

So what does this all mean? Well, at the outset of this thesis, I thought neonicotinoids were heavily embedded in all NZ's agricultural practices. What was being presented in the media at the time was rhetoric suggesting NZ's entire agricultural production and therefore, the economy, relied on this insecticide. What I have demonstrated here is that this is not actually the case. I have shown that NZ's agricultural industry cannot be considered as a single case study in terms of agricultural practice or hazardous substance research and I have also demonstrated that neonicotinoids are at various stages of making and maintenance depending on which agricultural sector you look at. More specifically neonicotinoids as an agricultural practice are very much embedded -and maintained- in the seed-producing and arable sectors of this country while at the same time it has been removed

from those fresh product sectors selling directly to international supermarkets, like the apples and pears sector.

6.4 What has the CSSF taught us about agricultural practices

During this research, I used Callon's key principles (1986) and Latour's CSSF (1999a) to answer the primary objective, how have neonicotinoids remained embedded in NZ's agricultural practices. To answer the fourth and final research question of this thesis: How can Latour's CSSF be used to investigate similar controversies in the future, in particular, those which involve hazardous chemicals used in NZ agriculture?; this section discusses how this tool helped deepen an understanding of hazardous chemical and agricultural practice controversies by bringing forward some aspects obscured in previous studies. During the presentation of the interview data (Chapter 5) and its subsequent analysis (Chapter 6), it has emerged that the making and maintenance of neonicotinoids, cannot be solely described as being a scientific enterprise (Ingram, 2007; Warner, 2016) or coming down to individuals' decisions, motivations and interests (Bangura, 1983; Lalani et al., 2016). Instead, it should be seen as having a collective relational nature, whereby each relationship is defined by the trade of material intermediaries (Callon, 1991, p. 134). Therefore, this section describes the main avenues in which Latour's CSSF (1999a), helped in understanding neonicotinoid use.

Previous studies have explained agricultural practices as being driven through economic, physical and environmental factors as well as by the values of individual farmers (Lalani et al., 2016). This study holds some underlying idea that the embedding, change or uptake of agricultural practices can be explained solely by the motivations, principles and actions of individuals. By doing this and adopting an individualistic point of view, it has overlooked the collective and relational nature of agricultural practices, which is obvious in this thesis. This collective and relational nature, is exactly what the CSSF has demonstrated in this thesis, neonicotinoids are made and maintained not just by the individual decisions of farmers, but it is dependent on the product being produced, the development of material relationships (Latour's 5 loops), the presence or absence of non-humans and the trade of intermediaries to translate meaning and interest powerful actors. By attempting to explain agricultural practices as being caused by isolated motivations, Lalani et al. (2016) has oversimplified the complexities behind agricultural practice decision making. By using the CSSF, this case study has highlighted the complex relational and collective nature of agricultural practices and moved away from the traditional explanations of action. Agricultural practice decision making must now be treated as a relational phenomenon which contradicts the view that farmer motivations and characteristics determine agricultural practices (Bangura, 1983). The CSSF has helped bring forward the relational nature of agricultural practices, doing away with the individualistic approach normally associated with studies of agricultural practices (see section 3.4.1). The relational focus of this

research is not restricted to humans but includes non-humans like grass grub and MRLs. Callon's key principle of "generalised symmetry" insist that non-humans are brought to the fore and are acknowledged as being active in relationships. By utilising these tools, I have observed how non-humans are active partners in some relationships. Subsequently, I have been able to describe how grass grub is contributing to the embedding of neonicotinoids in NZ's arable sector, and MRLs are contributing to the removal of neonicotinoids in the apples and pears sector.

The CSSF interpretation of neonicotinoid use (section 6.2 and 6.3) shows how the trade of resources (intermediaries) has influenced this agricultural practice in many different ways. For example, it shows how neonicotinoid use can vary between sectors, which ultimately depends on the material relations that connect growers to their markets and the presence or absence of particular non-humans. Rather than describing the embedding of neonicotinoids as being determined by the actions of particular individuals, I have followed Callon's key principles and used the CSSF to give greater importance to the relations between actors. Subsequently, I found that neonicotinoids are only used following successful negotiations between several actors. By adopting ANT, I was encouraged to view agricultural practices as being formed through the development, maintenance and break down of relations between actors. Subsequently, it is not accurate to describe agricultural practices as being isolated in action. Instead, they are in a continuous flux, shaped by the relational processes occurring in and out of NZ's agricultural communities. Agricultural practices, from a CSSF perspective, are shaped by the continuous negotiations, trade of "interessement devices" and resources that happen between actors over time. These processes subsequently strengthen and weaken the relationships between actors that embed neonicotinoids.

There is growing pressure for agricultural practices to change (Ingram, 2007), yet the factors driving agricultural practices remain poorly understood. Because Latour's CSSF (1999a) brings what is commonly called the "context" into the material relations that must be traced (pp., 98-99). The case study, or should I say case-studies, central to this thesis suggests that the context surrounding agricultural sectors play an influential role in shaping the on-going use -or discontinuation- of agricultural practices in each sector. Aspects such as political, ethical, environmental and scientific contexts help shape agricultural practices (Ingram, 2007; Warner, 2016). In line with these studies, the CSSF has improved an understanding of how the context surrounding an agricultural sector influences the making and maintenance of neonicotinoids in NZ. My research suggests that the relationship between the agricultural profession, their markets and the public is particularly important when identifying what shapes agricultural practices. For example, in the apples and pears case study it is a change in the public representation loop which has led to neonicotinoids being removed from agricultural practices. Like studies which suggest that looking beyond the boundaries of the laboratory can provide new light to understand the making and maintenance of scientific facts

(Edwards, 2014; Warner, 2016), this research suggests that the adoption of agricultural practices is better understood by looking beyond the boundaries of a particular community.

