Virtual Water: A Useful Concept for Informing Land Use in New Zealand

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This dissertation argues that the concept of virtual water should be used to inform future land use decisions within New Zealand. Virtual water is a contemporary concept, defined as the water needed to produce agricultural commodities. Separated by type – blue, green and grey – virtual water addresses the environmental problem of water scarcity and reveals a negative externality of global food trade. Virtual water flows, between and among countries, are intrinsically linked to a country's land use. Using a mixed methods approach, a case study of New Zealand is conducted exploring virtual water interactions and land use along with the development of a framework to assess the utility of virtual water as a policy concept. The case study finds that New Zealand has a net virtual water deficit and identifies that water resources are being over-exploited for economic gain. The policy evaluation framework indicates that virtual water can be a useful policy concept although further research quantifying virtual water flows is needed. This dissertation concludes that New Zealand is well placed to integrate the concept of virtual water into policy which would enable the government to make informed decisions regarding future land use. Through implementing a proactive policy, virtual water flows would be managed more effectively, altering industry behaviour and having a direct impact on land use in New Zealand.

Keywords: Case Study, Environmental Policy, Land Use, New Zealand, Virtual Water

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Chapter 1

Introduction

1.1 Overview

The objective of this research is to examine how the concept of virtual water can inform future land use policy decisions within New Zealand. In order to achieve this, the research will characterise virtual water, develop an evaluative framework to assess the utility of virtual water and explore New Zealand's virtual water interactions. This chapter discusses the underlying issue of water scarcity and provides a brief background of the virtual water concept. This leads to a discussion about the motivations for the research which informed the research question. The research question is derived from gaps identified within the literature and links the concept of virtual water to land use decisions within the context of New Zealand. Contributions of the dissertation are then explained, concluding with an outline of how the dissertation is organised.

1.2 Background

> *'Wicked' problems can't be solved, but they can be tamed. Increasingly, these are the problems that strategists face – and for which they are ill-equipped.*
>
> John Camillus, Harvard Business Review 2008 (Landcare Research, 2009 p.180)

Earth is often called the blue planet (Brichieri-Colombi, 2009; Niemeyer, 2008), primarily because from space it looks to be enveloped in one huge body of water (Niemeyer, 2008). Although, water is abundant on Earth, only a very small proportion is 'freshwater' with most water found in the oceans. There is no doubt that water is essential to life. Humans cannot survive long, no more than three or four days without water (Brichieri-Colombi, 2009). Population growth along with increasing general consumption are the main driving factors behind current, and increasing, water crises (Hengeveld, 2012; Smithies 2012). This situation is exacerbated by globalisation and the impacts of climate change (Vorosmarty et al., 2000; Grote et al., 2008).

The Earth's human population is projected to rise to 13.8 billion by 2025 (World Bank, 2010). It is estimated that food production will have to increase by at least 50% to feed this population increase, which will place significant stress on Earth's water resources. Already there is increasing per capita water consumption while global consumption of water has been doubling every 20 years (Barlow and Clarke, 2002 p. 7). Barlow and Clarke (2002) suggest that technology and sanitation systems used predominantly in developed nations allow people to use more water than they need. Industry and agriculture also utilise a large proportion of Earth's fresh water supplies and growth industries are water intensive. Furthermore, exacerbating these problems is climate change. According to Ludwig et al. (2009) climate change is affecting the distribution of global water resources, by altering the timing, variability and reliability of rainfall as well as the increasing occurrence of extreme weather events.

At a national or regional level water management and (re) allocation issues are often characterised as 'wicked' problems because of the high degree of complexity and uncertainty associated with them (Warner, 2003). The complexity is two-fold: within the river systems, a change in the physical or chemical aspect of a river affects other parts of the river and the surrounding environment; and there are multiple stakeholders with conflicting preferences (Hearnshaw et al., 2011). The dwindling supply of water resources exacerbates this problem: because of the different values that people attach to water, it is easy for water management issues to lead to value conflicts (Warner, 2003). Conflicting preferences also arise as many groups representing different interests and backgrounds are involved in solving environmental problems. Scientific knowledge plays a prominent role in policy development. However, scientific knowledge about environmental problems is characterised by high levels of uncertainty. In order to resolve or mitigate wicked environmental problems, such as water scarcity, policy is often written and developed in accordance with the policy process approach[1].

Water scarcity "refers to a situation when the water supply is inadequate in relation to the water demand for basic human and ecological necessities, including the production of food and other economic goods" (Uchtmann, 2011). It is commonly assumed that water scarcity will ultimately lead to war or conflict, with the rationale that each individual competes with other individuals for scarce resources therefore creating a situation of mutual rivalry (Warner, 2003)[2]. However, Tony Allan, the founder of the concept of virtual water, suggests that there have been no wars over water in regions such as the Middle East because they have been able to access water via trade (1997). This proposition implies that economic systems have solved water supply issues within this area. It is further suggested by Allan (1997) that Middle Eastern economies are already as dependent on global water as they are on their renewable water. The trading of 'global water' through products, specifically agricultural products, has led to the concept of virtual water.

1.2.1 Virtual Water Defined

In general, virtual water is defined as the water needed to produce agricultural commodities (Allan, 2003 p.5). However, there are two definitions of virtual water. The first defines virtual water as the

[1] The policy process approach is only one approach to policy analysis. Chapter 3 explains this approach in detail and describes the policy cycle, an intrinsic part of this approach.

[2] See also Homer-Dixon (1999) who suggests that scarcity of renewable resources can contribute to civil violence.

volume of water that is used in the production of a commodity which depends on the production conditions such as, climate and water efficiency (El-Sadek, 2011). The second defines virtual water as the volume of water in the product that would have been required to produce the product where it is needed or sold (El-Sadek, 2011). For practical reasons, the first definition is used as it measures the actual water used to produce the product[3].

Professor Tony Allan, the founder of the virtual water concept, applied the concept to Middle Eastern and Northern African countries. Allan's (1997) research suggested that the Middle East as a region ran out of water in the 1970s (p. 3). This is illustrated through rising demands for water which are less able to be met and the rising quantity of food imports. Allan (1997) notes that in practice, more water flows into the Middle East each year in its virtual form. Allan's book *The Middle East Water Question: Hydropolitics and the Global Economy* discusses 'non-evident' water, water utilised in vegetation and crops, which is held in the soil profile (2001). Essentially, this non-evident water becomes virtual water when crops are grown. Allan suggests that in the Middle East non-evident water has to be supplemented by irrigation from surface water or ground water. Allan further suggests that imported virtual water "solves the immediate and future of Middle Eastern and Northern African countries water deficit" (p. 49). From his perspective, the purpose of virtual water as a concept is to illustrate how countries can trade their way out of water deficits. Essentially, by trading food goods, a country can overcome its restrictions imposed by the domestically available water resources. However, a country's ability to do this is dependent on wealth and its trade balance; it must trade other resources in order for this to be achievable.

The concept of virtual water flows between and among nations draws attention to the value placed on water when producing and trading goods. In many countries, water is viewed as a small production cost because rain is free and irrigated water is either under-priced or simply not priced at all (Reimer, 2012). But water is scarce in many countries and the concept of virtual water has revealed that some countries face economic contradictions. For example, flowers are the second largest export for Kenya contributing approximately $250m per year to their economy (Jones, 2010 p. 173). Seventy percent of these exports are sold at Dutch flower auctions and 20% are sold within the United Kingdom (Jones, 2010). In 2006, it was estimated that 7.5 million m^3 of water was utilised in the Kenyan floriculture industry (Jones, 2010). However, water scarcity in Kenya has been an issue for decades (Snyder, n.d.). *"A flower is 90% water. We are one of the driest countries in the world and we are exporting them to one of the wettest"* (Severino Maitima, cited in Jones, 2010 p. 169). Consequently, questions have been asked as to why 'precious' water is being used to grow flowers rather than being utilised for basic human needs. The answer lies within economic incentives: there is a demand for high quality flowers and the subsequent profits. This is not only occurring in Kenya.

[3] See Section 2.2 for further discussion regarding the two definitions of virtual water.

Goods are being traded globally to derive export income while often degrading the quantity and quality of local water resources.

The concept of virtual water highlights these contradictions. It can show the amount of rainfall versus irrigated water used in the production of a good. It also gives a more realistic indicator of the scale of national water deficits and illustrates the increasing interconnectedness of the global trade system (Warner, 2003). Therefore, knowledge about the virtual water flows entering or leaving a country can cast a new light on the actual water scarcity of a country.

1.3 Motivations for Research

The importance of the research stems from concern about current and future global water shortages faced by nations around the world. Measuring the virtual water content of a product draws attention to the value placed on water when producing and trading goods as well as indicating how the water is being used within a country. For example, New Zealand is highly reliant on agricultural exports (often involving high-water consumption) for income and with the predicted changes in climate the concept of virtual water could inform international policy, and improve the global management of water as a scarce resource. Of significance, the concept of virtual water has potential to inform national and international land use decisions. Although the focus of Kumar and Singh's (2005) research was not informing land use change, they have alluded to the possibilities of using virtual water trade to improve land use efficiency from a global perspective.

The New Zealand national accounts show that New Zealand imports virtual water through crops, for example grain, but exports water through agricultural products, primarily dairy. The Royal Society of New Zealand (2009) suggests that different crops and varieties can be substituted along with land use change to reflect water availability. The concept of virtual water is related to land use because the amount of virtual water flowing in and out of a country is determined by the structure of a country's economy, i.e. what is imported and what is exported to satisfy consumer demand. The implications for land use and the lack of research regarding virtual water in New Zealand has led to the development of the following research question:

> *How can the concept of virtual water inform future land use policy decisions within New Zealand?*

1.4 Research Aims and Objectives

Three research aims were derived in order to answer the research question. These were:

1. Characterise virtual water and its development internationally.
2. Develop a policy evaluation framework to assess the utility of this concept for policy making.

3. Undertake a case study of New Zealand.

To achieve these research aims, the following research objectives were developed:

1. Conduct a literature review focusing on origins, definitions and virtual water flows.
2. Review policy evaluation literature to develop a framework and derive appropriate assessment criteria.
3. Investigate how land use has changed within New Zealand, over the past ten years, by reviewing the statistical data that shows the amount of land that has been converted from arable land to dairy grazing.
4. Characterise New Zealand's virtual water interactions nationally through mapping the water used in production by the top ten agricultural goods (in terms of quantity as at 2010) over the period 2005 – 2010 from existing data.
5. Characterise New Zealand's virtual water interactions internationally through mapping the water used by the top ten imported and exported agricultural goods (chosen by value or contribution to gross domestic product as at 2010) over the period 2005 – 2010 from existing data.
6. Utilise this case study of New Zealand to understand the potential of virtual water for land use as a policy concept.

1.5 Contribution of this Research

The contributions of this research are three-fold. Firstly, this study adds to the literature by providing a case study of virtual water interactions within New Zealand. To date there have been no studies outlining or measuring New Zealand's virtual water situation. Instead, the research released in New Zealand has been focused on water footprints. Recent research by Plant and Food has focused on the water footprint of specific crops, such as kiwifruit (see Deurer et al., 2011).

Secondly, this research focuses on the policy implications of virtual water for land use. There is no contemporary literature analysing land use and virtual water, although some case studies imply within their conclusions that the virtual water content of products should be linked with the land use of a country (see Section 2.6). There is no analysis suggesting why, or if, a change in land use is appropriate, only superficial suggestions regarding a particular crop using a significant portion of freshwater[4]. Therefore, this dissertation will contribute to a new body of knowledge, suggesting that virtual water (or the water used in production) could inform future land use decisions.

[4] For example, see 'Valentine Flowers from Kenya: A Perverse Trade' in Jones, 2011 p. 173.

Finally, there is also a significant debate in the contemporary literature about the policy relevance of virtual water. Some academics suggest that the concept is 'virtual' (rendered meaningless) (Merrett, 2005) or is only useful for drawing the attention of citizens, public officials and policy-makers to influence water resource use (Wichelns, 2010b). In contrast, there are authors who believe that virtual water flows should be incorporated within policy and 'integrated water resources management' (Allan, 2003; El-Sadek, 2011). Therefore, this research will also contribute to this area of research by providing a framework to evaluate the utility of virtual water as a policy concept.

1.6 Organisation of this Dissertation

Following this introduction, Chapter 2 reviews the virtual water literature, focusing on all aspects, providing a base for this research. Research considering virtual water varies from measuring virtual water flows to discussing the policy criteria and relevance of the concept.

Chapter 3 reviews the policy theory literature and describes the policy analysis approach undertaken in this dissertation. Chapter 4 outlines the research methodology and methods for data collection. This chapter also develops an evaluative framework for assessing the utility of the concept of virtual water.

The findings of the case study are presented in Chapter 5. This includes investigating New Zealand's virtual water interactions and recent land use change. Chapter 6 uses the policy evaluation framework to assess virtual water as a policy concept and links it to the context of New Zealand. This discussion focuses on whether virtual water can inform policies relating to land use in New Zealand. Finally, Chapter 7 summarises and concludes the research, provides recommendations and suggestions for future research[5].

[5] Appendix A includes a glossary of economic terms used within this dissertation for readers who are not familiar with the discipline of economics.

Chapter 2

Virtual Water Literature

2.1 Overview

This chapter reviews the virtual water literature initially focusing on the origins of the concept of virtual water and differentiating it from the water footprint. Secondly, this chapter examines virtual water flows between and among countries, the policy implications and relevance of the concept as well as case studies utilising the concept of virtual water. Finally, this chapter explores the concept of virtual water within the context of New Zealand.

2.2 Origins of the Concept

Professor Tony Allan, of the London University School of African and Oriental Studies, originally proposed the concept of 'virtual water' in a seminar in 1993 (Allan, 2003; Jones, 2010; Isalm et al., 2007). Previously, the term 'embedded water' had been used by Allan. However, this concept had not caught the attention of academics or others working within the water management community (Allan, 2003). Allan (2003 p. 4) claimed that the idea was derived from Israeli economists who had, by the mid-1980s, already concluded that exporting scarce water was ludicrous from an economic perspective. This occurred every time oranges and avocados were exported from the Israeli economy. Initially, Allan applied the concept to Middle Eastern and Northern African countries suggesting that their water shortages could be solved by relying on imported food (Jones, 2010 p. 165).

Goods that are traded generally require water to produce them; this is the unseen virtual water. Virtual water is defined as the water needed to produce agricultural commodities (Allan, 2003 p. 5). Important to the concept of virtual water are the categories of different types of water. There are three; green, blue and grey water. Green water falls as rain and is stored in the soil while blue water is located in rivers, lakes or aquifers and is used for irrigation. Grey water is water that is polluted by agrichemicals[6]. It is important to measure the different types of virtual water when conducting virtual water research as this determines what the water use management policy should be focused on. For example, if blue water is being over-utilised, then the policy implemented will relate to irrigation practices. The concept of virtual water could be expanded to include other commodities, however, at this stage it has only been applied to agricultural goods. For example, to produce one

[6] In agriculture an example of this would be the blue water that has been polluted with nutrients and pesticides. "Grey water volume can be quantified by calculating the blue water that would be required to dilute the receiving body of water to an acceptable quality standard" (Clothier et al., 2010 p. 82).

tonne of grain utilises 1,000L of water, its virtual water content, which can be further broken down into the three types of virtual water (Allan, 2003 p. 8). At an aggregated level, for example for a country or region, the concept of virtual water highlights the extent to which water resources are dedicated to a particular economic sector to the exclusion of another.

Virtual water, without explanation, is an ambiguous term. The adjective 'virtual' refers to the fact that most of the water used in production is not ultimately contained within the product (Hoekstra and Chapagain, 2008). In comparison to virtual water, the real water content is often negligible. For example, Hoekstra and Chapagain (2008) suggest that the virtual content of wheat is roughly 1,300 m^3/ton whereas the real water content is less than 1 m^3/ton. However, other scholars argue that the term 'virtual' is misleading because of its use within digital media (Haddadin, 2003). Therefore, Haddadin suggested using the term 'exogenous water'. However, virtual water is the term recognised by scholars.

Although the definition of virtual water is loosely defined as the water 'needed' to produce a product, it is important to recognise that water 'needed' is not necessarily the same as water actually used. The virtual water content of a product can be more precisely defined as the total volume of water used to produce a product (El-Sadek, 2011). This requires empirical measurement and validation, where the virtual water content of a product can be measured at the place(s) it was actually produced (Hoekstra and Chapagain, 2008). This is the most common definition of virtual water because it allows the virtual water flows between and among nations to be estimated from statistics on international product trade and the virtual water content of each product within the exporting country. The other definition of virtual water takes a user or consumer perspective rather than a producer perspective. This defines the virtual water content of a product as "the amount of water that would have been required to produce the product at the place where the product is needed" (El-Sadek, 2011, p. 249). Oki and Kane (2004) support this definition as it answers the question of how much water a country would save if the product was imported as opposed to being produced domestically. This is an important question, and its answers could inform land use decisions however, it is difficult to establish empirically as it is a hypothetical need rather than an actual volume. Therefore, the first definition of virtual water prevails in contemporary case studies of virtual water flows between and among nations and is used within this research, as it is empirically measurable.

The concept of virtual water resulted in authors posing ideas regarding trade, that is, if a country imports food then it is effectively using someone else's water resources and saving its own. This can result in strategic advantages if a country can save its domestic water resources, and is especially significant for water scarce nations. This idea of using someone else's resources is similar to the idea of resource stripping. Jared Diamond, in his book *Collapse: How Societies Choose to Fail or Succeed*, illustrates this concept using the example of Japan's forest management (Diamond, 2005 p. 306). After 1657, Japan starting utilising other nations' timber reserves rather than their own which they accessed through trade. This is also noted by Harper (2000) as a "transfer of environmental damage through trade effects and globalisation of markets" (p. 371). This raises the question of whether virtual water, as a policy concept, could be used to ensure that resource stripping does not occur for the purpose of economic gain (higher export income)? This research will provide insight into answering this question.

2.3 The Water Footprint

Another important concept within water resource management is the concept of the water footprint, which is often confused with the notion of virtual water (Velazquez et al., 2011). The initial notion of measuring a separate water footprint stemmed from Tony Allan developing the concept of virtual water (Chapagain and Tickner, 2012). The water footprint was introduced by Hoekstra and Hung in 2002 when they were looking for an indicator that could map the impact of human consumption on global freshwater resources (Hoekstra and Chapagain, 2008). Prior to this, Rees and Wackernagel (1996) introduced the 'ecological footprint' measure. This measure refers to the area used by an individual or group of people whereas the water footprint indicates the volume of water used (m^3 per year) (Hoekstra and Chapagain, 2008). The water footprint is defined as "the volume of water necessary to produce goods and services consumed by the inhabitants of a country defined as an indicator of the use of water in relation to the population's consumption level" (Chapagain and Hoekstra, 2004 cited in Velazquez et al., 2011 p. 746). Since not all goods consumed are produced in that particular country, the water footprint includes the use of domestic resources and the use of water resources outside the borders of a country (Hoekstra and Chapagain, 2008).

In general terms, the concept of the water footprint is an indicator of water use that takes the perspective of consumption. There are two methods of measuring a water footprint, top down and bottom up. In general, the top down approach is used. This approach is measured by taking the total water use of a country, subtracting the water used for exported products (outgoing virtual water) and adding the incoming water used in imports (incoming virtual water) (Hoekstra and Chapagain, 2008). From this information we can then calculate the internal and external water footprint of a country.

At a first glance, the concept of the water footprint and virtual water look the same. However, there are some fundamental differences. The main difference is that of perspective. Virtual water takes a post-production perspective whereas the water footprint takes a consumption perspective. Velazquez et al. (2011) uses the example of the production of an apple to distinguish the difference between the two measures. The virtual water content is the amount of water needed to produce the apple. In comparison, the water footprint is the amount of water needed so that a specific individual consumes the apple (Velazquez et al., 2011). Therefore, the water footprint takes into account the fact that the apple has been produced, transformed, distributed and commercialised before it reaches the consumer. This requires different amounts of water depending on whether it is consumed locally/nationally or exported. This implies that the key difference between the concepts is that the water footprint incorporates the amount of water needed to 'transport' the apple to the consumer.

Although the water footprint is a more inclusive measure as it has a broader scope, it includes too much information for the purposes of investigating land use. The concept of virtual water refers to volume alone, therefore giving an ability to measure the quantity of water being traded within products. This enables a researcher or policy analyst to drill into the data to determine what products are or are not utilising a significant proportion of a nation's water resources which is what this research proposes to do.

2.4 Virtual Water Trade and Flows[7]

The most common place to find the term 'virtual water' is within the international trade literature. Virtual water trade refers to the idea that when goods and services are exchanged, so is virtual water. When a county imports one ton of wheat, instead of producing it domestically it is saving 1,300 m^3 of indigenous water (Hoekstra and Chapagain, 2008). If the country is water scarce, then the water saved can be used for other purposes. If the exporting country is water scarce, then it has exported 1,300 m^3 of virtual water which will no longer be available for other purposes. Obviously, this has strategic implications for water scarce nations who will be less willing to sacrifice their indigenous water without a good reason. Considering these implications, it has been hypothesised that trade, especially in food goods, can allow a country to overcome the restrictions imposed by the water resources available domestically (Jones, 2010 p. 167; Diamond, 2005; Allan, 2003). This is called the virtual water hypothesis.

> *In theory, trade in virtual water could create a more equitable use of world water resources by allowing water intensive commodities to be produced where it is most efficient – where sufficient resources are available without damaging the environment or depriving other users, and where water use per tonne of a product is at a minimum (Jones, 2010 p. 174).*

[7] Criticisms from economists have made some scholars replace the term 'trade' with 'flow'. The economists suggested that using 'virtual water trade' is misleading because real things are traded (Hoekstra and Chapagain, 2008). This dissertation has used both the terms, trade and flow, but bear in mind that the use of the term 'trade' does not refer to a market with traders in virtual water.

Hoekstra and Chapagain (2008) suggest that virtual water transfers between nations are one means of increasing the world's water use efficiency. Oki and Kanae (2004) refer to the concept of global water savings. The authors postulate that international food trade can save water globally when a water intensive commodity is traded from an area where it is produced with high water productivity (low water input per unit of output) to an area with low water productivity (high water input per unit of output). However, it is noted that the economic efficiency between two countries should be evaluated based on a comparison of the opportunity costs of producing the commodity in each of the trading nations. In addition, other factors play a decisive role in countries' decisions about agricultural production, such as the scarcity of fertile land. Therefore, realised national water savings in a country can only be partially explained through national water scarcity (Hoekstra and Chapagain, 2008). For example, Germany annually saves 34 billion m^3 of water through importing tea, coffee and cocoa – products that Germany would not ordinarily produce. If the import of these products were reduced it would not create any additional pressure on Germany's water resources simply because they are unable to produce them (Hoekstra and Chapagain, 2008). A policy would not change Germany's behaviour making it less important from a policy perspective. In contrast, if Morocco shifted from imported to domestic production of cereal crop products, it would create additional pressure of 21 billion m^3/yr on its national water resources (Hoekstra and Chapagain, 2008). These examples illustrate the importance of context for developing policy. However, Hoekstra and Chapagain (2008 p. 49) list the following disadvantages a country could face when using virtual water imports as a solution to water scarcity. These include:

- A need to generate sufficient foreign exchange to import food which otherwise could be produced domestically;
- A risk of moving away from food self sufficiency;
- Increased urbanisation as import of virtual water reduces employment in the agricultural sector;
- An economic decline and degradation of land in rural areas;
- Reduced access to food for the poor;
- Increased risk of environmental impact in exporting countries, which is generally not accounted for in the price of imported products.

Consequently, increases in virtual water transfers may relieve pressure but also create additional pressure in other areas and sectors. These limitations suggest that the concept of virtual water may not be practical for all countries to use within policy to manage scarce water resources.