The CSSF did not explain the embedding of neonicotinoids as solely coming down to the need to deal with pasture pests across NZ, nor was it explained solely by the need to meet high yield requirements. Instead, the CSSF revealed that neonicotinoids use is being shaped by the relations developed between actors within and across networks, and the context surrounding NZ's agricultural sectors. For example, NZ's arable sector is one generation away from a final consumer, and its public can be considered those fresh product growers in Europe who buy their seed. That public is demanding the production of high-quality seed that is free of pests, weeds and diseases. A series of translations of this demand circulating through various relationships results in NZ's arable growers using neonicotinoids to minimise the vagaries of growing outdoors and secure market access.

On the other hand, there is no generational gap between the apples and pears sector and the final consumer, who are consumers of NZ's apples and pears in Europe. This public is demanding minimal use of agricultural chemicals in the production of their fruit and have a stigma against neonicotinoids, because of the bans in Europe. Again, through a series of relationships, translations and mobilizations of non-humans, apple and pear growers have been connected to their market and are shaping their agricultural practices to meet those demands of the public, they have removed neonicotinoids from their crop protection programmes.

6.5 Overcoming the limitations of the key principles of ANT and the CSSF

The previous section showed how this study has provided an alternative interpretation of hazardous chemical use in NZ's agricultural practices, particularly surrounding those which are very controversial. I argued that the CSSF (1999a) is a powerful theoretical tool for demonstrating and bringing forward the material, relational, historically shaped and evolving nature of agricultural practices, like the use of neonicotinoids. This section follows on by providing insight into how this research was shaped by the CSSF and Callon's key principles (1986). It also discusses how I was able to overcome some of these tools' limitations.

6.5.1 Responding to general critiques of ANT

Callon's key principle known as "general symmetry" demands that agency be ascribed to human and non-human actors (Callon 1986). It is argued that humans and non-humans must all be seen as active entities with an ability to "exert detectable influences on others" (Law, 1987, p. 132). However, this principle has been criticised by many who believe that the adoption of a symmetrical view "degrades our understanding of action by obscuring the fact that it is only through the intervention of humans that agency - and thus political transformation of social arrangements - can occur" (Whittle and

Spicer, 2008, p. 620). As Latour (1983) demonstrated how the development of an anthrax vaccine in 19th century France is made possible by Pasteur's ability to bring together diverse human and non-humans elements, I have demonstrated how neonicotinoids are embedded in NZ's arable sector because of a similar coming together of various humans and non-humans. Thus, by following the principle of "generalised symmetry", I have demonstrated how neonicotinoids are embedded -and remain- in NZ's arable sector. Essentially this principle enabled me to demonstrate how non-humans like grass grub, MRLs, seed treatment neonicotinoids and honeybees had agency in both the arable sector and the apples and pears sector networks. Like Dankert's (2011) assertion that "humans first shape the buildings and then are shaped by the same buildings", MRLs, for example, are shaped by supermarkets and then shape the action of apples and pears NZ as well as fresh product growers. In response to Whittle and Spicer's (2008) critique of "generalised symmetry", I say this, first and foremost ANT network representations are "about how to study things" (Latour, 2005, p.142), they have never professed to be about "the social" (Latour, 1999b, p.22). Therefore, by avoiding the hierarchies that privilege human agency, the CSSF in conjunction with Callon's key principles (1986) has allowed me to acknowledge and describe how things, as well as humans, are embedding neonicotinoids in NZ's arable sector and killing them in NZ's apples and pears sector.

Next, Callon's principle of "agnosticism" has been criticised for ignoring social demographics and power structures like racism and patriarchy (Bloor, 1999; Harding, 1992, 1998, 2008; Restivo, 2010). This mainly comes down to "agnosticism" rejecting the existence of any *a priori* attribution of scale to social entities, which therefore assumes that "networks are immersed in nothing" (Latour, 1999b, p. 128). Essentially Callon's principle of "agnosticism" is critiqued because it ignores social demographics and power structures like racism and patriarchy at the outset. This radical position suggests that society does not exist only actors and their relations exist (Latour, 1996; Munir and Jones, 2004). Subsequently, aspects which might have characterised the arable and apples and pears sectors were not appropriately illustrated through the CSSF (Latour, 1999a) when informed by Callon's key principles (1986). Although the CSSF helped me identify the relevant actors of each agricultural sector, it became very clear through the data collection and thematic analysis (Chapter 5) that more than just those actors identified, and their relationships influenced the use of neonicotinoids. For example farmers individual taste for crop protection practices (see section 5.2.5), reps desire to sell chemicals (see section 5.2.4), the resources required for the NZEPA to complete a reassessment and the resources required for product groups to find an alternative (see section 5.2.2), also influenced neonicotinoid use. Therefore, the strict use of the CSSF to analyse the data in sections 6.2 and 6.3 meant that these aspects were obscured and not discussed because the CSSF's loops are not sensitive to aspects such as individual preferences and the availability of resources. However, I was able to avoid a complete faux pas by employing a thematic analysis of the data.

6.5.2 Avoiding the objective and un-reflexive approach when following the actors

In his book "After Method" John Law (2004) states that researchers need to ask if they are able or willing to recognise that their methods also craft realities. Essentially, we should act in self-reference which

> *…requires an awareness of the researcher's contribution to the construction of meanings throughout the research process, and an acknowledgement of the impossibility of remaining 'outside of one's subject matter while conducting research. Reflexivity then urges us "to explore the ways in which a researcher's involvement with a particular study influences, acts upon and informs such research. (Nightingale and Cromby, 1999, p. 228).*

Law (2004) continues by saying that this act is not self-indulgent, but possible and necessary to do, especially in a world which has multiple 'goods'. These 'goods' are the truths and non-truths, realities and non-realities, presences and absences, but also arrangements with political implications which a collection of methods might create (p. 143).

> *[research methods] have effects; they make differences; they enact realities; and they can help to bring into being what they also discover (Law and Urry, 2004, pp. 392-393)*

Therefore Law (2004) challenges researchers to ask the questions: what does standard method assemblages silence? Which possible realities does it refuse to enact in its dominant insistence on that which is smooth? And how might it be crafted differently?

Network representations can act as a lens to view the world as a network of relations, distributed and networked equally between human and non-human actors (Latour, 1987, 2004). The way network representations distribute agency has been criticized because it is "never based on the reflexivity of the actor itself but depends wholly on the researcher or one voice in the field that speaks for the network. This voice becomes the only truth" (Jansen, 2016). Therefore, what follows is an account of my attempts to be self-reflexive, in doing this I hope to somewhat make up for this inevitable faux pas of using a network representation to make sense of reality. I also hope to shed light onto how I ascribed agency and followed the actors and finally alarm any future researchers of the traps I fell into.

Another relevant critique argues that network representations like Latour's CSSF (1999a) and research which uses Callon's key principles (1986) adopt an objective stance (Murdoch, 2001). This is because they tend to impose their "own theoretical lexicon" (Whittle and Spicer, 2008). The interpretation of the networks presented in this thesis by no means matches the world of the interview participants. This is largely because the vocabulary being used is vastly different from that used by the interview participants. Which can result in research, utilising the CSSF and Callon's key

principles, offering superior views and assuming that other explanations are wrong (Whittle and Spicer, 2008).

To combat these critiques, I provided a thorough description of the case and the participants. I also presented many quotations which give insight into my translation of the interview participants' responses. Furthermore, to ensure various perspectives were considered and therefore, a fair representation of the network given, interview participants from across NZ's agricultural and horticultural industries were considered. On top of this, interview participants were chosen from across what one described as a bell curve of agricultural practices (Arable Grower 3). This bell curve is regarding the involvement of landowners in the daily agricultural practices occurring on their property. At one end are the landowners who do everything themselves and at the other are those who rely entirely on someone else. There was a conscious effort to avoid using vocabulary from Callon (1986) and Latour (1999a) in the interview questions, so to avoid imposing this same vocabulary on the participants. By using a list of pre-determined questions, a fair representation of each actor was gauged, and the imposition of my views was avoided.

Another danger of using these two tools is the risk of applying them unreflectively in order to verify their universality. Whittle and Spicer (2008), discuss this in terms of Callon's (1986) four-stage model of translation, however, I can see how the same critique may be applied to Latour's (1999a) CSSF. Like how the four steps of translation might be good for interpreting scallop fishing, so might the CSSF be good for interpreting research on the potential of a nuclear chain reaction in uranium (Latour, 1999a). Nevertheless, in both cases, it would be problematic to assume that they can be applied to any setting (Whittle and Spicer, 2008). Essentially there is a danger that new studies using these models "are reduced to a series of deductive tests that confirm or refute" either framework, rather than "being a process of inductive theory generation theory that is grounded in and emergent from the empirical data" (p. 618). What results from this is that users of these network representations present their own interpretations as the truth, while treating those of others as relative (Whittle and Spicer, 2008). Unfortunately, I fell into this trap, by forcing the data into those categories, or loops, described by Latour (1999a). This only occurred after some effort to try and explain the empirical complexities of each case which I observed. However, due to time limitations, I conceded to pursuing the simpler and less accurate analysis of neonicotinoids. Rather than taking the CSSF (Latour, 1999a) and departing from its loops, as Edwards (2014) has done, I squeezed the relationships and actors I observed into the preconceived model.

It is the actors in the network who determine how the phenomena will proceed. Essentially the actors will set the research agenda and the researcher follows the actors (Latour, 1987). Therefore, the topic for a research project may have arisen because of the misinterpretation of the object of

study, e.g. my predisposition as a beekeeper may have meant I saw a controversy around neonicotinoids where one did not exist. In this case, it would make little or no sense to continue with the research. Furthermore, if the participants had not heard of or did not know about neonicotinoids, it would also make little sense to continue with the research project. During this thesis, this situation did arise in some circumstances. During my data collection, I found that the interview participants were either experts on neonicotinoids or knew very little about them. Rather than changing the actors whom I followed or changing the research topic, I focussed more on the broader concept of how agricultural practices become embedded in NZ, using neonicotinoids as a detailed case study throughout the thesis.