The limitations of the virtual water hypothesis have spawned considerable research on potential global water flows at the global scale. Wichelns (2010a) determines from his study that trading patterns are independent of water endowments. Moreover, access to arable land and secure markets are more likely to be the better predictor of trade patterns, especially in agriculture. Similarly, Kumar and Singh (2005) analysed the net virtual water trade of 146 countries and found that a country's virtual water trade is not determined by its own water situation. Water is viewed as a small production cost because rain is free and irrigated water is either under-priced or simply not priced at all (Reimer, 2012). Therefore, it is not surprising that these authors argue there is no empirical evidence for the virtual water hypothesis (Wichelns, 2010a p. 2208; Kumar and Singh, 2005 p. 759). Kumar and Singh (2005) find that virtual water trade increased with gross cropped land because of the increased access to water and water held in the soil. Their research concluded that more efficient global land use is often achieved through virtual water trade. Islam et al. (2007) analysed virtual water trading using a grid-based assessment with results showing that the "unequal spatial distribution of global water resources had been considerably neutralised by virtual water trading" (p. 19). More specifically, regions such as the Middle East can ease their water scarcity issues by importing virtual water. Hence, arguably the virtual water hypothesis is in action.

The concept of virtual water trade raises issues of equity, especially considering that if water was distributed equally around Earth there should be enough to support our entire population (Islam et al., 2007 p. 20). Seekell (2011 p. 1209) assesses the impact of virtual water trade on fresh water distributions around Earth and finds that virtual water trade could lead to a more equal global distribution of water resources. Seekell (2011) is viewing virtual water trade from a global perspective and uses the Lorenz curve[8], an economic framework, in order to illustrate this. The author also notes that the effect of promoting equality in water distribution is significant but restricted when countries do not utilise all of their own water resources. Seekell's (2011 p. 1209) argument is based on the idea that international trade may reduce inequality between and among nations, as water abundant nations are able to export to water scarce nations.

However, international virtual water trade may also reduce equity among nations. If a country has a comparative advantage in a product this can encourage a nation to exploit its resources, in this case water, for economic gain. This may result in water scarce nations exporting water intensive products to water abundant nations, such as Kenya exporting high-quality flowers to the European Union (Jones, 2010 p. 169). Further problems relating to equity can arise with transnational corporations producing water intensive products within a water-scarce nation for example, Coca Cola. Their production in Mehdiganj (India) caused the water table to drop by six metres and farmers did not

[8] See Appendix A for a glossary of economic terms.

have the technology to extract deeper ground water or the resources to fight this powerful corporation. This caused crops to fail and ruined the livelihoods of local farmers (Levitt, 2009).

A further equity consideration relates to a country's ability to participate. Yang et al. (2006 p. 15) find that the current global virtual water trade is mainly between and among nations that are not low-income in the World Bank classification. Low-income countries participate much less in global water trade, predominantly because of their reduced ability to exploit natural resources and invest in infrastructure. Furthermore, low-income nations are limited by their lack of financial resources and ability to purchase food from the export markets (Yang et al., 2006 p. 15). Therefore, the environmental implications of virtual water trading can both increase and, of greater concern, decrease equity (Seekell, 2011).

2.4.1 The Crop and Agriculture Context

"When countries trade agricultural and industrial goods, they are also trading virtual water"(Chapagain et al., 2006 cited in Seekell, 2011 p. 1206). To date, most virtual water trading has focused on agriculture (Hoekstra and Hung, 2005 p. 46) and many studies have sought to identify the amount of virtual water traded globally within this industry.

Hanasaki et al. (2010 p. 232) estimated that the virtual water flow of crops including barley, maize, rice, soybeans and wheat, along with livestock, such as beef, pork and chicken is 545 km^3 y^{-1} globally. Within this estimation, 11% of the virtual water flow contains blue water[9], while 5% is non-renewable and imported blue water. The distinction between the water used, whether it is blue or green, is important in terms of opportunity cost. A similar study was conducted in 2005 where Hoekstra and Hung estimated that virtual water flows among nations was 696 Gm^3 y^{-1} during the period 1995-1999. They also estimated that 13% of the water used for crop production within the world is exported, i.e. is in the form of virtual water. Hoff et al. (2010) estimate that "green water use in global crop production is four to five times greater than consumptive blue water use" (p. 177). Consequently, the question arising within the literature is: how much blue water can be withdrawn, in a particular region, for food production without compromising other environmental flows (i.e. rivers, ecosystems)? Siebert and Doll (2010) quantify blue and green virtual water flows and estimate that from the period 1998-2002, blue water usage was 1180 km^3 y^{-1}, green water for irrigated crops was 919 km^3 y^{-1} and for rain fed crops was 4586 km^3 y^{-1}. The authors use a global crop water model and estimate that the global amount of water used was 6685 km^3 y^{-1}. In contrast, Liu et al. (2009) suggest that green water makes up most of the virtual water flows between and among countries. Their study is also for the period 1998-2002 and shows that approximately 94% of the virtual water

[9] Blue water is located in rivers, lakes or aquifers and is used for irrigation. Green water falls as rain and is stored in the soil and grey water is the water that is polluted by agrichemicals.

trade between and among countries has its origin in green water (Liu et al., 2009 p. 1). This finding suggests that policies should not be solely focused on the management of blue water resources.

Agricultural trade also affects water quality. Dabrowski et al. (2009) use a proxy to investigate the impact of water quality and find the amount of water required to dilute agricultural chemicals. Their results indicate that the volume of water required for dilution is similar to the total amount of green and blue water required for crop production. The results from this study indicate that water quality impacts from agriculture need to be considered in virtual water trading scenarios. Firstly, this is because only blue water use impacts directly on water scarcity within a country. Secondly, because importing countries do not bear the consequences of any water quality deterioration that might occur.

An additional consequence of global trade related to virtual water is the transfer of nutrients in agricultural commodities (Seekell, 2011). Water and nutrients are utilised in the production of food, which is traded globally. Often this trade in nutrients is seen as the reason behind environmental problems. Consequently, coping with large inputs of nutrients in the environment is a major problem that policy-makers are facing, and will only heighten as populations increase. Grote et al. (2008) estimate that net global flows of nitrogen, phosphorous and potassium totalled 4.8 Tg in 1997 and will total 8.8 Tg in 2020. The net importers of these nutrients in products are predominantly located in West Asia and North Africa, while the largest net exporters are the United States, Australia, and Latin America (Grote et al., 2008). Grote et al. (2008) suggests that combining the management of water and nutrients would lead to a more sustainable outcome.

2.5 Policy Concept and Relevance

There is much discussion within contemporary literature about whether virtual water is a useful concept for policy. Authors, such as Allan, argue that virtual water needs to be incorporated when writing water management policy. However, other scholars, such as Merrett, argue that virtual water is not a useful policy criterion especially on its own (Allan, 2003; Merrett, 2005). The key ideas discussed within this debate are the economic concepts of opportunity cost(s) as well as absolute and comparative advantage.

Wichelns (2010a) argues that virtual water has been effective in drawing the attention of citizens and public officials to water scarcity issues. However, since it is not based on an underlying conceptual framework it cannot be used alone as a criterion for accepting or rejecting policies. The fundamental argument behind this conclusion is that “true policy relevance is gained only by including information regarding the scarcity of water (i.e. its opportunity cost) in a given country or region” (Wichelns, 2010a p. 2204). The concept of virtual water, itself, does not incorporate the opportunity cost of using the water within a nation. When talking about opportunity costs the argument is not whether water is scarce or not but what other uses the water could be applied to. Economists would argue that resources will not always go to their highest valued use, but will go to the user who has the ability to pay. It is often assumed that these two users are the same but in reality they are not (Mankiw, 2007). For example, rice production requires significant quantities of water but the opportunity cost might be small in humid regions. Therefore, the policy relevance of virtual water will be greater where the opportunity cost is higher.

Virtual water trade is occurring currently within food trade but for it to be conceived as a policy concept, it will need to be a legitimate economic concept. Reimer (2012) conceptualises virtual water flows within an economic framework finding that the concept of virtual water is legitimate within international trade theory and that it stems from comparative advantage. He uses the traditional Heckscher-Ohlin theorem with two countries, two factors of production, two goods and concludes that “virtual water is a potential source of comparative advantage” for nations (p. 138). In contrast, Wichelns (2010b) argues that virtual water by design resembles the application of absolute advantage. Therefore, it is not a sufficient criterion for determining optimal trading strategies for policy because countries follow the doctrine of comparative advantage (Wichelns, 2004). However, Wichelns (2004) also states that the concept of virtual water is helpful in starting policy discussions regarding optimal resource allocation.

From another perspective, El-Sadek (2011) suggests that the concept of virtual water should be an integral component of ‘integrated water resources management’. This concept uses demand and supply side management to manage water resources suggesting that real and virtual water should be managed together. According to El-Sadek (2011) the concept of virtual water is well founded and it could be used within the Arab region to mitigate water scarcity. Overall, his viewpoint illustrates that relying only on food imports is not the optimal solution.

There are two studies that address the incorporation of virtual water within policy. The first study looks at two watersheds in British Columbia, Canada. Brown et al. (2009) identify the industries that demand water, including livestock and fruit production, and calculate the amount of virtual water within this production. The authors do not explore the policy ramifications from their research but simply state that these results allow decision-makers to identify trade-offs and estimate how much water will be required if land use change occurred. The authors do remark that changes will need to be made on how to reduce water consumption in order to accommodate anticipated future agricultural growth.

The second study investigates the Mancha Occidental Region in Spain. Aldaya et al. (2010) analyse virtual water within this region and find that although it is only a first approximation, the region is a virtual water exporter. The region relies on its own water to produce food which suggests that there is room for virtual water imports to support the existing plans to restore the area's degraded water bodies. The authors do not explicitly state the ramifications of this research for policy but acknowledge the economic trade-off; it is economically productive to produce water intensive crops, such as vegetables and olives but at a cost to their own water resources. The authors recommend that new policies within the region need to be focused on either a change in cropping patterns or a reduction in the scale of irrigated land area. The findings of their study illustrate an imbalance between the region's land use and its water resources. From a policy perspective, both these case studies use the concept of virtual water to illustrate the trade-offs of production of agricultural goods within a region.

Turton (n.d. p. 8) has written a strategic decision-makers guide to virtual water. He identifies seven key issues that a decision-maker at a strategic level would need to understand. Turton (n.d.) concludes that virtual water can become a powerful tool for balancing the water budget at a regional level. The author's main argument is that there is a fine line between trade in virtual water and food aid dependence, which is actually the balance between food security and self-sufficiency. Turton (n.d.) also suggests that all policies are doomed to fail if the underlying driver of a water deficit is ignored. However, this is simply a manifestation of another underlying problem, increasing population and general consumption.

2.6 Case Studies

A significant proportion of the literature in the area of virtual water utilises case studies. The sustainability of water use is often the focus of case studies incorporating the concept of virtual water. Although the following three case studies focus on different issues, the underlying theme is land use.

Elena and Esther (2010) estimate the virtual water content of the amount of biofuel production that will be needed to reach Spain's targets for biofuel by 2010. Spain has a national target of reaching a biofuel share of 5.83% of the gas and diesel consumption by 2010. The authors estimate three key scenarios: real virtual water for Spanish production; real virtual water combining with Spanish biofuel imports; real virtual water for Spanish production in the case of a drought. The authors make a number of assumptions within their estimates but the results suggest that the amount of virtual water in ethanol is less than biodiesel. Additionally, the share of crop production used to produce ethanol with green water is higher than blue water. These results suggest that energy objectives may not coincide with water endowment or availability as the Plan For Renewable Energies opts for the production of biodiesel. It is also noted that the water impact of biofuels also depends on the use of blue water, which varies depending on the amount of annual rainfall distribution.

Fang et al. (2010) estimate the virtual water potential of the Turpan Basin, China. This basin is extremely short of water resources and is located at the centre of the Eurasian Continent. The results estimate that total useable surface area of water resources per year in the last decade was greater than the total adduction volume of surface water in 2003. The authors' results also estimated that the over-exploitation of ground water in the basin has reached the upper limit, resulting in the ground water table falling in recent years. The authors suggest that utilising this data is significant for decisions relating to developing the best social, ecological, and economic benefits as well as regional sustainable development of the Turpan Basin.

Singh et al. (2004) attempt to quantify the amount of virtual water trade through trading of milk in different regions of Gujarat, India. These authors hypothesise that dairying based rural livelihoods are threatening the limited water resources in certain areas. The study included five distinct regions of Gujarat. The results show that North Gujarat (an absolute water scarce region) is exporting a net volume of about 2,116 mm of virtual water annually through the dairy business. The conclusion of this study is that imported feed (for the dairy cows) is one way to reduce pressure on local irrigated water.

The concept of virtual water has been used within these case studies. They illustrate in various ways how local production decisions that have an impact on land use affect virtual water flows. This further highlights how land use decisions have implications for water scarcity.

2.7 The New Zealand Context

In New Zealand at a product level Brent Clothier, from Plant and Food, has undertaken research within the area of virtual water (see Clothier et al., 2010; Deurer et al., 2011; Herath, 2011). However, his quantitative work focuses primarily on collecting water footprint data. For example, he has worked on determining the water footprint of wine in Marlborough and hydroelectricity within New Zealand. However, this is not to say that virtual water is not being discussed. A recent release in the *Manawatu Standard* explains the concept of virtual water claiming that New Zealand is a lucky country due to the amount of its water resources (Galloway, 2010).

According to the Royal Society of New Zealand, New Zealand is a major exporter of virtual water and is placed in the top three countries around the world exporting virtual water per capita (2009). For New Zealand, agricultural water use will either become a major trade advantage or a possible trade risk. Virtual water trading could determine the outcome of this. "It will become an advantage if farmers or their industry can demonstrate and certify that water use has a low environmental impact and that they can meet overseas standards of environmental stewardship" (Royal Society of New Zealand, 2009 p. 3). New Zealand imports water through crops, for example grain, but exports it through agricultural products, primarily dairy. In recent years, the growth of irrigated dairy production has exaggerated this import/export gap creating an economic dependence on agriculture leading to an over allocation of water resources in some parts of the country, especially Canterbury. The Royal Society of New Zealand (2009) suggest that different crops and varieties can be substituted along with land use change to reflect water availability. Virtual water could inform resource productivity decisions, especially in Canterbury where limited water supply and challenges of providing infrastructure could limit agricultural production in the future.

2.8 Virtual Water and Externalities

The literature proposes that the concept of virtual water addresses water scarcity. However, fundamentally, it appears that virtual water is highlighting a negative externality of global food trade and its consequences. Roth and Warner (2007) suggest that these consequences affect both importers and exporters of virtual water. This externality is viewed from a global perspective. At a local level, the concept of virtual water highlights a negative externality of production.

Negative externalities can occur when water is used at the site of production. Baumol and Oates (1988 p. 17) define externalities as having two conditions:

> *Condition One: An externality is present whenever some individual's (A's) utility or production relationships is affected by another's (persons, corporations or governments) actions without them paying attention to the effects on A's welfare.*
>
> *Condition Two: The decision-maker, whose activity affects others' utility levels or enters their production functions, does not receive compensation for an amount equal to in value the resulting benefits (or costs) to others.*

Essentially, the consumption of water (which may or may not be considered an economic good) can have externalities at the site of production, which go unpaid for by consumers in other places.

An example of this is the Kenyan case study, explained in Section 1.2. Kenya is producing high quality flowers which are exported to the European Union. The proposition arising from this case study is that the export income earned by the flower industry is not being utilised to address basic human needs in Kenya (Jones, 2010). Therefore, negative externalities of production associated with water use in the production of goods are usually borne by the exporting countries and are not included in the price paid by consumers in importing countries. The example of Kenya can be argued as an example of over-exploitation of a resource, where the opportunity cost of the water resources has not been considered. It is important to note that these negative externalities can occur in different countries, however with differing value conflicts.

New Zealand exports a significant amount of virtual water (Royal Society of New Zealand, 2009) and this can be argued as a negative externality of production. The environmental cost of over allocating river water flows through to groundwater quantity and quality issues. Furthermore, over allocation raises concerns about future water security and intergenerational equity. For example, in Canterbury the damage to water resources from dairy farming includes surface water, ground water and loss of angler values (Tait and Cullen, 2006). The degradation of lowland streams caused by nutrients in the waterways is a current concern for many stakeholders within the Canterbury region (Tait and Cullen, 2006). These costs and others, such as carbon dioxide emissions, are not transmitted through the markets for dairy products (Tait and Cullen, 2006). The costs of mitigating the contamination of waterways from effluent and nutrients are instead partially borne by Canterbury ratepayers. Considering that these costs are not incorporated within the market price of dairy products, it suggests that the price of dairy products is too low and a misallocation of resources is occurring. Therefore, the perception of stakeholders that water is paid for at a fair cost or that water resources could be used to better advantage, or differently, according to their opportunity cost is important. These negative externalities of production represent allocation and equity concerns for regional policy-makers.

2.9 Summary

This chapter has explained the concept and origins of virtual water. The concept itself measures water used in the production of agricultural products from a post-production perspective in terms of blue, green and grey water. The literature has suggested that a country could overcome its water shortages by relying on imported food, or importing virtual water. Some authors maintain that this could optimise global land use efficiency and provide a more equitable distribution of water resources if nations do not over-exploit their water resources. However, this will result in increased dependency on trade with countries trading that have the ability to pay. Lower income countries will find it harder to participate as export income will be required to purchase imported food. Literature around policy incorporating virtual water as a concept shows disagreement about whether it measures the concept of absolute and comparative advantage and suggests that the concept is missing the idea of opportunity cost. New Zealand suggested as a net exporter of virtual water, which may become a possible trade advantage or risk in the future. Finally, this chapter suggests that virtual water is a concept that highlights the negative externalities of global food trade and has the ability to address these negative externalities of production (discussed in Chapter 6).

Overall, the literature review has identified a number of gaps within the area of virtual water. The policy relevance of the concept has been discussed within the literature, although this research focuses on conceptualising virtual water within an economic framework. No other literature has been identified which evaluates the utility of the concept for policy without using an economic framework. A significant proportion of the contemporary research in virtual water takes a case study approach. However, there has been no case study mapping New Zealand's virtual water interactions, nationally and internationally. Additionally, no research or case studies were found focusing on land use utilising the concept of virtual water. Therefore, this research fills a gap through conducting a case study of New Zealand linking the concept of virtual water with the intention of informing future policy decisions relating to land use.

Chapter 3

The Policy Analysis Approach

3.1 Overview

Within contemporary literature there are authors who suggest that the concept of virtual water should be incorporated within policy (Allan, 2003; El-Sadek, 2011). The purpose of this chapter is to develop the policy analysis approach undertaken within this dissertation. Therefore, this chapter reviews the literature regarding the policy cycle as a framework for the analysis. The ideas within the literature are also presented for inclusion in the framework for evaluating the utility of the virtual water concept, developed in Chapter 4. Finally, this chapter reflects on the stage that virtual water, as a concept, has reached within the policy cycle.

3.2 Policy Analysis Approaches

There are three general approaches to policy analysis: the analycentric approach, the policy process approach and meta-policy analysis (Bührs and Bartlett, 1993). Each policy analysis approach is focused at a different level of analysis and therefore interprets the problem differently. The analycentric approach involves analysis at the micro-level in comparison with the meta-policy analysis approach which involves analysis at the macro level.

The policy process approach is used in this analysis because the analysis is at the meso-level, focusing on processes and groups. The problem interpretation for this kind of analysis tends to be more political, with a focus on the relative power and influence of groups. The aim of the analysis, therefore, is to explain the role and relative influence of groups on policy, processes and means used. The *policy cycle model* is the core of this approach and as it is the framework used for this research, it will be explained in greater depth in Section 3.4. Considering virtual water has been proposed as a policy concept using the policy process approach enables the concept to be analysed in conjunction with the policy-making process.

3.3 Policy and Policy Concepts

Within the literature, the concept of virtual water has been proposed as an idea that could be useful for informing policy (Allan, 2003; Wilchens, 2004). Perhaps the most relevant and simple definition for policy comes from Dye (1972, p. 2): “whatever governments choose to do or not to do”. Similarly, a ‘concept’ is defined as, “an idea, a general idea or understanding, especially one derived from specific instances or occurrences” (Morris, 1975). This section defines public and environmental policy before proposing that virtual water is a ‘policy concept’.

Dye's (1972) definition of policy is simple and highlights that the agent of public policy-making is the government and that public policies involve a fundamental choice – to act or not (Howlett and Ramesh, 1995). Another definition of public policy is offered by William Jenkins: "a set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and means of achieving them within a specified situation where those decisions should in principle be within the power of those actors to achieve" (cited in Howlett and Ramesh, 1995 p. 5). This definition views public policy-making as a process rather than a choice. Jenkins' definition also suggests that capacity is an important consideration (i.e. that internal and external constraints exist) as well as acknowledging that it is likely to be a set of interrelated decisions (Howlett and Ramesh, 1995). Scott and Baehler (2010) identify three types of policy: strategic – taking a future position in relation to an upcoming issue influencing the government's agenda; operational – policy is put into practice and adjusted or redesigned in response to changing conditions/issues; and responsive – focusing on the government's current priorities and designing a solution. The success of policy depends on the quality of fit between the policy instruments and purpose, as well as the capacity of the government to allocate resources (Scott and Baehler, 2010).

In terms of defining 'environment' within environmental policy, Bührs and Bartlett (1993) describe it as having an ecological dimension (ecosystems), social dimension (quality of life) and an economic dimension (resource management). This is a more applicable definition in terms of helping define the environment in order to develop environmental policy. McCormick (2001 p. 21) suggests that environmental policy is:

> *"Any course of action deliberately taken or not taken to manage human activities with a view to prevent, reduce or mitigate harmful effects on nature and natural resources, and ensuring that man-made changes to the environment do not have harmful effects on humans".*

This is a comprehensive definition similar to Bührs and Bartlett's (1993) which mentions the actions of the government, relating to influencing the behaviour of humans toward their environment.

The notion of a 'policy concept' is not prevalent in the literature. However other scholars have used the term within their research. For example, Potter (2004) has suggested that *multifunctionality* is an agricultural and rural policy concept. Potter (2004) uses the term 'policy concept' synonymously with policy idea. The concept of virtual water is a policy idea, shown by the debate within contemporary literature regarding its usefulness. Section 2.5 has reviewed this literature on the policy relevance of virtual water, as a concept. This chapter also concludes with a discussion on the stage virtual water has reached in the policy cycle (Section 3.6). The conclusion of this section further strengthens the argument that virtual water is a policy concept, because it suggests that virtual water is currently at the first stage of the policy cycle (agenda setting). The next section develops the policy analysis approach and reviews the five steps in the policy cycle.

3.4 The Policy Cycle

The policy cycle model proposes a logical sequence of activities that affect the development of policies. More specifically, it depicts the policy-making process as well as the broad relationships among policy actors within each stage. The idea of simplifying the policy-making process into a few discrete stages was first introduced by Harold Lasswell. He described seven stages which described how policies were, or should be formulated (Howlett and Ramesh, 1995). However, his model focused on decision-making processes within the government and had little focus on external or environmental influences on government behaviour. Gary Brewer further developed the policy cycle model in the early 1970s. Brewer's model had six stages and discussed the process of problem recognition and introduced the notion of the policy cycle as an on-going cycle (Howlett and Ramesh, 1995). Brewer's model inspired several other versions of the policy cycle model to be developed in the 1970s and 1980s. Howlett and Ramesh (1995) suggest that the stages in the logic of applied problem solving correspond to the stages in the process of the policy cycle which is depicted in Figure 1.

Phases of Applied Problem Solving	Stages in Policy Cycle
1. Problem Recognition	1. Agenda Setting
2. Proposal of Solution	2. Policy Formulation
3. Choice of Solution	3. Decision Making
4. Putting Solution into Effect	4. Policy Implementation
5. Monitoring Results	5. Policy Evaluation

Figure 1. Five Stages of the Policy Cycle and their Relationship to Applied Problem-Solving

Source: Howlett and Ramesh, 1995, p. 11

In this model, *agenda setting* refers to the process of how problems come to the attention of governments; *policy formulation* refers to the process of how policy options are formulated within government; *decision making* refers to how governments decide on a particular course of action to take; *policy implementation* refers to the process of how the policy is put into effect; and *policy* *evaluation* refers to the process of monitoring the results of the policy. The five stages within the policy cycle will be explained further in the following sections.