I attempted to remain a passive observer outside of the network throughout this research. However, I quickly found out that actors react to being observed and followed. In one situation a NZ based seed and chemical company representative, who had agreed to be interviewed, pulled out due to the sensitivity of the neonicotinoid controversy. Fortunately, this reaction only happened in one circumstance, and it was not significant enough to result in any flow-on effects. This research was fortunate in that the size of the network and the sheer number of potential interview participants meant that I could study the phenomenon without my presence influencing the network itself.

To compensate for this participant pulling out of interviews, I not only found press releases, newspaper articles and other written information related to them, but I also interviewed individuals around that NZ seed and chemical company representative, asking questions about their relationship with them. A lot of the information I uncovered was directed to specific audiences and subsequently had a positive message regarding neonicotinoids. The large variety of information sources which I used had the added benefit of triangulating my interview data. Subsequently, I was able to continue following the actors. However, sometimes this was at a distance rather than through direct interviewing. This has illustrated the idea that there is no divide between subject and object (Latour 2012). Like Edwards (2014), I have highlighted this lack of divide as an important methodological issue that likely affects how research is conducted. Essentially researchers can be followed, enrolled and mobilised in the networks which they study, and therefore they cannot simply follow the actors.

6.5.3 Inclusion and exclusion of actors

When addressing the directive to follow the actors, how does one go about identifying who and what to include, and how does one know when to stop following? Therefore, this section discusses the issues I came across when deciding what actors to include and exclude from this thesis.

A significant issue I came across at the outset of this research was that ANT literature does not really offer strategies for defining research boundaries. Furthermore, it offers little direction on how to

decide what to include in the network? Therefore, before I could even begin thinking about my data, I came across two issues, where to set the boundary and when to stop looking for actors. In this research, a small change in one agricultural sector was enough to change the boundaries. It has been suggested by Bloomfield and Vurdubakis (1999) that while researchers using Callon's key principles (1986) must try to remain impartial and consider all actors, ultimately the process of selecting appropriate actors to study is dependent on the suppositions about what actors exist and their relative positions within possible networks. It has also been noted that networks continue to evolve and translate as some actors join, and others leave. Because Callon's principles (1986) require researchers to begin without preconceived notions, the researcher can include actors without predetermined criteria.

Therefore, one of the key issues is that previous works which utilise network representations rarely provide the boundaries of a research project. Subsequently, it is up to the researcher to select the paths he/she wishes to follow (including which actors) and to choose those which will be ignored. Most researchers using network representations likely have a much easier task at setting those boundaries than I had during this research. This is because network representations are normally applied to smaller-scale case-studies, like Edwards (2014) which focussed on a specific research project. Therefore, due to the scale of this case study, I had a much more difficult task.

Subsequently, I used Latour's CSSF (1999a) to set boundaries, and each loop directed me to look in a certain direction for the actors which I eventually found. As explained in Chapter 4, I utilised the loops illustrated by Latour in his CSSF (1999a) as a way of identifying actors. He describes the loops as being "5 types of activities that science studies needs to describe first if it seeks to begin to understand in any sort of realistic way what a given scientific discipline is up to"(p. 99). I set out already knowing that the "links and knots" of both networks were neonicotinoids and initially approached growers/landowners as they are the ones who use this chemical in their crop protection programmes. From here, I asked specific questions targeted at uncovering whom they held relationships with, in terms of neonicotinoid use, and what materials were traded in these relationships. From there, I followed neonicotinoids as they were translated, transformed and mobilised through the network.

Of course, this approach is imperfect. Latour (1993) tasks researchers to follow the actors, which I attempted to do. But this resulted in me continually finding more and more relations that may have contributed to the embedding -and maintenance- or removal of neonicotinoids. Subsequently, I had to be disciplined in deciding which actors and relationships were important. It was relatively easy to know when to stop interviewing participants. I stopped at the point where I did not hear anything new. However, this did not mean that I explored all the relationships mentioned in the interviews.

For example, Regulator 2 mentioned a relationship between the NZEPA and the Cabinet of NZ. Predominantly, I made decisions about what actors and relationships to include based on accessibility to data and how frequently it was referred to by the interview participants. For the most part, I heard about the same themes, relationships and actors during the interviews and the most common of these were discussed in Chapter 5, determining the discussions of sections 6.2 and 6.3. Furthermore, I made some decisions to exclude actors and relationships based on their perceived distance from the controversy at hand. For example, Arable Grower 3 spoke of how click-bait articles on social media are affecting the perception of the public about farming practices and how this is being exacerbated by global urbanisation. Not only were they the only participant to mention this relationship, but if I explored this, I would have to look at all those relationships which affect public perception of neonicotinoids.

This is by no means a perfect way of setting boundaries, particularly when analysing a case study or case studies that might impact most living things on this planet (Chapter 2). Subsequently, I must state that the results produced from this research can still be regarded as preliminary. An unfortunate but inevitable result of this limitation is that I may not have succeeded in realising the network and may, therefore, have produced an incomplete or misleading research story.

6.6 Summary

This chapter and more specifically sections 6.2 and 6.3 have answered the first three research questions: Who and what are the major actors that influence the scale and frequency of neonicotinoid use in NZ and what have been their roles? How have certain relationships formed between actors? How are neonicotinoids as an agricultural practice embedded -and maintained- in NZ, and why has opposing knowledge been unsuccessful in removing it?

The data which was collected and presented in Chapter 5 has been analysed here using Latour's (1999) CSSF. This enhanced my understanding of neonicotinoid use in NZ and more specifically the actors, relationships and materials which have led to them becoming embedded in the agricultural practices of NZ's arable sector and removed from NZ's apples and pears sector. These findings have suggested that the use of neonicotinoids as an agricultural practice in NZ is a very complex phenomenon that cannot be described as being solely shaped by scientific research or by the decisions, motivations and interests of individuals. It should instead be seen as having a collective relational nature. Not only has this analysis revealed that neonicotinoids are not as embedded in NZ's agricultural practices as previously thought, but its use and embedding depends on which agricultural commodity is being produced.

While on one hand neonicotinoids are embedded -and maintained- in the agricultural practices of NZ's arable sector they have effectively been removed from the apples and pears sector. NZ's apples and pears sector have removed neonicotinoids from their pest control programmes due to a change in the "public representation" loop and its circulation through the other loops of the network. Essentially, the apple and pears profession has responded to the international markets unfavourable view of neonicotinoids by restricting residue levels allowed on fruit and subsequently removing them from crop protection programmes.

Sections 6.4 and 6.5 have also answered the fourth question: How can Latour's CSSF (1999) be used to investigate similar controversies in the future, in particular, those which involve hazardous chemicals used in NZ agriculture? This has been achieved by outlining how the CSSF (Latour, 1999a) and Callon's key principles (1986) have contributed to my understanding of neonicotinoid use. Furthermore, I have outlined the issues which I came across while using these tools, as well as their common critiques. In doing this, I have described how I overcame those issues and combatted the critiques. Simultaneously, I have acknowledged where the boundaries and limitations of my research lie and admitted where I went wrong, offering some direction and solutions for future research. The following chapter will offer some examples of how this research has contributed to the literature as well as the ever-growing body of work considering agricultural practices.

Chapter 7

Conclusion

7.1 Summary of research findings

The overall aim of this thesis was to understand how neonicotinoids have become embedded -and remain- in NZ's agricultural practices. Subsequently, four research questions were identified and developed to reach this primary goal. The main findings of this research are presented below and are organised according to those research questions.

My first task was to identify and describe the major actors influencing neonicotinoid use in NZ. This began with an extensive review of publicly available documents which identified actors concerned with the use of neonicotinoids in NZ. The CSSF (Latour, 1999a) also help direct me towards those actors involved in the making and maintenance of agricultural practices. Once I had performed the initial interviews, I also used snowball sampling to try and encourage each participant to direct me towards individuals whom they thought would suitable for this research.

Some of the actors which this process identified were endemic insect pests whose abundance, and affinity to modified pastoral landscapes, have contributed to NZ's reliance on agricultural chemicals like neonicotinoids and are used by other actors to convince one another of the importance of neonicotinoids. Next, there are landowners, they are the ones using seed treatment neonicotinoids on their properties to combat the vagaries of growing outdoors, meet the expectations of their consumers and maximise their yields. There are also beekeepers, who endure the adverse effects of neonicotinoids so that they can maintain relationships with landowners and secure access to valuable bee sites. Therefore, they are unlikely to complain if their hives are poisoned. Next, there are seed and chemical company representatives and product group representatives, these actors form strong relationships with international markets to secure market access for landowners, while simultaneously providing landowners with crop protection programmes, which include neonicotinoids, to ensure that a crop is produced. They also try and convince regulators not to ban neonicotinoids by demonstrating to them that neonicotinoids are vital for the production of key export crops. There are also international and domestic markets, which demand neonicotinoids are used in the production of hybrid seed crops and which self-regulate chemical residues on food. Lastly, there are the consumers, these actors demand that high yielding crops and food, which are free of pests, weeds, diseases and in some cases chemical residues, are available all year round.

My next task was to describe how certain relationships were formed and maintained between those actors. The interview questions attempted to draw out empirical evidence regarding

neonicotinoids and encouraged the interview participants to discuss their relationships with the other actors listed above. This identified several relationships centred on the use of neonicotinoids in NZ's agricultural practices. To illustrate, analyse and discuss these relationships, Latour's CSSF (1999) was once again applied to the research. In summary, I found that neonicotinoids are embedded -and remain- in NZ's arable sector because of a series of material relations between arable growers, NZ seed and chemical companies, international seed companies, beekeepers, the NZEPA and consumers.