3.4.1 Agenda Setting

Agenda setting addresses the primary question, how do issues appear on a government's agenda? John Kingdon proposed a model in 1995 to explain how environmental issues became the objects of public attention, and how environmental policy takes the form it does (Kraft, 2004). Kingdon argued that there are three separate and independent 'streams' of activities related to problems, policies and politics that flow through the political system (Howlett and Ramesh, 1995; Kraft, 2004). The three streams are defined as the problem stream, the policy stream and the political stream. The *problem stream* refers to the perception of problems requiring government action and efforts to resolve them (Howlett and Ramesh, 1995). It influences the agenda by providing information regarding trends and conditions about the state of the environment (Kraft, 2004). Kingdon suggests that problems typically come to the attention of policy-makers because of environmental crises or disasters or from evaluation of existing programs. The *policy stream* concerns what might be done about environmental problems and therefore involves experts and analysts investigating problems and proposing various solutions to them (Howlett and Ramesh, 1995; Kraft, 2004). The *political stream* refers to factors such as political climate or national mood, election results, and the strength of competing interest groups (Howlett and Ramesh, 1995; Kraft, 2004). All these three streams are more or less independent until specific points in time or policy windows where their paths intersect. In these policy windows, solutions adjoin with problems, and both are joined with favourable political forces.

Agenda setting also incorporates how problems are perceived and defined. Defining a problem or problem framing is significantly important because "how one defines a problem determines one's understanding of and approach to that problem" (Bardwell, 1991 p. 603). Posner (1973 p. 149, cited in Bardwell 1991 p. 605) expresses that:

> *The initial representation of a problem may be the most crucial single factor governing the likelihood of problem solution. What may appear as a formidable problem in one representation may be solved immediately in another format. A mere change of representation may by itself provide a solution. Whether a problem is solved or not, and how long the solution will take depend a great deal upon initial representation.*

Bardwell (1991) uses two problem-solving perspectives, cognitive psychology and conflict management, to examine how humans solve 'wicked' environmental problems. The cognitive psychology perspective suggests that people organise and access knowledge in the form of 'cognitive maps'. These are intellectual pathways that are created over time in the brain from experience and, consequently, vary from person to person. A bias towards familiar solutions is then created because people tend to access readily stored information and processes (solving new problems by fitting them into their pre-existing cognitive maps). This means that new problems are often approached in familiar and similar ways, which can preclude innovative solutions (Bardwell, 1991). Conflict resolution tools are then utilised, as the differences between peoples' cognitive maps can be a source of conflict, as information is processed differently and different parties may not understand these internal processes. To deal with this potential problem, metaphors can be used to help relate new information to more familiar experiences, thus setting the frame for a common understanding and decreasing the anxiety created by uncertainty to reach a more adequate problem definition. This is a powerful strategy both to deal with conflict between stakeholders but also to promote critical discourse, thereby avoiding defining a problem based on previously identified solutions (Swaffield, 1998).

Furthermore, the problem solving effort involves several stages: the first is building an understanding of the problem – defining the problem space. It has been explained already that it is important to focus on this initial step, which is often overlooked. Bardwell (1991 p. 605) suggests that problem definition impacts decisions in three distinct ways:

- It implicitly embodies preconceptions and assumptions that underpin how one approaches the problem;
- It guides the strategies and actions taken to address the problem;
- The explanation of aspects of the problem influences the quality of solutions.

As stated, defining a problem has a significant influence on the policy outcome because it sets the basis for all subsequent steps. Therefore, dedicating a sufficient amount of time to the first step will assist the following ones, as well as help to avoid the tendency to 'solutionise' or develop solutions and agreements before the problem has been correctly identified. Such deviations can lead to solving the wrong problem or having the impression that the problem has no solution.

3.4.2 Policy Formulation

Once policy actors have acknowledged the existence of a problem and recognised that they need to do something about it, policy-makers need to decide on a course of action. Therefore, the policy formulation stage involves the development of proposed courses of action.

Considering that people perceive 'problems' differently because reality differs with reference to their desired state of affairs, it seems logical to assume that the characteristics of policy formulation are simply proposals that resolve someone's perceptions of the needs that exist in society (Howlett and Ramesh, 1995). It is noted however, that even if policy-makers agree on the existence of a problem they may not share the same understanding of its cause and consequences. Jones (cited in Howlett and Ramesh, 1995 p. 123) highlights the broad characteristics of policy formulation:

1. Formulation need not be limited to one set of actors. Thus, there may well be two or more formulation groups producing competing (or complementary) proposals;

2. Formulation may proceed without clear definition of the problem or without formulators ever having much contact with affected groups;

3. There is no necessary coincidence between formulation and particular institutions, though it is a frequent activity of bureaucratic agencies;

4. Formulation and reformulation may occur over a long period of time without ever building sufficient support for any one proposal;

5. There are often several appeal points for those who lose in the formulation process at any one level;

6. The process itself never has neutral effects. Somebody wins and somebody loses even in the workings of science.

Policy formulation involves the elimination of options until a few are left, where the policy-makers can make their final decision. Policy 'failure' generally is due to poor policy design (Schneider and Ingram, 1990).

Schneider and Ingram (1990) provide a schematic diagram of policy design (Figure 2).

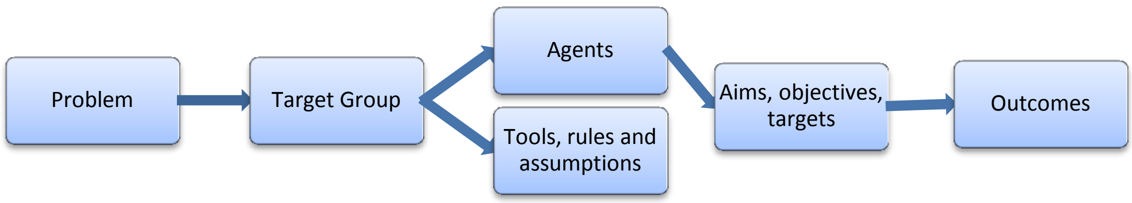


Figure 2. Elements of Policy Design

Source: Schneider and Ingram, 1990, p. 82

According to Schneider and Ingram (1990), this framework assumes that policy works through people to achieve results. For policies to 'achieve' desired outcomes many different actors will be required to take actions, therefore the framework begins by identifying agents, target populations and outcomes. The framework is built on a model of structural logic which is "a model of individual decision-makers whose behaviour impinges upon policy and a model of the contexts within which decisions relevant to policy are made" (Schneider and Ingram, 1990 p. 78). Structural logic is a powerful tool because it identifies that people and decision points are important if favourable results are to be achieved.

As mentioned earlier, the *problem definition* is arguably the most important step within the policy cycle as it has significant implications on the suggested response. The *target populations* may be characterised in terms of technical, political, administrative, and normative dimensions. Schneider and Ingram (1990) suggest that target groups may be chosen because of their direct influence on policy goals. The level of participation by the target group is also important, so it is logical that the target group will include people who are connected to the problem because they will be motivated to engage and participate as required. *Rules* specify the actions or decisions that are prohibited or permitted in order to achieve the set targets. *Tools* are incentives embedded within policy which change the likelihood of agents or the target group taking action in line with the policy goals. Examples include: grants, taxes, standards and fines. *Aims, objectives and targets*, i.e. goals, refer to desired outcomes and policies often have multiple goals. *Outcomes* refer to the effects of policy that are desired and those effects which actually occur. Elements of the framework are linked to each other through behavioural, normative and technical assumptions. The technical assumptions connect the decisions and behaviour of target groups to the policy impact. The normative assumptions connect the behaviour of the target group with value judgements regarding the welfare of society. The behavioural assumptions connect the policy tools to the behaviour of actors or agents as well as relating different behaviours to one another. In addition to these ideas it is also important to realise that policies are never finished but continue to evolve.

Schneider and Ingram's model focuses primarily on the 'process' considerations when making a policy, i.e. who are the target groups and implementing agents. But there are other ways to consider policy design. A simpler model suggests that there are three essential qualities to policies (Bührs, 2011). Firstly, a sound knowledge basis which incorporates a correct problem definition, plausible assumptions, considerations of multiple interpretations, uncertainty and acknowledging gaps in knowledge. Secondly, adequate support basis, which includes recognition of affected interests and values or ideologies, belief systems, ethics, legitimacy, costs and equity or fairness, need and political. Thirdly, feasibility and effectiveness, which includes practical, technical, instruments, financial, economic and power.

Environmental science also plays a key role in policy design or formulation because it is used as the basis for policy goals and policy design. According to Kraft (2004), the development of a proposed course of action involves the use of "scientific research on the causes and consequences of environmental problems, including projections of future trends" (p. 67). Douglas (2009) expresses the view that it is the authority and reliability of science that makes it important for policy and "without reliable knowledge from the natural world, we would be unable to achieve the agreed goals of a public policy decision" (p.3). Therefore, using scientific information within the policy process is important however, the uncertainty of it must be acknowledged.

3.4.3 Decision-Making

The process of decision-making involves choosing from among a relatively small number of alternative policy options as identified in the process of policy formulation. There are two well-known models of decision-making: the rational-comprehensive model and the incremental model.

The rational-comprehensive model can be traced back to Herbert Simon. In 1945 he developed a prescriptive model of rational choice for organisations based on the recognition that the decision-making process in organisations is not rational. Underlying this model is the idea that administrative behaviour should be guided by goals. Howlett and Ramesh (1995 p. 140) outline the elements of rational-comprehensive decision-making:

1. A goal for solving a problem is established;

2. All alternative strategies of achieving the goal are explored and listed;

3. All significant consequences of each alternative strategy are predicted and the probability of those consequences occurring is estimated;

4. The strategy that most nearly solves the problem or solves it at the least cost is selected.

The rational-comprehensive model describes procedures that will lead to the choice of most efficiently achieving policy goals. This theory is based on the belief that societies' problems ought to be solved in a 'scientific' manner. This model can be applied on an organisational level but also to society as a whole (Howlett and Ramesh, 1995). The rational-comprehensive model is goal-orientated, as mentioned earlier, and relies on knowledge for its development. At the same time, this method claims to be objective, so that the outcome of this process should be the same for everyone as value judgements are supposed to be outside the scope of the method. Questions regarding inclusiveness and participation are raised as this method assigns citizens a rather passive role in the policy design process. Perfect and complete knowledge is also assumed, which is quite unrealistic regarding environmental issues.

Concern about the usefulness and applicability of the rational-comprehensive model led to the development of the incremental model. This model attempts to approximate the actual behaviour of decision-makers by portraying decision-making as a political process characterised by bargaining and compromise. Charles Lindblom is given credit for the development of this model (Howlett and Ramesh, 1995). Lindblom emphasises the limitations facing policy-makers with respect to the gathering and analysis of information in the form of costs, capacity and time. The underlying idea within his model is that decision-makers work on the basis of past decisions and therefore new decisions and actions are only marginally adjusted (i.e. in small steps or incrementally). The rationale behind this is that decision-makers act this way because of the 'sunk costs' involved in existing policies and it is politically more acceptable to do it that way instead (i.e. big changes equate to big conflict). This method is said to avoid making serious mistakes, policy failures and is less costly. The main limitation of this approach is the perpetuation of the status quo, which may not be the optimal solution to a policy problem. Incrementalism is also criticised for lack of goal orientation, being inherently conservative and undemocratic (Howlett and Ramesh, 1995).

The limitations of both models led to the development of an alternative model. Amitai Etzioni developed his 'mixed scanning' model which proposes that optimal decision-making would consist of a preliminary search for alternatives followed by a detailed investigation into the most promising alternative (Howlett and Ramesh, 1995). This would allow greater innovation than the incremental model without imposing unrealistic demands suggested by the rational-comprehensive model.

3.4.4 Policy Implementation

Policy implementation is the process of carrying out those programs or policies once a choice has been made from among the proposed options. It involves the provision of institutional resources for putting these programs into effect (Kraft, 2004). The ease of implementation depends on the nature of the problems, i.e. their technical difficulty, the diversity of the problems the program is attempting to tackle, the size of the target group as well as the amount of behavioural change the policy requires (Howlett and Ramesh, 1995). Policy implementation is also affected by external factors, such as social and economic conditions as well as the availability of new technology. There are two main approaches to policy implementation, 'top-down' and 'bottom-up'.

The top-down approach starts with decisions from the government and places emphasis on executing the policy as it was intended by the policy-makers. Therefore, this approach places a high emphasis on achievement of stated objectives and ensures that the policy is not captured by vested interests. This view is aligned with the rational-comprehensive decision-making approach. The biggest criticism of this approach is that it focuses on senior decision-makers who often play a marginal role in implementation (Howlett and Ramesh, 1995). The neglect of its focus on the lower level officials led to the development of the bottom-up approach.

The bottom-up approach places emphasis on the role and importance of implementers in ensuring that the policy works in practice. It follows the public and private actors goals, strategies and networks of contacts they have (Howlett and Ramesh, 1995). This approach accounts for the fact that not everything is foreseen and taken into account when the policy is written. There is a need for adaptability, because policies need to be feasible and realistic. Therefore, it is important and legitimate for stakeholders to shape policy so it works best for them. The advantage of this approach is that it directs the focus towards policy problems by focusing on giving the private and public actors flexibility to enable the policy to work. This view is aligned with the incremental decision-making approach.

Both of these methods make important points. However, polarisation of ideas is not particularly informative. Therefore, some authors have advocated for a 'mixed approach'. This approach suggests that policy evolves through the interaction between design and practice. In contrast, others have opted for the study of instrument choice because policy implementation always involves applying a basic technique to solve the problem (Howlett and Ramesh, 1995). Policy instruments are mechanisms in the government toolbox such as regulation, taxes and subsidies. Policy instruments play an important role in policy and therefore are discussed in Section 3.5.

3.4.5 Policy Evaluation

Once implemented the question arises, is this policy working or not? Policy evaluation therefore is the measurement and assessment of a policy program (Kraft, 2004). Policy evaluation is a political activity, like the other parts of the policy process (Howlett and Ramesh, 1995). Often the question asked is, was the policy a success or failure? However, according to Bartlett (1994), the words ‘success’ or ‘failure’ suggest a level of ignorance and confidence which is unjustified. There are various methods of policy evaluation, and often what is used depends on the policy design approach. Although, the first step in any evaluation should involve determining goals/objectives, Bartlett (1994 p. 170 - 181) provides three categories of evaluation:

1. Outcomes: assessing the extent to which needs, values and opportunities have been realised through public action usually directed at the project, program or some broader more encompassing aspect of policy.

2. Process: these are assessments of the merit or worth of a policy process (information about what produced the observed outcomes and how).

3. Institutional: assessment of how processes work and outcomes are produced within a larger institutional framework created in part by policies within which policies are made and remade.

These three categories of evaluation are generic and therefore can evaluate different types of policy. It is also noted that policy evaluation is often not undertaken systematically for four reasons:

1. No political gain or benefit;

2. Monitoring or evaluation is not built into the policy;

3. There are weak institutional frameworks or requirements; and

4. Broad or vague goals make outcome evaluation problematic.

Policy evaluation plays a greater role within incremental approaches as these approaches rely on marginal adjustments. In comparison, rational-comprehensive approaches require a significant amount of initial information with the notion of finding the best option or solution at the policy formulation stage.

3.5 Policy Instruments

Policy instruments are embedded within the policy cycle. Policy instruments operationalise policies, therefore this section will review three important classifications. These will be linked to the policy concept of virtual water in Section 3.6 and Chapter 6. There are a variety of instruments available to policy-makers to address policy problems. Contemporary literature has attempted to classify them into meaningful categories, unfortunately no two schemes share much in common (Howlett and Ramesh, 1995; Vedung, 1998). Therefore, for the purposes of this research, one approach is explained.

Vedung (1998) suggests a threefold framework for classifying policy instruments, based on Amitai Etzioni's threefold classification of power. Vedung (1998) classifies his categories as regulations, economic means and information. These correspond to the popular expressions, the stick, the carrot and the sermon. His approach is based on the resource approach[10] to policy instrument classification which stems from the assumption that a decision has to be made regarding some form of policy intervention hence asking the question of which policy instrument to use. The basic threefold arrangement of policy instruments is presented below in Figure 3 with explanations of the classifications.

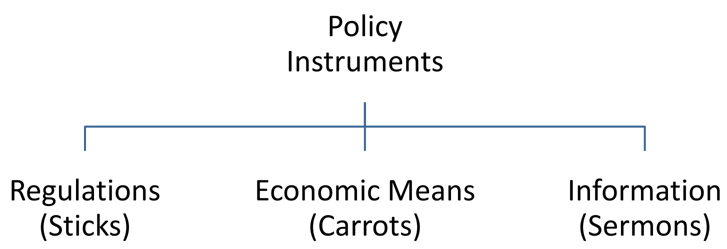


Figure 3. Three-fold Arrangement of Policy Instruments

Source: Vedung, 1998, p. 26

Regulations are measures taken by governments to influence people in the form of rules or instructions that make the receivers (often the public or firms) act in accordance with what is depicted in the rules.

Economic means (or policy instruments) involve either giving or taking material resources for example, cash or land allocations.

[10] The resource approach suggests that policy instruments ought to be classified from the perspective that the government has already decided to do something and the categories explain which resources the government can then use. In contrast, the choice approach categorises instruments in terms of the choices that the governments can make (Vedung, 1998 p. 22).

Information (or moral suasion) attempts to influence people through the transfer of knowledge, the communication of a well-reasoned argument and persuasion.

The previous sections have discussed the policy cycle and the different types of policy instruments. This leads to the following section which considers where virtual water is on the policy cycle.

3.6 Virtual Water and the Policy Cycle

Virtual water as a concept is currently in the first stage of the policy cycle, known as agenda setting. As mentioned previously, agenda setting is when an environmental issue has been brought to the attention of both the public and the political leaders (Section 3.4.1). Included also is the scientific research and government studies conducted surrounding the issue (Kraft, 2004 p. 67). Virtual water as a concept has been brought to the attention of the political leaders, within the World Water Forum in 2003 and by featuring in the United Nations Educational, Scientific and Cultural Organisation's International Hydrological Programme (known as UNESCO-IHE) (UNESCO-IHE, n.d.). Virtual water as a concept has also been brought to the attention of the public; for example, within New Zealand a recent article in the *Manawatu Standard* explains the concept of virtual water suggesting that New Zealand is lucky due to its significant water resources (Galloway, 2010). Similarly, the Royal Society of New Zealand has been involved through a media statement, radio interview and a paper discussing virtual water within New Zealand (2009). Dr Brent Clothier, the main contributor, is the leading researcher within the area of virtual water and water footprints in New Zealand[11].

Policy formulation is the next step in the policy cycle and involves the development of a proposed course of action (Kraft, 2004 p. 67). Virtual water has not reached this next stage of the policy process. Although research is being conducted globally and scholars argue that the concept could be used in policy or as a policy instrument, little policy is being developed. This further strengthens the notion that virtual water is a policy concept. The next chapter futhers this by developing an evaluative framework to assess the utility of virtual water as a policy concept.

3.7 Summary

Policy-making theory literature was discussed within this chapter. The policy process approach incorporates the policy cycle addressing the five logical stages of how policy is formulated. A brief investigation of the status of the concept of virtual water as a policy concept revealed that it is only at the agenda setting stage. This is the first stage of the policy cycle when an environmental issue has been brought to the attention of both the public and political leaders. Within this chapter, the

[11] For articles relating to the New Zealand context, see Clothier et al., 2010; Deurer et al., 2011; Herath, 2011.

concept of virtual water was also defined as a policy concept. The relevant ideas from the policy theory reviewed in this chapter will be used to develop a framework to determine the utility of the concept of virtual water in Chapter 4.

Chapter 4

Research Methodology

4.1 Overview

This chapter outlines the methodological approach undertaken in this study. A mixed methods approach incorporated both quantitative and qualitative data collection. The qualitative part of the research involved conducting a literature review. This encompassed virtual water and policy analysis literature from which a framework for evaluating the concept of virtual water is developed. This is followed by the quantitative aspect of the research and incorporates a case study of New Zealand. The case study initially quantifies virtual water interactions from 2005-2010 using data sourced from the Food and Agricultural Organization of the United Nations (FAO). The second aspect investigates land use change over the past decade predominantly through gathering data from Statistics New Zealand.

4.2 Methodology

4.2.1 Mixed Methods Approach

A brief definition provided by Creswell (2009) suggests that mixed methods incorporate both quantitative and qualitative research and methods in a research study. This approach utilises the strengths of both qualitative and quantitative research and allowing more insight into the research itself (Creswell, 2009). The explanatory design of the method was sequential and is shown by Figure 4 below.

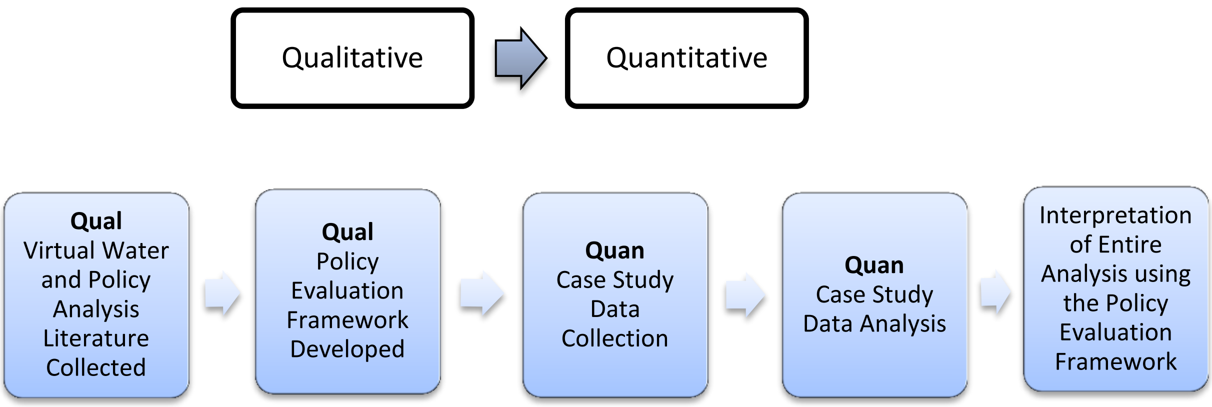


Figure 4. Sequential Explanatory Design

Source: Adapted from Creswell, 2009, p. 209

Qualitative data collection and analysis is used for the first part of the research which explores existing virtual water research and policy theory. Policy theory is used to develop a framework to evaluate the utility of the concept of virtual water. The quantitative analysis involves a case study of New Zealand. This data is utilised to calculate the virtual water interactions of New Zealand and drew from research related to land use with a view to applying the virtual water concept to New Zealand. These research methods are explained in Section 4.3.

4.2.2 Policy Evaluation Framework for the Concept of Virtual Water

Chapter 2 has suggested that the literature debates whether virtual water is a useful concept for policy based on economic frameworks. Chapter 3 argues that virtual water is a policy concept and is currently at the agenda setting stage of the policy cycle. Because the concept of virtual water is only at the agenda setting stage of the policy cycle, it is yet to be embedded in any policy. Ordinarily, a policy analyst could evaluate a policy using a policy analysis approach or framework. Instead, this section will develop a policy evaluation framework for a policy concept.

The following framework draws on Mickwitz's (2003) criteria, which are, in his view, the most important for evaluating policy instruments. Although, virtual water is a policy concept not a policy instrument, his approach is relevant and useful for meeting the aims of this study. Therefore, some of Mickwitz's (2003) criteria, along with other policy ideas, such as problem framing, have been developed as a framework (Table 1). Each criterion is listed with its key question, discussed below Table 1. This framework will be used in Chapter 6 to assess the utility of virtual water for informing land use decisions in New Zealand.

Table 1. Criteria for Evaluating Virtual Water as a Policy Concept

Criteria	Definition/Related Questions
Relevance	Does virtual water address the underlying environmental problem?
Problem Framing	Can the concept of virtual water frame or reframe the environmental problem to assist policy-making?
Persistence	Could virtual water, as a policy concept, have a lasting effect on the state of the environment?
Flexibility	Can virtual water change with changing environmental conditions?
Predictability	Is it possible to foresee the outcome when using virtual water as a policy concept?
Scope	Is virtual water as a policy concept too narrow or limited in scope to address the environmental problem?
Efficiency	Are the benefits of measuring virtual water and creating a policy worth the costs?
Legitimacy	To what degree will stakeholders be able to understand or accept virtual water as a policy concept?
Transparency	To what degree could the outputs and outcomes of virtual water policy be observable to outsiders?
Equity	How would the outcomes and costs of virtual water considerations be distributed?
Feasibility	Could virtual water, as a concept, be integrated within policy using data sources?

Source: Adapted from Mickwitz, 2003 p. 426 – 427

Relevance is perhaps the most important criterion. If the concept of virtual water does not address the underlying environmental problem then there is no point continuing on and using this policy concept. This criterion will also give an idea of whether this policy concept can be used in isolation or not. Knowledge of key issues and anticipated effects of the environmental problem should be identified within this criterion.