Firstly, what I have called the "arable profession" (autonomization) is formed by a three-way relationship between international seed companies, NZ seed and chemical companies and arable growers. International seed companies who demand high yielding and 100% seed crops interest NZ seed and chemical companies with payment and continued contracts to grow hybrid seeds in NZ, in return the NZ seed and chemical companies guarantee the production of 100% and high yielding seed crops by offering NZ's more relaxed rules when it comes to some substances deemed hazardous elsewhere (neonicotinoids). The NZ based seed and chemical companies subsequently mobilise crop protection programmes, payment and access to markets to influence the farming practices of NZ's arable growers. To secure their position NZ arable growers then mobilise a commitment to follow those crop management plans and use programs such as Agworld to confirm they have performed crop treatments as directed. Another relationship exists between arable growers and beekeepers (alliance). Essentially landowners convince beekeepers of their agricultural practices (use of neonicotinoids) by mobilising formal contracts, access to stances of highly valued Manuka and a fee for pollination services. Beekeepers similarly pay for access to honey-producing flora to interest arable growers in this relationship. Subsequently, due to the growth of NZ's honeybee population and the Manuka honey market, those beekeepers with access to Manuka are unlikely to complain even in cases where their hives have been poisoned, this is due to the risk it poses their income. Next is the relationship is between the NZEPA, arable product groups and arable growers (alliance). Once again, this relationship relies on the trade of resources; product groups collect levies from growers based on yield, land area or at a fixed rate and in return and growers receive marketing, research and development as well as some practical support in return. Arable product groups also provide lobbying of the NZEPA, convincing them that neonicotinoids are essential for the success of key export crops, by mobilising critical use cases. Subsequently, the NZEPA is convinced of neonicotinoids importance to NZ's agricultural production and are also convinced that biodiversity declines are not caused by neonicotinoids. In return the NZEPA do not changed neonicotinoid regulations. Finally, there is a relationship between the users of NZ grown hybrid (consumers) seeds and international seed companies (public representation). The international consumers interest the international seed companies with payment and those companies provide the consumers with the seed.

This demonstrates that each of the actors had a different role in the embedding and maintenance of neonicotinoids in NZ's arable sector. Furthermore, the relationships between the actors are caused by their shared need to achieve their goals. Therefore, the actors are connected in a way that makes neonicotinoids indispensable for each of them to achieve their goals. It is in this regard that the actors make up the network, and their material relations serve to make and maintain neonicotinoids in NZ's agricultural practices.

My third question was to explain why knowledge opposing the use of neonicotinoids has been unsuccessful in removing it from NZ's agricultural practices. Like the above question, this was answered through the application of Latour's CSSF (1999a) in Chapter 6, but its answer began during the data collection process. While performing the interviews, I found that the context surrounding an agricultural practice was present in the material relations I traced and therefore significantly impacted the application of neonicotinoids. Essentially, the embedding of an agricultural practice cannot simply be explained by the scientific resources supporting or opposing its use. To this end, I found that even the commodity being produced, and the agricultural sector was affecting practices. It became apparent very quickly that neonicotinoids were embedded in NZ's arable sector but have been removed from NZ's apples and pears sector. Through the application of Latour's CSSF (1999a), I observed that a slight change in the "public representation" loop of the CSSF (Latour, 1999a, p. 103), circulated through all the other loops of the network and led to neonicotinoids being removed from the apples and pears sector's pest control programmes. In summary, consumers of NZ's apples and pears want to know what practices are contributing to the production of their food. Moreover, they want to make sure that chemicals which they are concerned about and are banned where they live (neonicotinoids) are not being used in the production of the food which they eat. Supermarkets who are directly connected to the consumer, through the transfer of resources, translate this demand into MRLs. Subsequently, to ensure MRLs are met and to maintain market access, apples and pears NZ have removed neonicotinoids from the crop protection plans, introducing an alternative and advising growers about changes in supermarket regulation and consumer demand. Apple and pear growers have therefore "tended to move away from them [neonicotinoids] and look for alternatives" (Product Group Representative 1). Thus, neonicotinoids have been removed from the agricultural practices of NZ's apples and pears sector. This subsequently contradicts my initial assumption that neonicotinoids are embedded -and remain- in NZ's agricultural practices.

Finally, I was charged with understanding how Latour's CSSF (1999) could be used to investigate similar controversies in the future, in particular, those which involve hazardous substance use in NZ's agriculture. To achieve this, in light of my research I critiqued and responded to critiques of Latour's CSSF (1999a) and Callon's key principles (1986). Firstly the principle "generalized symmetry" was vital for this research, by allowing me to highlight that MRLs are first shaped by international

supermarkets and then shape the crop protection programs produced by apples and pears NZ and therefore fresh product growers ending neonicotinoid use. Similarly, it enabled me to demonstrate the importance of grass grub in helping shape the crop protection programmes of NZ seed and chemical companies and therefore arable growers use of neonicotinoids. Secondly, by presenting the conflicting viewpoints of all the actors and quoting the exact words of the interview respondents, limiting my biased commentary, I further addressed critiques of "generalized symmetry" as well of those of "agnosticism" (see section 3.5). Essentially through the use of a thematic analysis I have still identified power relations and social hierarchies as they have emerged from the data. Next I addressed critiques of the CSSF's imposition of its "own theoretical lexicon" (Whittle and Spicer, 2008). Essentially the CSSF's interpretation by no means matches the world of the interview participants. This is largely because the vocabulary being used is vastly different from that used by the interview participants. To address this, I provided a thorough description of the case and the participants and presented many quotations which give insight into my translation of the interview participants' responses. I also made a conscious effort to avoid using vocabulary from Callon (1986) and Latour (1999a) in the interview questions, so to avoid imposing this same vocabulary on the participants. Most importantly, Chapter 6 offers some insight into the major limitations and boundaries of myself and the research. By reflecting on my own limitations and the limitations of the tools which I used, I hope that future hazardous substance researchers will do a better job. To fully answer this question, the next section comments on what this research has contributed to CSSF and agricultural practice literature.

7.2 Contributions of this study

One of the main contributions of this study was that by adopting Latour's CSSF (1999a) and Callon's Key principles (1986) I have been able to bring forward the relational nature of agricultural practices in NZ, which has been obscured in previous studies. Furthermore, it helped affirm the work of Ingram (2007) and Warner (2016) who demonstrate that the CSSF can be used to makes sense of agricultural practices rather than its more intended application of understanding how scientific research is done. This thesis has also built on the work of Ingram (2007) and Warner (2016) by taking some direction from Fitzsimmons (2004) and Warner (2008) by applying the CSSF to a phenomenon broader than a specific instance of scientific work or a specific project aimed at understanding the adoption of different agricultural methods (Ingram, 2007). Previous studies have explained agricultural practices as being driven through economic, physical and environmental factors and by the values of individual farmers (Ilbery, 1978: Bangura, 1983; D'Souza, 1993; Lalani et al.,2016). Although these works have located farmer decision making, or the making and maintenance of agricultural practices, in the social, economic and political-ecological context, they tend to preserve the idea that the farmer is the sole, autonomous decision-maker. However, as Ingram (2007) emphasises,

> *All technology requires institutional and social support; even so-called natural technologies like breast-feeding (and organic agriculture) are unsuccessful without teachers to educate new practitioners, experts to solve problems, and groups to retain information, gather knowledge, and provide social approbation. Even where groups overtly tout motivations beyond some objective will to know (e.g., a religious, economic, or ecological mandate), they engage similar strategies to selectively engage with the material world, to build legitimate scientific arguments, and to disseminate ideas (Ingram, 2007, pp. 301-302).*

Therefore, a major contribution of this study is that it adds to the growing literature including Ingram (2007) and Warner (2016) which suggest that farmers are not necessarily free agents or unfettered actors deciding the daily agricultural practices occurring on their property. Indeed, my research resonates with their argument suggesting that various "economic, moral, political, and other relationships between humans and nonhumans" (Ingram, 2007, p. 301) affect the making and maintenance of agricultural practices like neonicotinoid use.

Another contribution of this research is its demonstration that the CSSF (Latour, 1999a) can be used as a means of assessing how an agricultural practice is made and maintained while highlighting what is influencing growers to use a particular hazardous substance. Essentially this thesis has shown how the CSSF can make sense of the network actors' roles in determining on the ground agricultural practices. For example, because of their goal to maximise yield and therefore profit, growers have become consumers of other's expert knowledge (spray programmes, etc.). This satisfies not only the goal of growers but also that of other network members as seen through the supply of seed crops. Therefore, this study has contributed to the body of literature which looks at how agricultural practices are made and maintained. Furthermore, this research offers guidelines for using the CSSF in order to identify research participants, follow the actors, and provide critical insight into a hazardous substance or agricultural practice controversy.

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Appendix

A.1 Interview Schedules

Thomas Scott

A network analysis of how neonicotinoids have become embedded in New Zealand agriculture

List of open-ended questions.

Introductory questions for all participants

1. What is your involvement in New Zealand agriculture, tell me your agricultural story?
2. What is your relationship with neonicotinoids?
3. What do you think about neonicotinoids, how would you describe them?
4. Who do you believe are the major proponents and opponents to neonicotinoids in New Zealand and what are they saying about it?
5. From who/where do you get the majority of your information regarding neonicotinoids?
6. Why are neonicotinoids so important to New Zealand agriculture and what would be the cost if they were not used?
7. Are there any individuals, groups or organisations that you affiliate with who are interested in neonicotinoids? How does your relationship with them function?
8. What is the government's role in agriculture in particular in regard to the use of chemicals?

Questions for farmers and Growers

1. Who performs your crop monitoring?
2. How do you determine which treatments are best for protecting your plants?
3. What are the procedures you take prior to treating a crop?
4. Is the use of agrichemicals a necessary management activity on your property?
5. Could you tell me about a time you have been criticized about using neonicotinoids and by who?
6. Could you tell me about a time you have been praised/encouraged to use neonicotinoids and by who?
7. What knowledge do you have of current regulation about the use of neonicotinoids in New Zealand?
8. What is the importance of pollinators to your farm? How do you receive pollination?
9. Do you have a relationship with beekeepers? If so please provide some details.
10. Do you take any measures to protect or enhance pollinator populations on the farm?
11. Do you hold a relationship with a specific retailer of seed and agri-chemicals?
12. Are there any alternatives to chemical treatments for the control of pests, in particular, are there any alternatives to neonicotinoids?

Questions for Regulators

1. Does your organisation perform crop monitoring for pests on farms? If yes, how often, why and what does this entail? If no, why not and who does it, if not you?
2. Does your organisation monitor the use of hazardous substances on the ground? If yes, how. If not, why not and who does this instead?
3. Does your organisation enforce the current regulations surrounding the use of neonicotinoids? If yes, how, if not why not and who does this?
4. Is there any legislation in place to regulate the use of neonicotinoids as a seed treatment? If yes, can you please explain it further? If no, why not?

5. Who/which groups do you consult when considering whether or not to change regulations surrounding hazardous chemicals? More specifically who/what groups do you consult in regards to neonicotinoids?