The criterion, *problem framing,* determines whether the problem can be defined, framed or reframed appropriately using this policy concept. How a problem is defined often determines how an actor or group of actors interpret or understand the problem therefore influencing the approach to the solution. Problem framing offers a means of approaching a problem that might have been avoided or solved poorly (Bardwell, 1991). It also helps actors to understand problems in a way that is not overwhelming, as people can only absorb and understand a certain amount of information (Bardwell, 1991). Essentially, this criterion is an important one to satisfy in order for an appropriate and innovative solution to be established.

P*ersistence* measures the lasting impact of a policy. It looks at all the anticipated effects and attempts to determine how long they will last over time. Particular importance is placed on the effects that may ultimately compromise the intended benefits.

Flexibility of an environmental policy concept is a very important feature. If the environmental conditions change and the policy does not adapt, then the policy will no longer be relevant. Environmental conditions can change without notice and this criterion is often in conflict with the next criterion, predictability.

Predictability is also an important criterion. If a policy is written and the outcomes of it are not able to be somewhat predicted, then politicians and the general public would be wary of the policy. This would adversely affect the likelihood of implementation.

The scope criterion assesses whether the policy concept fully addresses the environmental problem. If the scope of the policy concept is too narrow it will not address the wider implications of the environmental problem. In contrast, if a concept is too broad it probably only deals with the environmental problem at the surface, therefore not rectifying or determining the cause. This criterion measures the extent of the area that the policy concept addresses, consequently determining whether it is too narrow or broad.

Efficiency is an economic criterion which measures whether the benefits and costs of implementing a policy are worth it in monetary terms and in terms of resources. This is often hard to measure. However, it is important to ensure that policies themselves are not wasting time, money and resources. Economists also use 'static' and 'dynamic' efficiency in order to evaluate efficiency. Static efficiency refers only to the current period, where the policy aims to maximise net social benefits. In contrast, dynamic efficiency measures how well a policy encourages the efficient use of resources when faced with rapid technical change (Sterner, 2003). Dynamic efficiency takes into account both the current and future costs, therefore maximising the present value of net social benefits[12]. Both these types of efficiency are embedded within this criterion.

Legitimacy refers to the idea that people perceive that it is the right thing to do, i.e. the policy is understood and accepted. It depends partly on the type of policy, as some policies are more widely known and disliked. An example of this is taxes. People often do not believe that the government has

[12] The economic glossary explains the terms static and dynamic analysis. These terms refer to different time periods which is relevant for considering efficiency.

the right to continually tax their incomes. The concept of legitimacy is also important within the institutions that are involved, the implementation procedure of the policy as well as the outcome and outputs that are generated.

Transparency implies openness; the administration, output and outcomes for a policy concept can all be assessed on the basis of how transparent it is. Transparency is an important criterion because it will ultimately determine how well the public accept and react to the policy. It is conceivable that some aspects of a policy process are very transparent while others are not. This criterion should identify the level of transparency within the different processes and the policy itself.

Equity is another very important criterion. Equity is the quality of being fair and has implications for output, outcomes, processes and implementation for environmental policy. Current costs and effects are important but intergenerational equity also needs to be taken into account because many environmental problems occur over significant time periods. “The equality of the process, equal participation and access to information, should not be overlooked especially when the capabilities of the stakeholders vary considerably” (Mickwitz, 2003 p. 428). It is well known that policies impose different financial burdens for stakeholders and society (Sterner, 2003). Therefore, these costs should all be evaluated within this criterion.

Finally, *feasibility*, measures how possible and practical it is for the concept of virtual water to be integrated within policy. This criterion focuses on the availability of appropriate data sources. If data is not available or is found to be inaccurate, more empirical research will be required.

The eleven criteria within the framework will be evaluated using the concept of virtual water in Section 6.3. This will determine whether virtual water as a policy concept is useful, consequently determining whether it can inform future land use decisions in New Zealand.

4.2.3 Case Study Approach

Case studies are useful for exploring a situation where the phenomenon being studied has no clear single set of outcomes (Adams, Hoque and McNicholas, 2006). The rationale for utilising the case study strategy is they favour “how” and “why” research questions as well as investigating a “contemporary phenomenon within its real-life context” with weak boundaries between the phenomenon and context (Yin, 1994, p.13). This research is a case study that characterises New Zealand’s virtual water interactions, nationally and internationally, and land use. Initial research investigates virtual water publications within New Zealand and concludes that little aggregated research had been conducted. Using a case study methodology enables this research to practically apply virtual water as a policy concept.

4.3 Method

4.3.1 Virtual Water and Policy Theory Literature

A literature review regarding all aspects of virtual water research included literature sourced from both the Lincoln University Database and Google Scholar. Other websites were accessed for published material including UNESCO-IHE and relevant books were accessed from the Lincoln University Library.

Similarly, the policy theory section of the dissertation reviewed literature to determine three methods of conducting policy analysis. The policy cycle and theories within each stage use related literature in order to give an overview of how policy is created in accordance with the policy process approach. Relevant literature sourced from Lincoln University library included books and journal articles sourced from the Lincoln University Library Database.

4.3.2 Data Collection Methods

To investigate New Zealand's virtual water interactions (Research Objective 4 and 5) required production data and import/export data. Statistics New Zealand provides publicly available aggregated data of the New Zealand National Accounts but it was not suitable for this analysis as this research was aimed at the product level. An alternative source of data was found online from the Food and Agricultural Organization of the United States (FAO). The FAO provide FAOSTAT, an online database providing estimates of commodity data, primary crops, livestock and fish, food balance sheets, food supply, forestry, investment, population, prices, production, resources and trade for most countries of the world.

To estimate the top ten production products in New Zealand (Research Objective 4) the FAO estimates of production quantity are used. Specifically, drawbacks included estimates of crops processed, livestock processed and livestock primary. To estimate the top ten imports and exports of New Zealand, FAO trade data is used to determine the top ten products by export dollars and then the production data was downloaded for each of these products.

Virtual water estimates were sourced from Value of Water Research Report Series No. 48 and 50 published by UNESCO-IHE (Mekonnen and Hoekstra, 2010, 2011). Alternative data sources included estimates from Clothier et al. (2012) providing information for a limited number of products, including kiwifruit and wine. For reasons of consistency, only the FAO data was used.

4.3.3 Data Analysis

For characterising virtual water interactions nationally (Research Objective 4), the top ten agricultural products by 2010 FAO estimated/actual data[13] were chosen. These were determined to be milk, eggs, cattle meat, potatoes, sheep meat, wheat, butter, apples, cheese and kiwifruit. The estimated (or actual) quantity produced for each product from 2005 – 2010 was then multiplied by the estimated virtual water content of the product for production in New Zealand sourced from Mekonnen and Hoekstra (2010, 2011). This information was then analysed using Microsoft Excel. It is important to note that the products for which no virtual water estimates were available were not included in the final analysis, an example of this being kiwifruit.

For characterising virtual water interactions internationally (Research Objective 5), the top ten agricultural goods by export value were chosen from the 2010 FAO data. The rationale behind this was to analyse the impact of goods that contribute proportionately higher to the New Zealand economy in monetary terms. The data for these products was sourced from the FAO production data. The top ten exported products were determined to be milk, bovine meat, butter, sheep meat, apples, cheese, wine, onions, wool and kiwifruit. The top ten imported products were determined to be wheat, sugar, milk, bananas, wine, rice, pig meat, bovine meat, coffee and tobacco. The quantities from each year (2005 – 2010) were multiplied by the virtual water estimates. This information was then analysed using Microsoft Excel. It is important to note that the products for which no virtual water estimates were available were not included in the final analysis, an example of this being kiwifruit.

4.3.4 Land Use Data Collection Methods

The next part of the quantitative analysis involved collecting data relating to New Zealand's land use because land use determines how much virtual water is utilised in a country.

To investigate how land use has changed (Research Objective 3), data was collected from the Ministry for the Environment, Statistics New Zealand and Dairy New Zealand. The Ministry for the Environment provided a snapshot of New Zealand's land use as at 2004 in their report titled *Environment New Zealand 2007*. Statistics New Zealand conducted Agricultural Production Census as and Agricultural Production Surveys in recent years. This enabled enough time series data to be collected in order to map the production of some horticulture products (fruit, vegetables and grains) and livestock numbers using Infoshare[14]. Publicly available information was also accessed from Dairy New Zealand in order to determine how many hectares have been used for dairy farming in recent

[13] See Appendix B for actual and real data classifications.
[14] Infoshare is a free online tool which allows public access to a range of time series data. This can be accessed at http://www.stats.govt.nz/infoshare/.

years. Clarification from Dairy New Zealand was sought and obtained to determine how the data available was calculated.

4.4 Research Limitations

There are a number of limitations associated with this methodology.

1. The approach of a literature review is important as it aims to gather and review all published material which may alter the research question and help interpret the findings (Bryman and Bell, 2011). However, accessing all published material is not always possible. Considering that virtual water is a relatively new concept and most research has been conducted overseas, when completing the literature review some journal articles could not be accessed. This is a limitation because a wider range of alternative authors' findings, if relevant, could not be added to the analysis in this research.

2. Using a framework to evaluate virtual water, as a concept, could also be limiting. This is because there are many frameworks that could be used which may alter the research findings. This research has also assumed that virtual water is a policy concept that is currently at the stage of agenda setting. Therefore, it may not be developed into a policy or policy instrument (see Chapter 4).

3. New Zealand is used as a case study for this research. Case studies have both advantages and disadvantages. Yin (1994 p. 10) discusses the main disadvantages of case studies:

    a. Case studies may have a lack of rigour if biased views have influenced the direction of the findings and conclusions;

    b. Case studies provide little basis for scientific generalisation because they use a sample size of one;

    c. Case studies may be long, difficult to conduct and produce massive unreadable documents.

4. Within this case study, land use data was found to be limited and sporadic. Therefore, this research may not be able to fully inform land use change unless land use within New Zealand is documented systematically in the future.

5. The estimates of virtual water for agricultural goods are provided for a wide range of products but there is no clear or documented methodology. The lack of explanation surrounding the data raises questions about its reliability and accuracy.

4.5 Summary

This chapter outlines the research methodology explaining the mixed methods and case study research approach. A literature review collated virtual water research and reviewed policy theory. A quantitative research method was applied to the case study to map changes in New Zealand’s land use over the past ten years and to calculate New Zealand’s virtual water interactions, both nationally and internationally. Data for the case study was sourced from the FAO and Mekonnen and Hoekstra (2010, 2011). Microsoft Excel was used to manipulate this data and the limitations of this research method were also discussed.

Chapter 5

Case Study Findings

5.1 Overview

This section will describe the findings from the case study. The case study illustrates how the application of this concept could work in practice. The virtual water interactions for New Zealand, from 2005 – 2010, are discussed followed by New Zealand's land use over the past ten years. Finally, the main findings of the case study are presented with a further discussion of these results utilising other literature.

5.2 Water Use for Agricultural Goods in New Zealand

Agricultural production plays a significant role in the New Zealand Economy, contributing approximately 2.8% to gross domestic product and 10.4 billion New Zealand dollars to export earnings (Ministry of Primary Industries, 2012). In order to investigate New Zealand's virtual water interactions nationally, the top ten agricultural goods by production volume (in 2010) are considered (Table 2).

Table 2. The Top Ten Agricultural Products Produced in New Zealand 2010

Element	Element Type	Item	2010	Unit
Production	Livestock Primary	Cow milk, whole, fresh	17,010,500	tonnes
Production	Livestock Primary	Hen eggs, in shell (Number)	934,000	1000 No
Production	Livestock Primary	Cattle meat	635,289	tonnes
Production	Crops	Potatoes	531,100	tonnes
Production	Livestock Primary	Sheep meat	470,906	tonnes
Production	Crops	Wheat	444,891	tonnes
Production	Livestock Processed	Butter Cow Milk	385,000	tonnes
Production	Crops	Kiwi fruit	378,500	tonnes
Production	Crops	Apples	319,800	tonnes
Production	Livestock Processed	Cheese (All Kinds)	311,200	tonnes

Source: FAOSTAT, FAO

Data for the production of these ten products was sourced for 2005 – 2010 from the FAO. These figures can be found in Appendix B.

Table 3 gives the estimates for the water footprints of the products set out in Table 2 in m^3 per tonne. As mentioned in Chapter 4, these estimates are from Mekonnen and Hoekstra (2010, 2011) and are for the country of New Zealand (Table 3). These figures are used within this research to estimate the virtual water content of certain agricultural goods even though they are labelled as estimates for water footprints[15].

Table 3. Virtual Water Estimates for Agricultural Products (m^3 per tonne)

Item	Green	Blue	Grey	Total
Cow milk, whole, fresh	520	48	10	578
Hen eggs, in shell (Number)	1,011	72	128	1,211
Cattle meat	8,912	384	45	9,341
Potatoes	80	1	42	123
Sheep meat	4,440	366	1	4,807
Wheat	1,363	9	155	1,527
Butter Cow Milk	2,826	259	55	3,140
Apples	210	9	1	220
Cheese (All Kinds)	2,567	251	50	2,868

Source: Mekonnen and Hoekstra (2010, 2011), Report 49 and 50, UNESCO-IHE

Table 3 illustrates that New Zealand predominantly uses green water to produce its agricultural goods. Data that separates the virtual water content by type has policy implications for managing water resources. These implications are discussed in Section 5.5 and Chapter 6.

The total production for each product per year was then multiplied by the virtual water estimates. Aggregating this data over five years (2005 - 2010) highlights an increasing trend of the use of virtual water in New Zealand production of its top ten products (Figure 5). As mentioned in Section 4.3.3, the agricultural products for which no virtual water estimates were available were not included in the final analysis. Therefore, kiwifruit was excluded. Recall also that virtual water is also measured in three types blue, green and grey water. Figure 6 shows the virtual water for production split by type according to Mekonnen and Hoekstra (2010, 2011).

[15] Within Section 2.3, this dissertation discussed the differences between the concept of virtual water and the water footprint. Velazquez et al. (2011) distinguish clearly, the difference between the two concepts. However, other authors use the terms interchangeably. Mekonnen and Hoekstra (2010, 2011) use the terminology outlined in the *Water Footprint Assessment Manual* (Hoekstra et al., 2011). This suggests that the water footprint of a product is defined as the total volume of freshwater that is used directly or indirectly to produce a product. This definition is the same as the definition of virtual water within this dissertation.

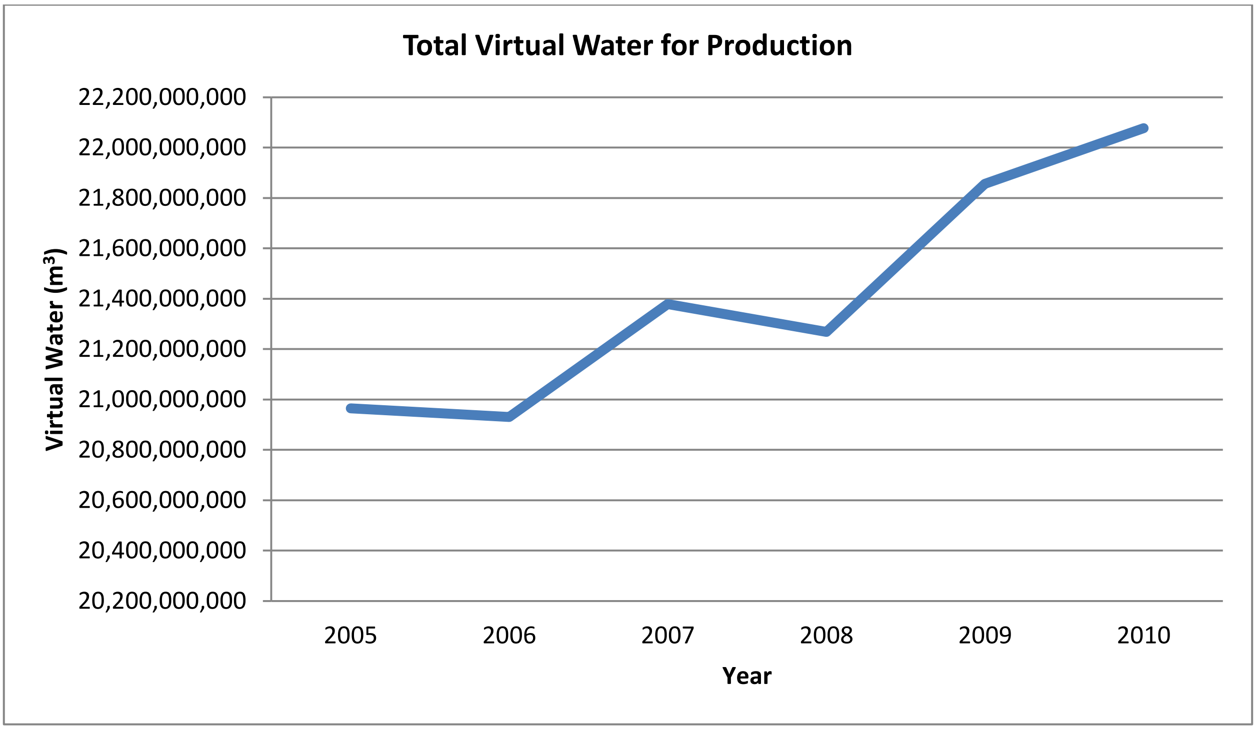


Figure 5. Total Virtual Water for Production

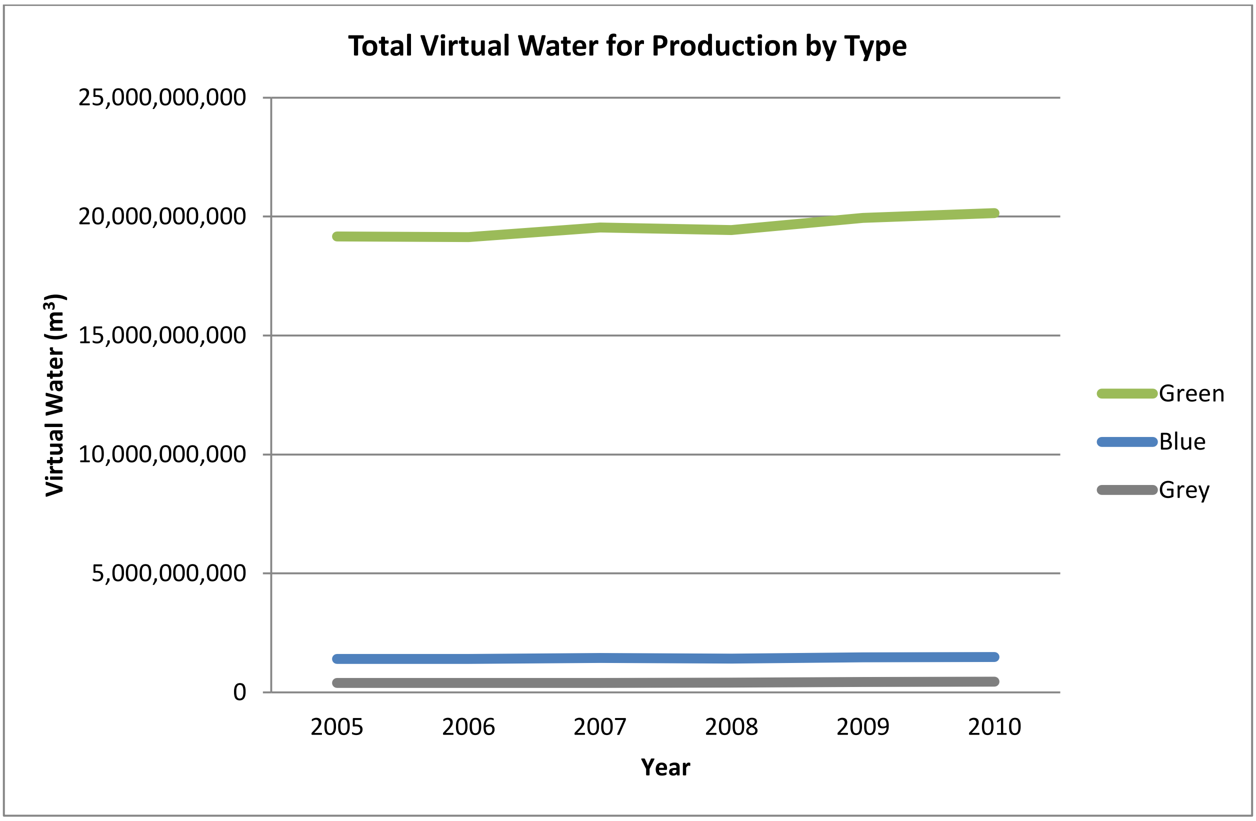


Figure 6. Total Virtual Water for Production by Type[16]

[16] The word 'total' in the graph title refers to the fact that this graph represents combined data for the nine agricultural goods.

The increasing trend in virtual water for production in New Zealand shown by Figure 5 is not surprising as the agricultural sector is continuing to increase production within New Zealand (Dairy NZ, 2012; Ministry of Primary Industries, 2012). However, Figure 6 shows an increase in all the types of virtual water at a similar rate. By type, green water makes up most of the virtual water. This result is expected because green water dominates water use even in dry areas (Brent Clothier, personal communication, January 25, 2013). This data limits the results of the research because the virtual water estimates stay constant throughout time. Therefore, the findings do not show if the use of irrigation increases in New Zealand. If irrigation had increased, it would be expected that blue water would increase at a different rate in comparison with green or grey water. A closer look at the virtual water estimates raises questions about the reliability and accuracy of measurement of the data. Water used in the production of milk, for example, is rather low in comparison to cattle meat. These issues will be discussed later in this chapter.

5.3 Net Virtual Water Balance of New Zealand

New Zealand is a large exporter of agricultural goods. In order to investigate New Zealand's international virtual water interactions, the top ten imported and exported agricultural goods (in 2010 by import and export value) are considered (Table 4).

Table 4. Top Imported and Exported Agricultural Products by Dollar Value

Element	Item	2010	
Export Value	Milk Equivalent	7,684,899	1000 US$
Export Value	Sheep meat	1,967,701	1000 US$
Export Value	Butter Cow Milk	1,567,891	1000 US$
Export Value	Bovine Meat	1,491,293	1000 US$
Export Value	Cheese and Curd	1,041,534	1000 US$
Export Value	Wine	789,130	1000 US$
Export Value	Kiwi fruit	697,578	1000 US$
Export Value	Wool (greasy + degreased)	450,981	1000 US$
Export Value	Apples	238,778	1000 US$
Export Value	Onions	84,504	1000 US$
Import Value	Sugar, Total (Raw Equiv.)	118,593	1000 US$
Import Value	Wine	106,590	1000 US$
Import Value	Pig Meat	98,074	1000 US$
Import Value	Milk Equivalent	85,906	1000 US$
Import Value	Wheat	80,866	1000 US$
Import Value	Tobacco	66,227	1000 US$
Import Value	Bananas	61,649	1000 US$
Import Value	Rice	48,577	1000 US$
Import Value	Coffee (Green + Roast)	43,702	1000 US$
Import Value	Bovine Meat	35,042	1000 US$

Source: FAOSTAT, FAO

For each product the production quantity for 2005 – 2010 is determined; Table 5 shows this for 2010. The data for 2005 – 2009 can be found in Appendix B.

Table 5. Export and Import Quantity for Top 10 Products for 2010

Element	Item	2010	
Export Quantity	Milk Equivalent	14,757,817.00	tonnes
Export Quantity	Bovine Meat	500,468.00	tonnes
Export Quantity	Butter Cow Milk	416,146.00	tonnes
Export Quantity	Kiwi fruit	406,380.00	tonnes
Export Quantity	Sheep meat	372,866.00	tonnes
Export Quantity	Apples	284,187.00	tonnes
Export Quantity	Cheese and Curd	277,758.00	tonnes
Export Quantity	Wine	244,098.00	tonnes
Export Quantity	Onions	185,009.00	tonnes
Export Quantity	Wool (greasy + degreased)	136,706.00	tonnes
Import Quantity	Wheat	289,624.00	tonnes
Import Quantity	Sugar, Total (Raw Equiv.)	217,021.00	tonnes
Import Quantity	Milk Equivalent	112,402.00	tonnes
Import Quantity	Bananas	85,867.00	tonnes
Import Quantity	Wine	51,697.00	tonnes
Import Quantity	Rice	44,582.00	tonnes
Import Quantity	Pig Meat	36,331.00	tonnes
Import Quantity	Bovine Meat	10,864.00	tonnes
Import Quantity	Coffee (Green + Roast)	10,737.00	tonnes
Import Quantity	Tobacco	5,632.00	tonnes

Source: FAOSTAT, FAO

Once again, these estimates are for the water footprints of the product in m^3 per tonne sourced from Mekonnen and Hoekstra (2010, 2011). The estimates for imported goods use the world average while the estimates for the exported goods use estimates for the country of New Zealand (Table 6).

Table 6. Virtual Water Estimates for Imported and Exported Agricultural Products (m^3 per tonne)

Element	Item	Green	Blue	Grey	Total
Export Quantity	Milk Equivalent	520	48	10	578
Export Quantity	Bovine Meat	8,912	384	45	9,341
Export Quantity	Butter Cow Milk	2,826	259	55	3,140
Export Quantity	Sheep meat	4,440	366	1	4,807
Export Quantity	Apples	210	9	1	220
Export Quantity	Cheese and Curd	2,567	251	50	2,868
Export Quantity	Wine	587	135	75	797
Export Quantity	Onions	183	118	39	340
Export Quantity	Wool (greasy + degreased)	2,759	175	9	2,943
Import Quantity	Wheat	1,277	342	207	1,826
Import Quantity	Sugar, Total (Raw Equiv.)	1,055	412	115	1,582
Import Quantity	Milk Equivalent	863	86	72	1,021
Import Quantity	Bananas	660	97	33	790
Import Quantity	Wine	607	138	124	869
Import Quantity	Rice	1,800	535	293	2,628
Import Quantity	Pig Meat	3,582	324	454	4,360
Import Quantity	Bovine Meat	14,414	544	451	15,409
Import Quantity	Coffee (Green + Roast)	15,249	116	532	15,897
Import Quantity	Tobacco	2,021	205	700	2,926

Source: Mekonnen and Hoekstra (2010, 2011), Report 49 and 50, UNESCO-IHE

The total production for each product per year is multiplied by the virtual water estimates. Aggregating this data over five years (2005 - 2010) and subtracting imports from exports gives the net virtual water balance of New Zealand (Figure 7). Furthering this, Figure 8 shows the net virtual water split by type. As mentioned in Section 4.3.3, the products for which no virtual water estimates were available were not included in the final analysis. Therefore, kiwifruit was excluded.

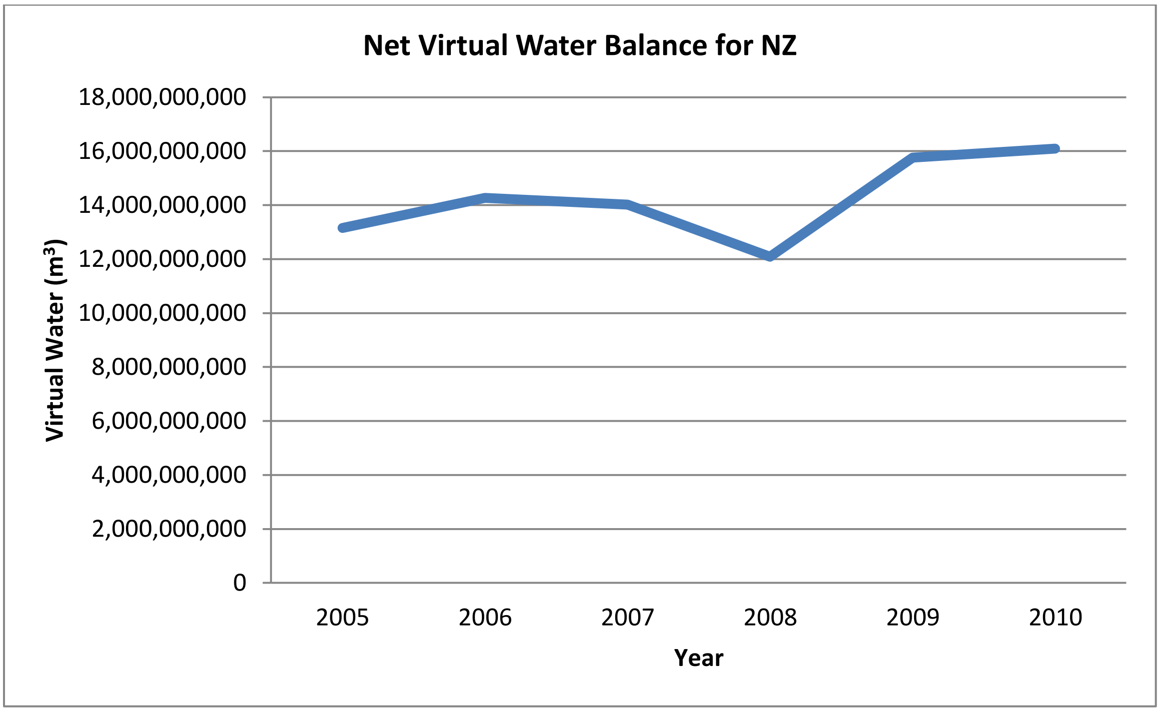


Figure 7. Net Virtual Water for New Zealand

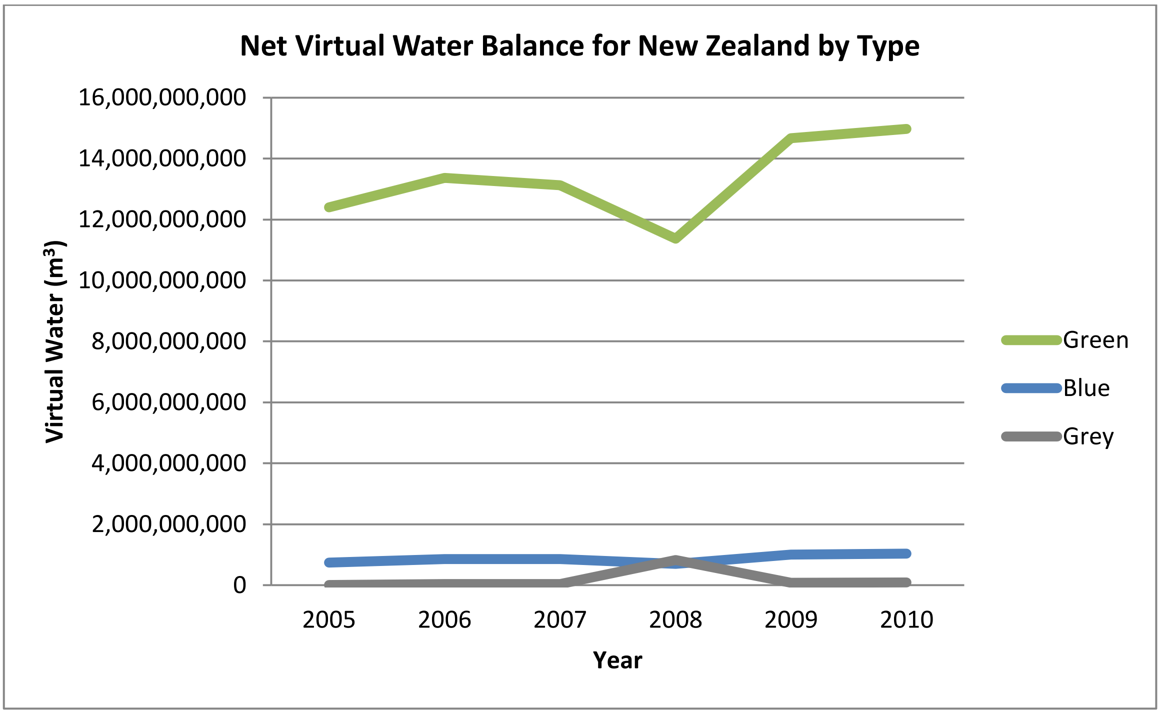


Figure 8. Net Virtual Water for Production by Type[17]

Figure 7 shows an increasing trend in net virtual water utilised for production in New Zealand. This is not surprising as the export market continues to grow, especially with regard to exported dairy products. Similar to Figure 6, Figure 8 shows an increase in the use of green water. This result is

[17] The word 'total' in the graph title refers to the fact that this graph represents the virtual water content of the chosen imported agricultural goods less the virtual water content for exported agricultural goods.

expected as green water dominates water use. However, this data is limiting because the virtual water estimates stay constant throughout time therefore, they would not identify whether the use of irrigation (blue water) is increasing within New Zealand. These results also raise questions about the reliability and accuracy of measurement because water used in the production of milk is low in comparison to sheep meat and wool.

The inaccuracy of the data in this research stems from the two data sources. Firstly, some of the products deemed to be the top imports and exports for New Zealand, sourced from the FAO, are suggested to be unlikely. For example, the FAO data suggests that New Zealand imports milk. FAO methodology and data is found in Appendix B where the FAO states that it only estimates data if a country's government does not provide actual quantities. Therefore, within this research there are some figures which are estimates and some that are real measured flows (see Appendix B for real and actual data figures). Secondly, the virtual water estimates for New Zealand are suggested to be somewhat inaccurate. Mekonnen and Hoekstra (2010, 2011) estimate how many litres of water per tonne of water are used for agricultural goods for a country. However, this is data is not further split by region. The climate in New Zealand varies significantly between regions and some crops are more productive in different climates than others. Clothier et al. (n.d.) discusses the discrepancies in measuring virtual water for apples. The authors suggest that in New Zealand the water use per apple per tree is 10.6 and 6.5 L/apple for a larger and smaller tree. These findings are in stark contrast to the FAO virtual water poster which suggests that the virtual water content of an apple is 70 L/apple. According to Clothier et al. (n.d.) the difference arises due to evapotranspiration and apple yield. Clearly, the virtual water content of a product differs depending on where and how it is grown. The FAO's aggregated figures cannot capture this local or regional specificity. However, due to limited data available, this research has used benchmark values for reference until better estimates are available.

5.4 Land Use change in New Zealand in the Recent Past

Reliance on land resources is a defining feature of New Zealand's national identity. The expertise we have developed in using our land resources has put New Zealand on the international stage. Land underpins New Zealand's top two export earners: tourism and primary production.

Ministry for the Environment (2007 p. 216)

Land supports a significant proportion of New Zealand's economy and can be defined as the part of the Earth's surface that is not covered by water. Land is the resource that crops are grown on and where animals are grazed. The concept of virtual water indirectly impacts land as the concept itself measures only the water used in the production of crops. However, this research asks how the concept of virtual water could influence decisions determining land use in New Zealand. The purpose of this section is to present findings of how land use has changed within New Zealand over the past ten years.

The terms *land cover* and *land use* need to be differentiated. “The term *land cover* relates to the type of feature present on the surface of the earth” (Lillsand and Kiefer, 1994 p. 170). For example, cornfields, lakes, maple trees, and concrete highways are all examples of land cover types. In contrast, “the term *land use* relates to the human activity or economic function associated with a specific piece of land” (Lillsand and Kiefer, 1994 p. 170). For example, commercially planted forestry and different types of farming or horticulture are examples of land use types. In New Zealand the measurement of land use has been sporadic with the majority of the information being collected through Agricultural Production and Census Surveys by Statistics New Zealand.

In the latest *Environment New Zealand 2007* report, the Ministry for the Environment provides a snapshot of land use as at 2004 (Ministry for the Environment, 2007). This is shown below in Figure 9. The map shows the location and extent of the 18 land use classes and the four classes of land cover.

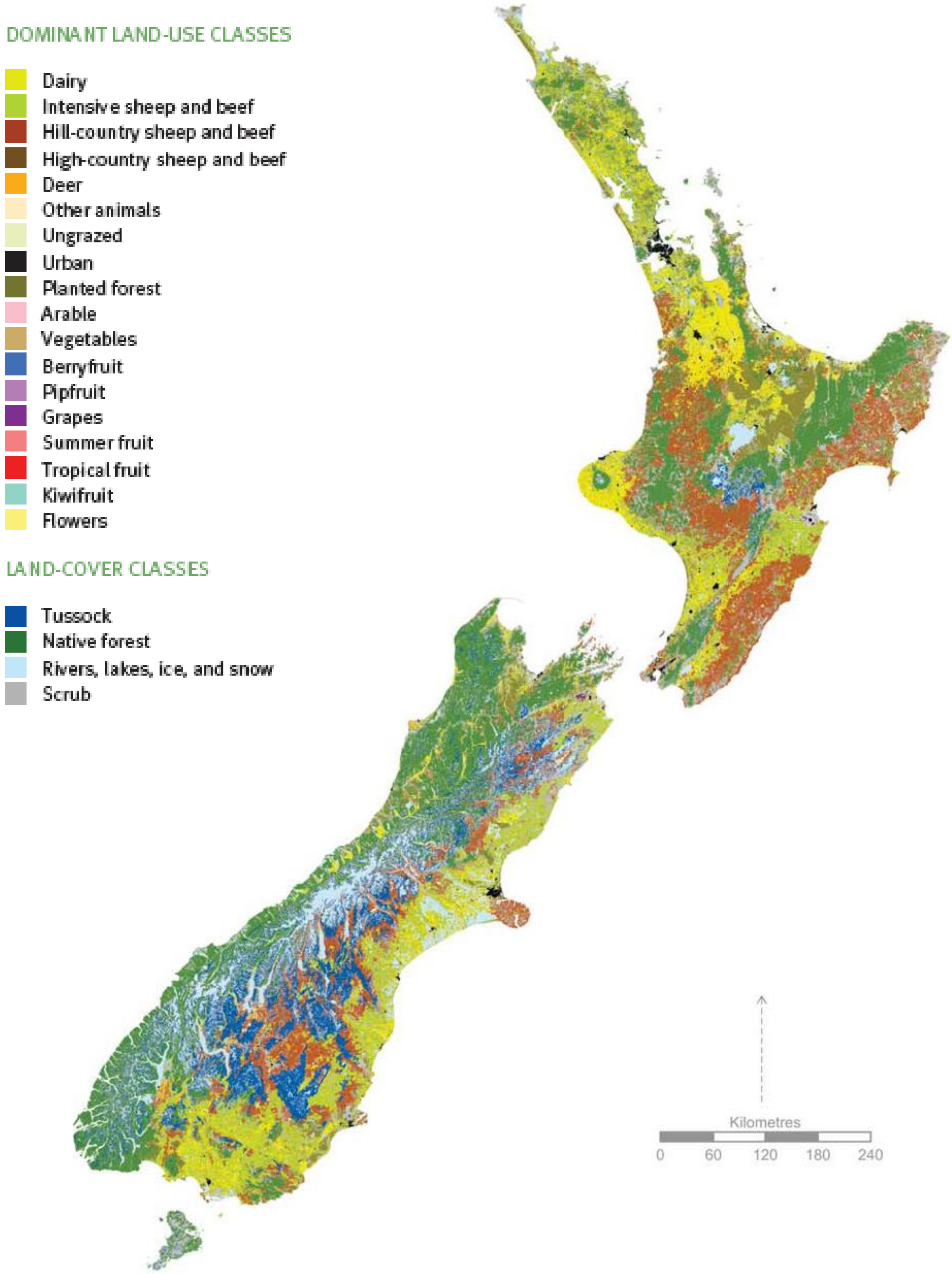


Figure 9. **Land Use in New Zealand, 2004**

Source: Ministry for the Environment, 2007, p. 230

The *Environment New Zealand 2007* report also provides a snapshot of land use and land cover classes in terms of hectares and the percentage of total land use, Table 7.

Table 7. Dominant Land Use and Selected Land Cover in New Zealand, 2004

LAND-USE CLASSES	HECTARES	PERCENTAGE OF TOTAL LAND AREA (%)
Dairy	1,879,600	7.00
Intensive sheep and beef	3,841,100	14.32
Hill-country sheep and beef	4,023,200	15.00
High-country sheep and beef	48,900	0.18
Deer	249,700	0.93
Other animals	64,900	0.24
Ungrazed	659,800	2.46
Urban	203,600	0.76
Planted forest	1,957,000	7.30
Arable crops	1,200	0.0044
Vegetables	2,200	0.0083
Berryfruit	1,200	0.0045
Pipfruit	10,200	0.038
Grapes	18,800	0.070
Summer fruit	1,800	0.0069
Tropical fruit	1,600	0.006
Kiwifruit	6,400	0.024
Flowers	57	0.0002
LAND-COVER CLASSES		
Tussock	2,645,200	9.86
Native forest	6,567,200	24.48
Rivers, lakes, snow, and ice	2,094,200	7.81
Scrub	2,543,600	9.48
Total	26,821,500	100

Source: Ministry for the Environment, 2007, p. 231

Table 7 and Figure 9 identify the largest human uses of land are for farming (dairy, sheep and beef). This equates to approximately 37 percent of New Zealand's total land area. New Zealand's natural land cover is also shown to be approximately 52 percent and this includes native forests, rivers, lakes and scrub. However, this data only shows New Zealand's land use at one point in time. This research is focused on looking at the last ten years of land use, in order to follow the patterns of New Zealand's land use change. When informing policy it is important to look at pre-existing patterns as well as writing goals and objectives in order to achieve an anticipated future.

In recent times, areas within New Zealand have been moving away from arable crops (such as grain) and sheep and beef farming to dairy grazing (Anderson et al., 2008). In Canterbury, for example, the land used for dairying has increased from approximately 20, 000 hectares to 190, 000 hectares during the period 1980 – 2009 (Pangborn and Woodford, 2011). The drivers of land use change in Canterbury have primarily been because of the development of irrigation and the lower land prices relative to elsewhere in New Zealand (Hearnshaw et al., 2011). Overseas demand for dairy products and willingness to pay by particular countries has also contributed to this. It is hypothesised that the quantity of land used for each purpose (i.e. farming or horticulture or forestry) will affect New Zealand's virtual water balance.

The Agricultural Production Survey[18] is annual and measures statistics on agricultural, horticultural and forestry activity. It measures area planted in outdoor fruit (apples, avocadoes, kiwifruit, wine grapes, blackcurrants, cherries) and harvested area of outdoor vegetables [onions, potatoes, buttercup squash, peas (fresh and processed) and sweet corn]. These statistics provide information on the changing land use of New Zealand and are displayed below in Figures 10 and 11.

[18] This data was sourced from the database Infoshare from Statistics New Zealand.
Footnotes from Statistics New Zealand:
From 2000 - 2005, the indoor vegetable question relates to harvested area including crop rotation and case area. In 2007 and 2009 the indoor vegetable question relates to harvested area and includes case area only.

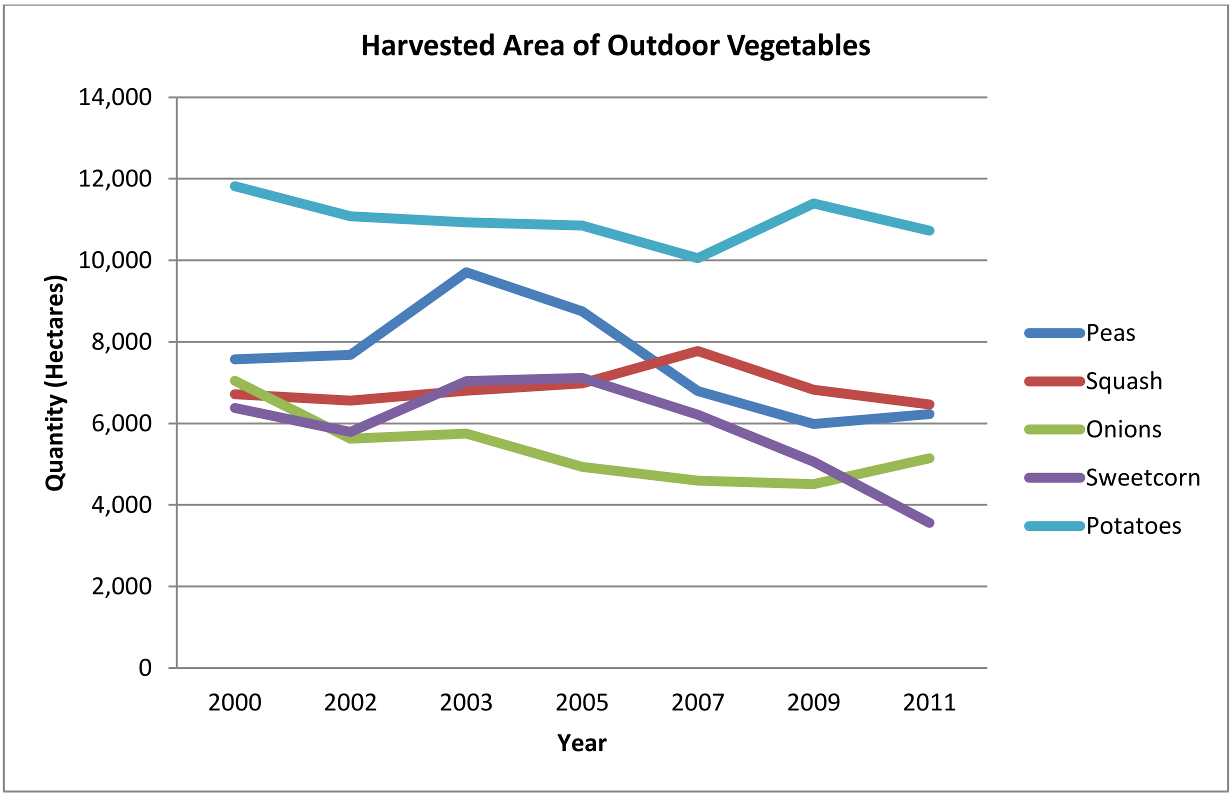


Figure 10. **Harvested Area of Outdoor Vegetables in New Zealand**

Source: Infoshare, Statistics New Zealand

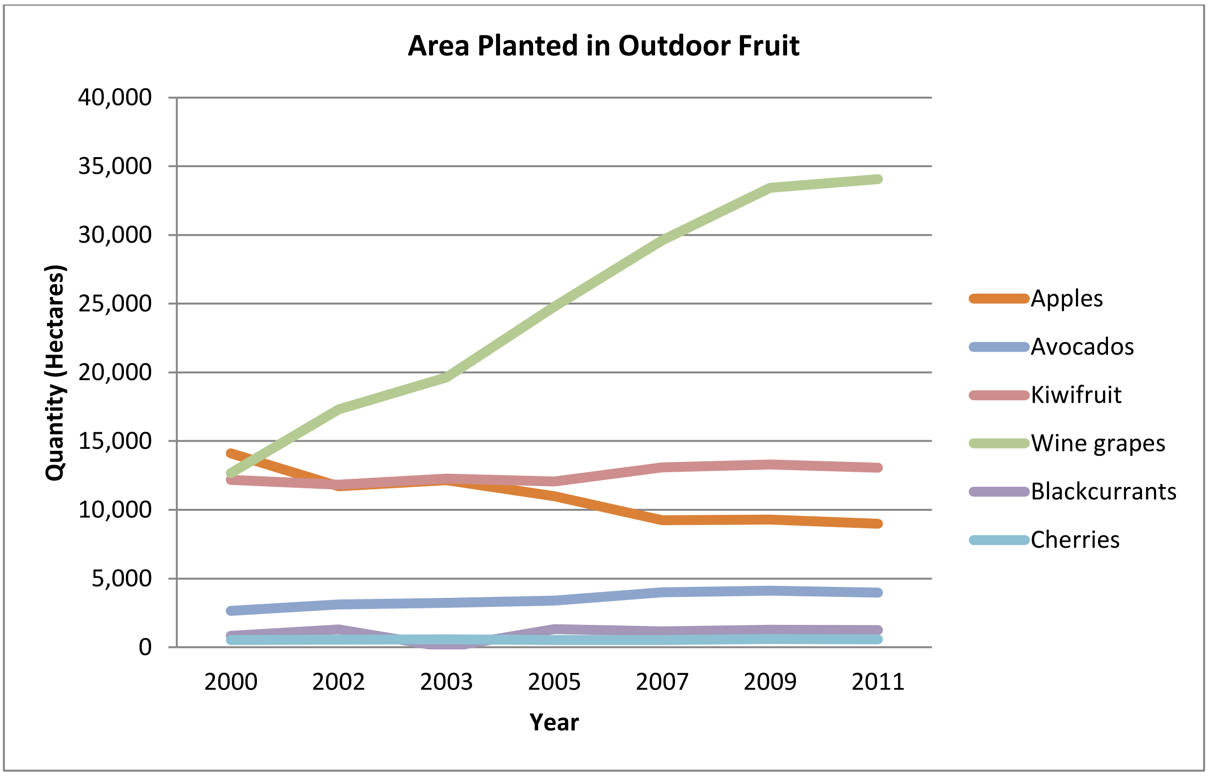


Figure 11. **Area Planted in Outdoor Fruit**

Source: Infoshare, Statistics New Zealand

The figures illustrate growth in specific industries, such as wine grapes, and declines in certain industries, such as sweet corn and peas. The survey also measures grain crop production, shown in Figure 12.

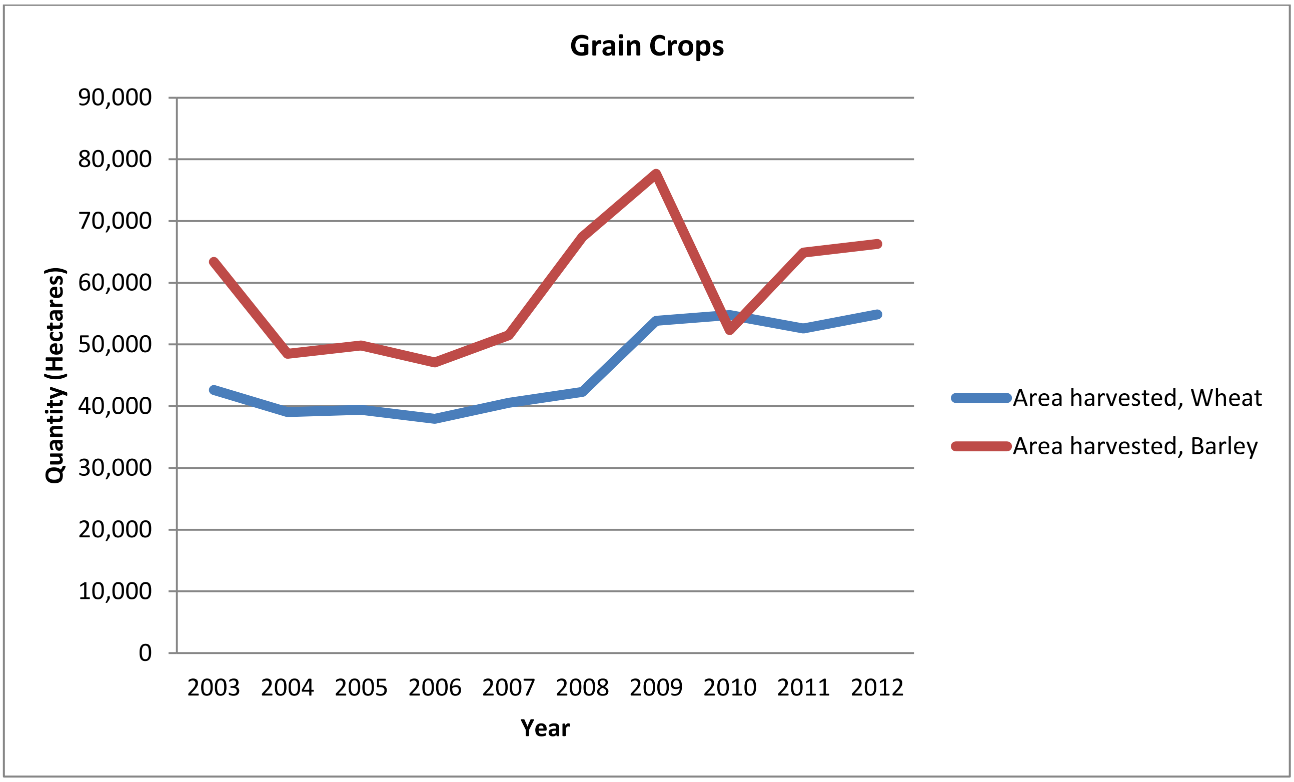


Figure 12. Grain Crops

Source: Infoshare, Statistics New Zealand

Figure 12 identifies a decline in Barley since 2009, although by 2012 it has risen again in the last two years. Wheat also has a highpoint in 2009 but seems to flatten off rather than decline.

Table 8 below determines that overall the total area of farms and grassland has remained relatively constant. These figures indicate that there has not been conversion from other land cover types to farm land in recent years.

Table 8. Variables Indicating Land Use and Land Cover for New Zealand

Variable by Total New Zealand (Annual-Jun)					
	Grassland	**Number of Farm Holdings**	**Crops, Grain, Nursery, Vegetables and Fruit**	**Land used for horticulture**	**Total Area of Farms**
2002	8,242,695	70,336	533,863	109,397	15,589,885
2003	8,115,379	66,057	470,358	120,088	15,435,517
2004	8,377,658	66,661	483,712	131,237	15,504,165
2005	8,241,926	64,488	488,515	119,124	15,305,843
2006	8,144,413	64,546	462,376	115,174	14,865,589
2007	8,086,160	63,337	500,296	132,892	14,700,897
2008	8,004,013	60,568	551,526	127,169	14,559,731
2009	8,037,755	59,268	588,761	123,871	14,726,274
2010	8,010,497	59,907	591,363	127,130	14,579,851
2011	8,010,593	58,041	586,372	125,488	14,569,233

Source: Infoshare, Statistics New Zealand

As recent literature suggests that dairy conversion has been occurring in the recent past the question then arises, how much land has been used for dairying in the recent past? Unfortunately, Statistics New Zealand does not provide any regular data showing this. The only accessible located data gives an indication of the number of cattle and the total effective hectares used for dairy cows. Table 9 shows the estimated number of livestock in New Zealand from Statistics New Zealand.

Table 9. Livestock Numbers in New Zealand

Variable by Total New Zealand (Annual-Jun)				
	Total Dairy Cattle	**Total Beef Cattle**	**Total Sheep**	**Total Deer**
2002	5,161,589	4,491,281	39,571,837	1,647,938
2003	5,101,603	4,626,617	39,552,113	1,689,444
2004	5,152,492	4,447,400	39,271,137	1,756,888
2005	5,087,176	4,423,626	39,879,668	1,705,084
2006	5,169,557	4,439,136	40,081,594	1,586,918
2007	5,260,850	4,393,617	38,460,477	1,396,023
2008	5,578,440	4,136,872	34,087,864	1,223,324
2009	5,860,776	4,100,718	32,383,589	1,145,858
2010	5,915,452	3,948,520	32,562,612	1,122,695
2011	6,174,503	3,846,414	31,132,329	1,088,533
2012	6,462,446	3,736,402	31,198,707	1,048,939

Source: Infoshare, Statistics New Zealand

Table 9 identifies that the total number of dairy cattle has increased significantly, while beef cattle, sheep and deer numbers have all decreased from 2002 – 2012. Figure 13 and 14 below were sourced from Dairy New Zealand and show the growth in the dairy industry.

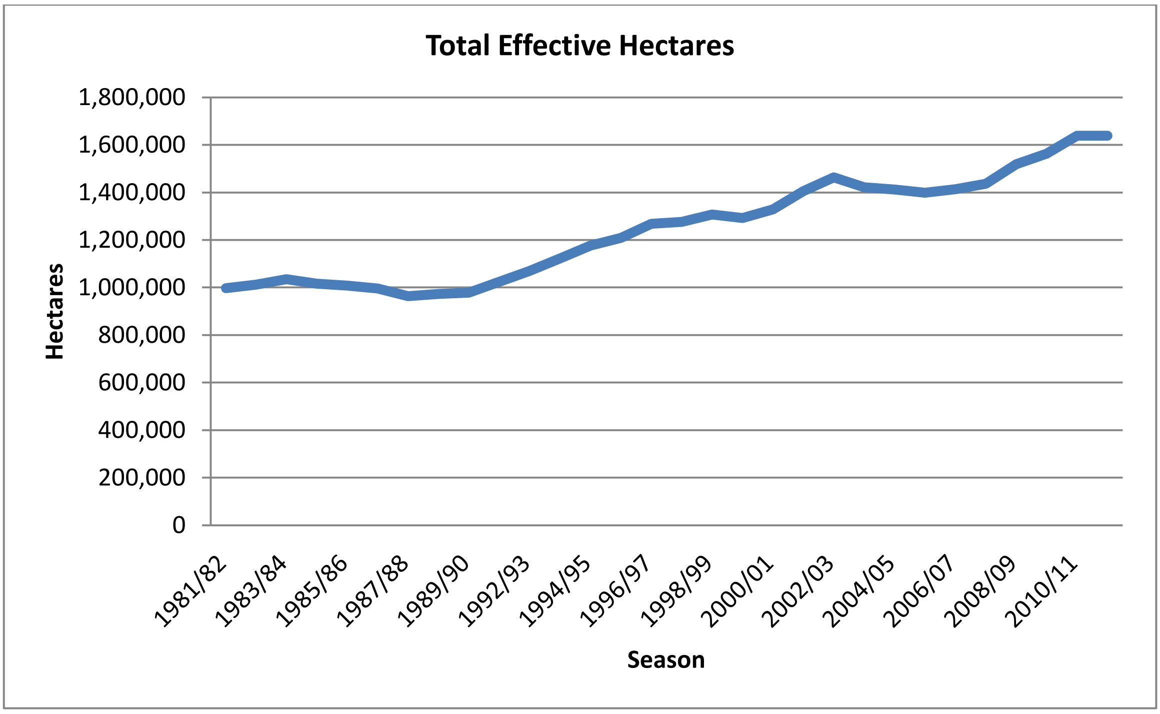


Figure 13. Total Effective Hectares Used for Dairying per Season[19]

Source: Dairy NZ, 2012, p. 7

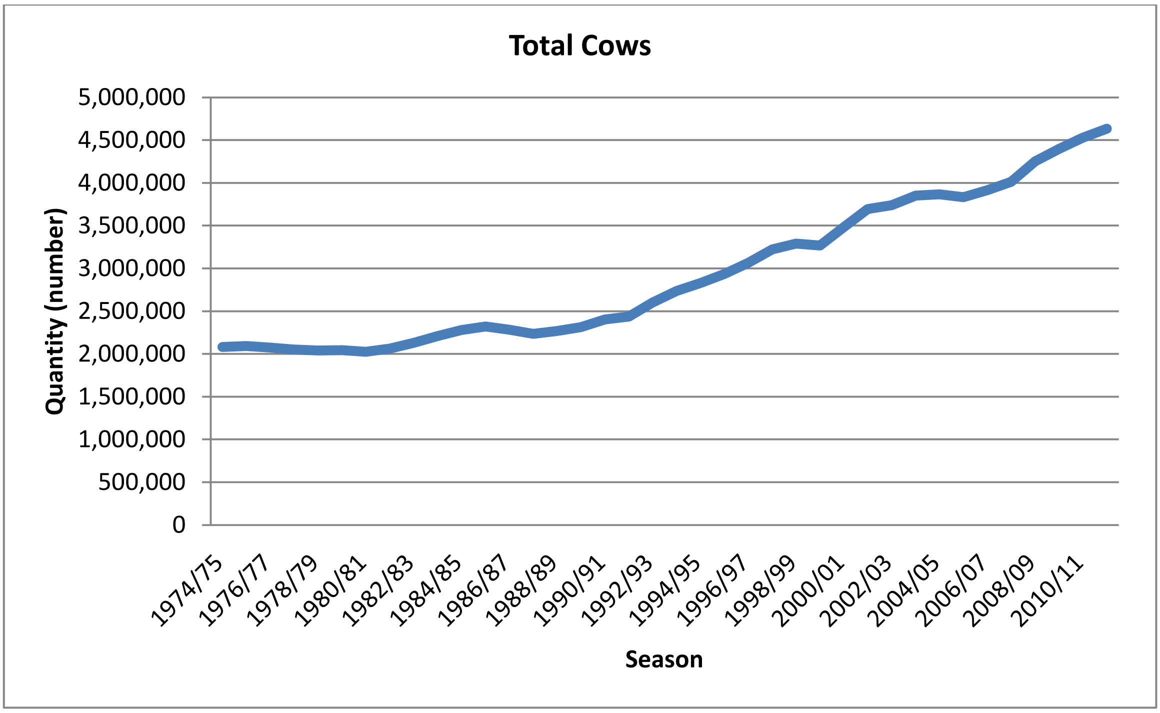


Figure 14. The Total Number of Dairy Cows per Season

Source: Dairy NZ, 2012, p. 7

[19] The total effective hectares measures land used for dairying - it is the milking platform or a way of measuring the size of a farm. However, it does not include support blocks which farmers may own or land where cows may be sent for grazing Essentially it measures the size of dairy farms (Angie Fisher, personal communication, December 20, 2012).

Both sources of data show a significant increase in the number of dairy cattle however, overall in New Zealand it seems that land used for dairying has not increased significantly. Dairy conversion has occurred in areas of New Zealand but this is not an overall trend for farms nationwide (Parkyn and Wilcox, 2004). The increases in the numbers of dairy cattle suggest intensification (higher stocking rates and stocking densities). Furthermore, long-term land use changes are often driven by long-term product prices (Ward et al., 1996). This intensification of agricultural land use has occurred as farmers have responded to economic signals, by converting land into more intensive dairy farms. High land prices could also explain why intensification has occurred as farmers may not have the financial ability to purchase more land. However, by intensifying production farmers will earn a greater income. This intensification, particularly in the South Island, has had significant environmental impacts, reducing freshwater quality in lowland rivers and changes in soil health (Ministry for the Environment, 2007). The intensification of pastoral land has also led to increased use of fertilisers and irrigation. All of these impacts affect the virtual water content of products which will be discussed within the next section.

5.5 Case Study Findings

The link between virtual water and land use has barely been explored within the literature. Although, Kumar and Singh's (2005) research suggested that virtual water trade could improve land use efficiency from a global perspective. It is not surprising that relative land endowments and access to arable land are large determinants of virtual water (Wichelns, 2010a; Kumar and Singh, 2005). Wichelns (2010a) suggests that:

> *Countries with less arable land per person are likely to import more crop and livestock products than countries with a larger amount of arable land per person, all else equal. Similarly, countries with less water available per person or per hectare might import more crop and livestock products than countries with larger water endowments. (p. 2209).*

Given, Wichelns proposition, it is not surprising that New Zealand exports a large amount of agricultural products per capita. The case study of New Zealand highlighted three key points. Firstly, New Zealand is a net exporter of virtual water or has a net virtual water deficit. Secondly, the same data identified that green water use dominates blue water use. Thirdly, in the investigation of New Zealand's land use, intensification of the dairy industry has occurred. The implications for New Zealand continuing to export dairy products and therefore virtual water are significant. Therefore, this section will discuss the intensification of the dairy industry and the future forecasts. It will also discuss, whether green or blue virtual water is significant for the dairy industry.

The findings of this research illustrate that the intensification of the dairy industry has occurred over the last decade (2002 – 2012). This intensification has led to increased water requirements for stock and land which increases the quantity of virtual water within products. The intensification of the dairy industry also results in increased production (Figure 15 and 16) and exports.

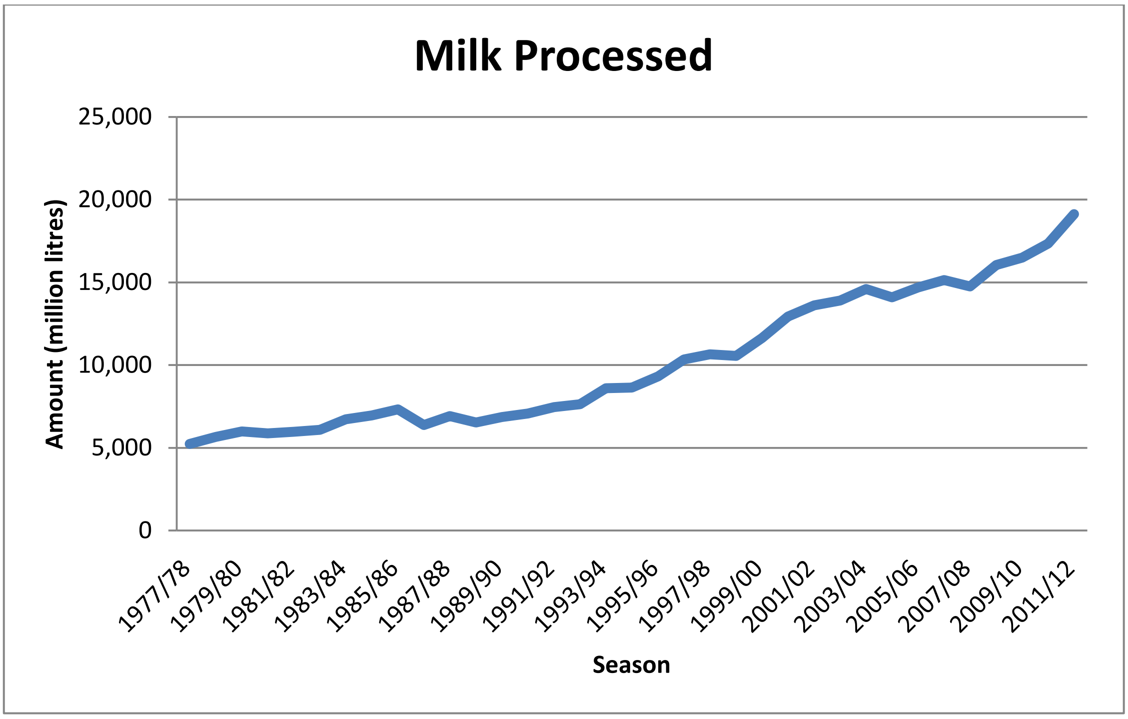


Figure 15. Production - Milk Processed

Source: Dairy NZ, 2012, p. 5

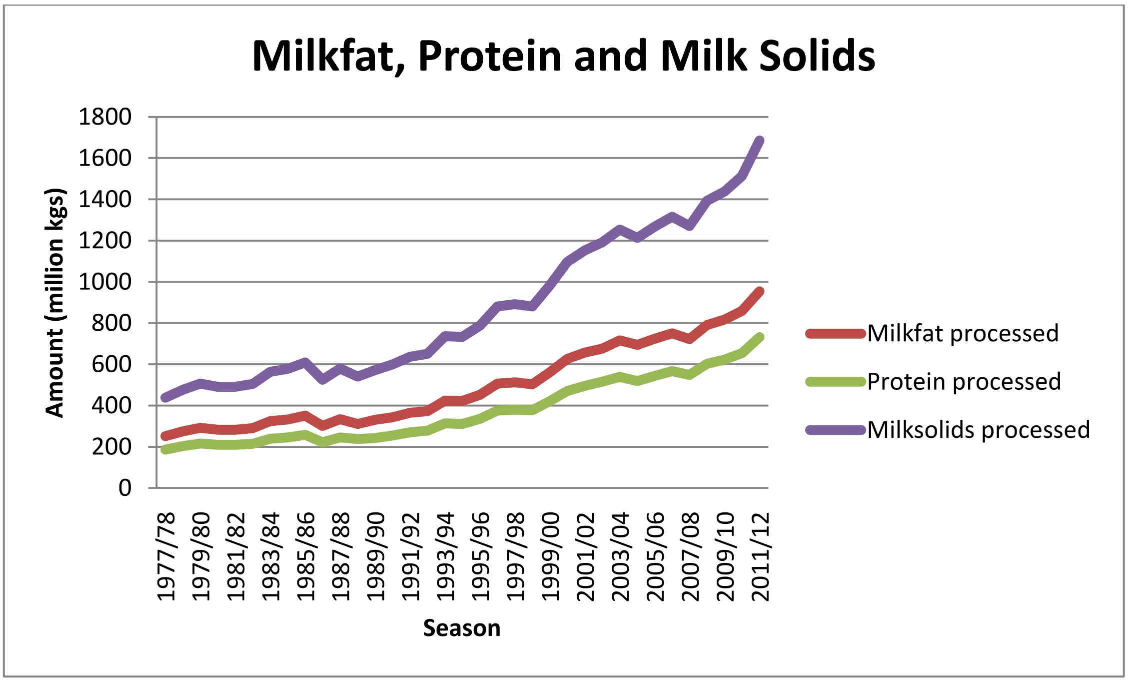


Figure 16. Production - Milkfat, Protein and Milk Solids

Source: Dairy NZ, 2012, p. 5

The dairy industry is also expected to continue to grow. Forecasts released by the Ministry of Primary Industries are shown in Table 10. This suggests that the export market is forecast to get stronger and more virtual water will be exported from New Zealand.

Table 10. Forecasts for the Dairy Industry[20]

	ACTUAL				FORECAST			
Year	**2009**	**2010**	**2011e**	**2012**	**2013**	**2014**	**2015**	**2016**
Cows and heifers in calf or in milk[1] (mil)	4.35	4.61	4.68	4.82	4.93	4.96	4.98	5.17
Milk solids produced[2] (mil kg)	1394	1437	1472	1555	1600	1619	1638	1768
Milk price[2] (cents per kg milk solids)	472	610	709	687	727	785	864	783
Total export value ($ million)[3]	11429	10562	13042	14576	15575	16742	18287	17033

Source: Ministry of Primary Industries, 2012

[20] Notes from Table 11:
1. As at 30 June (opening numbers).
2. Year to 31 May.
3. Year to 30 June.

The above data illustrates how New Zealand is using its water resources for economic gain. This use of New Zealand's water resources can be viewed as over-exploitation, depending on the effects on each type of virtual water, and results in value conflicts.

Whether the dairy industry is using predominantly green water or blue water is an important consideration for policy. Zonderland-Thomassen and Ledgard (2012) utilise case study methodology to assess the water footprint of New Zealand dairy farming in Waikato and Canterbury. Dairy farming in the region of Waikato utilises moderate rainfall without irrigation whereas Canterbury utilises irrigation and low rainfall. Although, this study uses a water footprint methodology, the findings are relevant because they highlight the different types of water used within the dairy industry. Following the Water Footprint Network methodology, Zonderland-Thomassen and Ledgard (2012) find that the Waikato farming system is made up of 72% green water, 28% grey water and 0.1% blue water. In contrast, the Canterbury dairy farming system was made up of 46% green, 23% blue and 31% grey water (Figure 17).

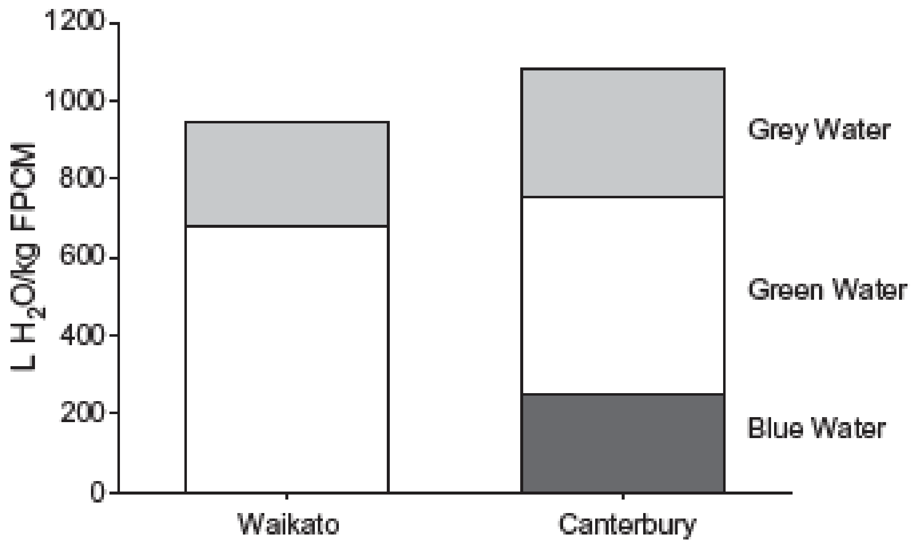


Figure 17. Blue, green, and grey water footprints of average dairy farm systems in the Waikato and Canterbury Regions

Source: Zonderland-Thomassen and Ledgard, 2012, p. 35

Zonderland-Thomassen and Ledgard (2012) find that "green water for both regions was from evapotranspiration from the various feed sources, with on-farm pasture and off-farm pasture grazed by replacement animals and wintered off cows as the main contributors. The blue water footprint of Canterbury dairy farming was mainly determined by irrigated pasture. The grey water footprint was mainly determined by leaching at farm level and leaching from off-farm pasture for replacements and winter grazing" (p. 35). The significant difference between the regions is whether pasture is irrigated or not. This irrigated pasture has effects on freshwater availability and freshwater depletion as well as water quality. This research illustrates that both blue and green water contribute to dairy farming and in some regions their contributions are almost equal. This result is in contention with the findings of the case study.

5.6 Summary

The case study highlights that New Zealand exports virtual water (a net virtual water deficit). This is not a surprising result as New Zealand's trade is mostly in agricultural products, such as milk and cheese, which are water intensive products. The data identified that New Zealand predominantly uses green water to grow its agricultural products, which is also increasing over time. It was suggested that blue water is also likely to increase at a different rate than green water or grey water due to increased irrigation, although the data could not show this. Changes in New Zealand land use was also presented which illustrates that intensification of livestock farming has occurred due to economic signals.

This chapter has also discussed the implications of land use for virtual water in the New Zealand context. The intensification of the dairy industry was discussed as well as what type of water was being used within this industry. It was suggested that different regions within New Zealand use different types of virtual water. The dairy industry is using more water resources and these demands are negatively impacting water quality within New Zealand. Virtual water could be used as a policy concept to inform future land use decisions in New Zealand, having beneficial environmental impacts in the long run.

The following chapter involves an in-depth discussion of these findings. The aim is to ascertain the usefulness of the concept of virtual water for informing policy in New Zealand to proactively determine future decisions relating to land use.

Chapter 6

Discussion

6.1 Overview

This chapter will discuss the findings of the research. The first section will describe the theoretical limitations of using virtual water as a policy concept drawn from the literature in Chapter 2. The second section utilises the policy evaluation framework developed in Chapter 4 to determine the utility of virtual water as a policy concept. Each criterion is evaluated at a global level as well as for the New Zealand context. This enables the findings from the case study to be used to draw out the implications of virtual water, as a policy concept for New Zealand. The third section discusses the implications of the intensification of the dairy sector on New Zealand's water resources.

6.2 Theoretical Limitations of using Virtual Water as a Concept

It is argued within the virtual water literature that the concept of virtual water can highlight economic contradictions or externalities of production and that water scarce nations can trade their way out of water deficits. However, the concept of virtual water has limitations within these aspects.

Firstly, virtual water cannot recognise that the value of water varies for geographic regions. For example, some countries grow rice while others do not. Rice is predominantly grown under flood conditions with water on the rice field, often called a paddy. In many parts of the world these paddies are irrigated from rainwater. In contrast, in the United States rice is irrigated from wells or surface water (Smith and Dilday, 2003). In the 1850s, before advanced technology, within the United States it is documented that rice production was limited to the regions of South Carolina and Georgia due to the ease of adding freshwater to the rice paddies via a series of dykes and gates caused by ocean tides (Smith and Dilday, 2003). Rice paddies that naturally flood have a lower opportunity cost of water than irrigated paddies. Virtual water, as a concept, does not measure this opportunity cost of water.

Secondly, a country importing food must generate sufficient foreign exchange to import food which creates dependencies and risks for food security. Increased urbanisation may also move people from rural areas thus reducing employment in the agricultural sector. This can also result in reduced access for the poor to food as well as increased risk of environmental impact in exporting countries. Therefore, clearly there are limitations to the concept of virtual water when applying it at an international scale.

Notwithstanding these limitations, virtual water has been proposed as a policy concept within the literature and this dissertation. An evaluative framework was developed in Section 4.2.2 to assess the utility of virtual water as a policy concept. This framework is used in the next section to evaluate virtual water from a policy concept perspective against each criterion to assess its capability of being used in policy to inform future land use decisions in New Zealand.

6.3 Policy Evaluation Framework

The policy evaluation framework developed in Section 4.2.2 is based upon Mickwitz's (2003) criteria for a policy instrument as well as incorporating other key components of environmental policy. The criteria are listed below, each with a key question. The framework is used within this section to evaluate the concept of virtual water from a global perspective and then apply it to the New Zealand context. Using this framework will add to contemporary literature through supporting (or not) authors who suggest that virtual water should progress to the next stage of the policy cycle, policy formulation.

Relevance – Does virtual water address the underlying environmental problem?

The obvious underlying environmental problem is water scarcity from a global perspective. The Human Development Report highlights the social, rather than environmental, origins of water scarcity: "the heart of the global water crisis is rooted in power, poverty and inequality, not in physical availability" (United Nations Development Programme, 2006 p. 2). Allan (1997) agrees with this proposition and suggests that there will be enough fresh water in the global system for a global population of double its present size.

The concept of virtual water reveals how countries are masking water scarcity through importing food. Furthermore, virtual water reveals the amount of water resources entering and leaving a country. This illustrates the scale of the water deficit in a country and whether semi-arid regions are importing water intensive products. According to Allan (1997), this is a major indicator of water scarcity because it shows the dominant consumptive use of water. It also identifies the products that a country or region is not willing to produce, relying instead on purchasing them through imports. Secondly, it highlights contradictions where limited water resources are being over-exploited. An example of this was discussed earlier in Kenya where high quality flowers, a water intensive commodity, are exported to the European Union while the Kenyan population does not have sufficient access to water. The main drawback of virtual water, as a policy concept, is that it cannot consider the humidity and climatic conditions. Therefore, the concept will not always recognise the opportunity cost of water resources for the geographic region. Obviously, a water scarce region would value water higher than a water abundant region. Overall, the concept of virtual water does address the environmental problem because by measuring which commodities are traded and the respective virtual water flows associated with trade, it informs researchers of a country's behaviour relative to their water resources. Hence, it can provide insight into social issues, including human well being, as well as environmental issues.

Applying the concept of virtual water has not revealed water scarcity in New Zealand as a whole. The data illustrates that New Zealand's virtual water exports far outweigh virtual water imports, a net virtual water deficit. This illustrates how New Zealand's water resources are being utilised for economic gain. The economic gain produced by this virtual water could be high in terms of opportunity cost if the production of other agricultural goods has a lower environmental impact and/or cost. It is known that water is relatively plentiful in New Zealand (Fisher and Russell, 2011). However, demand for water by the agricultural sector is particularly high and increasing and the environmental impact of this particular water use comes with a considerable cost in terms of loss of water quantity and quality. The negative environmental impacts flow on to the tourism industry and affects recreational values. Virtual water as a concept addresses the underlying environmental issue within New Zealand, that of, resource use for economic gain which may not be sustainable in the long run in terms of environmental impacts and costs (discussed further in Section 6.4).

Problem Framing – Can the concept of virtual water frame or reframe the environmental problem to assist policy-making?

Bardwell (1991) suggests that reframing the problem enhances one's understanding of the problem. Virtual water measures the use of water resources from a post-production perspective. This differs from the traditional perspective of attempting to measure water within aquifers, rivers or lakes so that permits can be allocated to farmers for irrigating crops and paddocks. Virtual water redefines the problem of water scarcity and its lack of recognition in terms of the use of water resources for the production of agricultural commodities. Virtual water can also offer an aggregated perspective, so it can be used for measuring the quantity of water imported and exported for regions, basins and countries as well. Overall, virtual water as a concept offers a different way to frame the environmental problem and could be researched alongside a country's land use to determine whether the amount of water resources being utilised for the production of agricultural commodities is appropriate, especially if these commodities are water intensive and exported.

Virtual water measures the amount of water New Zealand uses in the production of agricultural goods and these are predominantly exported. The findings of the case study suggest that exports are expected to increase, particularly within the dairy industry. The increasing quantity of dairy exports and intensification of dairy production are matched by increasing water usage, often through irrigation. New Zealand's economic reliance on increasing dairy exports has a direct effect on decisions relating to land use. Utilising the concept of virtual water to inform policy has the potential to proactively determine future land use change by making choices about land use more transparent so that people are informed about the environmental costs, for example pollution externalities, that some land use creates.

Persistence – Could virtual water, as a policy concept, have a lasting effect on the state of the environment?

From a time perspective, virtual water, as a concept, would endure because food will always be grown for consumption. As long as agricultural goods are grown and traded, virtual water has the potential to be measured. Currently all nations, to some degree, are reliant on each other for trade of goods and services. The concept of virtual water has the potential to change how water resources are being used through drawing attention to water scarcity, the costs involved and political commitments required to rely on importing food. This may result in a change in land use. If, for example, the land use changes in an area and the result is that less water is being utilised for irrigation then this will have a lasting effect on the state of the environment. It is noted though that the use of the concept of virtual water, is very context specific. Therefore, the benefits of this concept will depend on the social and political arrangements that influence its use. Overall, this criterion will have a lasting effect on the state of the environment if it induces behavioural change because this behavioural change has the potential to affect irrigation practices, land use and import/export markets.[21]

Applying this to New Zealand, the concept of virtual water will continue to measure the net outflows. The concept of virtual water has the potential to draw attention to which type of virtual water is being used for agricultural production. Recall Zonderland-Thomassen and Ledgard's (2012) research which showed the differences in water use for dairy production in Waikato and Canterbury. Their findings illustrate that Canterbury uses a significant proportion of blue water whereas Waikato does not. Mapping regional use of water resources may induce behavioural change in New Zealand if stakeholders realise that dairy production could be confined to areas where production is able to predominantly use green water. Currently irrigated areas, such as Canterbury, could better use the land to grow crops suitable for drier areas. This would impact on land use and import/export markets.

Flexibility – Can the virtual water concept change with changing environmental conditions?

[21] For the concept of virtual water to have a lasting effect on the state of the environment, it would have to evolve into a policy or policy instrument.

Virtual water measures the amount of water used to produce an agricultural commodity at the place of its production. Environmental conditions change over time and the impacts of climate change will exacerbate this change. Ludwig et al. (2009) suggests that climate change will affect the distribution of global water resources. Changes in temperature and the availability of water resources will affect virtual water. Primary agricultural goods, such as crops require certain climatic conditions to grow. If the surrounding conditions change, this will change what a product requires impacting on the virtual water content of the product. Overall, virtual water will incorporate these changing environmental conditions because they will affect the requirements of the agricultural commodities, consequently being detected by the virtual water concept which reframes the issue.

Over time, in New Zealand, the concept of virtual water will highlight changing environmental conditions. Water resources are not distributed evenly across New Zealand with water availability decreasing from west to east, along with regional variations in rainfall (Fisher and Russell, 2011). Climate change will also have uneven impacts. For example, higher temperatures and less rainfall are forecast for Canterbury, alongside increasing droughts (Ministry for the Environment, 2012). This will contribute to an increased demand for water. Therefore, the productivity of agriculture will depend on irrigation and the capacity of surface and ground water resources to meet this increased demand. The concept of virtual water will capture these changes as it measures the amount of water resources used in the production of agricultural goods and for regions like Canterbury it will illustrate increased use of blue water resources.

Predictability – Is it possible to foresee the outcome when using virtual water as a policy concept?

The outcomes can be somewhat predicted when using virtual water as a policy concept. This is because the scope of the concept focuses only on water used to produce products and predominantly applies this to trade. Therefore, virtual water flows between and among nations can be measured. This means that if the concept was to be used it could induce behavioural change thus changing how much water is used for a particular purpose. Therefore, irrigation and water use practices may change, along with land use, and the export/import markets for particular products might alter. Consequently, a country's trade portfolio may change as they may change the goods they import and export. Overall, it will depend upon how this policy concept is used to further predict what behavioural change might eventuate. This policy concept could be used in a variety of policy instruments and each would have advantages and disadvantages, as they would impact on various stakeholders in different ways. How virtual water could be used as a policy instrument is a topic for further research.

Predicting the outcomes of using virtual water within New Zealand will depend on the policy or policy instrument implemented. As mentioned previously, irrigation and water use practices may change, along with land use, and the export/import markets for particular products might alter. Which industries are affected will depend on the policy. However, it is likely that high-water use industries would be affected the most, such as the agricultural sector, specifically dairy.

Scope – Is virtual water as a policy concept too narrow or limited in scope to address the environmental problem?

The concept of virtual water attempts to address and expose water scarcity in water scarce nations. Although, the concept cannot create more water, it has potential to redistribute it. The scope is perfect for measuring water scarcity in relation to trade. As previously mentioned, virtual water flows between and among nations can inform researchers about the water scarcity within a nation. The quantitative data is not too complex to compile, requiring a nation's trade balance or production quantity of agricultural goods as well as the virtual water content associated with those products. Although, the water footprint is a more comprehensive measure it is harder to calculate because more information is required than international trade flows. Overall, the concept of virtual water is limited to trade flows, which addresses and reveals water scarcity in nations therefore satisfying this criterion. Furthermore, this scope allows for the consideration of land use decisions.

Applying the scope of the concept of virtual water is ideal for the New Zealand context. New Zealand is a small nation which is heavily dependent on international trade. The concept of virtual water shows that New Zealand is a net exporter of virtual water. The scope of this concept includes which type of virtual water is being used to produce agriculture goods and is consequently traded. This is important for policy. Of significance for New Zealand is applying the concept of virtual water to better understand the quantity of blue virtual water being exported and how much grey water is being produced.

Efficiency – Are the benefits of measuring virtual water and creating a policy around it worth the costs?

At this stage virtual water is only a policy concept, therefore the opportunity exists to implement it in many different ways. The trade-off is whether collecting quantitative data and enforcing the policy is worth the expected benefits. The key aspect of this criterion is determining what the costs will be in time, money and resources and weighing them against the benefits of expected behavioural change. These benefits could ensure that water resources around the globe are not being over-exploited and highlight the need for water scarce nations to be able to purchase water intensive goods through trade. The policy will be efficient if many individuals and businesses are required to alter their behaviour in order to prevent further water scarcity in nations. Further investigation into the efficiency of this policy concept will need to be conducted if a policy or policy instrument is proposed.

The efficiency of using virtual water will depend on the policy or policy instrument implemented in New Zealand. As mentioned previously, the trade-off will be whether collecting quantitative data and enforcing policy is worth the expected benefits. The benefits for New Zealand lie in informing future land use decisions and efficient water use, in terms of the opportunity cost of water used in the production of agricultural goods.

Legitimacy – To what degree will stakeholders be able to understand or accept virtual water as a policy concept?

There are two aspects of legitimacy, understandability and acceptance. The concept of virtual water, once explained, is relatively simple. Once aired in the public sphere it is anticipated that it will be understood. The acceptance of a new policy is dependent upon how specific stakeholders are affected. It is suggested that the majority of stakeholders would be happy with the goal of this policy concept; not to over-exploit water resources for a positive trade balance. The general public is likely to support this policy concept as they place a high value on water resources, especially for drinking and household use. However, if this requires change in certain industries, the affected parties are likely to object. Overall, the concept of virtual water should be understandable by stakeholders and should have an impact on proactively managing water resource, a collectively desirable outcome. Further investigation into the legitimacy of this policy concept will need to be conducted if a policy or policy instrument is proposed. At this stage the relevant stakeholders and institutions have not been identified.

The concept of virtual water is likely to be legitimate within New Zealand. The general public are likely to understand the concept of virtual water especially since it has already been exposed within the media. Access to clean water for household use and recreational purposes is a priority for New Zealanders. The agricultural sector is already being held responsible by the general public for damage to freshwater bodies (Hughey, Cullen and Kerr, 2010). The degree to which stakeholders are affected will determine which policy or policy instrument is developed and implemented. Stakeholders, such as dairy farmers, may well be averse to altering their behaviour. However, further research into this will need to be conducted when a policy or policy instrument is proposed.

Transparency – To what degree could the output and outcomes of virtual water policy be observable to outsiders?

As suggested within other criteria, if virtual water is to be used as a policy concept it is likely to affect global import/export markets, nations trade portfolio, irrigation practices and land use. If these changes occur they will be visible to stakeholders. Although the outcomes and outputs will be transparent, the development of virtual water policy itself is unlikely to be transparent unless there is stakeholder engagement and consultation[22]. The concept of virtual water also highlights which types of water are being used within agricultural production. Therefore, it has the potential to increase transparency around water scarcity or the export of virtual water and the existing policies which appear to be holding existing production practices in place for particular industries. Overall, this concept will be transparent by informing stakeholders about water scarcity and through the process of stakeholder engagement.

For New Zealand, the concept of virtual water is likely to be transparent. The general public will see change in affected industries, such as dairy farming. This will flow through to changes in export markets where this information is available to the public; Statistics New Zealand releases this information online every year. A virtual water policy or policy instrument is likely to be administered by the Ministry of Primary Industries, and depending on how this is undertaken will affect the transparency of the implementation process. The concept of virtual water will also expose which regions suffer from water scarcity within New Zealand. And which export markets dominate water use and how the government supports these industries. Within New Zealand dairy farming dominates agricultural production and the concept of virtual water could highlight the negative externalities associated with this production, such as negative effects on water quantity and quality.

Equity – How would the outcomes and costs of virtual water considerations be distributed?

The concept of virtual water could be used to give a more equal global distribution of water resources. A policy based on the concept of virtual water could enable nations to import water intensive goods, therefore relieving pressure on their water resources. Virtual water, as a policy concept, also identifies situations where water scarce nations are over-exploiting their water resources for economic gain. A policy recognising these contradictions and implementing restrictions for a country's virtual water flows could help resolve these issues. The main concern regarding equity is that a country needs to have the ability to purchase water intensive goods from other nations. A country with limited export income will be limited in what they can purchase. Yang et al. (2006) identify that lower income countries participate less in global virtual water trade. This suggests that the policy concept of virtual water will not fully rectify the situation of developing nations. Overall,

[22] Bruch et al. (2005) provides a full discussion on tools to achieve public participation for managing global freshwater resources.

virtual water as a policy concept will have an uneven impact across nations depending on whether they can use it to their advantage.

The concept of virtual water can be used to the inform intergenerational equity of water resources in New Zealand. The Royal Society of New Zealand (2009) suggests that freshwater resources provide a competitive advantage for New Zealand's exporting industries. Much of New Zealand's virtual water is exported via dairy products and the growth of irrigated agriculture in New Zealand has enabled dairy expansion. This growth is dependent on freshwater supplies which are over allocated in some regions. Virtual water as a policy concept has the ability to redistribute water resources in favour of environmental, social and cultural water services as it reveals the opportunity costs of using water resources for the production of agricultural goods. The concept of virtual water can be used to alter water resource use where water supplies are over allocated therefore altering land use.

Feasibility – Could virtual water, as a concept, be integrated within policy using data sources?

For virtual water to be used as a policy concept, a policy or policy instrument would need to be developed. This would result in guidelines regarding virtual water flows between and among nations, basins or regions. Underpinning this policy would be quantitative data. Finding and collecting quantitative data is an issue for the concept of virtual water. Williams (2009) "demonstrate[s] the care which must be taken when attempting to calculate the amount of water that is embodied in a particular commodity" (p. 67). Publications from UNESCO-IHE provided estimates for the virtual water of commodities, published as water footprints by their definition, however climate variations could make these estimates relatively inaccurate. Although, these calculations are at a country level it should be realised that countries vary substantially in climate across their regions. Quantities at a production level should not be difficult to obtain for governments. Once a country has measured the virtual water content for each of the agricultural commodities that they produce and export, they will not need to alter the estimates unless the climate alters dramatically. Once technology and systems are put in place for this purpose, it will be feasible for virtual water to be used as a policy concept. Williams (2009) also suggests that "policies may be misguided if researchers don't take the necessary precautions to ensure that the data is accurate" (p. 67). For the concept of virtual water to be utilised within policy, more empirical research will be required for countries.

The case study of New Zealand illustrates the issue of inaccurate quantitative data. FAO data was used for estimating the flows of agricultural goods to and from New Zealand because the published government data sourced from Statistics New Zealand was too aggregated. This resulted in some data figures being estimates and some being a real measured flow. Mekonnen and Hoekstra's (2010, 2011) estimates were used for the virtual water content of agricultural goods. However, as mentioned in Section 5.3, the climate varies within the regions of New Zealand and these estimates do not take that into account. Therefore, if the concept of virtual water is to be used in policy, more empirical research would be required for New Zealand.

Table 11 summarises the results of evaluating virtual water as a policy concept against the criteria.

Table 11. Summary of Policy Concept Evaluation

Criteria	Satisfy Criterion?	New Zealand Context
Relevance	Yes	Yes
Problem Framing	Yes	Yes
Persistence	Yes	Yes
Flexibility	Yes	Yes
Predictability	Yes	Yes
Scope	Yes	Yes
Efficiency	Unclear at this stage	Unclear at this stage
Legitimacy	Unclear at this stage	Unclear at this stage
Transparency	Yes	Yes
Equity	Yes	Yes
Feasibility	No	No

All of the evaluated criteria are satisfied apart from efficiency, legitimacy and feasibility. This framework has highlighted a strong case for virtual water to be used as a policy concept especially since it has the potential to address the issue of water scarcity by reframing the problem. Virtual water, as a policy concept, will change with environmental conditions and will have a lasting effect on the state of the environment. Through evaluating the policy concept of virtual water against the framework the potential to inform land use decisions is illustrated. The next section takes this evaluation a step further by discussing the implications of the land use patterns currently seen within New Zealand.

6.4 Implications for New Zealand

The case study illustrates New Zealand is a net exporter of virtual water and highlights the intensification of the dairy industry which is forecast to continue. This means that the net virtual water deficit is likely to increase. The data utilised in the case study suggested that green water dominates blue water use in New Zealand. However, other studies have shown that different regions use different proportions of blue, green and grey virtual water especially in the dairy industry. The dairy industry is New Zealand's largest contributor to the export market. Therefore, the following section discusses the implications of the intensification of dairy production and the industry's influence on virtual water flows.

According to Fisher and Russell (2011) water is relatively plentiful in New Zealand. However, the abstraction rate of water is two to three times higher than the average for OECD countries (Fisher and Russell, 2011). This is the result of high demand for water, particularly by the agricultural sector, which is increasing rapidly. Many catchments within New Zealand are heavily allocated and will face pressure from further land use intensification exacerbated by climate change. Certain regional catchments, for example Canterbury, are over allocated and further allocation will result in environmental harm (Fisher and Russell, 2011). The over allocation of water has significant impacts on the quality of a regions' water bodies and result in adverse environmental impacts including increasing the risk of salt water intrusion to aquifers (Waikato Regional Council, n.d.). Excessive nutrients from fertilisers and cow effluent is the primary issue in Canterbury arising from agricultural production.

The implication of the intensification of the dairy industry for virtual water depends upon which region it is occurring. For example, in Canterbury the impacts on freshwater (blue) resources would be high in comparison to Waikato. Zonderland-Thomassen and Ledgard (2012) suggest "the impact of New Zealand dairy farming on freshwater resources can be reduced by practices that increase efficiency of water use, reduce irrigation needs, optimise nutrient management and increase feed conversion efficiency" (p.39). Fisher and Russell (2011) also suggest that the increasing demands for water in New Zealand from the dairy sector have been associated with adverse environmental effects, including increases in amounts of nutrients, sediments and animal effluent in waterways. The issues surrounding water quality have raised questions regarding how to address water governance within New Zealand.

Virtual water, as a policy concept, can be used to highlight the negative externality of production within New Zealand. As a policy concept, virtual water can be used to reveal the varying contributions of blue, green and grey water resources of New Zealand. Importantly the concept of virtual water can highlight the environmental impacts of dedicating land use to the agricultural sector, specifically dairy, in regions of New Zealand which currently has inherent negative environmental impacts. The opportunity cost of using water resources for the dairy industry is the production of other agricultural goods which may have a lower environmental impact and/or cost. The contribution of the concept of virtual water is that it makes these choices transparent, so that stakeholders can decide whether they accept pollution externalities and the loss of amenities in return for higher export returns from the dairy market. Alternatively, stakeholders could prefer the production of a different agricultural good with lower environmental impact and/or costs although this may result in lower export income. Developing virtual water into a policy or policy instrument has the potential to inform these decisions which could result in land use change[23].

6.5 Summary

This chapter has discussed the theoretical limitations of using virtual water as a concept based on the literature reviewed in Chapter 2. It furthered this discussion by using a framework to evaluate the utility of virtual water as a policy concept. The framework highlights a strong case for the concept of virtual water to be used in policy. Especially, since it addresses the issue of water scarcity, it can reframe a problem, change with environmental conditions and is likely to have a lasting effect on the state of the environment. One criterion it currently fails on is feasibility because the concept of virtual water is quantitative and therefore requires data to be measured for a country.

This chapter has also discussed the implications of dairy intensification within New Zealand. The dairy industry is using more water resources and these demands are impacting on water quantity and quality. Overall, virtual water can be used as a policy concept to inform future land use decisions in New Zealand, having beneficial environmental impacts.

[23] Section 3.5 has already discussed the three different policy instruments that could be developed based on the concept of virtual water. This is an area for further research and relies on quantitative data being available.

Chapter 7
Conclusions

7.1 Overview

This chapter briefly summarises and presents the conclusions of the research. The purpose of this research will be outlined along with the main findings. This chapter will also make recommendations for future research.

7.2 Conclusions

This research set out to determine how the concept of virtual water could inform future land use policy decisions within New Zealand. It aimed to fill three important gaps within the literature: evaluating the concept of virtual water in a non-economic framework; linking the concept of virtual water and land use; and applying the concept to a case study of New Zealand. The policy process approach to policy analysis was used for this research, which explains how policy is developed, and determined that virtual water is a policy concept currently at the agenda setting stage.

The methodology used in this research was that of mixed methods. The quantitative aspect applied virtual water to a case study of New Zealand while the qualitative aspect of the research developed a framework to assess the utility of virtual water as a policy concept. The findings from the case study identified that New Zealand has a net virtual water deficit. Specifically, the dairy industry has intensified its production in recent years and predominantly uses mainly green water in agricultural production. The regional comparison between Canterbury and Waikato dairy farming demonstrated how important and insightful a higher resolution of analysis is.

The conclusion reached in this dissertation is that the concept of virtual water could be used to inform land use policy decisions in New Zealand. The concept of virtual water has considerable potential to address issues of water scarcity, which are intimately linked to a country's land use and production choices. Virtual water, as a concept, highlights externalities of production and suggests that water scarce nations can trade their way out of water deficits if they have the financial wherewithal to do so. Contemporary literature argued the policy relevance of the concept and outlined limitations.

The policy evaluation framework within this dissertation signals a strong case for the concept of virtual water to be used within policy because most of the criteria are satisfied. The framework gives a preliminary assessment of the usefulness of the concept of virtual water. However, if a policy or policy instrument were developed it would need to be re-evaluated, along with the inclusion of additional criteria, such as impact and effectiveness. The strength of the virtual water concept is that it measures water use from a post-production perspective, revealing the opportunity cost of using water resources for the production of agricultural goods that have negative environmental impacts and costs. Therefore, the concept of virtual water can inform a country's land use decisions to decide the most appropriate land use to utilise scarce water resources.

Applying the concept of virtual water to New Zealand establishes that New Zealand is a net exporter of virtual water. That is, significant quantities of water resources are used within the production of exported agricultural goods. The findings of the case study illustrate the intensification of the dairy industry operations over the past ten years thus considerably increasing New Zealand's net virtual water deficit. In New Zealand, the concept of virtual water has the potential to highlight the environmental impacts of dedicating land use to specific agricultural activities, such as the dairy industry. The concept of virtual water reveals the opportunity costs of the production of agricultural goods and their associated environmental impact and/or cost by separating out what type of water is used within production. This is increasingly relevant for New Zealand with varying regions relying on different types of virtual water. Managing the three types of virtual water will help mitigate the adverse environmental effects of dairy intensification within New Zealand regions. By implementing a policy, virtual water flows can be proactively managed altering industry behaviour having a direct impact on New Zealand's land use.

7.3 Future Research

Throughout the research a number of areas have been identified for future research. These areas relate to the context of New Zealand as well as international regimes.

For policy to be developed within New Zealand, an accurate quantification of virtual water flows, nationally and internationally will need to be ascertained. Within this, separating the different types of virtual water used (blue, green and grey) will enable policies to be implemented within different regions.

Similarly, investigation into what policy options are available for New Zealand should be researched in depth along with implications. These policy options will utilise the quantification of virtual water flows and may inform where the production of dairy products should be intensified. Further to this, the effects on competitiveness for industry sectors will need to be identified.

On an international scale, whether virtual water can be utilised as a policy concept without purely relying on quantitative data will need to be explored. Other contextual information, such as the value of water to a nation will need consideration and be utilised in conjunction with the concept.

Finally, whether international virtual water flows can be regulated via economic means should be researched. Using the concept of virtual water at an international scale can reveal economic contradictions and externalities. This could enhance a country's wellbeing and proactively alter land use to suit climate and water resource availability.

Appendix A

Glossary of Economic Terms

Absolute Advantage

A country has absolute advantage if it has the ability to produce more of a good or service than another country, using the same amount of resources.

Comparative Advantage

A country has comparative advantage if it has the ability to produce a particular good or service at a lower marginal and opportunity cost than another country. Even if one country is more efficient in the production of all goods and services than the other, the countries will still gain by trading with each other as long as they have different relevant efficiencies.

Dynamic Analysis

Dynamic Analysis refers generally to any analysis in which changes that occur only with the passage of time are explicitly and essentially considered. In economics, these changes frequently involve changes in stock variables due to flows in or out over time.

Efficiency

Efficiency refers to maximising the use of available resources. Efficiency in consumption means allocating goods between consumers so that it would not be possible by any reallocation to make some people better off without making anybody else worse off. Efficiency in production means allocating the available resources between industries so that it would not be possible to produce more of some goods without producing less of any others. Efficiency in the choice of goods to produce means choosing so that it would not be possible to change the set of goods so as to make some consumers better off without others becoming worse off.

Externality

An externality exists when an activity by one or more parties affects, for good or bad, another one or more parties who are not part of, or are external to, the activity. Expressed another way, externalities result from a failure of private costs (or benefits) to equal social costs (or benefits), and economic inefficiency is the consequence.

Gross Domestic Product

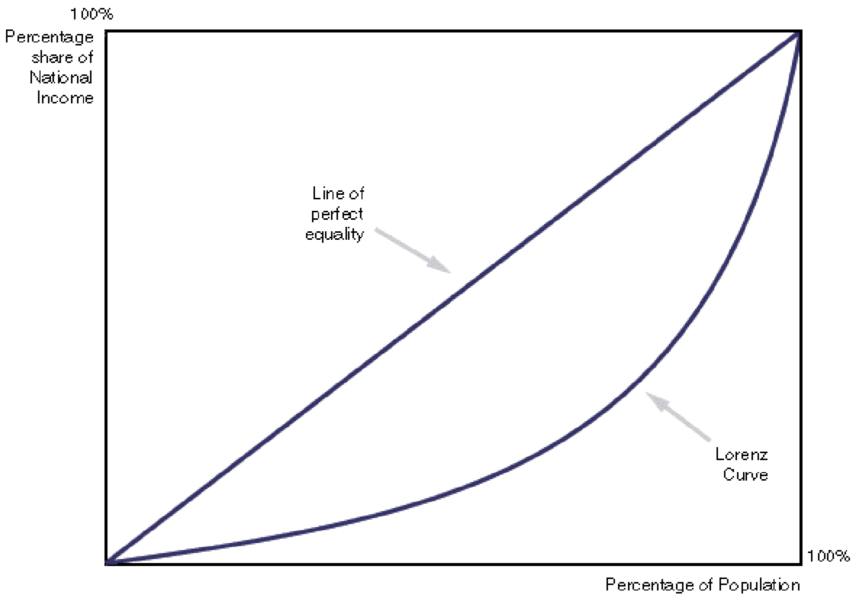
Gross Domestic Product (GDP) is one of the main measures of economic activity. The GDP of a country is defined as the total market value of all final goods and services produced within a country in a given period of time (usually a calendar year).

Heckscher-Ohlin Theorem

A country will tend to export the commodity that uses relatively more of the factor of production that is relatively abundant in that country. This theory assumes that countries have different quantities of the various factors of production, for example land, labour and capital, but have identical production functions.

Lorenz Curve

The Lorenz curve is a graph that depicts the extent of inequality in the size distribution of wealth or income and its components. The horizontal axis represents the cumulative share of population units which ranges from 0 to 100 percent. The vertical axis represents cumulative shares of income or wealth which ranges from 0 to 100 percent. A straight line represents perfect equality, and the closer the curved line is to the diagonal the smaller is the degree of inequality. The Lorenz Curve is depicted below.



Moral Suasion

The attempt to coerce private economic activity via governmental exhortation in directions not already defined or dictated by existing statute law.

Opportunity Cost

The opportunity cost of producing a good or service is the real economic cost associated with the production process. Opportunity costs consider what must be foregone in real terms to produce a unit of output or a good or service. For example, the opportunity cost of using resources (including labour and raw materials) to produce a unit of good X is the number of units of the next best alternative product that must be sacrificed to produce that unit of X.

Static Analysis

Static analysis refers generally to any analysis in which the passage of time does not play an essential role. A static analysis can be applied to flow variables (which are measured per unit of time) if the flows do not change any stocks which affect the equilibrium.

Sunk Costs

Sunk costs refer to those costs of an enterprise which cannot be recovered if it ceases operations, even in the long run.

Sources: Greenwald (1994), Black et al. (2009) and Romans (1966)

Appendix B

FAOSTAT Methodology and Data Estimates

B.1 FAOSTAT Methodology

This dissertation used data sourced from FAOSTAT. FAOSTAT, provided by the FAO, is a large time series data set with estimates of commodity data, primary crops, livestock and fish, food balance sheets, food supply, forestry, investment, population, prices, production, resources and trade for most countries of the world. For this dissertation two data sets were used, production and trade.

The datasets for production involved using data estimates of crops primary, crops processed and livestock processed. The data sources and collection methods by the FAO are cited below.

> *In general, figures have been supplied by governments through national publications and FAO questionnaires (both paper or electronic). To make the coverage of this data collection as complete as possible, official data have sometimes been supplemented with data from unofficial sources. Use has also been made of information supplied by other national or international agencies or organizations.*

The datasets for trade involved using data estimates of crop and livestock products. The data sources and collection methods by the FAO are cited below.

> *In general, figures have been supplied by governments through magnetic tapes, national publications and FAO questionnaires. In particular, for the European Union member countries, with the exception of Spain, data obtained from EUROSTAT have been used. In addition, maximum use has been made of the magnetic tapes provided by the United Nations Statistics Division. To make the coverage of this data collection as complete as possible, official trade data have sometimes been supplemented with data from unofficial sources. Use has also been made of trade information supplied by other national or international agencies or organizations.*

The estimates used are found in the next section and further information regarding methodology can be found at http://faostat3.fao.org/home/index.html#METADATA_METHODOLOGY

B.2 FAOSTAT Data Estimates

This section of the appendices presents the data used in this dissertation in its downloaded format. The columns next to the data points indicate where the data was sourced from and whether is it official or estimated. The Data Key below explains these flags (Table B. 1).

Table B. 1 Data Key

Data Key	
	Official Figure
*	Unofficial Figure
A	May include official, semi-official or estimated data
F	FAO Estimate
P	Provisional Official Data

Table B. 2 Production Data Estimates 2005 - 2007

Area	Element	Element Type	Item	2005	2005*	2005**	2006	2006*	2006**	2007	2007*	2007**
New Zealand	Production	Livestock Primary	Cow milk, whole, fresh	14,637,90	tonnes		15,172,500	tonnes		15,618,300	tonnes	
New Zealand	Production	Livestock Primary	Hen eggs, in shell (Number)	909,000	1000 No	*	910,000	1000 No	F	832,000	1000 No	F
New Zealand	Production	Livestock Primary	Cattle meat	651,772	tonnes		642,888	tonnes		632,378	tonnes	
New Zealand	Production	Crops	Potatoes	500,000	tonnes		501,000	tonnes		480,000	tonnes	F
New Zealand	Production	Livestock Primary	Sheep meat	542,811	tonnes		542,191	tonnes		573,166	tonnes	
New Zealand	Production	Crops	Wheat	318,946	tonnes		261,798	tonnes		344,434	tonnes	
New Zealand	Production	Livestock Processed	Butter Cow Milk	379,000	tonnes	*	341,000	tonnes	*	357,000	tonnes	*
New Zealand	Production	Crops	Kiwi fruit	318,000	tonnes		329,384	tonnes	P	365,000	tonnes	F
New Zealand	Production	Crops	Apples	524,000	tonnes		354,000	tonnes		421,000	tonnes	
New Zealand	Production	Livestock Processed	Cheese (All Kinds)	297,000	tonnes	A	292,000	tonnes	A	308,000	tonnes	A
New Zealand	Production	Crops	Barley	302,023	tonnes		277,020	tonnes		355,627	tonnes	
New Zealand	Production	Crops	Grapes	142,000	tonnes		185,000	tonnes		215,000	tonnes	F
New Zealand	Production	Crops	Onions (inc. shallots), green	165,000	tonnes		210,000	tonnes		205,620	tonnes	F
New Zealand	Production	Crops Processed	Wine	102,000	tonnes		133,200	tonnes	*	147,600	tonnes	*
New Zealand	Production	Crops	Maize	210,253	tonnes		227,054	tonnes		185,627	tonnes	
New Zealand	Production	Livestock Processed	Tallow	168,000	tonnes	*	187,000	tonnes	*	184,000	tonnes	*
New Zealand	Production	Livestock Primary	Wool, greasy	215,500	tonnes		224,700	tonnes		217,900	tonnes	
New Zealand	Production	Crops	Pumpkins, squash and gourds	124,000	tonnes		154,000	tonnes		185,000	tonnes	F
New Zealand	Production	Livestock Primary	Chicken meat	156,970	tonnes		148,968	tonnes		147,258	tonnes	
New Zealand	Production	Livestock Primary	Sheepskins	140,000	tonnes	F	144,000	tonnes	F	153,200	tonnes	F

Table B. 3 Production Data Estimates 2008 - 2010

Area	Element	Element Type	Item	2008	2008*	2008**	2009	2009*	2009**	2010	2010*	2010**
New Zealand	Production	Livestock Primary	Cow milk, whole, fresh	15,216,800.00	tonnes		16,483,000.00	tonnes		17,010,500.00	tonnes	
New Zealand	Production	Livestock Primary	Hen eggs, in shell (Number)	950,000.00	1000 No	F	925,000.00	1000 No	F	934,000.00	1000 No	F
New Zealand	Production	Livestock Primary	Cattle meat	634,558.00	tonnes		637,030.00	tonnes		635,289.00	tonnes	
New Zealand	Production	Crops	Potatoes	505,000.00	tonnes	F	545,000.00	tonnes	F	531,100.00	tonnes	F
New Zealand	Production	Livestock Primary	Sheep meat	598,094.00	tonnes		478,381.00	tonnes		470,906.00	tonnes	
New Zealand	Production	Crops	Wheat	343,350.00	tonnes		403,464.00	tonnes		444,891.00	tonnes	
New Zealand	Production	Livestock Processed	Butter Cow Milk	356,000.00	tonnes	*	413,000.00	tonnes	*	385,000.00	tonnes	*
New Zealand	Production	Crops	Kiwi fruit	385,000.00	tonnes	F	390,000.00	tonnes	F	378,500.00	tonnes	F
New Zealand	Production	Crops	Apples	446,000.00	tonnes		431,000.00	tonnes		319,800.00	tonnes	F
New Zealand	Production	Livestock Processed	Cheese (All Kinds)	250,000.00	tonnes	A	308,000.00	tonnes	A	311,200.00	tonnes	A
New Zealand	Production	Crops	Barley	408,730.00	tonnes		435,270.00	tonnes		308,298.00	tonnes	
New Zealand	Production	Crops	Grapes	285,000.00	tonnes	F	250,000.00	tonnes	F	230,000.00	tonnes	F
New Zealand	Production	Crops	Onions (inc. shallots), green	200,000.00	tonnes	F	203,000.00	tonnes	F	204,900.00	tonnes	F
New Zealand	Production	Crops Processed	Wine	205,200.00	tonnes	*	178,000.00	tonnes	F	189,800.00	tonnes	F
New Zealand	Production	Crops	Maize	205,557.00	tonnes		237,844.00	tonnes		188,812.00	tonnes	
New Zealand	Production	Livestock Processed	Tallow	188,600.00	tonnes	*	182,300.00	tonnes	*	182,100.00	tonnes	*
New Zealand	Production	Livestock Primary	Wool, greasy	197,273.00	tonnes	F	179,242.00	tonnes	F	165,800.00	tonnes	F
New Zealand	Production	Crops	Pumpkins, squash and gourds	175,000.00	tonnes	F	160,000.00	tonnes	F	161,500.00	tonnes	F
New Zealand	Production	Livestock Primary	Chicken meat	145,446.00	tonnes		134,999.00	tonnes		143,077.00	tonnes	
New Zealand	Production	Livestock Primary	Sheepskins	161,500.00	tonnes	F	129,000.00	tonnes	F	121,400.00	tonnes	F

Table B. 4 **Export and Import Values for Agricultural Goods in 2010**

Area	Element	Item	2010	2010*	2010**
New Zealand	Export Value	Milk Equivalent	7,684,899	1000 US$	A
New Zealand	Export Value	Sheep meat	1,967,701	1000 US$	
New Zealand	Export Value	Butter Cow Milk	1,567,891	1000 US$	
New Zealand	Export Value	Bovine Meat	1,491,293	1000 US$	A
New Zealand	Export Value	Cheese and Curd	1,041,534	1000 US$	A
New Zealand	Export Value	Wine	789,130	1000 US$	
New Zealand	Export Value	Kiwi fruit	697,578	1000 US$	
New Zealand	Export Value	Wool (greasy + degreased)	204,796	1000 US$	
New Zealand	Export Value	Apples	238,778	1000 US$	
New Zealand	Export Value	Onions	84,504	1000 US$	A
New Zealand	Import Value	Sugar, Total (Raw Equiv.)	118,593	1000 US$	A
New Zealand	Import Value	Wine	106,590	1000 US$	
New Zealand	Import Value	Pig Meat	98,074	1000 US$	A
New Zealand	Import Value	Milk Equivalent	85,906	1000 US$	A
New Zealand	Import Value	Wheat	80,866	1000 US$	
New Zealand	Import Value	Tobacco	66,227	1000 US$	A
New Zealand	Import Value	Bananas	61,649	1000 US$	
New Zealand	Import Value	Rice	48,577	1000 US$	A
New Zealand	Import Value	Coffee (green + roast)	43,702	1000 US$	A
New Zealand	Import Value	Bovine Meat	35,042	1000 US$	A

Table B. 5 Export Quantities for Agricultural Goods 2005 - 2007

Area	Element	Item	2005	2005*	2005**	2006	2006*	2006**	2007	2007*	2007**
New Zealand	Export Quantity	Milk Equivalent	10,147,482.00	tonnes	A	12,032,847.00	tonnes	A	12,031,623.00	tonnes	A
New Zealand	Export Quantity	Bovine Meat	527,288.00	tonnes	A	485,721.00	tonnes	A	454,174.00	tonnes	A
New Zealand	Export Quantity	Butter Cow Milk	319,715.00	tonnes		391,028.00	tonnes		363,866.00	tonnes	
New Zealand	Export Quantity	Kiwi fruit	312,545.00	tonnes		310,126.00	tonnes		347,916.00	tonnes	
New Zealand	Export Quantity	Sheep meat	361,814.00	tonnes		370,260.00	tonnes		400,286.00	tonnes	
New Zealand	Export Quantity	Apples	318,608.00	tonnes		265,436.00	tonnes		292,413.00	tonnes	
New Zealand	Export Quantity	Cheese and Curd	263,103.00	tonnes	A	299,008.00	tonnes	A	309,213.00	tonnes	A
New Zealand	Export Quantity	Wine	57,400.00	tonnes		64,765.00	tonnes		84,171.00	tonnes	
New Zealand	Export Quantity	Onions	160,705.00	tonnes	A	151,039.00	tonnes	A	188,327.00	tonnes	A
New Zealand	Export Quantity	Wool (greasy + degreased)	151,317.00	tonnes		157,152.00	tonnes		151,757.00	tonnes	

Table B. 6 Export Quantities for Agricultural Goods 2008 - 2010

Area	Element	Item	2008	2008*	2008**	2009	2009*	2009**	2010	2010*	2010**
New Zealand	Export Quantity	Milk Equivalent	9,640,863.00	tonnes	A	14,576,275.00	tonnes	A	14,757,817.00	tonnes	A
New Zealand	Export Quantity	Bovine Meat	446,337.00	tonnes	A	470,279.00	tonnes	A	500,468.00	tonnes	A
New Zealand	Export Quantity	Butter Cow Milk	299,778.00	tonnes		451,179.00	tonnes		416,146.00	tonnes	
New Zealand	Export Quantity	Kiwi fruit	376,598.00	tonnes		361,066.00	tonnes		406,380.00	tonnes	
New Zealand	Export Quantity	Sheep meat	393,865.00	tonnes		370,668.00	tonnes		372,866.00	tonnes	
New Zealand	Export Quantity	Apples	260,759.00	tonnes		302,854.00	tonnes		284,187.00	tonnes	
New Zealand	Export Quantity	Cheese and Curd	229,434.00	tonnes	A	290,097.00	tonnes	A	277,758.00	tonnes	A
New Zealand	Export Quantity	Wine	92,050.00	tonnes		128,555.00	tonnes		244,098.00	tonnes	*
New Zealand	Export Quantity	Onions	163,824.00	tonnes	A	129,461.00	tonnes	A	185,009.00	tonnes	A
New Zealand	Export Quantity	Wool (greasy + degreased)	125,821.00	tonnes		127,908.00	tonnes		136,706.00	tonnes	

Table B. 7 Import Quantities for Agricultural Goods 2005 - 2007

Area	Element	Item	2005	2005*	2005**	2006	2006*	2006**	2007	2007*	2007**
New Zealand	Import Quantity	Wheat	395,567.00	tonnes		356,071.00	tonnes		343,042.00	tonnes	
New Zealand	Import Quantity	Sugar,Total (Raw Equiv.)	227,144.00	tonnes	A	235,576.00	tonnes	A	232,153.00	tonnes	A
New Zealand	Import Quantity	Milk Equivalent	99,973.00	tonnes	A	78,325.00	tonnes	A	98,199.00	tonnes	A
New Zealand	Import Quantity	Bananas	77,478.00	tonnes		80,856.00	tonnes		80,458.00	tonnes	
New Zealand	Import Quantity	Wine	35,097.00	tonnes		39,094.00	tonnes		42,478.00	tonnes	*
New Zealand	Import Quantity	Rice	35,059.00	tonnes	A	37,393.00	tonnes	A	39,221.00	tonnes	A
New Zealand	Import Quantity	Pig Meat	29,897.00	tonnes	A	30,508.00	tonnes	A	34,290.00	tonnes	A
New Zealand	Import Quantity	Bovine Meat	8,072.00	tonnes	A	8,886.00	tonnes	A	11,177.00	tonnes	A
New Zealand	Import Quantity	Coffee Green+Roast	7,701.00	tonnes	A	8,694.00	tonnes	A	9,101.00	tonnes	A
New Zealand	Import Quantity	Tobacco	2,618.00	tonnes	A	3,189.00	tonnes	A	4,127.00	tonnes	A

Table B. 8 Import Quantities for Agricultural Goods 2008 - 2010

Area	Element	Item	2008	2008*	2008**	2009	2009*	2009**	2010	2010*	2010**
New Zealand	Import Quantity	Wheat	304,103.00	tonnes		257,191.00	tonnes		289,624.00	tonnes	
New Zealand	Import Quantity	Sugar,Total (Raw Equiv.)	239,809.00	tonnes	A	250,229.00	tonnes	A	217,021.00	tonnes	A
New Zealand	Import Quantity	Milk Equivalent	91,440.00	tonnes	A	140,159.00	tonnes	A	112,402.00	tonnes	A
New Zealand	Import Quantity	Bananas	79,968.00	tonnes		76,324.00	tonnes		85,867.00	tonnes	
New Zealand	Import Quantity	Wine	38,410.00	tonnes		31,791.00	tonnes		51,697.00	tonnes	
New Zealand	Import Quantity	Rice	40,999.00	tonnes	A	41,983.00	tonnes	A	44,582.00	tonnes	A
New Zealand	Import Quantity	Pig Meat	31,687.00	tonnes	A	35,401.00	tonnes	A	36,331.00	tonnes	A
New Zealand	Import Quantity	Bovine Meat	11,176.00	tonnes	A	9,091.00	tonnes	A	10,864.00	tonnes	A
New Zealand	Import Quantity	Coffee Green+Roast	9,203.00	tonnes	A	10,309.00	tonnes	A	10,737.00	tonnes	A
New Zealand	Import Quantity	Tobacco	4,379.00	tonnes	A	4,377.00	tonnes	A	5,632.00	tonnes	A

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