Questions for Seed and Chemical Retailers/Representatives

1. How close and how important is the relationship you hold with farmers? Can you tell me why it is so important?
2. Do you perform crop monitoring and pest control services for farmers? If yes, what is the procedure, if no then who performs this?
3. How do you determine whether a crop requires a treatment?
4. How do you decide which form of treatment is most suitable on a farm/crop?
5. Do you know what systemic seed treatment is?
6. Do you sell foliar spray form of neonicotinoids?
7. How often do you meet with an individual farmer and what activities/discussions do you perform?
8. How much influence/monitoring does the government, or a regulating body have on your activities?
9. Are you directed on which treatments/seeds to be selling/marketing to farmers each season? Who is giving this direction?
10. Are there any alternatives to chemical treatments to control pests, in particular, are there any alternatives to neonicotinoids?
11. Do you fund any research on neonicotinoids or pollinators? If no, why not, if yes who is performing this research and what is it investigating?

Questions for Beekeepers

1. Do you perform pollination services for farmers? Can you provide some detail about your relationship with those farmers?
2. Have you any agreements/procedures in place with farmers to protect your bees from exposure to the chemicals they apply?
3. Have you ever experienced hive deaths associated with insecticide application on the farm? I yes, can you outline the sequence of events that led to and followed this event?
4. Are there any measures in place to protect beekeepers from malpractice on farms?
5. Who are you able to turn to if your beehives die from pesticide exposure?

A.2 Research Information Sheet

Lincoln University

Faculty of Environment Society and Design

Research Information Sheet

I would like to invite you to participate in the project entitled "A network analysis of how neonicotinoids have become embedded in New Zealand agricultural practices."

This project is a thesis required for the degree: Master of Natural Resources Management and Ecological Engineering. The aim is to explore how and why certain agrichemicals are used over others. You have been asked to participate in this study due to your connection to the agricultural sector and expertise in either the use, regulation, research or effects of agrichemicals.

Your participation will involve the completion of an informal interview with myself, this is estimated to take up to an hour to complete. The interview will occur at a time and place chosen by you.

The results of this research will be assessed as a part of a master's thesis. They may also be subject to publication in an academic journal and presentation at a conference.

Your participation in this research is voluntary and you may decline to answer any question. You may also withdraw from this project, up to 4 weeks following the agreed upon interview date, by contacting me (Thomas Scott). If you choose to withdraw from the research all the data that you have provided shall be destroyed.

You may choose to keep your identity anonymous and data confidential.

If you have any concerns or questions about your participation or the project itself, please contact me as I am happy to discuss this further.

Researcher: Thomas Scott, Student
tom.scott@lincolnuni.ac.nz
Ph. +64 272644176

Supervisor: Sarah Edwards
sarah.edwards@lincoln.ac.nz

Supervisor: Suzanne Vallance
suzanne.Vallance@lincoln.ac.nz

Please note that this research has been reviewed and approved by the Lincoln University Human Ethics Committee.

A.3 Lincoln University Human Ethics Committee Approval

Research Management Office

T 64 3 423 0817
PO Box 85084, Lincoln University
Lincoln 7647, Christchurch
New Zealand
www.lincoln.ac.nz

9 July 2019
Application No: 2019-35
Title: A network analysis of how neonicotinoids have become embedded in New Zealand's agricultural practices.

Applicant: T Scott

The Lincoln University Human Ethics Committee has reviewed the above noted application. Thank you for your response to the questions which were forwarded to you on the Committee's behalf.

I am satisfied on the Committee's behalf that the issues of concern have been satisfactorily addressed. I am pleased to give final approval to your project.

Please note that this approval is valid for three years from today's date at which time you will need to reapply for renewal.

Once your field work has finished can you please advise the Human Ethics Secretary, Alison Hind, and confirm that you have complied with the terms of the ethical approval.

May I, on behalf of the Committee, wish you success in your research.

Yours sincerely

Grant Tavinor
Chair, Human Ethics Committee

PLEASE NOTE: The Human Ethics Committee has an audit process in place for applications. Please see 7.3 of the Human Ethics Committee Operating Procedures (ACHE) in the Lincoln University Policies and Procedures Manual for more information.

A.4 Email to participants

Thomas Scott

A network analysis of how neonicotinoids have become embedded in New Zealand agricultural practices.

Dear [Name of recruited participant],

My name is Thomas Scott, I am a postgraduate student at Lincoln University in the faculty of environment-society and design. We spoke on the *[date of the recruitment phone call]* regarding your participation in my research project titled: A network analysis of how neonicotinoids have become embedded in New Zealand agricultural practices.

This email is to again confirm your participation and willingness to be interviewed by me as a part of this research. Attached is a research information sheet that further outlines the project, your role as a participant and the procedures I have taken to protect your identity and minimise risk. Please read through this prior to the interview.

If you are willing to be interviewed could you please reply to this email detailing a date, place and time which you are able to meet for a little over an hour (the interview itself is expected to take 1 hour).

I look forward to hearing from you soon.

Sincerely,

Thomas Scott.

A.5 Consent Form

Lincoln University

Consent Form

A network analysis of how neonicotinoids have become embedded in New Zealand agricultural practices.

I have read and understood the description of the above-named project. On this basis, I agree to participate in the project, and I consent to the publication of the results of the project with the understanding that anonymity will be preserved. I also understand that I may at any time withdraw from the project, including withdrawal of any information I have provided during the interview up until 4 weeks following the agreed upon interview date.

I agree that my participation in this research is voluntary.

☐ I consent to have an audio recording made of my interview.

☐ I consent to notes being made during my interview.

☐ I consent to being identified by my name and profession (please specify) _____

☐ I consent to being identified by my profession only (please specify) _____

Name:

Signed:

Date: