Ministry for the Environment
Manatū Mō Te Taiao

Environmental Reporting

Technical Paper

Ecological Footprints of New Zealand and its Regions

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September 2003

Signposts for sustainability

Ecological Footprints of New Zealand and its Regions, 1997/98

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September 2003

Published in September 2003 by the
Ministry for the Environment
PO Box 10-362, Wellington, New Zealand

ISBN 0-478-24085-6

This document is available on the Ministry for the Environment's Environmental Reporting website: www.environment.govt.nz

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Preface

This report assesses New Zealand's sustainability performance against two criteria – the amount of land 'appropriated' by each person to support their consumption (ecological footprint per capita), and whether we're living within the 'carrying capacity' of the land we have available.

So, how are we doing? This report shows that, overall, New Zealand is one of the few developed countries that is living within its carrying capacity. However, the picture is somewhat different around the country. The report gives a valuable insight into the nature and extent of interdependence of regions around New Zealand. Regions that are more urbanised and have a higher population density (such as Auckland, Wellington, and Nelson) 'overshoot' their carrying capacity in that they rely on the use of land in other regions (and other countries) to support their consumption levels. This is sustainable as long as New Zealand as a whole is living within its carrying capacity. To continue this good performance is a goal to which the Government is firmly committed.

The publication of this report and its companion web-based indicator report card and personal footprint calculator (see www.environment.govt.nz/footprint) signal a milestone for environmental and sustainability reporting in New Zealand. As a technical report, it includes sufficient detail for those who want to explore the regional pictures more closely. For others, it provides a new way of thinking about sustainable development at both the regional and national levels.

I hope it will stimulate further discussion and debate, not only about the way we measure sustainability performance in New Zealand but also about the implications for sustainable development policy directions and objectives.

Marian L. Hobbs

Hon. Marian Hobbs,
MINISTER FOR THE ENVIRONMENT

Acknowledgements

We would like to acknowledge the useful comments received from the reviewers of the first draft of this publication: Dr Barney Foran (Resource Futures Group, CSIRO, Canberra) and Dr Beat Huser (Environment Waikato, Hamilton). In particular, their comments enabled us to fine-tune the presentation of the report and hopefully make it more accessible to a wider audience.

We would also like to thank Kirsty Johnston and Robyn Reid for managing this project and the related work on the ecological footprint Calculator. We are also grateful to the Ministry for the Environment for providing funding for this report, which enabled us to expeditiously implement the first recommendation of the report *Headline Indicators for Tracking Progress to Sustainability in New Zealand*.

Finally, we would like to thank Panjama Ampanthong, Vicki Martin and Ann Flintoft for their assistance in compiling this report for publication.

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This report estimates the ecological footprints for New Zealand and its 16 regional council areas for the year 1997/98. The ecological footprint measures the total amount of productive land (in hectares) required to support a given population. It is increasingly being used as an indicator of sustainability performance after being developed by Wackernagel and Rees (1996) in the early 1990s.

An input–output methodology based on the one developed by Bicknell et al (1998) is extended in this report and then used in the calculation of the ecological footprints. The report also critically reviews the ecological footprint concept and methodology, particularly as it relates to the analysis and calculations contained in the report.

New Zealand's ecological footprint

The New Zealand ecological footprint was calculated to be 11,684,500 ha for 1997/98. This represents the total amount of land required to sustain the New Zealand population in 1997/98. It consists of inputs of agricultural land (8,036,600 ha), forest land (744,410 ha), degraded/ built-up land (959,250 ha) and of so-called energy land (1,944,940 ha) which is the hypothetical amount of land required to absorb the CO_2 emissions produced by New Zealand.

The amount of usable land available in New Zealand is calculated to be 17,783,949 ha. Usable land is defined as the total land area of New Zealand excluding national parks, forest parks, reserves and non-productive land. On this basis, the ecological footprint of the New Zealand population occupies 65.70 percent of the usable land. This means, assuming the per capita footprint remains unchanged, New Zealand could increase its population by 1.52 times before it overshoots its carrying capacity. New Zealand is, in fact, one of the few developed countries along with Canada and Australia that lives within its land-based carrying capacity, and in that sense can be considered a sustainable economy.

An analysis of the Balance of Trade for New Zealand indicates that a further role for the New Zealand economy is to provide the rest of the world with land-based ecological capital. Overall, through the export of mainly agricultural products (meat, dairy, wool) but also horticultural products, forestry products and to a lesser extent some manufacturing products, New Zealand exports embodied land, amounting to 11,090,370 ha, to other countries. This means that in embodied land terms, about half of the production of the New Zealand economy is channelled into local consumption and about half into products for exports. In comparison, the land embodied in imported products such as food, motor vehicles, computers, textiles and raw materials for industry is much smaller at 3,293,000 ha.

The per capita footprint for New Zealand is calculated to be 3.08 ha per person. This was compared with the per capita footprint of other countries after making adjustments for land productivity, as is recommended by Wackernagel and Rees (1996) and Loh (2000). On an adjusted basis, New Zealand's ecological footprint increases to 8.35 hectares (global equivalents/person), due to New Zealand land being 2.5 times more productive than the global average (ie. a hectare of New Zealand land is equivalent to 2.5 ha of the global average land). The United States (+46.70%), Denmark (+25.86%), Ireland (+14.13%) and Australia (+1.80%)

all had higher adjusted per capita ecological footprints than New Zealand. These differences can be explained by the higher income, higher levels of material affluence and consumption in these countries. There are however a number of countries that have higher per capita income (per capita GDP) than New Zealand, but somewhat surprisingly have lower ecological footprints per capita: Canada (-8.02%), France (-12.57%), Hong Kong (-14.49%), Germany (-25.03%), United Kingdom (-25.03%), the Netherlands (-28.33%) and Japan (-29.34%). There appears to be a greater decoupling between economic growth (income per capita) and the ecological footprint (embodied land per capita) in these countries, seemingly due to higher population densities usually but not always associated with urbanisation, diet and lifestyle factors, and technological factors all of which reduce the use of land and resource use in general.

Regional ecological footprints

The bulk of the report involves a detailed and systematic analysis of the ecological footprints for the 16 regional council areas in New Zealand. A particular feature of this analysis is the quantification of interregional flows of embodied land; which leads to insights into the ecological interdependencies between the regions and also between regions and other countries.

The largest regional ecological footprint is Auckland's at 2,319,940 ha which is not surprising given that it has the largest population of any region in New Zealand. Auckland makes up 21.66 percent of the New Zealand ecological footprint. Canterbury is a clear second with an ecological footprint of 1,737,860 ha that makes up 16.23 percent of New Zealand's ecological footprint. Although Canterbury has a similar population to Wellington, it has a relatively higher per capita footprint that gives it a much larger footprint than Wellington's of 1,029,010 ha. Waikato (1,048,860 ha) and Otago (1,019,050 ha) have similar size footprints to Wellington.

Next in the rankings is a cluster of provincial regions: Manawatu–Wanganui (879,500 ha), Northland (384,660 ha), Southland (375,310 ha), and Taranaki (233,150 ha). Last in the rankings come a number of smaller more peripheral regions: Marlborough (163,180 ha), Gisborne (141,660 ha), West Coast (121,810 ha), Tasman (82,180 ha) and Nelson (76,910 ha). Although population is the main determinant of size of these ecological footprints, the per capita footprint is important and varies according to regional differences in land productivity, consumption patterns, the degree of urbanisation and population densities.

Assessing the sustainability performance of the regions

The sustainability performance of the 16 regions can be assessed against two criteria:

(1) *Ecological footprint per capita*. This measures the amount of land appropriated by a person (in a nation, region or city) in supporting their consumption. The smaller this amount of land, then the more sustainable this pattern of consumption is deemed to be, because it requires less appropriated natural capital (as measured by embodied land).

(2) *Degree of overshoot*. It is argued that to be sustainable, a population (of a nation, region or city) must consume less embodied land, than the amount of useful land which is available. That is, the population must live within its carrying capacity or biocapacity. If the population overshoots its carrying capacity, by using too much land, then it is argued that this amount of land cannot sustain the population.

Graphical analysis reveals, that in terms of these two criterion, there are three significant clusters of regions:

(1) *Auckland, Wellington and Nelson*. These regions have overshot their carrying capacity, but all have a per capita footprint below the New Zealand average. Notably, these are the three most urban regions in New Zealand. It is predictable, that if an ecological footprint analysis was undertaken for any other 'urban' area in New Zealand that a similar result would occur (eg. if an ecological footprint was calculated for Christchurch City, instead of the entire Canterbury region). The reason why one indicator (per capita footprint) is performing well, and the other (overshoot) is performing poorly is straight forward – urban areas simply use land more efficiently in terms of retail, housing, infrastructure and transport functions, as high population densities reduce space requirements. At the same time the more urban a region is, the more it has to draw resources (particularly food) from outside the region, resulting in an ecological deficit or overshoot situation.

(2) *Waikato, Bay of Plenty, Gisborne, Hawke's Bay, Taranaki and Tasman*. These are apparently the 'best' performing regions. They perform favourably for both indicators – their footprint per capita is below the New Zealand average and they are not in an ecological deficit or overshoot situation. This result however needs to be interpreted with caution. All of these regions have above average land productivities (except Gisborne) which will decrease their per capita footprint – in other words, the per capita footprint is lower, not so much because people in these regions consume less products or live more sustainably, but more because the land in their region is more productive and therefore less of it is required to produce the same amount of products. None of these regions is urban, and if a footprint analysis was undertaken for any one of the urban areas within these regions (eg. Hamilton City) undoubtedly an ecological deficit or overshoot situation would arise.

(3) *Northland, Manawatu–Wanganui, Marlborough, West Coast, Canterbury, Otago and Southland*. These regions are not in an overshoot or ecological deficit situation which is a favourable outcome. However, their per capita footprints are above the New Zealand average which is not a favourable outcome. Again, the interpretation of these results needs to be approached with caution. The unfavourable outcome, in terms of the relatively high per capita footprint, in most cases can be explained away purely by the low land productivities in these regions. All of these regions (except Northland and Manawatu–Wanganui) have land productivities below the national average, meaning more land is required to produce the same amount of product that inflates their per capita footprint. This is particularly the case for Otago. Therefore, it could be argued that these regions do not necessarily consume more products and resources than other regions on a per capita basis, rather they require more land to produce the same amount of products.

Outstanding research issues

This analysis represents the first comprehensive and systematic quantification of regional level ecological footprints in New Zealand. The analysis could however be improved by:

(1) undertaking the analysis at the 48 sector (or greater) level, instead of at 23 sectors. This would lead to more accurate results particularly concerning the appropriation of agricultural land. This would be especially useful in understanding the impact of diet on the ecological footprint

(2) a series of New Zealand based land productivity factors need to be derived and applied to the data. This should allow for a more rigorous comparison of sustainability performance across the regions

(3) improving the accuracy of the regional input–output matrices and the interregional trade flow model which were used in the ecological footprint calculations

(4) including coastal and marine 'land' in the analysis. It is recommended in any future application of this methodology to calculate regional-level ecological footprints that these improvements be implemented.

The report also contains a number of specific suggestions for enhancing the relevance of the analytical results for individuals, policymakers and other end-users. For individuals, the calculations could be refocused to show people how they can reduce their footprint by changing their consumption behaviour and lifestyles. The recently instigated personal ecological footprint calculator which is available on the Ministry for the Environment's website, is a positive move in this direction. For policymakers, the strategic and policy implications of future trends in the ecological footprints are of particular relevance, and this is an area that requires further research. The setting of targets and performance standards for ecological footprints is another area that requires attention by policymakers and planners.

1 Introduction

1.1 Scope of the report

The Ministry for the Environment has worked with other government departments to produce the Sustainable Development of New Zealand Programme of Action (January 2003) that includes the development of headline indicators of sustainability. This report represents a first step to establish a headline indicator of sustainability for New Zealand and its regions based on the ecological footprint concept. After originally being developed at the University of British Columbia's School of Community and Regional Planning in the early 1990s by Wackernagel and Rees (1996), the ecological footprint is increasingly being used as an indicator of sustainability,. The ecological footprint has recently been calculated for 150 countries in the World Wildlife Fund's report *Living Planet Report 2000* (Loh, 2000).

Specifically the research objectives for this report are:

(1) To develop a scientifically defensible and replicatible methodology for the calculation of ecological footprints of New Zealand and its regions based on extending Bicknell et al's (1998) input–output approach.

(2) To calculate the ecological footprint for New Zealand, for the base year 1997/98, using the above methodology. These calculations will pay particular attention to disaggregating the ecological footprint into its component land types (agricultural, forest, degraded, energy) and according to categories of commodities that are consumed.

(3) To compare New Zealand's ecological footprint with those from other countries and to understand the key reasons behind any significant differences.

(4) To calculate the ecological footprint for the 16 regional council areas in New Zealand, for 1997/98, disaggregating according to land types and type of commodities that are consumed. This regional analysis will be used to understand the ecological interdependencies between regions as indicated by the interregional flows of embodied land.

(5) To compare the 16 regional ecological footprints and to understand the key reasons for any significant differences in the numerical magnitude of these footprints. These regional ecological footprints will then be used to assess the sustainability performance of the various regions.

(6) To extend the regional and national ecological footprint calculations to take account of international exports and imports of embodied land. The ecological footprint measures the embodied land required by local consumption within New Zealand but a considerable amount of New Zealand land-based production supports consumption in other countries.

(7) To identify and briefly discuss any theoretical and methodological limitations of the ecological footprint as a headline sustainability indicator, particularly as it relates to the foregoing analysis and calculations.

1.2 Ecological footprint concept and its measurement

1.2.1 What is the ecological footprint?

The ecological footprint is defined by Rees (2000) as the "area of productive land and water ecosystems required to produce the resources that a population consumes and to assimilate the wastes that the population produces, wherever on Earth that land and water may be located". It can be seen as a sustainability indicator in two senses. Firstly, it measures the total ecological cost (in land area) of supplying all of the goods and services to a human population. This recognises that people not only directly require land for agricultural production, roads, buildings and so forth, but land is indirectly embodied in the goods and services that people consume. For example, the indirect (or embodied) land required to produce a kilogram of butter includes not only the land used directly in manufacturing but all land embodied in the inputs that went into producing the butter – dairy farm land, land required to produce the packaging and so forth. In this sense, the ecological footprint can be used to make visible the hidden ecological cost of an activity or population.

A second, and more controversial interpretation of the ecological footprint as a sustainability indicator, invokes the idea of carrying capacity. Carrying capacity in ecology is the maximum population a given land area can support indefinitely. The idea is relatively straightforward when applied to well-defined biological populations (eg. a certain number of hectares are required to support a herd of deer). If the number of deer exceeds the carrying capacity then the population is said to be in overshoot. Resources (mainly food) will become scarce and population die-back will occur. This idea is more controversial when applied to human populations, as in the *Limits to Growth* study which predicted a decline in global human population as it overshot its carrying capacity (Meadows et al, 1972; Meadows et al, 1992). Some proponents of the ecological footprint argue that the total embodied land area required by a population should not overshoot its biocapacity[1] (eg. Loh (2000) argues that the ecological footprint of the Netherlands at 92.9 million ha, considerably overshoots its biocapacity of 37.4 million ha). Less dogmatically, it can be concluded that the Netherlands is in ecological deficit, in the sense it is using more biologically productive land than is available within its borders.

Using this second interpretation, Wackernagel and Rees (1996) argue that the ecological footprints of most developed nations are unsustainable as they exceed available biocapacity. At the global level the ecological footprint for humanity exceeds global biocapacity by 34 percent (Loh, 2000).

1.2.2 History of the ecological footprint concept

The University of British Columbia's School of Community and Regional Planning developed the ecological footprint in the early 1990s. The concept was popularised by Wackernagel and Rees (1996) in the publication *Our Ecological Footprint: Reducing Human Impact on the Earth*. Wackernagel et al (1999) acknowledge Vitousek et al's (1986) study on the human appropriation of photosynthesis products as the intellectual predecessor to the ecological footprint concept. However its antecedents can be traced back a lot further.

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[1] Biocapacity is a measure of the total biologically productive land available to a specified population.

In the 18th century the Physiocrats argued that the embodied land content of a commodity determined its value. For the Physiocrats, all value was derived from the land (nature), and in this sense agriculture was the only productive sector in the economy with the manufacturing and service sectors considered 'sterile'.

Classical economists, although not subscribing to an embodied land theory of value did emphasise the idea of carrying capacity. Both Thomas Malthus (1766–1834) and David Ricardo (1772–1823) saw population being constrained by the carrying capacity imposed by land availability. Malthus argued that population growth wasn't sustainable in the long run, as it grew according to a geometric progression and it would eventually overshoot food supply from land that grew arithmetically. Ricardo didn't foresee an overshoot, as Malthus did, but instead suggested that population growth would gradually approach its carrying capacity as food production was forced to use less fertile land.

In the modern era, Borgstrom (1967, 1973) developed the concept of 'ghost acreage' which is similar to the idea of the ecological footprint. This idea was further promoted by sociologist Catton (1982) in his book *Overshoot: The Ecological Basis of Revolutionary Change*. Ghost acreage is the additional land a nation needs in order to supply the net amount of food and fuel, from sources outside the nation (ie. the net imports of agricultural products, oceanic fisheries and fossil fuels). The appropriation of ecosystem areas and services has also been a central theme in other approaches (refer to Folke et al, 1997; Brown and Ulgiati, 1998). Brown and Ulgiati (1998) for example measure the ecological footprint of various countries and the globe, using an energy indicator instead of the more widely used land indicator. Folke et al (1997) estimated the 'appropriated ecosystem areas' by cities in the Baltic area based on their resource consumption and waste assimilation.

1.2.3 How is the ecological footprint calculated?

Several methods have been advanced for calculation of ecological footprints (eg. Wackernagel and Rees (1996), Folke et al (1997), Bicknell et al (1998), Wackernagel et al (1999), Loh (2000), van Vuuren and Smeets (2000) and so on). Although each of these methods has its own peculiarities and insights, many have their roots in the work of Wackernagel and Rees (1996).

The Wackernagel and Rees calculation method begins with construction of a 'consumption by land use' matrix. The consumption dimension covers food, housing, transport, consumer goods and services, while the land use dimension encompasses built-up areas (supporting roads, housing and other infrastructure), crop land and pasture (for production of food and other goods), managed forest (for production of wood products), and energy land (for sequestering carbon dioxide emissions resulting from the burning of fossil fuels). This consumption by land use matrix provides a snapshot, for a given population, of the land use types required for production and consumption of goods and services.

Population data, together with consumption information, for each land use category are used to derive an average annual consumption per person. Consumption is calculated by adding imports to domestic production and excluding exports. Referred to as 'apparent' consumption, this differs from true household consumption due to the inclusion of resources processed for export, while at the same time excluding resources embodied in imported finished products. The land area utilised by each consumption category is then determined for each land use category. This requires dividing consumption in each category, by a relevant global average yield, to obtain land area. Global average yields are used so that comparisons can be made between the ecological footprints of different nations and with the globe.

The land appropriated for energy consumption is treated separately primarily due to the size of the contribution it makes. Wackernagel et al (1999) distinguish between five types of energy, namely: gas fossil, liquid fossil, solid fossil, firewood and hydropower.[2] The energy land requirement for fossil fuels is calculated by assessing the amount of planted forest land required to absorb the CO_2 emissions resulting from energy consumption. The role played by the oceans in CO_2 sequestration is also acknowledged. The oceans are assumed to absorb some 35 percent of CO_2 emissions at the global level. Correction for trade is required because energy is utilised in the production of exported goods and services, and conversely embodied in imports. This requires multiplying imports and exports for various trade categories by their energy intensities and determining the difference.[3]

Aggregating the land area appropriated by each land use category generates the ecological footprint. Prior to aggregation each category is multiplied by an equivalence factor to take account of differences in biological productivity (eg. for built up areas, forest land and pasture equivalence factors of 3.16, 1.78 and 0.39 are respectively applied (Loh, 2000)). Wackernagel et al (1997) also argue, in accordance with the Brundtland report (WCED, 1987), that an additional 12 percent of land area is required as a backstop for the preservation of biodiversity.[4] The ecological footprint may also be expressed in per capita terms which permits the comparison between different nations, regions or populations.

The ecological footprint can also be calculated by using input–output analysis to track the flow of embodied land. This method of analysis which was first developed by Bicknell et al (1998) and refined by Ferng (2001) and others has not to date been widely used. It should, however, be noted that the calculation of embodied resources using input–output analysis was first pioneered in the early 1970s by analysts such as Hite and Laurent (1971), Herendeen (1972) and Wright (1975), and it could be argued that the calculation of ecological footprint (in land terms) in just a special case of the more general method. The input–output method of calculating the ecological footprint attempts to situate the analysis in a rigorous mathematical framework but draws upon many of the ideas and principles of the Wackernagel Rees method.

1.3 Critique of the ecological footprint

Costanza (2000) and Moffatt (2000) argue that the key feature of the ecological footprint is that it provides an effective heuristic and pedagogic tool that captures current human resource use in an easily digestible form. In this way, the ecological footprint frequently promotes discussion on issues directly relevant to sustainable development – in other words, issues such as:

(a) the finite dimensions of human activity

(b) the key resources and ecosystem functions for sustainable development

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[2] Nuclear power is treated as a fossil fuel. It is unclear why nuclear power and fossil fuels are equated, as they have quite different biophysical inputs and have substantially different ecological impacts and risks. Energy generated from other sources is considered to be negligible and is not included (eg. geothermal and wind).

[3] Wackernagel et al (1999) apply energy intensities taken from Hofstetter (1992). Interestingly, van Vuuren and Smeets (2000) note that energy intensity data is only available for developed nations. Furthermore, they consider it to be insufficiently accurate to permit calculation of trade related energy emissions.

[4] Wackernagel et al (1997) note that authors such as Noss (1991), and Noss and Cooperrider (1994) argue that this estimate is probably insufficient to support this backstop.

(c) the role played by trade in distributing ecological resources and pressures

(d) the selection of indicators for monitoring progress toward sustainable development and so forth.

The ecological footprint methodology does, however, have a number of well-known weaknesses and limitations that are described below.

1.3.1 Lack of common definitions and methodologies

There is no accepted methodology for calculating the ecological footprint. The ecological footprint is not, for example, constructed according to widely accepted international conventions such as that used in the United Nations System of National Accounts (UNSNA). This has led to ambiguities in interpreting the results of various ecological footprint studies. For instance, estimates of New Zealand's ecological footprint range between 3.49 and 9.6 ha per capita (Bicknell et al, 1998; Wackernagel et al, 1999; Loh, 2000). Investigation of these studies reveals that differences result largely from the assumptions made concerning biological productivity, the use of equivalence factors, and the calculation of energy land. To avoid misinterpretation in this report, and to allow comparison with earlier ecological footprint estimates, differences in assumptions between three different calculation methods are outlined in Table 1.1.

Table 1.1 Assumptions made by three different ecological footprint calculation methods

Bicknell et al (1998)	Loh (2000)	This report
Applies local yields for pasture, arable and forest land	Applies global average yields for pasture, arable and forest land	Applies local yields for pasture, arable and forest land
Does not apply equivalence factors	Applies equivalence factors when aggregating land types	Does not apply equivalence factors
Applies an international energy-to-land ratio obtained from Wackernagel and Rees (1996)	Applies world average CO_2 absorption factor	Applies CO_2 absorption factor for New Zealand *Pinus radiata* (Hollinger et al, 1993)
Ignores CO_2 absorption by oceans	Assumes oceans absorb 35 percent of CO_2 emissions	Ignores CO_2 absorption by oceans
No allowance for securing biodiversity	Assumes 12 percent of biocapacity is set aside for securing biodiversity (as per WCED, 1987)	No allowance for securing biodiversity
Excludes sea space	Includes sea space, estimated to be 0.1 ha per capita for New Zealand	Excludes sea space
Considers ecological interdependencies between regions as an aggregate (total imports)	Considers ecological interdependencies between regions as an aggregate (total imports)	Makes explicit ecological interdependencies between regions
Based on input–output analysis	Based on work of Wackernagel and Rees (1996)	Based on input–output analysis

There is however a reasonable prospect that many of these conventions and methodologies for the calculation of ecological footprints will be standardised in the near future. The United Nations (1993) SEEA System of Environmental Accounting provides a good example of how environmental accounting protocols have been established and are now widely accepted in a field which hitherto had few commonly used conventions and methodologies in the 1970s and 1980s.

1.3.2 Why use land as the numeraire?

Why should embodied land be used as the numeraire for a sustainability indicator? Others have argued (Slesser, 1973; Gilliland, 1975; Costanza, 1980; Odum, 1983; Herendeen, 1998) that embodied energy or embodied solar energy is a more appropriate numeraire. Land isn't the only scarce natural resource, so why should it be the only resource entered into the calculation of a sustainability indicator? Arguments alluding to the non-substitutability of land are not compelling, as it could be argued that other natural resources also don't have substitutes (eg. solar energy). By using input–output analysis to calculate the ecological footprint, as is applied in this report, the ecological consequences of human activity on other key resources (eg. energy and water) are easily determined. Energy analysis, for example, has been widely applied in estimating energy embodied in human activities. Examples include work of Bullard and Herendeen (1975), Gilliland (1975), Hannon (1979), Costanza (1980) and Giampietro and Pimentel (1991). The focus of this report is, however, on the appropriation of biologically productive land.

1.3.3 Why include hypothetical energy land?

The hypothetical land required to absorb atmospheric CO_2 emissions, resulting from the burning of fossil fuels, often constitutes more than 50 percent of the ecological footprint. Critics such as Ayres (2000) find this result questionable. It assumes that afforestation is the preferred option for CO_2 sequestering. Serious alternatives already exist such as liquefying CO_2 and pumping it into the ocean depths where it would remain for thousands of years, or into oil and gas fields replacing the fuel extracted, while increasing pressure of the remaining reserves. Planting production forest to sequester CO_2 is arguably only a temporary measure. The forests will grow old, die. be harvested or are used as a fuel source, all of which will eventually result in CO_2 being re-released back into the atmosphere.

Another critical issue with the ecological footprint is that it exclusively focuses on energy related CO_2 emissions, neglecting the ecological consequences caused by other emissions (eg. the depletion of ozone by CFCs, or acidification caused by SO_2 and NO_x). More importantly, the ecological footprint as it is currently formulated overlooks pollution and wastes generated by other unsustainable practices such as the disposal of non-biodegradable consumer wastes (eg. plastics, metals) and persistent toxins (eg. rubbish leachate). These issues are not addressed in this report, although it is recognised that they are important issues that need to be addressed in the further development of the ecological footprint indicator.

1.3.4 Is all land the same?

The use of equivalence factors during the aggregation of ecological footprint components (built area, arable land, forest land etc) is contentious. These equivalence factors recognise that adjustments need to be made to land areas (ha) to take account of variations in biological productivities. For example, fertile flood plains may have a biological productivity several times that of mountainous land, and adjustments need to be made to reflect this difference. It can be argued that this narrow focus on biological productivity, ignores other factors that determine the relative value of different types of land (eg. cultural values, social preferences or relative scarcity, as are often reflected in market prices).

International comparison of ecological footprints requires consideration of differences in biological productivity. Such differences are primarily due to environmental factors (ie. solar flux, soil type, climatic conditions and type of vegetation cover). This issue is addressed in ecological footprint calculations by relating consumption to global average yields rather than local yields.[5] Such an approach is problematical as it produces results that are not comparable with the actual land area occupied by the appropriating population. At a national, or sub-national level, it is often desirable to be able to examine ecological consequences in terms of actual occupied land area – a unit of measurement familiar to the resident communities.

In this report neither global average yields or equivalence factors are used, except when international comparisons are made in Section 3.

1.3.5 What spatial boundaries?

The selection of appropriate spatial boundaries is a critical issue in ecological footprinting. For example, ecological footprints can be calculated at global, national, regional and local (city) scales. Wackernagel and Silverstein (2000) argue for political or cultural boundaries as they represent the level at which environmental policy and decision-making is most often made. By contrast, van den Bergh and Verbruggen (1999) dispute the use of such boundaries on the grounds that they have no environmental meaning, favouring instead hydrological, climate zone, or larger connected ecosystem boundaries. In this report, New Zealand regional council areas are used which reflect both political[6] and environmental boundaries.[7]

Closely associated with the selection of ecological footprint spatial boundaries are the ecological implications of trade. Rees (1992) argues that trade has the effect of physically and psychologically distancing populations from the ecosystems that sustain them. From a regional perspective, information is required not only on footprint size (and on its component shares, for example, agricultural, forest, degraded (built up) and energy land), but also on the origins of contributions made by each imported component and how sustainable it is. For this reason in this report the ecological footprint methodology is extended to include an analysis of the ecological interdependencies of New Zealand regions, in order to consider not only the ecological footprint from the consumption (end-use) perspective, but also the production (source) perspective.

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[5] Global (Loh, 2000) average yields may differ substantially from local yields. In New Zealand, for example, the local yield for milk production is 1,759 kg ha^{-1}, compared with a global average yield of 336 kg ha^{-1}. Therefore, applying a global average milk production yield for the calculation of the New Zealand footprint, results in an ecological footprint contribution that is 5.24 times the actual land area used for milk production.

[6] Regional councils are the key agencies responsible for environmental governance in New Zealand.

[7] The boundaries of regional councils are based on major river catchments.

1.3.6 Dynamics – what about the future?

The ecological footprint provides a snapshot of a population's environmental requirements using current technology under prevailing management practices and social values. Even if the ecological footprint for a particular population is calculated at regular intervals, the results are always out of date – in this respect, the ecological footprint only tells us 'yesterday's news'. Key dynamic components of the sustainability equation such as intergenerational equity, technological change, and the adaptability of social systems are simply overlooked. Moreover, nature is characterised by complex adaptive systems with non-linearities, feedback loops, and thresholds (Holling, 1973; Levin, 1998). By ignoring such dynamics the ecological footprint cannot inform us on the ecological consequences of likely futures or even possible scenarios. This report makes no attempt to address these issues.

1.4 Related New Zealand studies

Input-output analysis was used to calculate the ecological footprints of New Zealand and its regions. That is, the direct and indirect land required to support local consumption was calculated using input–output analysis. Input-output analysis can also be used to calculate not only the embodied (direct + indirect) land content but also embodied inputs for other natural resources. These methods of analysis were first developed in the early 1970s by analysts such as Herendeen (1972), Hite and Laurent (1972) and Wright (1975). These input–output methods were not only applied to resource inputs (into the economy) but also to pollutant outputs (from the economy).

In New Zealand Carter, Peet and Baines (1981) pioneered the use of input–output analysis for calculating the embodied energy content of the output from various sectors in the economy. Initially Peet and his colleagues calculated embodied energy requirements based on the 1971–72 input–output table of the New Zealand economy, but subsequently updated this analysis to cover the 1976–77 and 1981–82 input–output tables (Peet, 1985). In addition, they extended their analysis to cover dynamic input–output scenario models, employment issues, New Zealand's energy Balance of Trade, as well as more recently CO_2 emissions policy issues.

Patterson and McDonald (1996) undertook an input–output analysis of regional data from the Manawatu–Wanganui and Wellington regions to quantify the indirect land, water, air pollutants and water pollutants embodied in economic products. This analysis used data primarily from regional council consents and monitoring databases, and used regionalised versions of the national input–output matrix. This work was extended in the *Eco*link project sponsored both by councils and the Ministry for Environment's Sustainable Management Fund. This project again quantified ecological multipliers (direct and indirect effects) for land energy, greenhouse gases, water takes/discharges and water pollutants for all territorial local authorities in the Northland, Auckland and Waikato Regional Council areas (McDonald and Patterson, 1999a).

Bicknell et al (1998) specifically developed a new methodology for calculating national ecological footprints using input–output analysis which was published in the journal *Ecological Economics*. This methodology was the first published application of input–output analysis methodology for calculating ecological footprints and has since been extended by analysts such as Ferng (2001) and Lenzen and Murray (2001). Bicknell et al (1998) applied their methodology to New Zealand data in order to calculate the New Zealand ecological footprint as a demonstration case.

More recently Patterson and McDonald (2002) have used input–output analysis to calculate various ecological multipliers for the New Zealand tourism industry. These multipliers show that the indirect environmental effects of tourism in New Zealand are very significant and challenge the idea that tourism in New Zealand is 'clean and green'.

New Zealand also has a history of regional input–output analysis which is relevant to our current study. Hubbard and Brown (1981) pioneered regional input–output analysis in New Zealand in their analysis of the income and employment effects of irrigation development in the Lower Waitaki. Moore (1981) constructed a 50 sector input–output model of Northland based on a survey method and used this model to quantify the indirect effects of forestry options for Northland. However, probably the most widely used and known work is that of Butcher (1985) who developed regional employment and income multipliers from regional input–output matrices generated by the GRIT method. The GRIT method is a non-survey based method developed by Jensen et al (1977) for generating reliable regional input–output matrices from national matrices. The GRIT method is also used in this current study to generate regional input–output matrices for the 16 regional council economies. The calculation of ecological multipliers (instead of income and employment multipliers) can be seen as an extension of this type of regional economic analysis.

1.5 Key definitions

1.5.1 Location quotient

Location quotient analysis was used in sections 4–19 of this report. This enabled us to gain some insights into the economic strengths and weaknesses of the various regional economies being analysed.

The location quotient is a statistical measure of the extent to which a particular economic sector is over-represented or under-represented in a regional economy. If the location quotient is greater than one (LQ>1), then that economic sector is over-represented in the regional economy compared with the national economy. If the location quotient is less than one (LQ<1) then that economic sector is underrepresented in the regional economy compared with the national economy. If the location quotient is one (LQ=1), then that economic sector is represented in the regional economy at exactly the same proportion as in the national economy.

It is preferable to measure the location quotient in terms of value-added output ($). However, such data is not available at a regional level in New Zealand. Therefore, in accordance with common international practice, we have used employment as a surrogate measure of value added ($) production. This surrogate measurement assumes that the labour productivity for a given sector in the region is the same as for that given sector nationally.

1.5.2 Ecological footprint indicators

Rees (2002) defines the ecological footprint as the "area of productive land and water ecosystems required to produce the resources that population consumes and to assimilate the wastes that population produces". In our analysis, we use this definition, with the exception that water ecosystems aren't included.

The ecological footprint consists of four different types of land in our analysis:

(1) *Agricultural land*. This is land used for food and fibre production, encompassing: dairy, sheep, beef, other livestock, horticulture, cropping, vegetable production and fruit growing.

(2) *Forest land*. This land is used for the production of commercial forests. It does not include non-commercial forests such as those in National Parks or those in the conservation estate. It also does not include land directly used in the downstream processing of forest products.

(3) *Degraded land*. This represents built up areas that host human settlement. This includes land used for housing, commercial and governmental purposes as well as land covered by the transport network.

(4) *Energy land*. This represents the hypothetical amount of land required to sequester CO_2 emissions resulting from the burning of fossil fuels.

Different sectors in international, national and regional economic systems utilise these four types of land (agricultural, forest, degraded, and energy). There is a complex pattern of flow of these types of land through and between these economic systems. Figure 2.1 provides a schematic summary of these flows and how they relate to the ecological footprint concept. This schematic diagram shows that the ecological footprint is the total (direct and indirect) amount of land consumed by households, when they purchase and consume products. Economic systems, however, do not just produce commodities for households; they also produce commodities for export. Once this is recognised, it is useful to also use the concept of *Ecological Balance of Trade*. The Ecological Balance of Trade is the land embodied in exports minus the land embodied in imports for a national or regional economy. If a national or regional economy has a positive Ecological Balance of Trade, it is a net provider of ecological capital to other economies. New Zealand, for example, has a positive Ecological Balance of Trade which means that we ecologically support other economies more than they support us.

2 Methodology

2.1 Rationale for the input–output approach

Much of the ecological footprint work undertaken to date has been based on methodologies that lack formal structure. Some approaches may even be considered to be ad hoc. A major limitation of such methods is that they may lead to results that are not easily reproduced either through time or across space. In turn, this restricts comparability or leads to inconsistencies that are more an artefact of the method rather than actual differences. Such concerns led Bicknell et al (1998) to develop an alternative formulation of the ecological footprint calculation based on input–output analysis.

Input–output analysis, developed by Wassily Leontief during the 1930s, provides a comprehensive snapshot of the structure of inter-industry linkages in an economy. Most developed nations prepare input–output tables at regular intervals. Generally speaking, an input–output table of a nation is conceptually reconcilable with its system of national accounts (SNA). In addition, input–output tables adopt internationally recognised systems of commodity/industry classification (eg. the International Standard Industrial Classification (ISIC)). This facilitates comparison over time, between nations and with standard economic aggregates such as GDP and Balance of Trade.

Although input–output tables are usually presented in monetary terms, authors such as Daly (1968), Isard (1968), Leontief (1970) and Victor (1972) have demonstrated that biophysical information on resource use and pollution generation may also be placed in an input–output framework. A major strength of input–output analysis is that it may be used to calculate the indirect effects of economic change, including indirect effects relating to resource use and pollution generation if this information is included in the input–output table.

The advantages of using the input–output method in calculating the ecological footprint are:

(1) It is a more comprehensive method covering a wider range of inputs than the ad hoc methods. Typically, for example, ad hoc methods tend to ignore service sector inputs (banking, insurance) all of which have significant embodied land inputs. This neglect of several categories of inputs typically reduces the magnitude of the calculated ecological footprint. The mathematics of the input–output analysis also means that the first, second, third ... nth round effects (infinite regress) can be more accurately and comprehensively calculated.

(2) It is a systematic method. The input–output matrices provide a convenient checklist to ensure that all flows in the economy are taken into account. The conservation principles (inputs = outputs) of input–output accounting further ensures that there are no unintentional blind spots, as all inputs and outputs must be taken account of.

(3) Input–output analysis avoids a number of methodological problems – in other words:

   (a) double-counting is a problem in ad hoc methods particularly when dealing with complicated networks of indirect flows that have significant feedbacks. This type of problem is generally overcome by using input–output analysis

   (b) joint production causes problems when using ad hoc methods due to the need to allocate land inputs across multiple outputs of commodities from a process – joint production matrices of the type used by Costanza and Hannon (1989) overcome this problem.

(4) It is a mathematically rigorous method. The use of matrix algebra is not only efficient in dealing with large datasets but also enables the analysis to be undertaken in an internally consistent mathematical framework.

The disadvantages in using the input–output method for calculating ecological footprints are:

(1) The input–output sector categories are often too broad which can lead to inaccurate results. For example, the type of food consumed by a person (ie. diet) is a well-known determinant of the size of that person's ecological footprint. The input–output matrices usually do not provide enough disaggregation into different food types to take account of these dietary differences – typically there might be only one input–output sector category 'food' that does not even distinguish between meat and vegetable consumption.

(2) Accurate and up-to-date input–output matrices often do not exist for a nation or a region. For example, in New Zealand accurate national-level input–output tables are only produced on a five-yearly basis, and there is often a delay of up to five years before they are published. This could be problematical, particularly if there has been rapid technological or structural change in the economy over the intervening years. Survey-based regional input–output tables do not exist in New Zealand, and they have to be estimated using non-survey methods (eg. like the GRIT method).

(3) The inter-industry linkages in an economy generally represent flows of physical goods. In input–output analysis such flows are usually summarised in a transactions table denominated in monetary units. Certainly, monetised transaction tables are widely available both at the national and regional levels, which facilitates the widespread application of the methodology described in Sections 2.2 and 2.3. However, the use of monetised tables can lead to problems if the price paid for a given product differs across purchasing industries. If Industry 1, for example, purchases 10 kg of goods at 20 cents per kg and Industry 2 purchases 10 kg of goods at 10 cents per kg from the same industry, then both industries receive the same physical quantity of goods 10 kg, but spend different amounts, $2.00 and $1.00 respectively. This implies from a monetary transaction perspective, that the land embodied in Industry 1 purchases is twice that of Industry 2 purchases – whereas, from a physical perspective both industries are purchasing the same physical quantity of goods. This effect may result in both under- and over-estimation of sector contributions made to the ecological footprint. This problem can be overcome, using various mixed price methods, if the price deficiencies across industries are known.

2.2 Methodology for measuring New Zealand's ecological footprint

As noted above this report uses an input–output based methodology to calculate the New Zealand ecological footprint. This method was first devised and applied at Lincoln University by Bicknell et al (1998), using New Zealand as a case study. Rather than repeat this methodology here, a summary of the main procedural steps is provided below. Readers interested in the strict technical aspects of this method are directed to Bicknell et al (1998).

The method is developed in two parts. In the first part the domestic land embodied in goods and services consumed by the New Zealand population is determined. The second part extends the first part to include land embodied in products purchased from overseas and removes the land embodied in products sold overseas. In broad terms, the method requires the calculation of input–output coefficients that are subsequently multiplied by land to value-of-output ratios on a sector by sector basis. Multiplying the elements of the resulting matrix (expressed in hectares

per dollar of output) by a vector of final demand (consumption) determines the land supporting the New Zealand population.

2.2.1 Domestic land calculation

Step A: Calculation of the technical coefficient matrix

The procedure begins with a standard New Zealand inter-industry (input–output) table. A technical coefficient matrix is derived from the New Zealand inter-industry table by dividing each table element by its corresponding industry gross input/output total. The technical coefficient matrix **A** shows the amount of inputs in monetary terms that row sector *i* needs to increase output in column sector *j* by one monetary unit. Such purchases, which are ultimately driven by consumer demand for final goods and services, initiate a chain of economic activity throughout the productive sectors of the economy.

Step B: Calculation of the Leontief inverse matrix

The total repercussionary effects associated with all chains of economic activity in an economy may be summarised by calculation of the Leontief inverse matrix. Calculation of the Leontief inverse matrix requires:

(1) the technical coefficients matrix **A** be subtracted from an identity matrix I

(2) that the result of this calculation be inverted to obtain $(\mathbf{I}–\mathbf{A})^{-1}$.

Each element in this matrix represents the amount of economic activity generated for row industry *i*, both directly and indirectly, to increase output in column industry *j* by one monetary unit.

Step C: Calculation of land multipliers

The land area required to increase output in each industry by a particular monetary amount is then calculated. This requires the total land area occupied by each sector of the New Zealand economy (expressed in hectares) to be divided by the corresponding industry's total gross input/output (column total) figure. The resulting ratios are referred to as 'land multipliers', and represent the number of hectares required to increase output by one monetary unit in each column industry.

Step D: Calculation of embodied land requirements

Total embodied (direct plus indirect) land requirements can then be obtained by premultiplying the Leontief inverse matrix by a diagonal matrix containing the New Zealand land multipliers. Column totals of the resulting matrix represent the total number of hectares required to increase output in each column industry by one monetary unit.

Step E: Calculation of the land required to meet domestic final demand

The land required to meet current levels of domestic final demand for each industry can be derived by multiplying total land input requirements for each industry (as calculated in Step D) by the corresponding component of the final demand vector. This provides a 'first' estimate of New Zealand's ecological footprint. Two additional steps are required to generate the 'final' estimate, namely:

(1) energy land needs to be added

(2) land embodied in goods/services purchased from overseas be added, and conversely, land embodied in goods/services sold overseas be subtracted.

These are dealt with below.

Step F: Calculation of energy land component of the ecological footprint

Energy land represents the hypothetical land needed to sequester the CO_2 emissions resulting from the burning of fossil fuels. Fossil fuels are used in New Zealand for a wide range of economic activities including electricity generation, fuel for our cars, production of plastics, rubber and numerous other goods. The energy land required to sustain a population is easily calculated using an input–output approach, mirroring the process described above for domestic land component of the ecological footprint. Specifically, all that is required in the calculations is the substitution of energy multipliers for land multipliers. Total fossil fuel use by each industry in the New Zealand was determined by using data obtained from the ECCA Energy End-Use Database. The multipliers were in turn calculated by dividing the fossil fuel usage (by type) by each column industry's gross output (column) total. Domestic fossil fuel requirements (by type) were then derived in an analogous way to domestic land requirements (ie. by repeating Steps D and E using the energy information).

Conversion of fossil fuel into hypothetical land equivalents required two conversions. Firstly, the domestic fossil fuel requirements (by type) were converted to CO_2 emissions using appropriate emission factors. Secondly, CO_2 emissions were expressed in land equivalent terms using a sequestration rate for *Pinus radiata*. In this way, energy land represents a hypothetical estimate of the area of planted forest needed to absorb the CO_2 emissions resulting from the use of fossil fuels by New Zealanders.

2.2.2 Dealing with land embodied in overseas trade

In a closed economy (ie. without trade) the above analysis would be satisfactory. Trade with other countries, however, means that New Zealanders consume land (and energy) embodied in the goods and services they purchase from overseas. Conversely, New Zealanders export land (and energy) embodied in the goods and services they sell abroad. One further adjustment is therefore required to complete the calculation of New Zealand's ecological footprint.

Step G: Calculation of land embodied in overseas trade

The lack of availability of information on overseas land use by economic sector makes the analysis of land embodied in imports difficult. By assuming similar production technologies however it is possible to derive crude estimates. In this way, the land (and energy land) embodied in goods and services purchased abroad by final demand may be calculated by multiplying the value of imports by its corresponding domestic land (or energy) multiplier.

The process of calculating the land embodied in imports used by intermediate demand (industries in the New Zealand economy) and then sold onto final demand is, however, more difficult. This requires a detailed breakdown of the imports to each productive column industry. In this matrix, columns represent the domestic purchasing industry, and rows represent the overseas producing industry, with all elements expressed in monetary terms. Once again, the conversion to hectares would ideally require detailed information from each country providing intermediate inputs. Such information is however not available but crude estimates can be established using the New Zealand economy as a proxy. The land embodied in imports used by intermediate demand is derived in turn by premultiplying the matrix of imports by the vector of embodied (direct plus indirect) land requirements for the New Zealand economy. It is implicitly assumed that the goods are in near finished state ready for final demand consumption.

It is important to recognise that some of the land (and energy land) embodied in New Zealand's imported goods and services will, in turn, be exported abroad. In other words,, only a fraction of the land embodied in imported products will support New Zealand's domestic final demand. The land embodied in imported products for each industry is therefore multiplied by the fraction of final demand that is consumed domestically.

The 'final' estimate of New Zealand's ecological footprint is then calculated by adding:

(1) the domestic land embodied in products consumed locally (from Step E)

(2) domestic energy land required to sequester CO_2 emissions embodied in products consumed locally (from Step F)

(3) the land (and energy land) embodied in products purchased overseas but consumed locally (Step G).

The ecological footprint for the entire economy may then be converted to a per capita basis by dividing by the New Zealand population.

2.3 Methodology for measuring regional ecological footprints

2.3.1 Accounting identity of the component parts of the ecological footprint

In this report an approach is presented that:

(1) provides a formal structure for ecological footprint calculations

(2) permits calculation of the ecological footprint at a regional (sub-national) level

(3) makes explicit interregional appropriation of biologically productive land.

Essentially, the method requires the calculation of ecological footprint land contributions as defined by the following accounting identity:

$$EF \equiv \alpha + (\beta_1 + \beta_2 + ... + \beta_n) + \delta \qquad (1)$$

where:

α = land appropriated from within the study region

$\beta_1 + \beta_2 + ... + \beta_n$ = land appropriated from other regions (1 ... *n*)

δ = land appropriated from other countries

The method is illustrated using a three-sector hypothetical regional economy – termed the study region.

2.3.2 Generation of regional input–output tables

The method begins with calculation of input–output tables for the study region and for all the other regions it trades with. These tables were derived using the GRIT (Generation of Regional Input Output Tables) system developed by Jensen et al (1979) and West et al (1980).[8] This method consists of a series of mechanical steps that reduce national input–output coefficients to sub-national (regional) equivalents while providing opportunities for the insertion of 'superior data'.[9] It is most frequently utilised, as in this report, when time, cost and data constraints preclude generation of regional input–output tables based on survey data.

2.3.3 Estimation of land appropriated within the region

Step One: Calculation of the Leontief Inverse

Determining the land appropriated from within the region α begins with calculation of a technical coefficients matrix **A**. This matrix is derived by dividing each element in a transactions matrix **Ax** (Table 2.1), by its associated output **x**. The resulting technical coefficients matrix **A** (Table 2.2), represents the direct inputs from row sector *i* required to increase column sector *j* by an additional dollar (eg. the agriculture sector requires a $0.19 direct purchase from the services sector). The contribution made by a sector to an economy is not solely limited to the value it creates directly – an increase in final demand in a sector has repercussions throughout the entire economy, causing indirect increases in output beyond the initial change in final demand. Such repercussions are captured in the Leontief Inverse Matrix $\mathbf{(I - A)^{-1}}$.

[8] Studies that have applied the GRIT method in New Zealand include Hubbard and Brown (1981), Butcher (1985), Kerr, Sharp and Gough (1986) and the Ministry of Agriculture (1997).

[9] Data considered by the implementing analyst to be more reliable than those produced by the mechanical process (Jensen et al, 1979).

Table 2.1 Transactions matrix for the hypothetical study region

	Agriculture	Manufacturing	Services	Domestic final demand	Interregional exports	International exports	Total output
Agriculture	606	1,214	46	99	486	350	2,801
Manufacturing	184	748	700	1,213	83	1,997	4,925
Services	543	854	2,628	4,793	106	505	9,429
Value added	1,312	1,357	5,415	621	0	52	8,758
Interregional imports	10	64	60	142	0	0	276
International imports	145	688	580	1,130	0	0	2,543
Total input	2,801	4,925	9,429	7,998	675	2,905	28,732
Land input (ha)	1,883,800	2,900	120,000	2,031,200			
CO_2 input (t)	332,700	1,956,800	701,200	4,168,200			

Note: All values are expressed in millions of dollars unless otherwise stated.

Table 2.2 Technical coefficients matrix for the hypothetical study region

	Agriculture	Manufacturing	Services
Agriculture	0.216	0.247	0.005
Manufacturing	0.066	0.152	0.074
Services	0.194	0.173	0.279

Note: All values are in dollars per year.

The Leontief inverse matrix $\mathbf{(I - A)^{-1}}$ is derived by subtracting the matrix of technical coefficients **A** from an identity matrix **I** of the same dimensions and inverting the result. Each element represents the direct and indirect economic requirements in row sector *i* needed to generate an additional unit of output in column sector *j*. For example, a dollar increase in the service sector final demand will require $0.05 of the agriculture sector output (refer to Table 2.3).

Table 2.3 Leontief inverse matrix for the hypothetical study region

	Agriculture	Manufacturing	Services
Agriculture	1.322	0.394	0.050
Manufacturing	0.136	1.245	0.129
Services	0.388	0.405	1.431

Note: All values are in dollars per year.

Step Two: Determination of the direct and indirect land requirements for each sector

The embodied (direct plus indirect) land required to increase final demand in each sector by an additional unit is calculated as follows. Firstly, land-to-output ratios (known as land coefficients) are obtained by dividing the total land use in each sector by its corresponding total output (eg. the land coefficient for the agriculture sector is 672.55 ha $\$m^{-1}$ (1,883,800 ha ÷ 2801 $m)). Secondly, these coefficients are then diagonalised to form the matrix $\hat{\mathbf{B}}$. Finally, embodied land requirements **C** are calculated by premultiplying the Leontief Inverse matrix by the diagonalised matrix of land coefficients:

$$\mathbf{C} = \hat{\mathbf{B}}\,(\mathbf{I} - \mathbf{A})^{-1} \qquad (2)$$

Results for the hypothetical study region are shown in Table 2.4. This analysis provides a deeper appreciation of the land requirements of sectors, particularly for those that initially appear not to be intensive land users. For example, to produce a million dollars of final demand the manufacturing sector requires not only 0.73 ha of manufacturing land but also indirectly requires 265.13 ha of agricultural land.

Table 2.4 Matrix of direct plus indirect land requirements for the hypothetical study region

	Agriculture	Manufacturing	Services
Agriculture	888.71	265.13	33.30
Manufacturing	0.08	0.73	0.08
Services	4.94	5.16	18.21

Note: All values are in ha $\$m^{-1}$ per year of final demand.

Step Three: Apportion direct and indirect land requirements between domestic final demand and exports

Not all of the land appropriated supports domestic consumption. A portion passes out of the study region as land embodied in exports. The land supporting domestic final demand **E** is calculated by multiplying the matrix of direct plus indirect requirements **C** by a matrix representing domestic final demand $\hat{\mathbf{D}}$. Thus:

$$\mathbf{E} = \mathbf{C}\,\hat{\mathbf{D}} \qquad (3)$$

The domestic final demand matrix $\hat{\mathbf{D}}$ is obtained by diagonalising the 'domestic final demand' column of Table 2.1. Results for the hypothetical study region are shown in Table 2.5. Domestic final demand for manufactured products in the study region requires the appropriation of 321,725 ha of agricultural land, 890 ha of manufacturing land and 6261 ha of service sector land.

Table 2.5 Within-region land supporting domestic final demand for the hypothetical study region

	Agriculture	Manufacturing	Services
Agriculture	87,566	321,725	159,597
Manufacturing	8	890	364
Services	487	6,261	87,271
Total	88,061	328,876	247,232

Note: All values are in ha per year.

Step Four: Repeat Steps One to Three for the calculation of energy land

Energy land represents the area of planted forest needed to sequester CO_2 emissions resulting from the burning of fossil fuels. The approach used to calculate energy land appropriated within the region is analogous to that used to calculate the within-region land supporting domestic final demand. Essentially, there are two differences:

(1) CO_2 coefficients are used instead of land coefficients

(2) total embodied CO_2 emissions are converted into planted forest using a *Pinus radiata* sequestration rate of 0.0758 ha per t of CO_2.

Within region appropriation of energy land by the study region is shown in Table 2.6.

Table 2.6 Within region energy land supporting domestic final demand for the hypothetical study region

	Agriculture	Manufacturing	Services
Agriculture	1,172	4,307	2,137
Manufacturing	404	45,502	18,628
Services	216	2,773	38,656
Total	1,792	52,582	59,421

Note: All values are in ha per year.

Step Five: Calculation of the total within region appropriated land (δ)

Summing the column totals in Tables 2.5 and 2.6 provides an estimate of the quantity within-region land required to meet current levels of domestic final demand for each sector. Domestic final demand for manufactured goods requires a total land appropriation of 381,458 ha (328,876 ha + 52,582 ha, for the manufacturing sector column totals in Tables 2.5 and 2.6).

2.3.4 Estimation of land appropriated from other regions

Land embodied in interregional trade may have a considerable influence on the size of the ecological footprint, particularly if the ecological footprint is being calculated for an urban region. It is argued here that not only must the size of such a contribution be known but also the locations from where it originated. Adjustments can then be made for differences in biological productivity resulting from land management practices and environmental factors such as soil type, climatic conditions and so on. In this way, significantly improved interpretations of the ecological footprint are possible. An approach is developed here that not only calculates the interregional land appropriated, but also attributes each appropriation to its region of origin. This approach is illustrated using the three hypothetical regions that share ecological interdependencies with the study region (refer to Table 2.7).

Table 2.7 Imports for three hypothetical regions

	Agriculture	Manufacturing	Services	Domestic final demand	Region total
Region 1					
Agriculture	0.1	0.6	0.0	0.0	0.7
Manufacturing	0.2	19.4	6.6	5.9	32.1
Services	3.9	5.7	28.3	76.9	114.8
Region 2					
Agriculture	0.5	2.9	0.1	0.0	3.5
Manufacturing	0.1	5.7	1.9	1.7	9.4
Services	2.8	4.1	20.4	55.4	82.7
Region 3					
Agriculture	2.9	19.0	0.5	0.0	22.5
Manufacturing	0.1	6.4	2.2	2.0	10.7
Services	0.0	0.0	0.0	0.0	0.0

Note: All values are in $m per year.

Step Six: Determination of interregional flows

In order to estimate the land appropriated from other regions, the interregional flows of commodities between regions had to be first of all calculated. In the analysis reported in Sections 4 to 19 of this report, these flows needed to be determined at the 23 sector level – hence, there were 5520 possible flows (16 regions x (16-1) regions x 23 sectors). Unfortunately, interregional flow data at this level of detail is not available from statistical sources in New Zealand but could be estimated using an optimisation method which is described in Appendix A.

Minimisation of travel time is set as the objective function while known levels of imports/ exports for each sector (by region) are used to formulate binding constraints.[10] This optimisation approach could also be used in any other country which lacks interregional flow ($) data. The origins of imports for the hypothetical study region, as generated by this optimisation, are shown in Table 2.7.

Step Seven: Determination the direct and indirect land and energy land appropriated from other regions

The land (and energy land)[11] embodied in interregional imports is derived by premultiplying the imports (Table 2.7) by the direct plus indirect land requirements needed to make them (Table 2.8). This is performed for each region sharing ecological interdependencies with the study region:

$$\mathbf{K} = \mathbf{G}\,\mathbf{H} \qquad (4)$$

where **K** = land matrix (*i x j*) which describes the land appropriated from *i* sector to *j* sectors for a given region; **G** = Leontief inverse matrix (*i x j*) which describes the direct plus indirect requirement **I** into *j* sectors, for a given region; **H** = imports (*i x j*) which describes the inputs into *j* sectors for a given region. It is assumed here that imported goods and services are essentially final or finished goods. This implies that only backward linkages through the economy in the region of origin are measured. If, however, there are imported goods requiring further processing in the study region, then forward linkages may also need to be estimated.

Table 2.8 Direct plus indirect land requirements for the hypothetical study region

	Agriculture	Manufacturing	Services
Region 1			
Agriculture	860.6	62.2	9.2
Manufacturing	0.0	0.5	0.1
Services	0.7	0.9	3.0
Region 2			
Agriculture	1344.8	240.7	30.2
Manufacturing	0.1	0.7	0.1
Services	3.5	3.6	12.4
Region 3			
Agriculture	1899.5	504.6	71.9
Manufacturing	0.2	1.4	0.2
Services	3.3	3.6	11.4

Note: All values are in ha $\$m^{-1}$ per year of final demand.

[10] This optimisation model assumes that transport operators will only minimise their travel times, whereas in actuality other factors may also come into play. This approach however doesn't seem unreasonable and it is very commonly used in transportation network models. Furthermore, analytical tests show that the optimisation problem is relatively constrained, therefore having a small feasibility space which means that there will not be a too significant difference between the 'optimal' and 'actual' flows.

[11] The calculation of energy land is based on 'direct plus indirect energy land' rather than 'direct plus indirect land'.

The land embodied in interregional imports appropriated by the hypothetical study region is shown in Table 2.9. The manufacturing sector, for example, appropriates 46,711 ha (manufacturing column total in Table 2.9). This is comprised of 46,482 ha of agricultural land (1773 ha for Region 1 + 5448 ha Region 2 + 39,261 ha for Region 3).

Table 2.9 Land appropriated from other regions for the hypothetical study region

	Agriculture	Manufacturing	Services	Domestic final demand
Region 1				
Agriculture	129	1,773	685	1,079
Manufacturing	0	10	5	8
Services	12	36	91	237
Region 2				
Agriculture	713	5,448	1,187	2,094
Manufacturing	0	4	3	5
Services	36	82	260	693
Region 3				
Agriculture	5,611	39,261	2,114	1,042
Manufacturing	1	12	3	3
Services	10	85	10	7
Sector totals	6,512	46,711	4,357	5,168

Note: All values are in ha per year.

Step Eight: Apportion direct and indirect land requirements between domestic final demand and exports

Not all of the interregional land appropriated supports domestic consumption. A portion passes out of the study region as land embodied in exports. The fraction of final demand supporting domestic consumption is derived from Table 2.1 (ie. 36.8 percent of manufactured products,[12] 10.5 percent of agricultural products and 88.7 percent of services). Multiplying interregional land appropriated $\mathbf{K_r}$ by the fraction of final demand $\hat{\mathbf{L}}$ calculates the interregional land supporting domestic consumption $\mathbf{M_r}$:

$$\mathbf{M_r} = \mathbf{K_r}\hat{\mathbf{L}} \tag{5}$$

where $\hat{\mathbf{L}}$ is a diagonalised matrix containing the fractions of final demand consumed locally.[13] Interregional land supporting domestic consumption in the hypothetical study region is shown in Table 2.10. Summing the final column (or row) of Table 2.10 determines the total amount of land appropriated from other regions ($\beta_1 + \beta_2 + ... + \beta_n$) (ie. 26,929 ha which represents 0.07 ha per capita).

[12] Calculated by dividing domestic final demand for manufactured products by total final demand for manufactured products (ie. (1213 ÷ (1213 + 83 + 1997)) x 100).

[13] The number 1 is placed in the bottom right hand corner of matrix $\hat{\mathbf{L}}$ so that land appropriated directly by domestic final demand is included.

Table 2.10 Land appropriated from other regions supporting domestic consumption for the hypothetical study region

	Agriculture	Manufacturing	Services	Domestic final demand	Region total
Region 1					
Agriculture	14	653	607	1,079	2,353
Manufacturing	0	4	5	8	16
Services	1	13	81	237	332
Region 2					
Agriculture	75	2,007	1,053	2,094	5230
Manufacturing	0	2	2	5	9
Services	4	30	230	693	957
Region 3					
Agriculture	591	14,465	1,875	1,042	17,974
Manufacturing	0	4	3	3	10
Services	1	31	8	7	48
Sector totals	687	17,210	3,865	5,168	26,929

Note: All values are in ha per year.

2.3.5 Estimation of land appropriated from other nations (δ)

The availability of land (and energy land) data is a major issue when determining the amount of land appropriated internationally. Ideally this would involve the acquisition of detailed information by economic sector from each international trading partner. In this report it is assumed that the direct and indirect land required to produce one dollar's worth of product from a sector is exactly the same internationally as it is nationally. This in turn implies that the technologies, land management practices and sectoral interlinkages are similar between the nation and its international trading partners which may not be the case. In this way, crude estimates of the land (and energy land) embodied in international imports can be made. The approach is demonstrated here using a hypothetical national economy – an actual national input–output matrix with land inputs and CO_2 emissions for this economy is available from the authors.

Step Nine: Calculation of the land appropriated from other nations

The calculation procedure is analogous to that employed for interregional trade. Firstly, international imports matrix **O** are pre-multiplied by the direct plus indirect land requirements matrix **N** needed to make them. This derives a matrix of the amount of international land appropriated **P**. Therefore:

$$\mathbf{P} = \mathbf{ON} \tag{6}$$

Secondly, land supporting domestic consumption **R** is calculated by multiplying the international land appropriated **P** by the fraction of final demand consumed locally $\hat{\mathbf{L}}$. Hence:

$$\mathbf{R} = \mathbf{P}\hat{\mathbf{L}} \tag{7}$$

Results for the study region are shown in Table 2.11. Summing the final column (or row) of Table 2.11 provides an estimate of the international land appropriated to support domestic consumption, δ (ie. 411,442 ha which represents 1.13 ha per capita).

Table 2.11 Land appropriated from other nations supporting domestic consumption for the hypothetical study region

	Agriculture	Manufacturing	Services	Domestic final demand	International totals
Agriculture	5,046	76,729	115,112	204,461	401,348
Manufacturing	9	179	322	564	1,074
Services	57	845	2,180	5,938	9,020
Sector totals	5,113	77,752	117,614	210,963	411,442

Note: All values are in ha per year.

2.3.6 Components of the ecological footprint and Ecological Balance of Trade

The ecological footprint is the sum total of purchases from intermediate demand sectors of the economy (P_1+ P_2+ P_3+ P_4+ P_5+ P_6+ ... + P_n) and from domestic final demand inputs (D_1+ D_2+ D_3+ D_4). The domestic final demand inputs consist of purchases of overseas imports (D_1) and purchases of regional imports (D_4) as well as the direct land occupied by the household dwellings (D_2) and its surrounding section, and the energy land required to absorb direct household CO_2 emissions (D_3). All of these inputs absorb can be tracked back to primary inputs of agricultural land, forest land, degraded land or energy land, using input–output analysis.

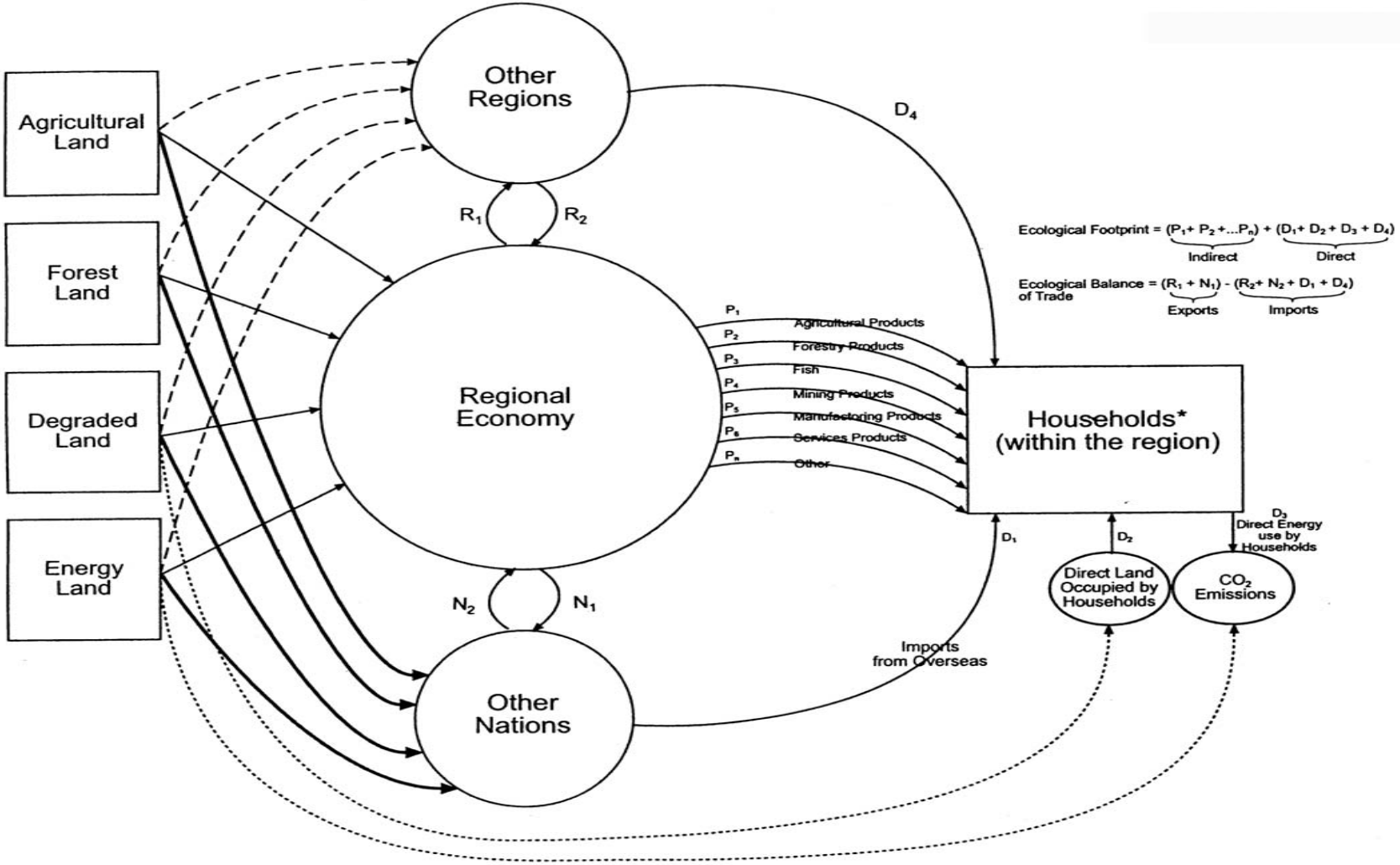
The Ecological Balance of Trade for a region is the exports (R_1+ N_1) minus the imports (R_2+ N_2+ D_1+ D_4). Again, these exports and imports can be tracked back to primary inputs of agricultural land, forest land, degraded land and energy land, using input–output analysis. This analytical framework is used to present the results in sections 4 to 19 of this report.

2.4 Data sources

Regional input–output matrices (16) are derived from the national input–output table produced by Statistics New Zealand using the GRIT methodology (1991, 1996, 1998, 1998a, 1999). Each input–output matrix covers 23 sectors. Estimates of land use data by economic sector are based on data gathered from Quotable Value New Zealand (1998), Statistics New Zealand (1998b, 1998c), Ministry of Agriculture and Forestry (1999), and Works Consultancy Services Ltd (1996). These estimates exclude national parks, inland water bodies (lakes and rivers) and marine land. Energy-related CO_2 emissions by economic sector were obtained from the Energy Efficiency and Conservation Authority (1997). The conversion of CO_2 emissions into energy land is based on sequestration data obtained from Hollinger et al (1993). They estimate that an average hectare of *Pinus radiata* in New Zealand absorbs 3.6 t of C per ha per year which equates to 0.0758 ha per t of CO_2 per year.[14] Population statistics are based on sub-national estimates produced by Statistics New Zealand (1998d).

[14] It is worth noting that these figures may vary considerably between regions depending on plantation age, soil type, climatic conditions and so on. The possibility of planting indigenous forest to sequester CO_2 emissions is also ignored (refer to Hall and Hollinger (1997) for further debate concerning this issue).

Figure 2.1 Components of the ecological footprint and Ecological Balance of Trade



3 New Zealand's Ecological Footprint

3.1 Overall ecological footprint and comparison with other countries

3.1.1 New Zealand's ecological footprint

The first estimate of New Zealand's ecological footprint that used an input–output approach was undertaken by Bicknell et al (1998). They used an 80 sector transactions matrix produced by Statistics New Zealand (1991) matched with land data from Statistics New Zealand's Yearbooks and Transit New Zealand (1994) and energy data from Peet (1991) to calculate New Zealand's ecological footprint for 1991. It was calculated that New Zealand's per capita ecological footprint was 3.49 ha. This consisted of 1.41 ha agricultural land, 0.28 ha forest land, 0.53 ha energy land, 0.36 degraded land and 0.91 ha imported land.

Our current study calculated the ecological footprint of New Zealand to be 11,684,650 ha for the year 1997/98. This compares with the amount of usable land available in New Zealand which is calculated to be 17,783,949 ha. The amount of usable land is defined as the total land area of New Zealand excluding national parks, forest parks, reserves and non-productive land. On this basis, the ecological footprint of New Zealand occupies 65.70 percent of the usable land. This means, assuming our current per capita footprint, New Zealand could increase its population by 1.52 times before it overshoots its ecological carrying capacity.

Based on these calculations from our current study, the per capita ecological footprint for New Zealand is 3.08 ha per person for 1997/98. This compared with Bicknell et al's (1998) estimate of 3.49 ha per person for 1991. The reasons why Bicknell et al's (1998) estimate is higher than ours are:

(1) Bicknell et al (1998) seems to have inappropriately used an energy-to-land ratio based on international data from Wackernagel and Rees (1996). The New Zealand energy-to-land ratio is different to international averages in two important respects:

   (a) New Zealand produces less CO_2 emissions per joule of energy due to the relatively high percentage of hydro-generated electricity in New Zealand. Hydroelectricity generation has no direct CO_2 emissions and hence this weighs down New Zealand's CO_2-to-joule ratio.

   (b) New Zealand land absorbs more CO_2 per hectare than the global average. Hollinger et al (1993) derived a ratio of 3.6 tonnes of carbon per hectare for *Pinus radiata* and Hall and Hollinger (1997) derives a figure of 1.6 tonnes of carbon per hectare for indigenous forests in New Zealand. Both of these sequestration factors are significantly higher than Wackernagel and Rees' (1996) average of 0.9563 tonnes of carbon which Bicknell et al (1998) appears to have used. Bicknell et al (1998) consequently calculates that 23 percent of the New Zealand ecological footprint is energy land compared with 16.6 percent in our study. The difference is directly attributable to factors 1(a) and 1(b) spelt out above. The higher energy land estimate by Bicknell et al (1998) increases New Zealand's ecological footprint by 0.29 ha/person.

(2) Bicknell et al's (1998) estimate for land used by sectors in the New Zealand economy is in the order of 10 percent higher than our estimate. This will result in the ecological footprint calculations for Bicknell et al (1998) being inflated relative to our estimates.

3.1.2 Comparison with other countries

New Zealand's ecological footprint per capita of 3.08 ha/person can be compared with the per capita footprint for different countries. However, according to the Wackernagel and Rees' (1996) method, this requires the New Zealand footprint be adjusted for:

(1) *global yields*. Loh (2000) estimates New Zealand's average pasture yield factor to be 5.24, with the average yield factors for arable and forest land estimated to be 2.09 and 0.61 respectively. In the case of built-up land the average arable yield factor is applied.

(2) *biological equivalence factors*. The following equivalence factors based on Loh (2000) were applied: hypothetical energy land 1.78, for arable land 3.16, for forest land 1.78 and for pasture land 0.39. The equivalence factor for arable land was used as a proxy for built-up areas.

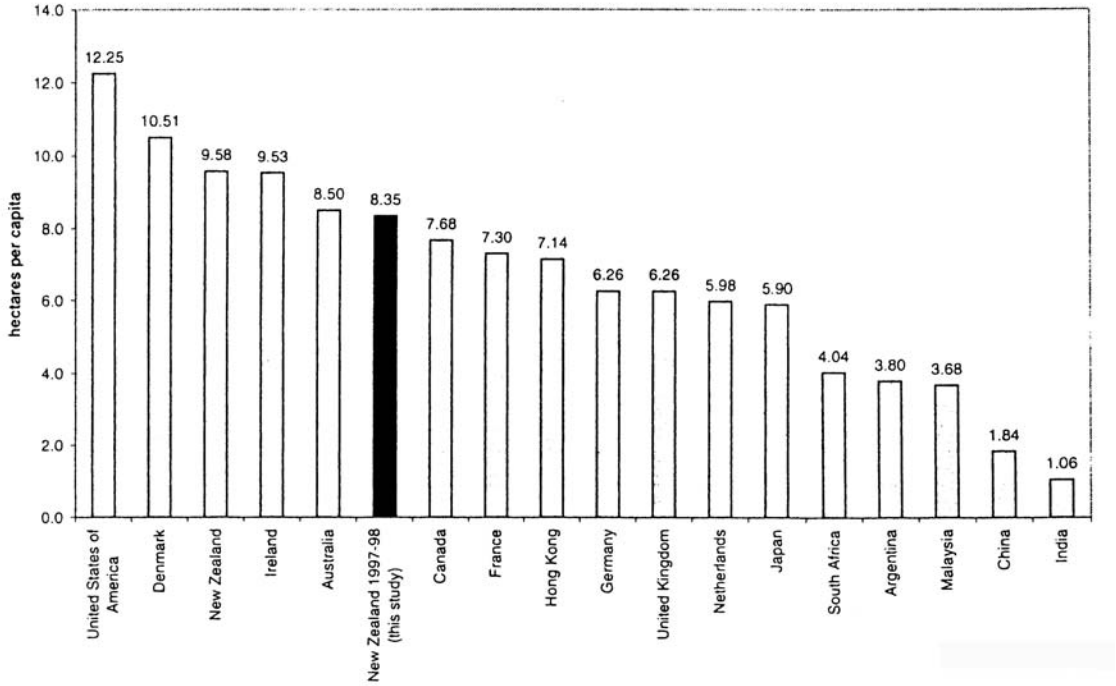
(3) *global average CO_2 sequestration factors*. Loh (2000) estimates the world average carbon absorption (including roots) to be 0.956 tonnes of carbon per hectare. In accordance with Loh (2000) oceans are also assumed to take up 35 percent of CO_2 emissions.

Essentially (1) and (2) adjust the international data to allow for land productivity differences between different types of land across the globe. The basic premise in these adjustments is that land is of different quality, and therefore land productivity factors need to be applied, to reflect the relative 'usefulness' of different types of land. In this sense, a hectare of New Zealand pastoral land is 5.24 times more 'useful' (productive) than the global average, and a quality factor needs to be applied to the data to account for this difference.

Once these adjustments have been made Loh (2000), Wackernagel and Rees (1996) and others argue that the ecological footprint of different countries can be validly compared. For example, once these adjustments have been made, New Zealand's ecological footprint becomes 8.35 hectare per person,[15] and it can then be compared with adjusted ecological footprints for other countries (refer to Figure 3.1).

[15] The increase in the footprint size from 3.08 ha/person to 8.35 ha/person reflects the fact New Zealand's land is more productive than the global average. That is, on average, New Zealand's land is about 2½ times more productive than the global average and also absorbs more CO_2 emissions. Therefore, in this sense New Zealand's land is 2½ times 'more valuable' than the global average land.

Figure 3.1 Comparison of the New Zealand per capita ecological footprint with other countries after making adjustments for land productivity



United States has the highest adjusted ecological footprint per capita at 12.23 ha per person. That is, the average US citizen has an ecological footprint 46.70 percent higher than the average New Zealander. This is due to the greater affluence and higher level of material consumption of US citizens. Not only do they consume more product than an average New Zealander (the US GDP per capita is about twice New Zealand GDP per capita), US citizens live energy-intensive lifestyles as reflected in the high energy land component of their footprint.

Countries that have larger ecological footprints per capita than New Zealand include: Denmark (25.86 percent more), Ireland (14.13 percent more) and Australia (1.80 percent more). These differences can be explained by the higher income and therefore higher material consumption of these countries. There are however a number of countries that have higher per capita income (GDP) than New Zealand but somewhat surprisingly have lower ecological footprints per capita: Canada (8.02 percent less), France (12.57 percent less), Hong Kong (14.49 percent less), Germany (25.03 percent less), United Kingdom (25.03 percent less), Netherlands (28.33 percent less) and Japan (29.34 percent less). There seems to be a greater 'decoupling' between economic growth (income per capita) and the ecological footprint (embodied land per capita) in these countries than in New Zealand. There are a number of possible explanations for this. Firstly, a number of these countries have high population densities (Hong Kong, Netherlands, United Kingdom) which means that the energy used in transport is likely to be less and urban compaction also leads to other land-use efficiencies that do not occur in countries such as Australia and New Zealand. Secondly, in some cases lifestyle patterns and diet play a role. For example, vegetarian diets have smaller energy and land requirements which could significantly reduce the size of the ecological footprint as the food component of the footprint is considerable – this could at least partially explain Japan's relatively low ecological footprint. Thirdly, there could be genuine technical efficiency improvements in these countries in terms of their use of land and other resources which would reduces the size of their ecological footprints. Many of these countries for example record high levels of energy efficiency (Patterson, 1993) and the same could be the case for their use of other biophysical resources.

There are a bracket of poorer countries in Figure 3.1 that have considerably smaller ecological footprints per capita than New Zealand: South Africa (4.04 ha/capita), Argentina (3.80 ha/capita), Malaysia (3.68 ha/capita), China (1.84 ha/capita) and India (1.06 ha/capita). All of these countries have significantly less income per capita and hence less expenditure on material goods and less resource intensive lifestyles. Most notably the average Indian citizen has an ecological footprint nearly an eighth the size of the average New Zealander's.

The ecological footprint for most developed countries exceeds the amount of biologically productive land that is available. That is, these countries overshoot their ecological carrying capacity or, put alternatively, they are in ecological deficit. The ecological footprint of the global population also exceeds the availability of productive land. Loh (2000), in this vein, estimates that the global ecological footprint is 30 percent larger than the amount of biologically productive land on the globe. He argues on this basis that the 'regenerative capacity of the Earth has been overshot'.

Some countries such as the Netherlands indeed have ecological footprints that very significantly overshoot the availability of biologically productive land – for the Netherlands it is by a factor of about 2–3 times (van Vurren and Smeets, 2000). In fact, most developed countries at least to some extent are in this situation with the notable exceptions being Canada, Australia and New Zealand. The large land areas of Canada and Australia mean even though they have per capita footprints that are commensurate with other high income countries, they do not overshoot their carrying capacities. This study has found that New Zealand is in the same situation as Canada and Australia – its ecological footprint is 34.3 percent below the area of biologically productive land available. In New Zealand, there would need to be a substantial increase either in population or the levels of material affluence before an overshoot situation would arise.

3.2 Footprint disaggregated by land type

3.2.1 Agricultural land

The largest percentage (68.8 percent) of New Zealand's ecological footprint consists of agricultural land (refer to Table 3.1). In other words,, agricultural land inputs (8,036,060 ha) make up most of New Zealand's ecological footprint of 11,684,660 ha. A smaller figure for the agricultural land component of the New Zealand ecological footprint is derived by Bicknell et al (1998), although they are not explicit about the agricultural land component of imports, making direct comparisons difficult. There is a higher percentage of agricultural land in the New Zealand footprint, than the global average of about 35 percent which has been calculated by Loh (2002). This is because for the global situation the energy land component is much higher, at about 49 percent compared with 16.6 percent for New Zealand. However, given the abundance of agricultural land in New Zealand, plus lifestyle and diet factors, it is not surprising that the agricultural land is a large percentage of the New Zealand ecological footprint. For example, with respect to diet, New Zealanders tend to have relatively heavy consumption of meat and animal products which are more land intensive than a vegetarian diet.

Table 3.1 New Zealand's ecological footprint, by land type, 1997–98[16]

Land type	New Zealand land (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	6,399,410	1,636,650	8,036,060	2.12	68.8
Forest land	595,430	148,980	744,410	0.20	6.4
Degraded land	844,100	115,150	959,250	0.25	8.2
Energy land	1,409,960	534,980	1,944,940	0.51	16.6
Total	9,248,900	2,435,760	11,684,660	3.08	100.0

Most (6,399,410 ha) of New Zealand's agricultural land is sourced within New Zealand. Surprisingly however there is 1,636,650 ha of embodied agricultural land which is imported from other countries, in the form of imported food, manufacturing goods and other products.

3.2.2 Energy land

Energy land is the second largest component, next to agricultural land, in terms of the land types that make up the New Zealand ecological footprint. The energy land component of the New Zealand ecological footprint is 1,944,940 ha. That is, an area the size of the entire Waikato region, would be required to be planted in *Pinus radiata* trees, in order to absorb the CO_2 emitted in making the products that New Zealanders annually consume. This makes up 16.6 percent of the entire New Zealand ecological footprint.

Previously, Bicknell et al (1998) calculated the energy component of the New Zealand ecological footprint to be 23 percent of the total footprint or 0.80 ha per capita. This compares with 0.51 ha per capita in this study. Bicknell's et al (1998) figure is higher, as previously stated, because they used international data for the energy-to-land ratio, which does not allow for a lower New Zealand CO_2/MJ ratio (due to hydro electricity generation) and a higher carbon sequestration rate in New Zealand due to faster growing exotic and indigenous trees.

By international standards, whether our figure of 16.6 percent or Bicknell's et al (1998) figure of 23 percent is used, New Zealand's energy component of the ecological footprint is low. Wackernagel and Rees (1996) indicate, for example, that the energy component of Canada's ecological footprint is 55 percent and the Netherland's is 65 percent. Loh (2000) estimates Australia's energy land contribution to be 56.8 percent and United States to be 60.8 percent. Loh's (2000) global average indicates that about 49 percent of the global ecological footprint is energy land. The reason for our comparatively low energy land are:

(1) New Zealand can absorb CO_2 emissions very efficiently by using *Pinus radiata*. Hollinger et al (1993) estimates that an average hectare of *Pinus radiata* in New Zealand absorbs 3.6 tonnes of carbon per hectare. Even for indigenous forests, Hall and Hollinger (1997) estimates 1.6 tonnes of carbon per hectare is absorbed. Both of these figures particularly the *Pinus radiata* figure, which was used in this study, are considerably higher than the global average figure of 0.9563 tonnes of carbon per hectare used by Wackernagel and Rees (1996). If we were to use Wackernagel and Rees' (1996) carbon sequestration rate, the energy component of the New Zealand ecological footprint would

[16] Table elements in the remaining report sections may not add up exactly to row and column totals due to rounding.

increase 3.76 times to 1.91 hectare per capita. This would then represent 42.76 percent of New Zealand's ecological footprint.

(2) New Zealand's CO_2 emissions are relatively low compared with its energy consumption. This is because 65.37 percent of New Zealand's electricity is generated from hydroelectric sources which involves no direct emissions of CO_2 (Statistics New Zealand, 2000). In almost all other countries nearly all of their electricity is generated from fossil fuels resulting in CO_2 emissions. If New Zealand entirely generated its electricity from fossil fuels like other countries, and did not have any efficient *Pinus radiata* trees for absorbing CO_2 emissions, then New Zealand's energy component of its ecological footprint would be about 50 percent, which is around the global average and close to the figure calculated for other similar countries such as Australia.

Not all of the energy component of the New Zealand ecological footprint is a result of CO_2 emissions in New Zealand. In total, energy used to make products in New Zealand for consumption by New Zealanders, requires 1,409,960 ha to absorb the resultant CO_2 emissions. However, significantly, imported products into New Zealand which are produced overseas, also require energy land which amounts to a further 534,900 ha. This means that 37.94 percent of the energy land component in the New Zealand ecological footprint is 'overseas' energy land. Bicknell et al (1998) calculates a similar percentage of 34 percent.

3.2.3 Degraded land

Degraded land represents built up areas that host human settlement. This includes land area for housing, commercial and governmental purposes, as well as land covered by the transport network.

The degraded land component of the New Zealand ecological footprint is 959,250 ha. This represents 8.2 percent of the New Zealand ecological footprint. Most (844,100 ha) of this degraded land is land sourced from within New Zealand. The remainder (155,150 ha) is degraded land embodied in products imported into New Zealand which are consumed by New Zealanders.

On a global basis, about 5 percent of the ecological footprint consists of degraded (or built-up) land, based on data from Loh (2000). This compares with 8.2 percent for New Zealand calculated in this study; and a figure of 10.3 percent calculated for New Zealand by Bicknell et al (1998) which does not include the degraded land embodied in imports. It can be concluded that New Zealand has a relatively high proportion of degraded land in its ecological footprint, up to about double the global average. This is probably best explained by the relatively urban nature of the New Zealand's population, meaning there is a greater requirement for degraded (built up) land as this is where most people live.

3.2.4 Forest land

The forest land component of New Zealand's ecological footprint is the smallest of the four categories of land, behind agricultural, energy and degraded land. The forest land component is calculated to be 744,410 ha. This represents 6.4 percent of New Zealand's ecological footprint.

Most (595,430 ha) of the forest land is sourced from within New Zealand. A significant amount of this forest land (148,980 ha) however is embodied in products imported from overseas for local consumption in New Zealand.

On a global basis, about 10 percent of the ecological footprint consists of forest land, based on data from Loh (2000). This compares with 6.4 percent calculated in this study for New Zealand; and an estimate of 8.0 percent calculated for New Zealand by Bicknell et al (1998) which does not include forest land embodied in imports.

3.3 Footprint disaggregated by economic sector

3.3.1 Classification framework

The ecological footprint consists of various products purchased by householders from various intermediate demand sectors in the economy:

- products purchased from the agricultural sector
- products purchased from the forestry sector
- products purchased from the mining and quarrying sector
- products purchased from the manufacturing sector
- products purchased from the utilities and construction sector
- products purchased from the services sector.

In addition, the ecological footprint consists of the following domestic demand sector items:

- imported products purchased by householders
- direct land occupied by the household dwelling and surrounding section
- energy land required to absorb the CO_2 emissions directly produced by households.

All of these inputs into the ecological footprint are measured in terms of embodied land (ha), split into the Agricultural, Forest, Degraded and energy land categories. Figure 2.1 schematically describes all of these components of the ecological footprint for regional economies. The national case is analogous to the regional case, except by definition, there are no 'other regions' and the 'regional economy' is replaced by the 'national economy' in the diagram.

3.3.2 Purchase of manufacturing sector products

The land embodied in manufacturing sector products amounts to 5,200,110 ha, and makes up a considerable percentage (44.5 percent) of New Zealand's ecological footprint (refer to Table 3.2). Most of this embodied land in manufacturing products for household consumption in New Zealand is land appropriated from New Zealand sources. Some land (534,950 ha) is appropriated from overseas in supplying these manufactured products to New Zealand households. The manufacturing sector imports raw materials (eg. bauxite), machinery and equipment, and so forth into New Zealand to support its operations. There is a significant amount of embodied land required to produce these inputs in countries other than New Zealand.

Table 3.2 New Zealand's ecological footprint, by economic sector, 1997–98

Economic products consumed	New Zealand land (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	869,320	43,820	913,140	0.24	7.8
Forestry	32,760	490	33,240	0.01	0.3
Fishing and hunting	280	220	500	0.00	0.0
Mining and quarrying	3,070	350	3,430	0.00	0.0
Manufacturing	4,665,160	534,950	5,200,110	1.37	44.5
Utilities and construction	538,080	104,200	642,270	0.17	5.5
Services	2,523,860	518,960	3,042,820	0.80	26.0
Domestic final demand	616,370	1,232,760	1,849,130	0.49	15.8
Total	9,248,900	2,435,750	11,684,650	3.08	100.0

3.3.3 Purchase of service sector products

The land embodied in service sector products purchased by New Zealand households, amounts to 3,042,820 ha. This makes up 26.0 percent of New Zealand's ecological footprint. Service Sector products include purchases by households from the wholesale and retail trade, communication, finance, real estate, businesses sectors and government sectors. Service sector products are often considered to have a small land component. This is largely a false impression, as analysis such as that undertaken by McDonald and Patterson (1999a) indicates that there is a considerable indirect land component in most service sector products. For example, although an accountant may consume little direct land (ie. the land occupied by his/her business), the indirect land is considerable as an accountant purchases computers, paper, equipment, furniture and other services that all require considerable land inputs for their production, not to mention the construction of office buildings for the accountant which would also have a significant embodied land content.

Most (2,523,860 ha) of the land embodied in service sector products is appropriated from within New Zealand. However, about one-sixth of the service sector's embodied land comes from overseas, which is a higher proportion than the manufacturing sector. This is not surprising because many of these inputs required by the services sector, such as computers, are imports into New Zealand.

3.3.4 Purchase of primary sector products

The land embodied in the purchase of primary sector products by households amounts to 950,310 ha. This represents 8.1 percent of New Zealand's ecological footprint, and is much smaller than the purchase of manufacturing and service sector products. Most (913,140 ha) of these primary sector purchases are from the 'agriculture sector', with much smaller amounts from the forestry, fishing and hunting, and mining and quarrying sectors.

Most of the primary sector output is processed by the manufacturing sector before being sold to householders. However, fresh fruit and vegetables for example, are sold to householders without any further processing and these type of purchases are included in the primary sector component of the ecological footprint.

Primary sector products embody a large proportion of New Zealand land (905,430 ha out of 950,310 ha). Only a relatively small amount of overseas land (441,880 ha) is appropriated to produce primary sector products.

3.3.5 Purchase of utilities and construction

The land embodied in the direct purchase of utilities (water, gas and electricity) and construction services by households, is 642,270 ha. This represents 5.3 percent of New Zealand's ecological footprint. Most of this land (538,080 ha) is appropriated from within New Zealand. However, these sectors do require significant amount of inputs (eg. plant and equipment) from overseas which means 104,200 ha of land is appropriated from overseas to supply these inputs.

3.3.6 Domestic final demand purchases and other inputs

Householders purchase products that are imported from overseas (eg. computers, electronics, motor vehicles, and so forth). The embodied land associated with such purchases is calculated to be 1,232,760 ha (with the retail margin for these purchases being included in the service sector). These purchases of imported products by householders make up 10.55 percent of the New Zealand ecological footprint.

Another component of the 'final domestic demand' is the land actually occupied by the household dwelling and surrounding section, as well as the hypothetical energy land required to absorb CO_2 emissions which are directly produced by households. Collectively, this amounts to a further 616,730 ha which represents 5.28 percent of the New Zealand ecological footprint.

3.4 Footprint disaggregated by region

The New Zealand ecological footprint can be disaggregated into the 16 regional council areas. Detailed analyses of the 16 regional ecological footprints are contained in sections 4 to 19 of this report.

3.4.1 Regional ecological footprint (total hectares)

The ecological footprint of the 16 regions are summarised by Table 3.3 and Figure 3.2. It should be noted that the sum of all of the regional footprints amounts to 10,709,170 ha, whereas the New Zealand ecological footprint amounts to 11,684,650 ha. That is, there is an apparent discrepancy of 975,480 ha which represents 8.34 percent shortfall. Part of this is explained by the ecological footprint (46,600 ha) calculated for the Chatham Islands and other outlying islands that are not part of Regional Council areas. This still leaves 928,880 ha (7.95 percent) unexplained. The reason for this discrepancy is that for a given regional economy, the ecological footprint calculations only account for embodied land flows from the regions it immediately imports from (first order effects) – it does not track back flows to subsequent

regions (second order to nth order effects).[17] If the calculation did take account of these second order to nth order effects, the sum of regional ecological footprints would equal the national ecological footprint.

Table 3.3 Ecological footprints of New Zealand regions, 1997/98

Region	Ecological footprint (ha)	Ecological footprint (%)
Auckland	2,319,940	21.7
Canterbury	1,737,840	16.2
Waikato	1,048,860	9.8
Wellington	1,029,010	9.6
Otago	1,019,050	9.5
Manawatu–Wanganui	879,520	8.2
Bay of Plenty	618,260	5.8
Northland	477,120	4.5
Hawkes Bay	384,660	3.6
Southland	375,310	3.5
Taranaki	233,150	2.2
Marlborough	163,810	1.5
Gisborne	141,660	1.3
West Coast	121,890	1.1
Tasman	82,180	0.8
Nelson	76,910	0.7
Total	10,709,170	100.0

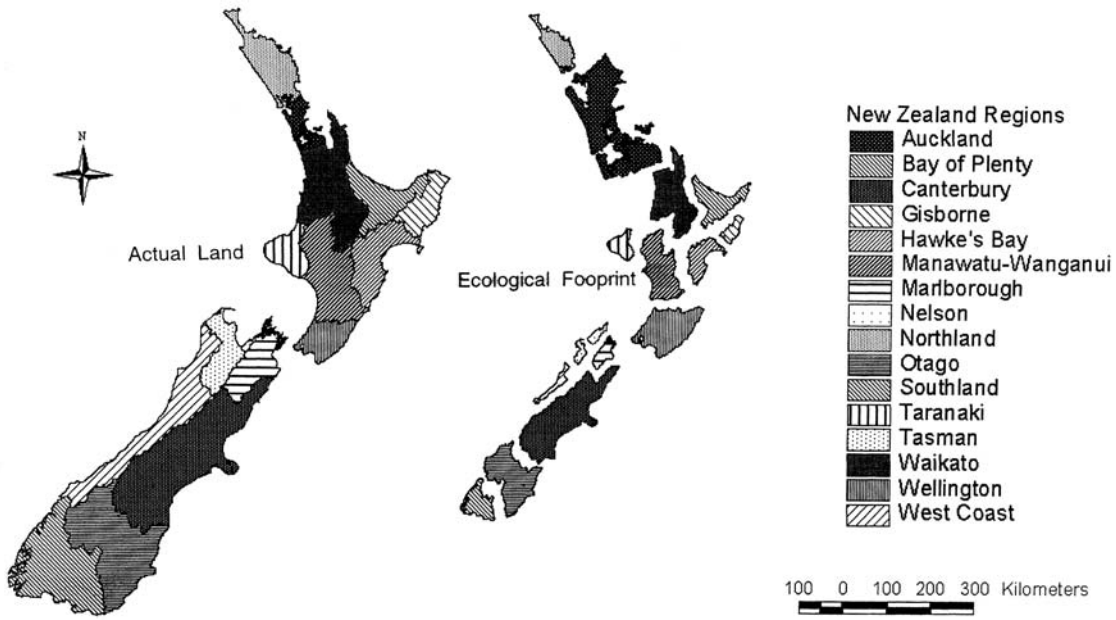
The largest regional ecological footprint was Auckland at 2,319,940 ha, which is not surprising given that it has the largest population of any region in New Zealand. Auckland makes up 21.66 percent of the New Zealand ecological footprint.[18] Canterbury is a clear second, with an ecological footprint of 1,737,840 ha making up 16.23 percent of the New Zealand ecological footprint. Although Canterbury has a population similar to Wellington, it has a relatively high per capita footprint which gives it a much larger footprint than Wellington.

Next in the ranking is a cluster of four regions: Waikato, Wellington, Otago and Manawatu–Wanganui. All of these regions have similar size ecological footprints: Waikato (1,048,860 ha; 9.79 percent); Wellington (1,029,010 ha; 9.61 percent); Otago (1,019,050 ha; 9.52 percent); and Manawatu–Wanganui (879,520 ha; 8.21 percent). All of these regions have above average population sizes (188,300 to 428,699 residents) which is the main determinant of the size of their ecological footprints. However, the per capita footprint is also an important factor with Wellington's footprint most notably being decreased by a lower than average per capita footprint, and Otago's footprint being increased by a higher than average per capita footprint.

[17] The only reason for not calculating the second to nth order effects in this analysis was a software limitation. To take account of these effects at the 23 sector level requires a matrix of 391 x 391 would need to be inverted which is too large for the software available to us.

[18] For the purposes of these percentages, the New Zealand ecological footprint is taken to be the sum of the regional ecological footprints.

Figure 3.2 Ecological footprints of New Zealand regions



Next follows a cluster of provincial regions which have ecological footprint rankings from seventh to 12th: Bay of Plenty, Northland, Hawke's Bay, Southland and Taranaki. All of these regions are provincial in nature having average population sizes ranging from 95,701 (Southland) to 238,299 (Bay of Plenty). As a consequence of their population size, their ecological footprints are in a similar range: Bay of Plenty (618,260 ha; 5.77 percent); Northland (477,120 ha; 4.46 percent); Hawke's Bay (384,660ha; 3.59 percent); Southland (357,310 ha; 3.50 percent) and Taranaki (233,130 ha; 2.18 percent).

Last in term of the rankings, are the regions that have small populations, which consequently rank 13th to 16th in terms of their ecological footprint. The population of these regions range from 32,900 (West Coast) to 46,701 (Marlborough). The ecological footprint of these regions are: Marlborough (163,810 ha; 1.53 percent), Gisborne (141,660 ha; 1.32 percent); West Coast (121,890 ha; 1.14 percent); Tasman (82,180 ha; 0.77 percent) and Nelson (76,910 ha; 0.72 percent). Nelson's ecological footprint is the lowest in the country, not only because of its small population, but also because its low per capita footprint which is the second lowest of any region.

3.4.2 Regional per capita footprint (hectares/person)

Ecological footprints are often calculated on a per capita basis to facilitate the comparison between nations, regions and cities. Often to make this comparison more rigorous, adjustments are made to take account of land quality or productivity in differences between nations, regions or cities. The lack of New Zealand specific data made this productivity adjustment impossible – however, it needs to be borne in mind that apparent differences in the per capita footprint between regions can be largely explained by land productivity differences rather than any significant differences in levels of material consumption and resource use.

Otago has the highest ecological footprint per capita of any region in New Zealand at 5.41 ha per person (refer to Table 3.4). This can be mainly attributed to the low productivity of Otago land which is the second to lowest in the country. Marlborough has the second highest ecological footprint at 4.13 ha/person, again attributable to the region's low land productivity.

Table 3.4 Per capita ecological footprints and land productivity of New Zealand regions, 1997/98

Region	Ecological footprint (ha/person)	Land productivity ranking[1]
Otago	5.41	15th
Marlborough	4.13	16th
Southland	3.92	9th
Manawatu–Wanganui	3.80	6th
West Coast	3.70	12th
Canterbury	3.57	13th
Northland	3.33	5th
Gisborne	3.03	11th
Waikato	2.87	2nd
Hawkes Bay	2.63	7th
Bay of Plenty	2.59	1st
Wellington	2.40	10th
Taranaki	2.19	4th
Tasman	2.08	8th
Auckland	2.00	3rd
Nelson	1.86	14th
New Zealand	3.08	

1 Stock units/ha is a crude indicator of land productivity.

Data to construct this indicator was obtained from Statistics New Zealand's (1998c) *Agriculture Statistics* publication.

Southland (3.92 ha/person) and Manawatu–Wanganui (3.80 ha/person) rank third and fourth in terms of the size of their per capita footprint. It is difficult to explain why these footprints are so high as the land in both of these regions is relatively productive and hence a lower per capita ecological footprint for each region would be expected. Manawatu–Wanganui has a higher per capita degraded (built-up) land, which partly explains its relatively high per capita ecological footprint. Southland has a higher per capita energy land (due to its colder climate) which does explain some of apparent discrepancy.

West Coast (3.70 ha/person), Canterbury (3.57 ha/person), Northland (3.33 ha/person), Gisborne (3.03 ha/person) and Hawke's Bay (2.63 ha/person) all have ecological footprints around the New Zealand average which would be expected on the basis of their land productivities.

Waikato (2.87 ha/person) and Bay of Plenty (2.59 ha/person) both have per capita footprints just below the New Zealand average. These regions have relatively high land productivities (first and second in the country) and you would in fact expect their per capita ecological footprints to be even lower on the basis of their land productivities. The spread-out nature of their settlement which is less urban than some other regions may explain why the ecological footprints of these regions are not quite as low as otherwise expected.

Taranaki (2.19 ha/person) and Tasman (2.08 ha/person) have the third and fourth lowest per capita ecological footprints of any region. In both cases this seems to be almost entirely explained by the relatively high land productivities in these two regions.

Wellington (2.40 ha/person), Auckland (2.00 ha/person) and Nelson (1.80 ha/person) all have very low ecological footprints per capita. Nelson and Auckland footprints are the smallest and second smallest in the country. These are the three most urban areas in New Zealand, and this seems to be the main determinant of their low ecological footprints. Urban settlement and consumption patterns are more efficient in their use of land – in other words, land requirements per capita for retailing, housing, infrastructure and transport are considerably lower in urban areas compared with rural areas.

3.4.3 Overshoot of useful land area

The sustainability performance of the regions can also be measured in terms of the extent by which the ecological footprint of a region exceeds the area of useful land available in the region. If the ecological footprint represents more land than is actually available in the region, the region is considered to have overshot its carrying capacity or biocapacity. In other words, there is not enough land to sustain the regional population given the region's current level of material consumption, resource use and technological development. Table 3.5 ranks the regions in terms of the degree of overshoot.

Table 3.5 Ecological surplus/deficit and degree of overshoot of New Zealand regions, 1997/98

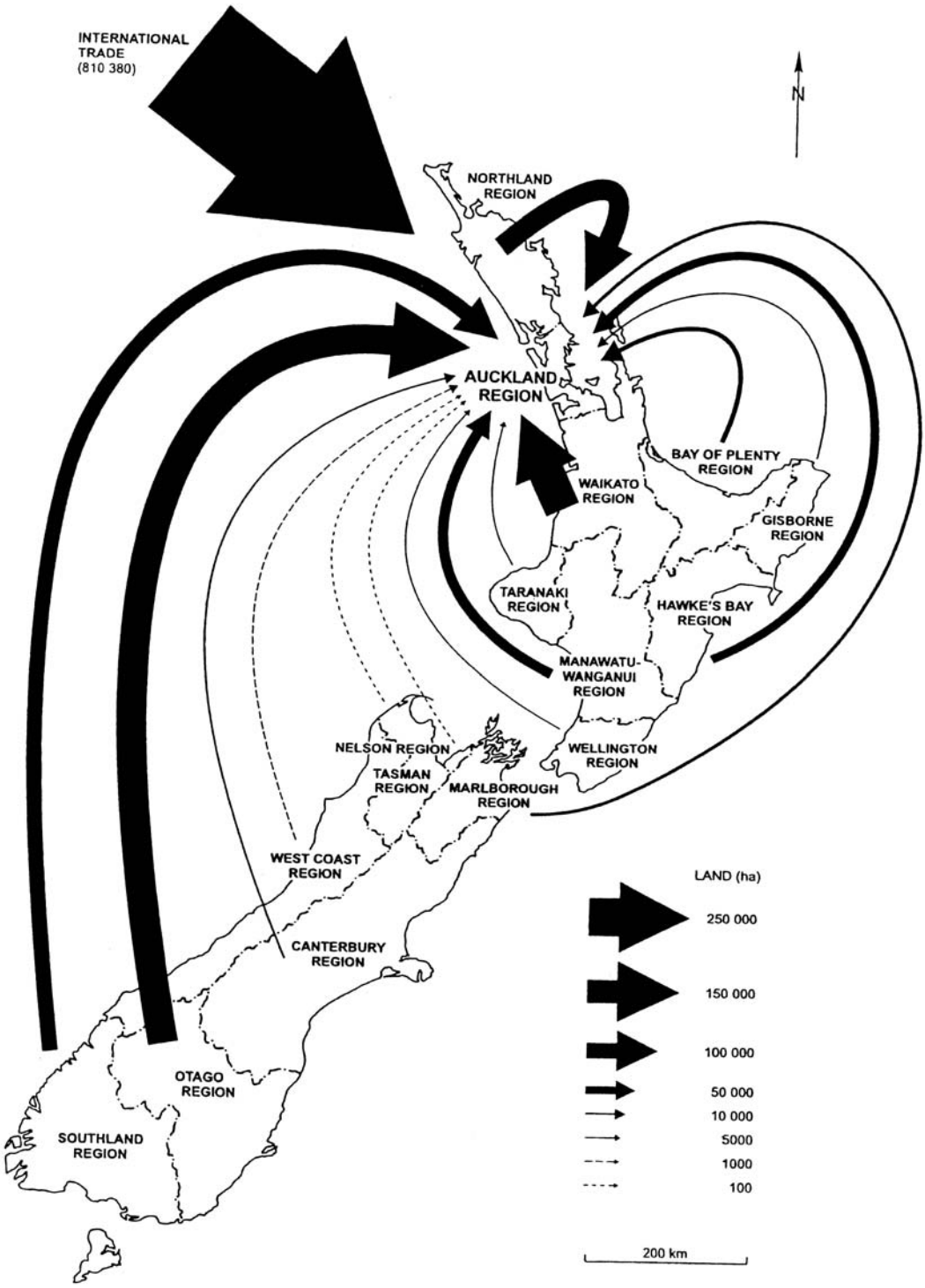
Region	Ecological footprint (ha)	Usable land area[1] (ha)	Ecological surplus/ deficit[2] (ha)	Degree of overshoot[3] (%)
Auckland	2,319,940	481,370	-1,838,570	481.9
Nelson	76,910	35,230	-41,680	218.3
Wellington	1,029,010	723,190	-305,820	142.3
Bay of Plenty	618,260	925,530	307,270	66.8
Waikato	1,048,860	2,018,920	970,060	52.0
Manawatu–Wanganui	879,520	1,833,120	953,600	48.0
Canterbury	1,737,840	3,636,070	1,898,230	47.8
Otago	1,019,050	2,155,440	1,136,390	47.3
West Coast	121,890	266,250	144,360	45.8
Northland	477,120	1,089,020	611,900	43.8
Taranaki	233,150	635,250	402,100	36.7
Hawkes Bay	384,660	1,048,480	663,820	36.7
Southland	375,310	1,257,430	882,120	29.8
Marlborough	163,810	606,090	442,280	27.0
Tasman	82,180	332,910	250,730	24.7
Gisborne	141,660	732,100	590,440	19.3
New Zealand	11,684,650	17,783,950	6,099,300	65.7

1 Usable land is the total amount of land in each region; minus land in national parks, forest parks and reserves; minus remaining biologically non-productive land.

2 The ecological surplus/deficit is the usable land area minus the ecological footprint. A positive number means that the region is in ecological surplus, while a negative number means that the region is in ecological deficit.

3 The degree of overshoot is the ecological footprint divided by the usable land area, expressed as a percentage. Greater than 100 percent means the region has overshot its biocapacity, while less than 100 percent means the region is living within its biocapacity.

Figure 3.3 Regional and international origins of Auckland's ecological footprint, 1997/98



Predictably all three urban regions overshoot their useful land area. Auckland overshoots by 481.95 percent, Nelson by 218.31 percent and Wellington by 142.29 percent. All of these three urban regions need to draw land from the rural hinterland that surrounds them. Auckland draws land from predominantly Waikato or Northland but also significant amounts of land from Manawatu–Wanganui, Otago and Southland (refer to Figure 3.3). In a similar fashion, Nelson draws land mainly from neighbouring Tasman as well as other South Island and lower North Island regions. Wellington is very dependent on the appropriation of land from Taranaki and

Canterbury and notably from overseas. None of these urban regions, like urban areas the world over, are self-sufficient in terms of land.

Of the remaining regions, Bay of Plenty and the Waikato most closely approach an overshoot or ecological deficit situation. Bay of Plenty's ecological footprint is equivalent to 66.80 percent of the useful land available in the region. Waikato's ecological footprint is 51.95 percent of useful land available in that region. This is to be expected given the fact that Bay of Plenty and the Waikato are two next most densely populated regions after the three urban regions.

The next grouping of regions all have ecological footprints that are equivalent to 36–48 percent of the useful land available in the region: Manawatu–Wanganui (47.98 percent), Canterbury (47.79 percent), Otago (47.28 percent), West Coast (45.78 percent), Northland (43.81 percent) Taranaki (36.70 percent) and Hawke's Bay (36.09 percent). With the exception of Otago, all of these regions have about mid-range population densities but as not densely populated as Bay of Plenty or Waikato. Otago has a very high per capita footprint bringing its ecological footprint closer to the overshoot threshold than you would otherwise expect.

The last grouping of regions have ecological footprints less than 30 percent of their available useful land area: Southland (29.85 percent), Marlborough (27.03 percent), Tasman (24.09 percent) and Gisborne (19.35 percent). They have large tracts of available land that are not used for supporting consumption by the local population. Instead, in all of these regions this apparent excess of land is almost all used to produce commodities for exports primarily to international markets. All of these regions have 'ecological balances of trade' in excess of a 7:1 ratio for exports to imports, which are amongst the highest ratios in the country.

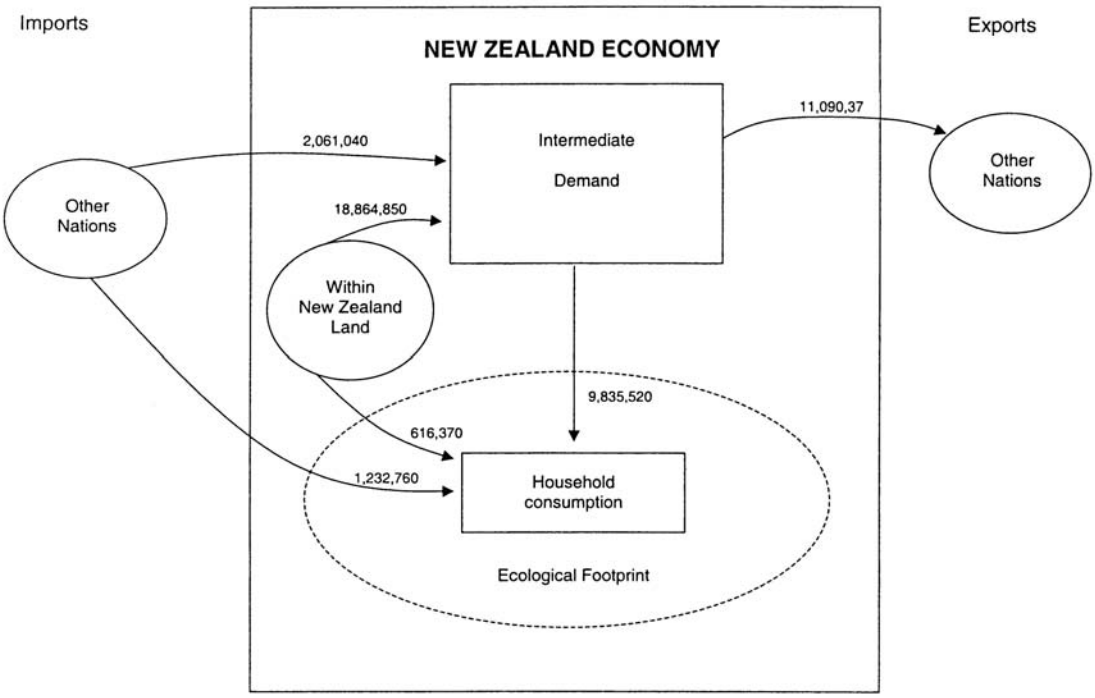
3.5 Ecological Balance of Trade

3.5.1 Overall picture

The ecological footprint calculations measure the embodied land consumed by New Zealanders. This amounted to 11,684,650 ha of embodied land in 1997/98. The New Zealand economy however not only provides goods and services for the local population but also provides goods and services for export to other countries. The New Zealand economy also imports goods and services produced in other countries. Exports and imports are an important aspect of New Zealand's embodied land accounts and cannot be ignored (refer to Figure 3.4).

Overall, New Zealand exported 11,090,370 ha of embodied land and imported 3,293,800 ha of embodied land. Notably, the land embodied in exports (11,090,370 ha) is only slightly less than the ecological footprint for New Zealand. This means in embodied land terms about half of the production of the New Zealand economy is channelled into local consumption and about half into products for export overseas. On the basis of the above figures, the Ecological Balance of Trade for New Zealand is 7,796,570 ha (11,090,370–3,293,800 ha). New Zealand can therefore be seen as a net provider of ecological capital to other countries as well as living well within our own biocapacity in terms of local consumption of resources.

Figure 3.4 Flows of embodied land through the New Zealand economy, 1997/98



3.5.2 Exports and imports by economic sector

The high export volumes of New Zealand are reflected in the ecological balance and trade data for the agriculture, manufacturing and to a lesser extent the forestry sector (refer to Table 3.6). The agricultural sector exports 2,567,950 ha of unprocessed produce (apples, other fruit and vegetables, wool, live animals). The importation of embodied land into the agricultural sector is only 167,060 ha, resulting in an Ecological Balance of Trade for agriculture of 2,400,890 ha.

Table 3.6 New Zealand's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Agriculture	167,060	2,567,950	2,400,890
Forestry	9,730	629,970	620,240
Fishing and hunting[1]	13,630	30,320	16,690
Mining and quarrying	3,590	31,380	27,790
Manufacturing	1,112,400	7,085,550	5,973,150
Utilities and construction	104,570	2,360	-102,210
Services	650,060	742,840	92,780
Domestic final demand	1,232,760	0	-1,232,760
Total land	3,293,800	11,090,370	7,796,570

1 This does not include marine land used directly or indirectly by the fishing sector.

The exports from the manufacturing sector are the highest at 7,085,550 ha. In terms of embodied land, most of these exports are processed agricultural products with the embodied land content of other exports such as machinery being a lot smaller.

There are also significant imports of plant and equipment, energy and other raw materials into the New Zealand manufacturing sector from overseas. The embodied land content of these imports amounts to 1,112,500 ha. Overall, the Ecological Balance of Trade of the manufacturing sector was found to be 5,973,150 ha.

The exports from the forestry sector amounted to 629,970 ha. This consisted of the exports of logs and wood chips. The export of processed forestry products is included in the manufacturing sector exports. The Ecological Balance of Trade for the forestry sector is 620,240 ha, as there are only 9730 ha of land embodied in imports into this sector.

The fishing and hunting (16,690 ha) and mining and quarrying (27,790 ha) sectors have relatively small positive ecological balances of trade, reflecting small export volumes and even smaller import volumes. The Ecological Balance of Trade for the fishing and hunting sector would be considerably higher if marine 'land' was included in the calculations. New Zealand's Exclusive Economic Zone is 26 times larger than the terrestrial land area of New Zealand, and even if only a small proportion of this marine 'land' was included in the calculations, the fishing and hunting sector estimate would be much greater.

The service sector has relatively large imports of embodied land (650,060 ha) as well as relatively large exports of embodied land (742,600 ha). This sector needs to import equipment (eg. computers) materials (eg. publications) and business services from overseas, but this is more than counter-balanced by the export of services from New Zealand. Overall, the Ecological Balance of Trade of the service sector is 92,780 ha.

The utilities and construction sector is one of only two sectors that has a negative Ecological Balance of Trade of -102,210 ha. There are considerable imports of oil and oil products into this sector as well as plant and equipment, meaning that there are 104,570 ha of embodied land imported. The exports in comparison from this sector are very small at 2300 ha of embodied land.

There are very considerable imports into the domestic demand sector (1,232,760 ha). These are imports purchased by householders either directly or more usually through a retailer. The retail margin is included in the services sector. This involves the imported cars, household items, apparel, furniture, computers, publications and so forth purchased by householders. As there are exports by householders, the Ecological Balance of Trade of domestic demand sector is -1,232,760 ha.

3.5.3 Exports and imports by land type

New Zealand is an exporter of a very large amount of agricultural land (9,193,210 ha). An area of agricultural land equivalent to 78.6 percent of New Zealand's ecological footprint is exported to other countries. This is not surprising given that the traditional basis to the New Zealand economy has been one of exporting agricultural commodities such as wool, meat, dairy and horticultural products. A considerable amount of agricultural land is, however, also imported into New Zealand (2,277,280 ha), in the form of imported foodstuffs and textiles. Overall, for agricultural land, there is an Ecological Balance of Trade of 6,915,930 ha (refer to Table 3.7).

Table 3.7 New Zealand's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Agricultural land	2,277,280	9,193,210	6,915,930
Forest land	193,930	939,580	745,650
Degraded land	203,420	155,320	-48,100
Energy land	619,170	802,260	183,090
Total land	3,293,800	11,090,370	7,796,570

A large amount of forest land is also exported from New Zealand – 939,500 ha. This includes products such as logs, paper, paper-board, wood pulp, waste paper and board products such as fibreboard. With increasing wood volumes coming on stream over the next decade, the amount of forest land which will be exported is also expected to increase. There is however also a significant amount of forest land imported into New Zealand, embodied in the importation of wood based products such as furniture and printed material. These imports collectively amount to 193,930 ha. The Ecological Balance of Trade for forest land is 745,650 ha with exports far out-weighing imports in terms of embodied land.

The overall Ecological Balance of Trade for energy land is also positive (103,090 ha). There are considerable amounts of manufactured products imported into New Zealand which embody much energy land, as well as other imports such as motor vehicles which are purchased by householders. The energy land embodied in these imports is calculated to be 619,700 ha. There are, however, a large volume of manufactured products (especially processed agro-food products) that are relatively energy intensive which means that there are 802,260 ha embodied in exports from New Zealand.

Degraded land is the only land type which has a negative Ecological Balance of Trade. Many of the products New Zealand imports from overseas require considerable degraded land for their production (eg. motor vehicles) whereas the products (mainly agro-food commodities) that we export tend to require less degraded land and more agricultural land. Hence, imports into New Zealand have a degraded land component of 230,420 ha compared with exports having 155,320 ha of degraded land. The resultant Ecological Balance of Trade for degraded land is -48,100 ha.

3.6 Assessing the ecological performance of New Zealand regions

It has been suggested that the ecological footprint can be used to measure sustainability performance in two ways:

(1) *Ecological footprint per capita*. This measures the amount of land appropriated by a person (in a nation, region or city) in supporting their consumption. The smaller this amount of land, the more sustainable this pattern of consumption is deemed to be because it requires less appropriated natural capital (as measured by embodied land).

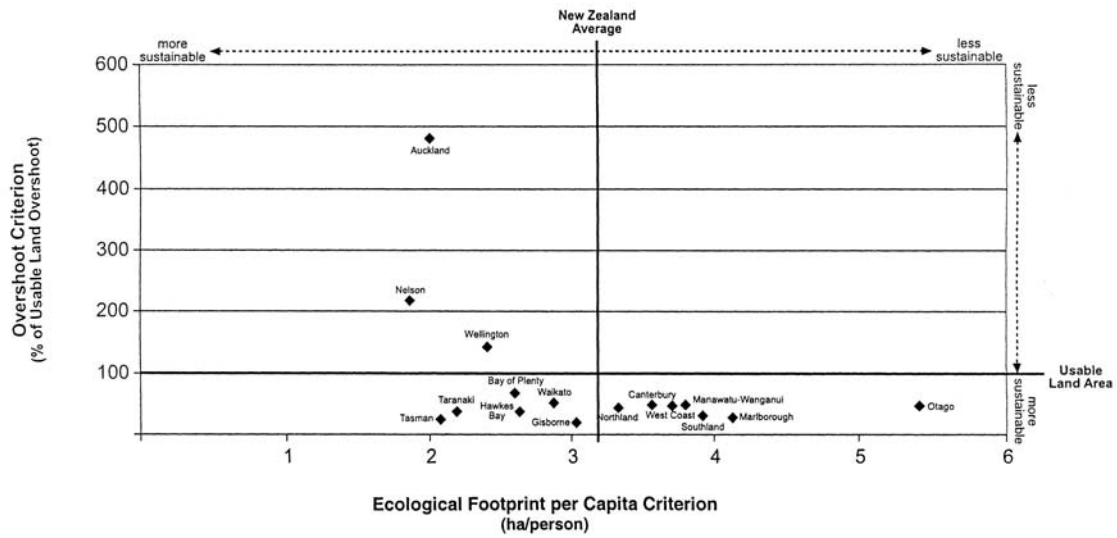
(2) *Degree of overshoot.* It is argued that to be sustainable a population (of a nation, region or city) must consume less embodied land than the amount of useful land that is available. That is, the population must live within its carrying capacity or biocapacity. If the population overshoots its carrying capacity by using too much land, then it is argued that this amount of land cannot sustain the population.

Both of these measures of sustainability performance are controversial and not without methodological problems. Firstly, the ecological footprint per capita requires land of different quality or productivity to be added up. The addition of land areas (ha) of different quality tacitly assumes that all land is equally valuable or productive when measured on a per hectare basis (eg. it assumes that Class I land in the Waikato is equally valuable or productive as Class V land in Otago). Wackernagel and Rees (1996) propose a series of productivity factors that can be used to allow for land productivity (quality) differences. It is, however, problematical using their land productivity factors in this study largely because their international productivity factors have little relevance to New Zealand. In addition, these Wackernagal and Rees (1996) productivity factors are crudely constructed across four land use types that do not really have the degree of refinement required for this study.

Secondly, the degree of overshoot measure is also problematical as it assumes a hypothetical closed system where a population is purported to be supporting itself without any external inputs or outputs of embodied land. Modern economies, such as New Zealand, are on the other hand open systems. As previously alluded to, it is also questionable whether land is the only (or the most important) limiting factor as is assumed by this overshoot argument. Land certainly is not the only unsubstitutable primary input into economic activity. Many ecologists such as Odum (1996) argue that energy is a more fundamental factor.

Nevertheless, it is instructive (even with these limitations) to measure the sustainability performance of New Zealand regions using these two indicators – in other words ecological footprint per capita and degree of overshoot (refer to Figure 3.5).

Figure 3.5: Assessing the sustainability performance of 16 New Zealand regions, using ecological footprint indicators



It can be ascertained from analysing Figure 3.5 that there are three significant clusters of regions.

(1) *Auckland, Wellington and Nelson*. These regions have overshot their carrying capacity, but all have a per capita footprint below the New Zealand average. Notably, these are the three most urban regions in New Zealand. It is predictable, that if an ecological footprint analysis was undertaken for any other urban area in New Zealand that a similar result would occur (eg. if an ecological footprint was calculated for Christchurch City instead of the entire Canterbury region). The reason why one indicator (per capita footprint) is performing well and the other (overshoot) is performing poorly is straight forward – urban areas simply use land more efficiently in terms of retail, housing, infrastructure and transport functions, as high population densities reduce space requirements. At the same time the more urban an area is, the more it has to draw resources (particularly food) from outside the region, resulting in an ecological deficit or overshoot situation.

(2) *Waikato, Bay of Plenty, Gisborne, Hawke's Bay, Taranaki and Tasman*. These are apparently the 'best' performing regions. They perform favourably for both indicators – their footprint per capita is below the New Zealand average and they are not in an ecological deficit or overshoot situation. This result however needs to be interpreted with caution. All of these regions have above average land productivities (except Gisborne) which will decrease their per capita footprint – in other words, the per capita footprint is lower, not so much because people in these regions consume less products or live more sustainability, but more because the land in their region is more productive and therefore less of it is required to produce the same amount of products. None of these regions is urban, and if a footprint analysis were to be undertaken for any one of the urban areas within these regions (eg. Hamilton City) undoubtedly an ecological deficit or overshoot situation would result.

(3) *Northland, Manawatu–Wanganui, Marlborough, West Coast, Canterbury, Otago and Southland*. These regions are not in an overshoot or ecological deficit situation and this is a favourable outcome. However, their per capita footprints are above the New Zealand average which is not favourable. Again, the interpretation of these results needs to be approached with caution. The unfavourable outcome in terms of the relatively high per capita footprint in most cases can be explained away purely by the low land productivities in these regions. All of these regions (except Northland and Manawatu–Wanganui) have land productivities below the national average, meaning more land is required to produce the same amount of product which inflates their per capita footprint. This is particularly the case for Otago. Therefore, it could be argued that these regions do not necessarily consume more products and resources than other regions on a per capita basis, rather they require more land to produce the same amount of products.

Two further insights emerge from examining Figure 3.5. Firstly, there are no regions in the top right side quadrant of Figure 3.5. In this quadrant there is both an overshoot of carrying capacity and an above average per capita footprint, both arguably undesirable outcomes from a sustainability point of view. Secondly, and related to the first point, there could be a trend line sloping downwards meaning there is a broad trade-off between urban areas (overshoot, but a low per capita footprint) and rural areas (no overshoot, but a large per capita footprint). A linear regression indicates that there is only a weak linear trend ($R^2 = 0.45$) of this nature.

4 Northland's Ecological Footprint

4.1 Profile of the region

Northland is the least urbanised region in New Zealand with only slightly more than half the population living in urban areas (Statistics New Zealand, 1998e). The region had 143,400 residents in 1997/98 or 3.7 percent of the national population. The major urban area is Whangarei which accounts for 32.9 percent of the regional population. Northland's estimated population density of 9.7 people per square kilometre is significantly below the New Zealand average of just over 13. During the 1996–2001 intercensal period Northland recorded a population growth rate of 8.1 percent, slightly higher than the national average of 7.2 percent.

Northland is New Zealand's northern most region. It is bounded to the east by the Tasman Sea, to the west by the Pacific Ocean and to the south by the Auckland region. This peninsula shaped region has an approximate length of 250 kilometres and at its widest point 80 kilometres. Geographically it covers 1,394,100 ha or 5.1 percent of New Zealand's land area. This land is predominantly hill country with flats restricted to river valleys and coastal areas. Of this area farming utilises 45.5 percent and forestry 11.5 percent.

Northland's 1997–98 GDP is estimated at 3.3 billion or 3.4 percent of the nation's GDP. The economy is based on strengths in agriculture, horticulture, forestry and fishing. The predominant agricultural industry is beef cattle farming. Beef cattle stock numbers are the third highest of any region in New Zealand. Sub-tropical temperatures mean that Northland experiences warm humid summers and mild winters. This makes the region ideal for the growing of citrus and sub-tropical fruits. Principal fruits grown include lemon, mandarins, persimmons, oranges and tamarillos. Extensive indigenous and exotic forests are a feature of the Northland landscape. These forests, of predominantly *Pinus radiata*, are among the highest density and fastest growing in the country. It is perhaps not surprising that given these significant forestry holdings the wood and paper manufacturing industries also make a sizeable contribution to the regional economy. A well-developed transport infrastructure links forestry and forest processing to the ports at Whangarei and Auckland. Given the region's extensive coastline, the contribution made by fishing is also not unexpected.

Northland is home to New Zealand's only oil refinery. Marsden Point oil refinery is located near the mouth of the Whangarei harbour. Slightly less than half of the refinery's crude intake comes from the Taranaki region with the remainder imported predominantly from the Middle East in particular Saudi Arabia and the United Arab Emirates. Closely associated with the refinery is the Marsden A thermal power station which pipes heavy oil from the refinery for electricity production. Marsden A has a 240 megawatt capacity.

4.2 Overall ecological footprint and comparison with other regions

Northland has an ecological footprint of 477,120 ha. This represents 4.44 percent of New Zealand's total ecological footprint, meaning that the Northland region's ecological footprint is the eighth largest nationally. Northland's ecological footprint is 25 percent higher than the Hawke's Bay ecological footprint but 30 percent lower than Bay of Plenty, the nearest regions in ecological footprint terms.

On a per capita basis, Northland's ecological footprint is 3.33 ha per person, slightly higher than the national average of 3.08 ha per capita. This is the seventh highest per capita ecological footprint of any region in the country. This means, on a per capita basis, that Northland requires more land to produce the goods and services consumed by its residents than the nation does. One possible reason for this is lower than average yields per hectare for dairy farms and horticultural crops. Another possible explanation is that land occupied by manufacturing industries is used less efficiently than nationally (ie. Northland manufacturing requires more land per dollar of output than manufacturing nationwide).

Northland's useful land area is 1,089,020 ha, meaning that the region has an ecological surplus of 611,900 ha. The region's surplus is 28 percent greater than its footprint and is the seventh largest surplus by any region. In per capita terms, each Northland resident has a surplus of 4.3 ha. In ecological footprint terms, the region is self-sufficient and is largely ecologically independent of other regions and nations.

4.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 333,760 ha (refer to Table 4.1). This represents 70.0 percent of Northland's ecological footprint. Nearly 80 percent of this agricultural land is embodied in products produced within the region with lesser amounts (51,200 ha) being imported from other nations. On a per capita basis the consumption of agricultural land accounts for 2.33 ha per person.

Table 4.1 Northland's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	263,550	19,010	51,200	333,760	2.33	70.0
Forest land	26,890	70	4,330	31,290	0.22	6.6
Degraded land	39,690	330	5,900	45,920	0.32	9.6
Energy land	47,790	1,060	17,240	66,090	0.46	13.9
Total	377,920	20,470	78,670	477,060	3.33	100.0

The forest land component of the ecological footprint equates to 31,290 ha. This represents 6.6 percent of Northland's ecological footprint. Just over 85 percent of this land is appropriated from within the region. The remaining 15 percent is almost entirely embodied in goods and services purchased from other nations. The forest land component does not include the hypothetical land required to sequester CO_2 emissions.

The degraded land component of the ecological footprint makes up 9.6 percent (45,920 ha) of Northland's ecological footprint. Among other things this figure is made up of three key parts:

(1) land occupied by Northland businesses (other than farming and forestry business)

(2) land occupied by the homes of Northland residents

(3) degraded land embodied in purchases of goods and services by households from other nations.

Land occupied by Northland resident's homes and businesses accounts for around 86 percent of the degraded total.

The energy land component of Northland's ecological footprint is 66,090 ha or 13.9 percent of the Northland ecological footprint. This is slightly lower than the New Zealand average. One possible explanation for this is higher than average temperatures, meaning Northland residents use less energy for heating than the residents of other regions. Another explanation is that the manufacturing industries that produce goods for consumption locally are more energy efficient than manufacturing industries elsewhere in the country.

4.4 Ecological footprint disaggregated by goods and services purchased

4.4.1 Purchase of Northland produced goods and services (P_1+P_2 ... P_n)

Northland's residents appropriated 229,120 ha of land embodied in manufactured products (refer to Table 4.2). This amounts to 48.0 percent of the region's ecological footprint. The bulk of this land is embodied in manufactured goods produced locally (195,920 ha), in particular processed food products from the region's farms. Smaller quantities of land (18,880 ha) are also embodied in manufactured goods purchased by the Northland residents from other regions. On a per capita basis, land embodied in manufactured products consumed by Northland residents (1.60 ha per person) is significantly higher than the national average (1.37 ha per person).

Table 4.2 Northland's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	33,370	290	620	34,280	0.24	7.2
Forestry	1,690	0	10	1,710	0.01	0.4
Fishing and hunting	10	0	10	20	0.00	0.0
Mining and quarrying	70	0	30	100	0.00	0.0
Manufacturing	195,920	18,880	14,310	229,120	1.60	48.0
Utilities and construction	26,290	60	3,070	29,420	0.21	6.2
Services	97,110	230	15,100	112,440	0.78	23.6
Domestic final demand	23,450	1,070	45,520	70,040	0.49	14.7
Total	377,920	20,540	78,670	477,120	3.33	100.0

Service sector products consumed by Northland residents (112,440 ha) also account for large quantities of embodied land. At first glance this may appear high, particularly given that service sector businesses occupy a relatively low amount of physical space. Service sector businesses, however, reside near the top of the production chain and may have significant backward

linkages. In this way, service sector purchases (eg. food, paper, equipment, machinery etc) can account for a substantial amount of embodied land. Most of the land embodied in purchases of service sector products by Northland residents originates from within the region (97,110 ha).

By contrast, land embodied in residents' purchases from the remaining sectors of the economy is relatively small. Such purchases account for 65,530 ha, or 13.8 percent of the region's ecological footprint. This means that 0.46 ha of embodied land on average is required to support a Northland resident from sectors other than manufacturing and services which is higher than the corresponding figure of 0.42 ha nationally.

4.4.2 Purchase of goods and services produced outside Northland (D_1+D_4)

Northland residents also directly purchase products from outside the region, accounting for 46,590 ha of land. The vast majority of the land embodied in these purchases (45,520 ha) comes from offshore. These figures include land embodied in retail products purchased overseas and then sold in New Zealand with additional mark-ups. In this way, land embodied in purchases of motor vehicles, computers, many household appliances and foreign foods may be included in these figures.

4.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Northland regional economy is 158,630 ha. By comparison land embodied in exports from the Northland economy equates to 838,580 ha. This means that Northland has a positive Ecological Balance of Trade of 679,950 ha (refer to Table 4.3).

4.5.1 Exports and imports by economic sectors

Over half of the land embodied in imports (79,270 ha) into the Northland region is embodied in goods and services purchased by the manufacturing sector. Although this may appear high, it is comparatively small compared to the region's exports of land embodied in manufactured products (414,650 ha). However, a significant proportion of the embodied land exported overseas is contained within sheep and beef products and thus, indirectly, the land occupied by extensive farming in the region.

A significant amount of land is embodied in agricultural products that are exports from the Northland region (321,130 ha). This is attributable to livestock sales (predominantly sheep and beef), horticultural produce being sold to other regions and to wool sales internationally. It is perhaps not surprising therefore that most of this embodied land is destined for other regions (192,650 ha) and, after processing, to offshore locations.

The Northland service sector is also a significant importer of embodied land (17,750 ha). The vast majority of this land is embodied in goods and services purchased by the service sector from overseas sources. This includes products ranging from computers to specialist technical services required in the day-to-day operation of the Marsden Point oil refinery. The service sector also uses paper products, equipment, furniture, and other capital items with high embodied land content. Some of this embodied land is re-exported in products sold, in turn, by

the region's service sector. Northland's service sector businesses export an estimated 18,460 ha of embodied land, slightly larger than the figure imported.

Table 4.3 Northland's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	3,010	192,650	189,640
Forestry	40	27,110	27,070
Fishing and hunting	0	1,050	1,050
Mining and quarrying	30	220	190
Manufacturing	27,140	24,620	-2,520
Utilities and construction	80	2,310	2,230
Services	280	690	410
Domestic final demand	1,070	0	-1,070
Interregional Balance of Trade	31,650	248,650	217,000
International trade			
Agriculture	6,450	128,480	122,030
Forestry	580	49,960	49,380
Fishing and hunting	1,060	2,290	1,230
Mining and quarrying	240	570	330
Manufacturing	52,130	390,030	337,900
Utilities and construction	3,250	130	-3,120
Services	17,750	18,460	710
Domestic final demand	45,520	0	-45,520
International Balance of Trade	126,980	589,930	462,950
Total Balance of Trade	158,630	838,580	679,950

4.5.2 Exports and imports by type of land

The Northland region is a very large net provider of agricultural land to other regions and nations (588,110 ha) (refer to Table 4.4). The region's economy is thus very dependent upon the export of agricultural land to generate income and employment. Over two-thirds (413,770 ha) of this net land is embodied in products that are sold internationally while the remainder (174,340 ha) is embodied in products sold to other regions.

Table 4.4 Northland's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	29,750	204,090	174,340
Forest land	140	29,140	29,000
Degraded land	460	7,550	7,090
Energy land	1,290	7,870	6,580

Interregional Balance of Trade	31,640	248,650	217,010
International trade			
Agricultural land	72,010	485,780	413,770
Forest land	6,810	64,690	57,880
Degraded land	22,460	12,820	-9,640
Energy land	25,700	26,650	950
International Balance of Trade	126,980	589,940	462,960
Total Balance of Trade	158,620	838,590	679,970

The Northland economy is also strongly driven by international demand for forest products. Log exports out of Whangarei's Northland Port account for 64,690 ha of embodied land while timber exports from the region's southern forests account for 29,140 ha of the embodied land going to other regions. The importation of forest products from Auckland is captured in the purchase of 6810 ha of embodied land.

Lesser amounts of degraded land (20,370 ha) and energy land (34,520 ha) embodied in goods and services are also exported from the region. Only in the purchase of products that embodied significant quantities of degraded land does the region have a small negative Ecological Balance of Trade of 2550 ha, resulting mostly from embodied land originating overseas (22,460 ha).

4.5.3 Overall picture

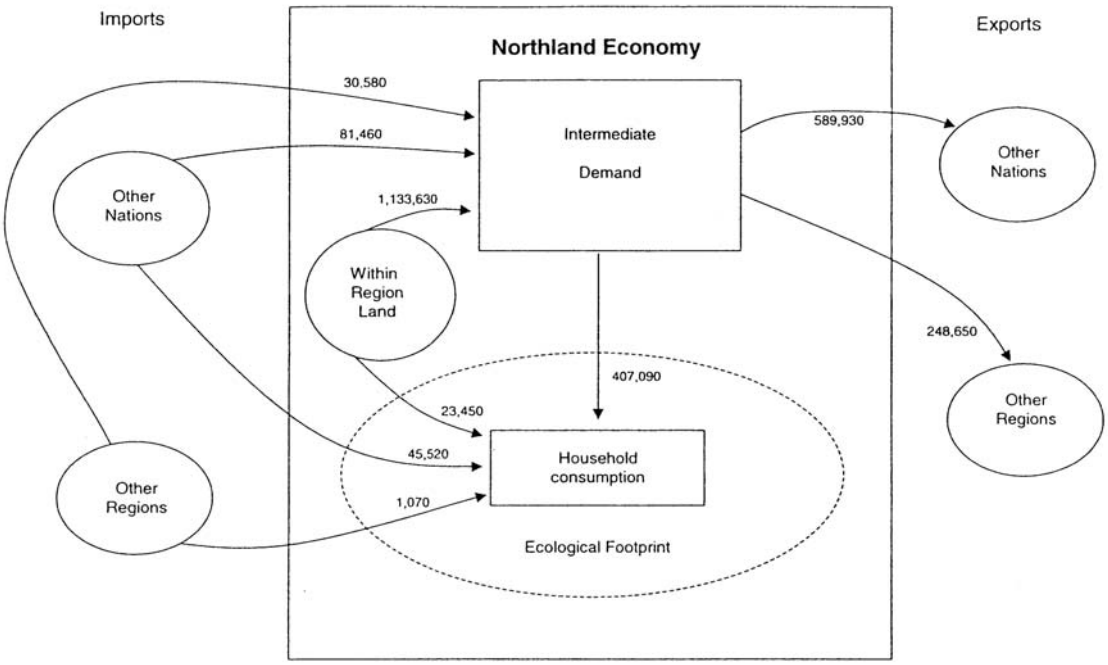
The embodied land flows associated with the Northland economy are shown in Figure 4.1. This diagram indicates that the Northland region is:

(1) comparatively self-sufficient in terms of land, with a relatively low embodied land area associated with household consumption

(2) an internationally driven export economy with substantial outward embodied land flows.

Land embodied in international exports (589,930 ha) outweighs land embodied in international imports (81,460 ha) by 7.2 times. Taking account of both international and interregional trade flows, Northland has a large positive Ecological Balance of Trade of 725,470 ha. It is therefore a net provider of land to other regions and nations.

Figure 4.1 Flows of embodied land through the Northland economy



5 Auckland's Ecological Footprint

5.1 Profile of the region

The Auckland region is New Zealand's largest and most rapidly growing region with a population of 1,159,399 in 1997/98. Over 30 percent of New Zealanders live in the Auckland region. Most of the region's residents live in the Auckland metropolitan area. This makes Auckland by far New Zealand's most densely populated region at 224 people per square kilometre in 1997/98.

Much of the population increase in the Auckland region is due to high fertility rates and a youthful age structure resulting in a high natural increase in the population. Overseas immigration into Auckland in recent years particularly from Asia has also been an important driver of Auckland's population growth. The growth attributable to inwards migration from the regions, has been relatively minor, and often overstated, with an actual net outward flow to some regions over the 1991 to 1996 census period (eg. to Northland, Waikato, Bay of Plenty).

Geographically the Auckland metropolitan area is located on an isthmus between two natural harbours. From north to south the region measures 120 kilometres and at its widest point is 60 kilometres. The land area of the region is 519,032 ha (2 percent of New Zealand's land area). Of the total land area, 53.7 percent is used for farming purposes which is high given the fact that much of land is covered by urban dwellings and activities.

The Auckland economy is driven by strengths in both the manufacturing and service sectors. A large and diverse labour force, its close proximity to New Zealand's largest domestic market and port facilities all reinforced by various government policies resulted in a concentration of manufacturing activities in the Auckland region in the post-World War II period. Rubber, plastics and chemical products (location quotient of 1.63), printing and publishing (LQ 1.53), fabricated metal products (LQ 1.43) basic metals (LQ 1.53) and beverage manufacturing (LQ 1.53) sectors particularly dominated. The biggest single industrial site is the Glenbrook Steel Mill which produces 700,000 tonnes of steel per annum from ironsands. In the 1980s through to the 1990s many of these traditional manufacturing industries, however, have experienced some decline due to the impact of trade liberalisation and deregulation (eg. removal of tariff protection).

The service sector on the other hand has had an ascendant importance in the Auckland economy in recent years. This is reflected in the relatively high location quotients and growth rates for a number of the service sectors: business services (LQ 1.38), real estate (LQ 1.38), insurance (LQ 1.27), services to finance (LQ 1.26), cultural and recreation services (LQ 1.19) and communication services (LQ 1.23). There is an increasing trend for many service sector businesses to relocate to Auckland particularly from Wellington.

Auckland is also New Zealand's foremost cargo and transport hub. It is the nation's largest port, handling 3.4 million tonnes of exports and 6.7 million tonnes of imports in the year ending 30 June 1996. It also has New Zealand's largest airport both in terms of passenger numbers and cargo throughput.

5.2 Overall ecological footprint and comparison with other regions

Auckland has an ecological footprint of 2,319,940 ha. This represents 19.85 percent of New Zealand's total ecological footprint and is the highest ecological footprint of any region. It is a third larger than Canterbury's ecological footprint, the second highest.

On a per capita basis, Auckland has the second lowest ecological footprint out all of the 16 regions at 2.00 ha per capita. This figure is relatively low compared with the national average, primarily because of the high productivity of land within Auckland, meaning that less land is required to produce the same amount of product. There is also possibly savings in terms of land use due to economies of scale of having a large population which decreases the 'within region land requirements'. For example, Auckland's high population density does lead to certain land use efficiencies in terms of infrastructure provision and for activities such as retailing.

The useful land area of Auckland is 481,370 ha, meaning that Auckland has an ecological deficit of 1,838,567 ha. Or, put alternatively, Auckland overshoots its useful land area by 4.82 times. This means that Auckland is not self-sufficient and ecologically depends on land appropriated from other regions and overseas. Auckland has the highest ecological deficit of any region in New Zealand both in terms of total hectares and its overshoot ratio.

5.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 1,525,000 ha (refer to Table 5.1). This represents 65.7 percent of Auckland's ecological footprint. Most of this agricultural land is embodied in products imported into the region from other regions in New Zealand: Waikato (203,330 ha), Otago (183,170 ha), Northland (119,620 ha), Southland (96,680 ha), Manawatu–Wanganui (70,500 ha), Hawke's Bay (52,200 ha), Canterbury (41,420 ha) and other (37,730 ha). There is also an additional 551,950 ha of agricultural land embodied in overseas products imported into Auckland.

Table 5.1 Auckland's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	168,330	804,720	551,950	1,525,000	1.32	65.7
Forest land	5,510	45,410	50,060	100,980	0.09	4.4
Degraded land	95,840	16,610	31,860	144,310	0.12	6.2
Energy land	354,750	18,180	176,510	549,440	0.47	23.7
Total	624,430	884,920	810,380	2,319,730	2.00	100.0

The forest land component of the ecological footprint consists of 101,000 ha. This represents only 4.4 percent of Auckland's ecological footprint. Over half of the forest land is embodied in products imported from overseas. Most of the remainder of this forest land component consists of land embodied in products (predominantly wood based) imported from the Bay of Plenty and Waikato regions.

The degraded land component of the ecological footprint makes up 6.2 percent (144,310 ha) of Auckland's ecological footprint. Most of this is degraded land derived from the Auckland

region. This is not surprising given the relatively high proportion of urban (degraded) land within the region. A significant amount of degraded land is also embodied in products imported from overseas. The degraded land embodied in products imported from other regions within New Zealand is relatively small.

The energy land component of Auckland's ecological footprint is 549,440 ha. This represents 23.7 percent of Auckland's ecological footprint - significantly higher than the national average of 16.6 percent. Auckland's relatively high energy footprint is due to heavy energy use within the region rather than energy embodied in imported products. Auckland's industries tend to supply products for relatively energy intensive household consumption within Auckland as well as some activities in Auckland (eg. personal transport) that may have an energy intensity above the national average.

5.4 Ecological footprint disaggregated by goods and services purchased

5.4.1 Purchase of Auckland produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 1,126,000 ha of embodied land in Auckland's ecological footprint (refer to Table 5.2). This amounts to nearly 48.6 percent of the entire ecological footprint of the Auckland region. Most (733,860 ha) of this embodied land is in manufacturing products imported into Auckland, most notably food and agricultural products from New Zealand's rural hinterland. Significant amounts of land (223,890 ha) are also embodied in manufacturing products imported from overseas into Auckland for local consumption.

Table 5.2 Auckland's ecological footprint, by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	105,010	36,890	4,920	146,820	0.13	6.3
Forestry	2,080	17,530	100	19,710	0.02	0.8
Fishing and hunting	60	0	60	120	0.00	0.0
Mining and quarrying	340	140	210	690	0.00	0.0
Manufacturing	108,940	793,860	223,890	1,126,690	0.97	48.6
Utilities and construction	44,010	16,080	35,470	95,560	0.08	4.1
Services	195,110	7,270	166,390	368,770	0.32	15.9
Domestic final demand	168,870	13,370	379,340	561,580	0.48	24.2
Total	624,430	885,140	810,370	2,319,940	2.00	100.0

The picture is quite different from the land embodied in the products purchased from the service sector (eg. insurance, financial, business consulting, restaurants). In total, this amounted to 338,770 ha (15.9 percent) of the footprint but more significantly most of this land is appropriated from within Auckland. That is, unlike manufacturing, the service sector products draw on land within Auckland rather than land appropriated from other regions. Although the land required for service sector products from other regions is very low (7270 ha), the land drawn from overseas in providing service sector products for Auckland is surprisingly high (166,390 ha).

The land embodied in other products consumed by Aucklanders is much smaller than for manufacturing and service sector products: agricultural products (146,820 ha), utilities of construction products (95,560 ha) and forestry products (19,710 ha).

5.4.2 Purchase of goods and services produced outside Auckland (D_1+D_4)

Aucklanders also purchase products from outside the region, and this accounts for 392,710 ha of land. Most of these purchases include overseas products such as computers, motor vehicles, foreign foodstuffs and various household items (379,340 ha). There is only a small amount of land embodied in the purchases of products from other regions (13,370 ha).

5.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Auckland regional economy is 2,509,040 ha (refer to Table 5.3). Whereas, the land embodied in exports from the Auckland economy is 1,089,430 ha. This means that the Ecological Balance of Trade of the Auckland economy is negative 1,419,610 ha, meaning it is overall a net consumer of land from outside the region.

Table 5.3 Auckland's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	57,890	80	-57,810
Forestry	81,910	3,420	-78,490
Fishing and hunting	110	0	-110
Mining and quarrying	360	0	-360
Manufacturing	1,282,960	15,530	-1,267,430
Utilities and construction	16,340	1,460	-14,880
Services	10,580	8,980	-1,600
Domestic final demand	13,370	0	-13,370
Interregional Balance of Trade	1,463,520	29,480	-1,434,040
International trade			
Agriculture	7,720	83,480	75,760
Forestry	470	68,950	68,480
Fishing and hunting	1,440	2,820	1,380
Mining and quarrying	550	1,110	560
Manufacturing	390,550	752,210	361,660
Utilities and construction	36,150	280	-35,870
Services	229,300	151,090	-78,210
Domestic final demand	379,340	0	-379,340
International Balance of Trade	1,045,520	1,059,950	14,430
Total Balance of Trade	2,509,040	1,089,430	-1,419,610

5.5.1 Exports and imports by economic sectors

A large percentage (66.7 percent) of the land embodied in imports into Auckland is associated with purchases of products by the manufacturing sector. Most of these purchases by the Auckland manufacturing sector are for the raw materials purchased from other regions for further processing. Approximately half of the land embodied in these imported raw materials is eventually re-exported from Auckland with approximately half being consumed within the Auckland economy.

The service sector in Auckland is also a significant consumer of land embodied in interregional imports (229,300 ha of embodied land). The service sector uses paper products, equipment, furniture, and other capital items imported from other regions in New Zealand, which cumulatively have a high embodied land content. In turn, the service sector in Auckland also exports embodied land back to other regions as service sector businesses in Auckland sell their services to other regions in New Zealand.

5.5.2 Exports and imports by type of land

Auckland is a very large net consumer of agricultural land from outside the region (refer to Table 5.4). International exports (721,028 ha) and imports (711,280 ha) of agricultural land more-or-less balance. Most of the agricultural land drawn from the regions is however channelled into household consumption within Auckland or exported internationally with little being returned to the regions. This means with respect to interregional trade Auckland has a negative Ecological Balance of Trade of 1,278,500 ha for agricultural land. Overall, accounting for these trade flows, the net effect is that Auckland consumed 1,268,500 ha of agricultural land appropriated from outside the region in 1997/98.

Table 5.4 Auckland's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	1,292,580	14,280	-1,278,300
Forest land	123,530	5,330	-118,200
Degraded land	19,120	1,130	-17,990
Energy land	28,280	8,730	-19,550
Interregional Balance of Trade	1,463,510	29,470	-1,434,040
International trade			
Agricultural land	711,280	721,080	9,800
Forest land	62,790	94,380	31,590
Degraded land	58,790	20,900	-37,890
Energy land	212,650	223,590	10,940
International Balance of Trade	1,045,510	1,059,950	14,440
Total Balance of Trade	2,509,020	1,089,420	-1,419,600

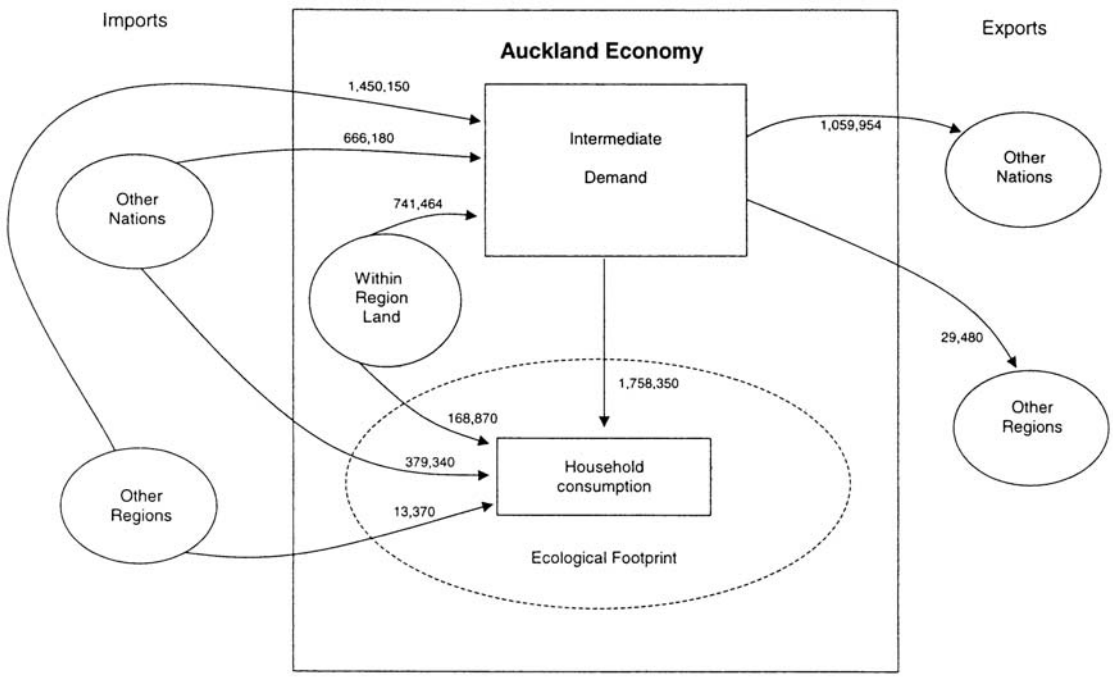
Energy land embodied in imports is also a significant proportion of land appropriated by imports into Auckland, amounting to 240,930 ha. Of this 212,650 ha is embodied in international imports. Auckland exports 232,320 ha of energy land, meaning that Auckland is a net consumer of only 8610 of energy land.

Lesser amounts of forest land (186,320 ha) and degraded land (77,910 ha) are appropriated by imports into Auckland. Auckland exports 99,910 ha of forest land and 22,030 ha of degraded land. Therefore, in overall terms, Auckland is also a net consumer of forest land (-86,610 ha), and degraded land (-55,880 ha) from outside the region as reflected in the respective ecological balances of trade for these land types.

5.5.3 Overall picture

Figure 5.1 provides a summary of the overall flows of embodied land through the Auckland region economy. This diagram indicates that even though Auckland's domestic consumption of land is high (2,319,940 ha) as measured by its ecological footprint, the interactions Auckland has with other regions and countries is also very important. Exports of embodied land (1,089,430 ha) are significantly out-weighed by imports of embodied land (2,509,640 ha). This gives Auckland a negative Ecological Balance of Trade of 1,438,830 ha. Auckland is therefore a consumer rather than a producer of ecological capital.

Figure 5.1 Flows of embodied land through the Auckland economy



6 Waikato's Ecological Footprint

6.1 Profile of the region

Waikato is the fourth largest region in New Zealand covering 2,497,340 ha. It is a geographically diverse area encompassing the rugged Coromandel Peninsula, the fertile Hauraki Plains and those surrounding the Waikato River, the hilly west and King Country areas and the volcanic plateau in the south.

The Waikato region also ranks fourth in terms of population with 357,726 people at the 2001 Census. Waikato has a large Maori population, with 21.3 percent identifying themselves as Maori, which is the second highest of any region behind Gisborne. Waikato's population is relatively youthful, having the second lowest median age of any region. Although the Waikato has experienced steady population growth over the last decade, there has been some significant outward migration from the region particularly to the neighbouring Bay of Plenty region.

The Waikato region has a relatively high population density of 14.02 people per km^2 ranking sixth out of the 16 regions. Overall, 76 percent of the population is urban with a large concentration of people living in the Hamilton urban area which had a population of 158,046 at the 1996 Census.

Agricultural production, and more particularly dairy farming, is the driving force of the Waikato economy. The contour as well as the favourable climate and soils of the Waikato make it one of the most well suited areas in the world for dairy farming. Over the last decade there has been steady growth in dairy cow numbers in the region with the region now having 37 percent of New Zealand's dairy herd. The processing of milk into a wide variety of value-added products is also critical to the Waikato economy. Most of this production of dairy products is focused on nine large factory sites that are by world standards technologically advanced and very efficient. The location quotients for both dairy farming (LQ 3.96) and dairy processing (LQ 2.77) reflect the importance of dairying to the region. There is also a relatively high location quotient for sheep, beef and mixed livestock farming (LQ 1.33).

Plantation forests cover approximately 12 percent of the Waikato region and represent about a quarter of New Zealand's plantation forests. Most forestry is situated around Taupo and South Waikato. The income and jobs generated from forestry production and processing in the Waikato is very significant. All of the forestry related sectors in the Waikato economy have high location quotients: forestry and logging (LQ 1.91), wood and wood products (LQ 1.43) and pulp and paper manufacturing (LQ 1.63).

The Waikato region also contributes significantly to New Zealand's electricity generation and distribution infrastructure. Within the region there are 12 hydroelectric, one thermal (Huntly) and five geothermal power stations. This represents nearly three-quarters of the North Island's generation capacity.

Service sector activity, other than health and community services (LQ 1.07), local government (LQ 1.08) and education (LQ 1.16), is relatively weak in the Waikato region. There are nevertheless particular strengths in education (mainly through the presence of Waikato University) and in scientific research with several key scientific research centres being located in the region.

6.2 Overall ecological footprint and comparison with other regions

Waikato has an ecological footprint of 1,048,860 ha. This represents 9.75 percent of New Zealand's total ecological footprint, the third largest of any region in New Zealand behind Auckland and Canterbury.

On a per capita basis the Waikato, at 2.87 ha per person, has the ninth largest ecological footprint out of all 16 regions. This represents 6.81 percent less than the national average of 3.08 ha per person. The highly productive land of the Waikato is a major factor in explaining the relatively low ecological footprint for the Waikato (ie. it takes less Waikato land to produce the same amount of product). On the other hand, the Waikato is not a highly urban region (like Auckland and Nelson), which would otherwise decrease its ecological footprint even further. If the Waikato were more urban, it would benefit from economies of scale and efficiencies of land use.

According to the ecological footprint calculation, 1,048,860 ha of land is required to support consumption by the Waikato population. In contrast, there are 2,018,917 ha of useful land available, meaning that the Waikato has more than enough land to sustain its current level of consumption. In fact, the Waikato would need to increase its consumption 1.92 times before it would overshoot the availability of useful land. Overall, in net terms, this means the Waikato is ecologically self-sufficient and actually has an ecological surplus of 970,057 ha of useful land. This situation is typical of rural regions such as the Waikato.

6.3 Ecological footprint disaggregated by land type

The agricultural land component of the Waikato ecological footprint consists of 572,380 ha (refer to Table 6.1). This represents 54.6 percent of Waikato's ecological footprint. Not surprisingly, most of this agricultural land (411,570 ha) is sourced from within the Waikato. There is little need to import agricultural based products into the Waikato given the abundance of fertile land available to produce such products within the Waikato. Only a small amount (22,280 ha) of agricultural land is drawn from other regions in New Zealand mainly from Gisborne, Hawke's Bay, Manawatu–Wanganui, Otago and Canterbury. A significant amount (138,500 ha) of agricultural land is embodied in products imported from overseas. The agricultural land component of the Waikato footprint (54.6 percent), on a percentage basis, is considerably smaller than the New Zealand average (68.8 percent). This undoubtedly is explained by the high productivity of Waikato land, meaning that it generally requires less land to produce the same amount of product.

Table 6.1 Waikato's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	411,570	22,280	138,530	572,380	1.57	54.6
Forest land	104,690	310	13,060	118,060	0.32	11.3
Degraded land	130,020	9,340	9,160	148,520	0.41	14.2
Energy land	159,570	3,070	46,960	209,600	0.57	20.0
Total	805,850	35,000	207,710	1,048,560	2.87	100.0

The forest land component of the Waikato ecological footprint consists of 118,060 ha. This represents only 11.3 percent of the Waikato ecological footprint. Nearly all of the forest land (104,690 ha) is drawn from within the region – to be expected given that the Waikato has about one-quarter of New Zealand's plantation forests, and all of the forest processing sectors have relatively high location quotients for the Waikato. Most of the remainder of this forest land component consists of land embodied in wood-based products imported from overseas.

The degraded land component of the ecological footprint makes up 14.2 percent (148,520 ha) of the Waikato ecological footprint. Most (130,020 ha) of this degraded land is drawn from commodities produced from urban-based businesses within the Waikato. The degraded land embodied in products imported either from other regions (9340 ha) or other countries (9160 ha) is relatively insignificant.

The energy land component of the Waikato ecological footprint is 209,600 ha. This represents 20.0 percent of the Waikato ecological footprint, which is higher than the national average of 16.6 percent. Most of (159,570 ha) Waikato's energy footprint can be attributed to direct and indirect energy use within the Waikato economy rather than energy embodied in products imported into the region. All of this points to relatively inefficient energy use in the Waikato. This in part could be explained by the relatively spread-out nature of the settlement within the region requiring more transport energy use per person.

6.4 Ecological footprint disaggregated by goods and services purchased

6.4.1 Purchase of Waikato produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 437,560 ha of embodied land in Waikato's ecological footprint (refer to Table 6.2). This amounts to 41.7 percent of the entire ecological footprint of the Waikato region. The Waikato is self-sufficient in producing these manufactured goods (primarily food) within the region. Only a small amount of land (55,350 ha) is embodied in manufactured products imported to the region.

Table 6.2 Waikato's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	49,600	250	1,930	51,780	0.14	4.9
Forestry	4,850	0	50	4,910	0.01	0.5
Fishing and hunting	30	10	20	60	0.00	0.0
Mining and quarrying	320	10	50	370	0.00	0.0
Manufacturing	382,210	19,740	35,610	437,560	1.20	41.7
Utilities and construction	66,360	80	9,430	75,880	0.21	7.2
Services	245,620	1,390	42,420	289,420	0.79	27.6
Domestic final demand	56,870	13,800	118,210	188,880	0.52	18.0
Total	805,850	35,280	207,730	1,048,860	2.87	100.0

The purchase of service sector products accounted for 289,420 ha of the embodied land in the Waikato ecological footprint. This amounts to 27.6 percent of the entire ecological footprint of

the Waikato region. Most of these service sector products (insurance, finance, retail margin) are drawn from direct and indirect land from within the Waikato. Only a very insignificant amount of land (1390 ha) is embodied in service sector products purchased from other regions. Surprisingly, however, service sector products purchased by Waikato consumers have a much higher overseas embodied land content (42,420 ha). This probably results from the land embodied in computers, printed material and so forth imported from overseas used as inputs into the Waikato service sector.

The land embodied in other products purchased by Waikato consumers is much smaller than that for manufacturing and service sector products: agricultural products (51,780 ha), forestry products (4910 ha), mining and quarrying products (370 ha) and utilities and construction products (75,880 ha).

6.4.2 Purchase of goods and services produced outside the Waikato (D_1+D_4)

Consumers in the Waikato also purchase products from outside the region which accounted for 132,010 ha of land. This represents 12.57 percent of the entire Waikato ecological footprint. Most (118,210 ha) of these purchases are for products such as computers, motor vehicles, household items and consumables imported from overseas for direct use by householders. There is only a small amount of land (13,800 ha) embodied in consumer products imported from other regions in New Zealand directly used by Waikato households.

6.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Waikato economy is 341,520 ha whereas the land embodied in exports from the Waikato economy is 1,780,350 ha (refer to Table 6.3). This results in a positive Ecological Balance of Trade for the Waikato economy of 1,438,830 ha, meaning that overall it is a net provider of land to other regions and countries.

6.5.1 Exports and imports by economic sectors

The Waikato economy is based on land-oriented export industries. This is reflected in the pattern of exports and imports by economic sectors in the Waikato. Much embodied land (442,350 ha) is exported to other regions in New Zealand. This represents agricultural products that are directly exported out of the Waikato to other regions for further processing. Even more land (891,580 ha) is embodied in agricultural products (mainly dairy products) that are further processed in the Waikato and then exported internationally. There is also a significant amount of land embodied (205,700 ha) in the international exports of forestry products from the Waikato.

In overall terms, the Waikato is therefore a net exporter of land embodied in agricultural products (569,610 ha) forestry products (203,490 ha) and manufacturing products (806,910 ha). These manufactured products are almost entirely derived from land based raw materials (logs, milk, wool, sheep, cattle) that have been further processed. The net balances of trade for the other sectors in the Waikato economy are much smaller with imports and exports in broad terms tending to cancel each other out. For instance, the service sector imports 51,280 ha of embodied land into the region (purchase of equipment, computers, services) but it also exports 41,480 of

embodied land to outside the region, as it sells these services to businesses in other regions (eg. the scientific research institutes in the Waikato, which are part of the service sector, sell their output both interregionally and internationally).

Although the Waikato does import some manufactured goods for local use (76,740 ha), this is dwarfed by the export of manufactured products from the Waikato.

Table 6.3 Waikato's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	3,140	442,350	439,210
Forestry	160	32,670	32,510
Fishing and hunting	370	0	-370
Mining and quarrying	80	360	280
Manufacturing	40,230	32,300	-7,930
Utilities and construction	100	5,210	5,110
Services	1,740	2,740	1,000
Domestic final demand	13,800	0	-13,800
Interregional Balance of Trade	59,620	515,630	456,010
International trade			
Agriculture	24,220	154,620	130,400
Forestry	2,050	173,030	170,980
Fishing and hunting	650	2,030	1,380
Mining and quarrying	730	4,390	3,660
Manufacturing	76,740	891,580	814,840
Utilities and construction	9,760	330	-9,430
Services	49,540	38,740	-10,800
Domestic final demand	118,210	0	-118,210
International Balance of Trade	281,900	1,264,720	982,820
Total Balance of Trade	341,520	1,780,350	1,438,830

6.5.2 Exports and imports by land type

The Waikato is a very large net provider of agricultural land (1,077,600 ha) to other regions and nations (refer to Table 6.4). The Waikato economy very much depends on the export of land to generate income and jobs. Over half (672,030 ha) of this net land is embodied in products exported internationally with the remainder (402,570 ha) embodied in products exported interregionally.

Table 6.4 Waikato's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)

Interregional trade			
Agricultural land	45,070	447,640	402,570
Forest land	540	44,580	44,040
Degraded land	9,790	8,060	-1,730
Energy land	4,210	15,340	11,130
Interregional Balance of Trade	59,610	515,620	456,010
International trade			
Agricultural land	193,430	868,460	675,030
Forest land	19,010	263,250	244,240
Degraded land	16,600	17,530	930
Energy land	52,860	115,480	62,620
International Balance of Trade	281,900	1,264,720	982,820
Total Balance of Trade	341,510	1,780,340	1,438,830

A similar picture exists with forest land with the Waikato also being a net exporter of forest land (288,280 ha). Although a small amount of forest land is imported into the region (19,550 ha), this is far outweighed by the exports of forest land (307,830 ha). With forest land, the international exports are more important (203,230 ha) compared with the interregional exports (44,580 ha).

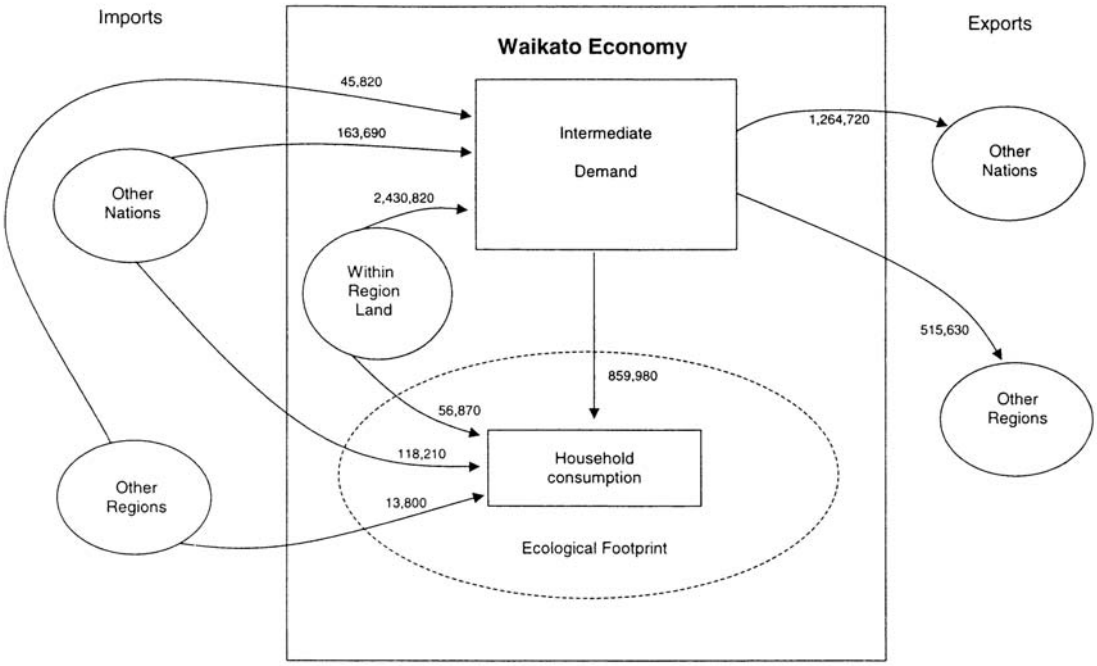
With energy land, the Waikato imports a considerable amount of products that require energy for their production, having an energy land component of 57,070 ha. Nevertheless the exports of energy intensive goods (eg. dairy products) means that there is an even greater amount (130,820 ha) of energy land embodied in Waikato exports.

The imports (26,390 ha) and exports (25,590 ha) of degraded land are small and, in any case, more or less balance.

6.5.3 Overall picture

Figure 6.1 provides a summary of the overall flows of embodied land through the Waikato economy. This diagram indicates that even though the local household consumption of land by Waikato residents is significant (1,048,860 ha), the Waikato economy is dominated by the exports of land to outside the region (1,780,350 ha). The Waikato is therefore a net provider of land to other regions and nations as reflected in its positive Ecological Balance of Trade of 1,438,830 ha. Waikato is therefore a producer of ecological capital for use by other regions and nations.

Figure 6.1 Flows of embodied land through the Waikato economy



7 Bay of Plenty's Ecological Footprint

7.1 Profile of the region

The Bay of Plenty region is the third-fastest growing region in New Zealand with the resident population increasing by 6.7 percent between the 1996 and 2001 censuses. At census night 2001 the resident population was estimated to be 239,412 or 6.4 percent of the nation's people. The majority of the population growth has occurred on the western half of the region, particularly Tauranga and Western Bay of Plenty districts. Respectively these districts were the second (16.9 percent) and eighth (9.3 percent) fastest growing districts in the country in the last intercensal period. By comparison, the eastern Kawerau and Whakatane districts showed negative population growth. The region has an estimated population density of just over 18 people per square kilometre, significantly higher than the national average.

One of the main reasons for this growth has been internal migration. For example, between 1991 and 1996 the Bay of Plenty showed the highest net internal migration gain of a region in the country (Statistics New Zealand, 1998h). Climatic conditions are a key factor attracting people, particularly the elderly, to the region. Nevertheless, the Bay of Plenty region also has higher than New Zealand average numbers of children.

The Bay of Plenty region occupies a total land area of 12,447 square kilometres. The region is characterised by volcanic activity. It has numerous volcanoes, hot pools and geysers. The eastern boundary of the region follows the Bay of Plenty coastline while the west, south and southeast boundaries are formed respectively by the Waikato, Hawke's Bay and Gisborne regions.

The Bay of Plenty economy has a comparative advantage in tourism, forestry, horticulture and dairy farming. Tourism is the region's most prominent industry. The accommodation, restaurants and cafe sector has a location quotient of 1.13. Rotorua is the main tourist destination in the region, with geothermal wonders, Maori culture and easily accessible outdoor pursuits as the key attractions. The region accounts for more than 10 percent of total guest-nights nationally (Statistics New Zealand, 1998h). Forestry and logging (LQ 3.37), wood and wood product processing (LQ 1.93), and paper and paper product processing (LQ 4.61) are also major industries in the region. The Norske Skog Tasman Pulp Mill in Kawerau is the major forest processing site. The Bay of Plenty region has an estimated 30 percent of the central North Island forests and includes the Kaingaroa State Forest. Nearly all of the forest milled is radiata pine. Favourable climate, soil, topography and a well-established roading system are key factors behind the success of forestry in the region. The region's temperate climate sustains a significant horticultural industry (LQ 2.47). More than 75 percent of the country's kiwifruit production is undertaken in the Bay of Plenty. Other sub-tropical fruit grown include tangelos, nashi, avocado, feijoas, tamarillos and passionfruit. Dairy farming, (LQ 1.21), is a growing industry. The 1997–98 GDP of the Bay of Plenty region is estimated to be $5.6 billion or 5.7 percent of the national GDP.

The port of Tauranga is the major exit point for the region's processed wood products. It is the largest port in New Zealand by volume of cargo loaded. With the so-called 'wall of wood'(the projected maturity of significant tracts of forest) expected in the near future, it is predicted that timber volumes across the port will increase substantially.

7.2 Overall ecological footprint and comparison with other regions

The Bay of Plenty region has an estimated ecological footprint of 618,260 ha, or 5.75 percent of New Zealand's total ecological footprint. This is the seventh largest ecological footprint of any region in New Zealand. By comparison, Bay of Plenty's ecological footprint is smaller than the Manawatu–Wanganui region (879,520 ha) but greater than the Northland region (477,120 ha), its two nearest neighbours in ecological footprint terms.

Per capita, Bay of Plenty's ecological footprint is the sixth smallest out of all regions at 2.59 ha per person. This means that Bay of Plenty residents have a similar per capita ecological footprint to Hawke's Bay residents (2.63 ha). The region's per capita ecological footprint is, thus, in relative terms, smaller than the average New Zealander's. On a per capita basis, a Bay of Plenty resident requires only 84.1 percent of that required to sustain an average New Zealander. This is a consequence of the region's agricultural land having higher than average yields per hectare. Given the region's comparative advantage in intensive farming activities requiring highly fertile land such as dairy farming, horticulture and fruit growing this would seem plausible.

The area of useful land available in the Bay of Plenty region is estimated to be 925,530 ha, giving the Bay of Plenty region an ecological surplus of 307,270 ha. The Bay of Plenty region's ecological footprint accounts for 66.8 percent of total available useful land. This is the 11th largest ecological surplus of any region in New Zealand, equating to 1.3 ha per Bay of Plenty resident.

7.3 Ecological footprint disaggregated by land type

The agricultural land component of Bay of Plenty's ecological footprint consists of 372,770 ha, or 60.3 percent of the region's footprint (refer to Table 7.1). An estimated 56.6 percent of this land is appropriated from within the region. This is lower relative to the nation but is largely explained by the region's higher agricultural yields per hectare. Despite the region's higher land productivities across all farming activities the region's sheep, beef and mixed livestock industry is unable to meet local demand. This has resulted in such products being appropriated from nearby regions with surpluses, in particular Gisborne and Manawatu–Wanganui regions. Some 69,020 ha of agricultural land is embodied in purchases of products made in other regions.

Table 7.1 Bay of Plenty's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	211,000	69,020	92,750	372,770	1.56	60.3
Forest land	50,120	300	8,110	58,530	0.25	9.5
Degraded land	56,720	6,200	5,990	68,910	0.29	11.1
Energy land	87,050	1,840	29,120	118,010	0.50	19.1
Total	404,890	77,360	135,970	618,220	2.59	100.0

The forest land component of the ecological footprint consists of 58,530 ha, 9.5 percent of Bay of Plenty's ecological footprint. Most of this land is appropriated from within the region although slightly less than 15 percent is embodied in goods and services purchased from other nations. The forest land component of the ecological footprint does not include the hypothetical land planted in trees required to sequester CO_2 emissions.

The degraded land component of the ecological footprint makes up 11.1 percent (68,910 ha) of Bay of Plenty ecological footprint. This consists mostly of land occupied by local businesses (excluding farming and forestry businesses) and residential properties. A further 17.7 percent of degraded land is embodied in the purchases made by Bay of Plenty residents from other regions and nations.

The energy land component of the Bay of Plenty's ecological footprint is 118,010 ha, 0.5 ha per capita or 19.1 percent of the region's footprint. In relative terms this is 15 percent higher than the nation. This suggests that local industries supplying goods and services to households are more energy intensive than their counterparts nationally. Overall, 73.8 percent of energy land is appropriated from within the region with an additional 24.7 percent embodied in goods and services produced from international sources.

7.4 Ecological footprint disaggregated by goods and services purchased

7.4.1 Purchase of Bay of Plenty produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products by Bay of Plenty residents accounted for 266,980 ha, representing 43.2 percent of the region's ecological footprint (refer to Table 7.2). The vast majority of this land is embodied in manufactured goods produced locally (177,090 ha) in particular processed food products. Significant quantities of land (66,800 ha) are also embodied in manufactured goods purchased by the region's residents from elsewhere within the country, in particular Gisborne and Manawatu–Wanganui regions. On a per capita basis, each Bay of Plenty resident consumes 18.2 percent less land embodied in manufactured goods (1.12 ha per person) than the average New Zealander does (1.37 ha per person).

Table 7.2 Bay of Plenty's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	35,190	1,120	1,640	37,950	0.16	6.1
Forestry	2,280	0	30	2,310	0.01	0.4
Fishing and hunting	10	0	10	30	0.00	0.0
Mining and quarrying	40	10	30	80	0.00	0.0
Manufacturing	177,090	66,800	23,090	266,980	1.12	43.2
Utilities and construction	30,890	140	6,750	37,770	0.16	6.1
Services	121,390	960	28,000	150,350	0.63	24.3
Domestic final demand	38,010	8,380	76,400	122,800	0.52	19.9
Total	404,890	77,420	135,960	618,260	2.59	100.0

Significant quantities of land are also embodied in service sector products consumed by Bay of Plenty residents. This equates to 150,350 ha of the region's ecological footprint or 0.63 ha per Bay of Plenty resident. At a first glance this figure appears very high but can be explained by backward linkages to primary sectors in the economy. Thus, while a service sector business may physically occupy only a small land area, the products that it purchases from other industries (such as food, paper, equipment, machinery etc) may contain substantial amounts of embodied land. Over 80 percent of land embodied in service sector products is appropriated from within the region with smaller amounts encapsulated in services purchased from abroad.

Purchases from other sectors by Bay of Plenty residents are much smaller than for manufacturing and service sector products. Such purchases accounted for 78,140 ha or 11.9 percent of the region's ecological footprint. This figure is primarily made up similar quantities of land embodied in agricultural products (37,950 ha) and utility and construction products (37,770 ha).

7.4.2 Purchase of goods and services produced outside Bay of Plenty (D_1+D_4)

Bay of Plenty residents also directly purchase products from outside the region. This accounts for 84,780 ha of the region's footprint. The vast majority of this embodied land is derived from international sources (76,400 ha). This includes land embodied in goods purchased from retailers that were made overseas, but sold locally with additional mark-up. Land embodied in items such as motor vehicles, computers, household appliances and imported food products is included in this figure. In relative terms, the land embodied in purchases made directly by households from aboard equates to 0.32 ha per capita, comparable with the New Zealand average of 0.33 ha per capita.

7.5 Ecological Balance of Trade and ecological interdependencies

Imports into the Bay of Plenty regional economy embody 288,860 ha of land, while exports from the region embody 731,000 ha. In this way, the region's economy has a large positive Ecological Balance of Trade, exporting 2.5 times more embodied land than it imports (refer to Table 7.3).

Table 7.3 Bay of Plenty's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	7,340	30,710	23,370
Forestry	110	41,290	41,180
Fishing and hunting	10	180	170
Mining and quarrying	50	0	-50
Manufacturing	92,500	18,590	-73,190
Utilities and construction	150	1,630	1,480
Services	1,220	2,390	1,170
Domestic final demand	8,380	0	-8,380
Interregional Balance of Trade	109,760	94,790	-14,970
International trade			
Agriculture	10,790	180,920	170,130
Forestry	2,140	115,150	113,010
Fishing and hunting	870	1,680	810
Mining and quarrying	140	270	130
Manufacturing	48,080	312,260	264,180
Utilities and construction	7,070	130	-6,940
Services	33,610	25,800	-7,810
Domestic final demand	76,400	0	-76,400
International Balance of Trade	179,100	636,210	457,110
Total Balance of Trade	288,860	731,000	442,140

7.5.1 Exports and imports by economic sectors

Over half of the land embodied in imports (140,580 ha) into the Bay of Plenty region is encapsulated in goods and services purchased by the manufacturing sector. Although this may appear high it is comparatively small when compared with the region's exports of land embodied in manufactured products (330,850 ha). A significant proportion of the land exported overseas is embodied in processed food products, particularly dairy products and fruits.

A significant amount of land is embodied in agricultural products that are exports from the Bay of Plenty region (211,630 ha). This is primarily land embodied in agricultural products sold overseas (180,920 ha) and is partially explained by the region's large fruit exports (eg. kiwifruit). Lesser quantities of agricultural land (39,710 ha) are embodied in sales to other regions, including livestock and horticultural produce destined for processing in other regions.

The Bay of Plenty service sector is a significant importer of embodied land (34,830 ha). The vast majority of this land (33,610 ha) is embodied in goods and services purchased by the service sector from international sources. The service sector uses paper products, equipment, furniture, and other capital items that have a high embodied land content. Some of this embodied land is re-exported in products sold, in turn, by the region's service sector. Sales of service sector products from the Bay of Plenty account for 28,190 ha of embodied land.

Overall, the service sector has a relatively small negative Ecological Balance of Trade of 6640 ha.

7.5.2 Exports and imports by type of land

Bay of Plenty is a net producer of agricultural land (refer to Table 7.4). International exports (355,560 ha) outweigh international imports (120,770 ha) by 2.9 times. Much of the land embodied in the region's exports is associated with horticultural products. On an interregional basis, the region is a significant net importer of agricultural land (68,210 ha). This includes significant imports of land embodied in sheep and beef products which are land intensive compared with other farming products such as those produced by dairying.

Table 7.4 Bay of Plenty's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	100,560	32,350	-68,210
Forest land	470	50,450	49,980
Degraded land	6,370	1,180	-5,190
Energy land	2,360	10,810	8,450
Interregional Balance of Trade	109,760	94,790	-14,970
International trade			
Agricultural land	120,770	355,560	234,790
Forest land	13,760	185,390	171,630
Degraded land	11,030	6,820	-4,210
Energy land	33,530	88,440	54,910
International Balance of Trade	179,090	636,210	457,120
Total Balance of Trade	288,850	731,000	442,150

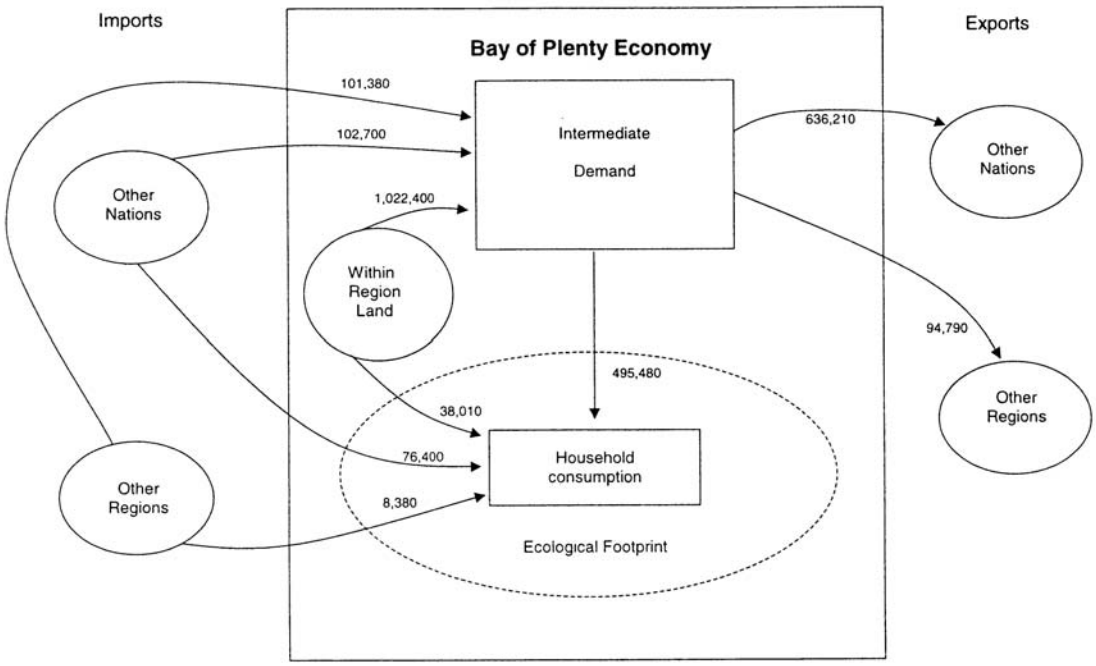
The region's economy is also a major net exporter of land embodied in forest products (221,610 ha), exporting over 16 times more forest land than it imports. With the region's proximity to the vast central North Island forests and the presence of the pulp mill at Kawerau, this is perhaps not surprising.

Although the quantity of energy land embodied in trade flows in the Bay of Plenty economy is smaller than both agriculture and forest land, it is still important. The energy land embodied in products exported internationally (88,440 ha) exceeds energy land imported from overseas (33,530 ha) by slightly more than 2.6 times. In terms of degraded land, the region has a small Ecological Balance of Trade deficit of 9400 ha.

7.5.3 Overall picture

The flow of embodied land through the Bay of Plenty economy is shown in Figure 7.1. This diagram shows that the Bay of Plenty region is largely driven by overseas demand for its products and is therefore a significant net exporter of embodied land. Exports to other nations account for 636,210 ha, an area slightly larger than the Bay of Plenty region's ecological footprint of 618,270 ha. Furthermore, the land embodied in international exports is 6.3 times larger than the land embodied in international imports. In embodied land terms, the region therefore has a positive Balance of Trade of some 442,140 ha.

Figure 7.1 Flows of embodied land through the Bay of Plenty economy



8 Gisborne's Ecological Footprint

8.1 Profile of the region

The Gisborne region has the smallest population of any region in the North Island. The 2001 Census recorded a resident population of 43,974, equating to 1.2 percent of the national population. The region's population reduced by 1,521 between the 1996 and 2001, a 4.0 percent drop in population. An analysis of the age-cohort structure of the resident population reveals that Gisborne has the youngest population of all regions in New Zealand. The region also has the largest proportion of people identifying themselves as Maori. The Gisborne urban area accounts for 72.1 percent of the region's population in 2001. It is the most sparsely populated region in the North Island with an estimated population density of 5.59 people per square kilometre in 1998.

The Gisborne region is the most eastern of all regions and has a land area of 835,100 ha or 3.0 percent of New Zealand's land area. The topography of the region makes it one of New Zealand's most isolated regions. The Bay of Plenty region forms the north-western boundary of the region, the Hawke's Bay region the south-western boundary, and the Pacific Ocean the eastern boundary. The Gisborne urban area lies at the confluence of three rivers, the Turanganui, Waimata and Taruheru. Much of the land is steep hill country. An estimated 88.2 percent of the region's land area is used for farming, the highest of any region in New Zealand (Statistics New Zealand, 1998i).

Sheep and beef farming (LQ 3.05), horticulture (LQ 4.32), forestry (LQ 4.48), fishing (LQ 1.36) and education (LQ 1.27) are the most important industries in the region. Sheep and beef farming is the dominant farming type in the region but is heavily dependent upon conservation tree planting to allow sustainable farming. Other agricultural farming includes horticulture, fruit growing and viticulture. The main crops grown are sweetcorn and squash. The region contains just under 25 percent of New Zealand's citrus plantations and an estimated 36 percent of its production (Statistics New Zealand, 1998i). The region is the third largest grape-producing region in New Zealand. Education is also a significant industry perhaps not surprisingly given that the region has the largest proportion of children of any region nationally. The region's 1997–98 GDP is estimated to be 0.9 billion or 1.0 percent of New Zealand's GDP.

During the last 20 years significant reforestation has occurred within the region. This is the result of the Gisborne region landforms (uplifted soft rock derived from marine sediments) having some of the greatest rates of natural erosion in the world. There are an estimated 359,000 ha of erosion prone hill country in the region, most of which is used for pastoral farming. Sustainable farming is only possible with soil conservation measures based around reforestation. The forestry and logging industry is thus a growing industry in the region. The east coast wood supply area accounts for 15.4 percent of the North Islands forestry estate. The region is also home to several wood processing facilities which produce laminated veneer, finger-jointed products and custom cut and treated timber.

8.2 Overall ecological footprint and comparison with other regions

The ecological footprint of Gisborne region is 141,660 ha, 1.32 percent of New Zealand's total ecological footprint. It is the fourth lowest of any region in the country. The region's ecological footprint compares with those of the West Coast (121,890 ha) and Marlborough (163,810 ha) regions. In comparison, Gisborne's ecological footprint is only 6.1 percent of Auckland region's ecological footprint (2,319,940 ha).

Per capita, Gisborne's ecological footprint, at 3.03 ha per person, is comparable with the national per capita footprint. This may appear surprising given the region's erosion prone nature which would suggest lower than average yields for farming activities. This is not however true. More than 92 percent of the region's farming land is used for sheep and beef farming at higher yields per ha than the nation. Land embodied in the products of other farming types is largely imported. Finally, erosion prone land has been made sustainable through forestry plantings. Taken together, these explanations mean that Gisborne requires less land to produce the goods and services consumed by its residents than the nation does.

The useful land area of Gisborne is 732,100 ha, meaning that Gisborne has an ecological surplus of 590,440 ha. Gisborne's ecological footprint accounts for only 19.3 percent of total useful land available in the region. In this way, the region has the highest ecological surplus per capita of any region. Overall, Gisborne is self-sufficient in ecological footprint terms with a considerable ecological surplus available.

8.3 Ecological footprint disaggregated by land type

The agricultural land component of Gisborne's ecological footprint is estimated to be 96,010 ha (refer to Table 8.1). This represents 67.8 percent of the region's ecological footprint. Like most New Zealand regions this is predominantly made up of land appropriated from within the region (68,290 ha). Nevertheless, an estimated 9,470, or 6.7 percent of the region's footprint is embodied in goods and services purchased from primarily Bay of Plenty (7,600 ha) and Hawke's Bay (1380 ha) regions. On a per capita basis, agricultural land equates to 2.06 ha per Gisborne resident.

Table 8.1 Gisborne's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	68,290	9,470	18,250	96,010	2.06	67.8
Forest land	10,940	330	1,310	12,580	0.27	8.9
Degraded land	13,790	780	910	15,480	0.33	10.9
Energy land	11,910	730	4,930	17,570	0.38	12.4
Total	104,930	11,310	25,400	141,640	3.03	100.0

The forest land component of the ecological footprint amounts to 12,580 ha. This represents 8.9 percent of the region's ecological footprint. Over 86 percent of forest land appropriated by Gisborne residents originates from within the region. The forest land component does not include the hypothetical land appropriated to sequester CO_2 emissions associated with the goods and services consumed by Gisborne residents.

The degraded land component of the region's ecological footprint makes up 10.9 percent, or 15,480 ha, of the total Gisborne ecological footprint. This land primarily consists of land occupied by the residential properties, although it also encapsulates non-agricultural land embodied in goods and services purchased by residents. In this way, the degraded land component of the Gisborne ecological footprint is almost entirely (over 89 percent) appropriated from within the region.

The energy land component of Gisborne's ecological footprint is estimated to be 17,570 ha, 12.4 percent of the region's footprint. This is lower relative to the nation where energy land constitutes 16.6 percent of the total footprint. This would seem to infer that Gisborne industries produce goods and services that are less energy intensive than the New Zealand average. However, other possible explanations exist, including:

(1) the region's climate is significantly warmer, which in turn, means that less energy is required for heating purposes

(2) per capita incomes are lower restricting household purchases of appliances and machinery

(3) higher numbers of children, rather than adults, may mean less energy is used per capita.

8.4 Ecological footprint disaggregated by goods and services purchased

8.4.1 Purchase of Gisborne produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products by Gisborne residents accounts for 56,240 ha (39.7 percent) of the region's ecological footprint (refer to Table 8.2). The vast majority of this land is embodied in manufactured goods produced locally (41,950 ha), in particular processed food products grown on the region's farmland. Smaller quantities of land are also embodied in manufactured goods purchased by the region's residents from the Bay of Plenty (8060 ha) and Hawke's Bay (1150 ha) regions. On a per capita basis, the land embodied in manufactured product purchases by Gisborne residents (1.20 ha per person) is lower relative to the nation (1.37 ha per person).

Table 8.2 Gisborne's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	19,370	10	360	19,740	0.42	13.9
Forestry	840	0	0	850	0.02	0.6
Fishing and hunting	0	0	0	0	0.00	0.0
Mining and quarrying	10	0	10	20	0.00	0.0
Manufacturing	41,950	9,570	4,710	56,240	1.20	39.7
Utilities and construction	6,960	60	860	7,880	0.17	5.6
Services	29,640	370	4,560	34,570	0.74	24.4
Domestic final demand	6,140	1,330	14,890	22,350	0.48	15.8
Total	104,920	11,340	25,400	141,660	3.03	100.0

Service sector products consumed by Gisborne residents also embody significant quantities of land. Such land accounts for 24.4 percent (0.74 ha per person) of the region's ecological

footprint. At first this figure may appear high but closer examination reveals it occurs because of backward linkages to farming, forestry and other sectors. Although the actual physical land occupied by a service sector business may be small, the land embodied in products the business purchases can be very high (eg. land embodied in food, paper, equipment, machinery and so forth). In Gisborne's case most of the land embodied in service sector commodities is provided locally (29,640 ha) with smaller amounts derived from overseas (4550 ha).

Land embodied in residents' purchases from the remaining sectors of the economy is relatively small in comparison with the land embodied in manufactured and service sector products. Such purchases account for 28,490 ha of embodied land, or 20.1 percent of the region's ecological footprint.

8.4.2 Purchase of goods and services produced outside Gisborne (D_1+D_4)

Gisborne residents also directly purchase products from outside the region, accounting for 16,220 ha of the region's footprint. Just over 92 percent of this embodied land comes from international sources. This includes land embodied in goods purchased from retailers that were made overseas but sold locally with an additional mark-up. In this way, land embodied in items such as motor vehicles, computers, household appliances and imported food products is included in this figure.

8.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Gisborne regional economy is 54,030 ha (refer Table 8.3). By contrast, the land embodied in exports from the Gisborne economy is 398,760 ha. Gisborne therefore has a substantial positive Ecological Balance of Trade, exporting nearly 7.4 times more embodied land than it imports.

Table 8.3 Gisborne's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	150	77,940	77,790
Forestry	40	31,240	31,200
Fishing and hunting	20	160	140
Mining and quarrying	10	10	0
Manufacturing	17,370	2,010	-15,360
Utilities and construction	70	350	280
Services	440	350	-90
Domestic final demand	1,330	0	-1,330
Interregional Balance of Trade	19,430	112,050	92,620
International trade			
Agriculture	5,120	181,620	176,500
Forestry	470	49,060	48,590
Fishing and hunting	250	420	170

Mining and quarrying	30	80	50
Manufacturing	7,710	51,050	43,340
Utilities and construction	890	40	-850
Services	5,240	4,440	-800
Domestic final demand	14,890	0	-14,890
International Balance of Trade	34,600	286,710	252,110
Total Balance of Trade	54,030	398,760	344,730

8.5.1 Exports and imports by economic sectors

Some 259,560 ha of embodied land is exported from the Gisborne region in agriculture sector products while only 5,270 ha is embodied in imported agriculture sector products. In this way the region is a substantial net exporter of land embodied in agricultural products, exporting 57.5 times more land than it imports. Over 70 percent of the land embodied in agricultural products is exported overseas.

The strong primary sector export focus of the region is further reinforced by the quantity of land embodied in forest products exported outside of the region. Unlike agriculture sector products, which are predominantly sent offshore, the region's forest products are sold to nearby regions (31,240 ha) as well as overseas (49,060 ha). The land embodied in the sales of forest products accounts for 23.1 percent of the region's Ecological Balance of Trade surplus.

Although Gisborne's manufacturing sector is a net exporter of embodied land (27,960 ha), it is a significant net importer in interregional terms requiring some 15,350 ha to sustain its activities. Other industries in the region have smaller and near neutral ecological balances of trade: fishing and hunting (310 ha), utilities and construction (-570 ha) and services (-890 ha).

8.5.2 Exports and imports by type of land

Gisborne is a net producer of agricultural land having an ecological trade surplus of 259,810 ha, an estimated 198,180 ha of which is embodied in products sold internationally (refer to Table 8.4). In this way exports of embodied agricultural land outweigh imports of embodied agricultural land by just over seven times.

Table 8.4 Gisborne's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	17,100	78,730	61,630
Forest land	440	31,700	31,260
Degraded land	850	450	-400
Energy land	1,030	1,170	140
Interregional Balance of Trade	19,420	112,050	92,630
International trade			
Agricultural land	25,880	224,060	198,180
Forest land	1,930	56,090	54,160
Degraded land	1,710	1,030	-680

Energy land	5,080	5,530	450
International Balance of Trade	34,600	286,710	252,110
Total Balance of Trade	54,020	398,760	344,740

Forest land embodied in exports also represents a significant proportion of the region's trade surplus, amounting to 85,420 ha (25 percent) in net terms. This is not surprising given the region's comparative advantage in forestry. An estimated 56,090 ha of forest land is embodied in products destined for other nations while the remaining 31,700 ha is exported interregionally primarily for processing purposes.

Lesser quantities of embodied energy and degraded land are traded within the Gisborne economy. In embodied energy land terms, the Gisborne region has a close to neutral Balance of Trade both interregionally (140 ha) and internationally (450 ha). Only in the trading of degraded land does the region require more embodied land from external sources (2560 ha) than it exports outside the region (1480 ha). This is not surprising given that many of the region's service sector industries are unable to satisfy local demand for their products.

8.5.3 Overall picture

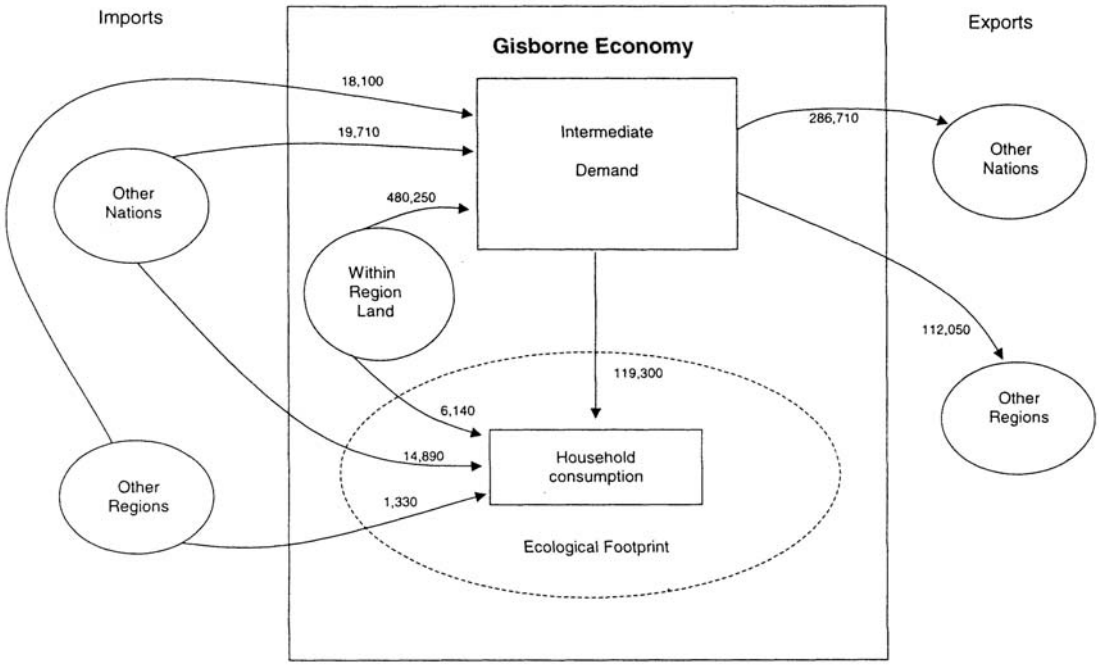
Figure 8.1 provides a summary of the overall flows of embodied land associated with the Gisborne economy. This diagram indicates that Gisborne is:

(1) comparatively self-sufficient in terms of land, with relatively small embodied land areas required to meet domestic consumption

(2) exports a significant component of its biologically productive land abroad. In this way, the land embodied in international exports (286,710 ha) considerably outweighs land embodied in international imports (19,710 ha).

Overall, considering both international and interregional trade, Gisborne has an embodied land Balance of Trade surplus of 344,730 ha.

Figure 8.1 Flows of embodied land through the Gisborne economy



9 Hawke's Bay's Ecological Footprint

9.1 Profile of the region

The Hawke's Bay region is one of the most urbanised regions in the country with only Nelson, Auckland and Wellington regions more urbanised. The 2001 Census estimates the resident population to be 142,947 people. This accounts for 3.8 percent of the national population, making the region the 11th largest in the country. The regional population has remained stable between the 1996 and 2001 censuses, with only a small increase of 159 people. Most people reside in the two main urban areas of Napier and Hastings, together accounting for 79.5 percent of the region's population in 2001. The age structure of the population reveals that the region had fewer people aged 20–34 years than the national average. Greater employment, career advancement and education opportunities account for migration out of the region by this age group. The region has an estimated population density of 10.23 people per square kilometre, making the region more sparsely populated than the New Zealand average (Statistics New Zealand, 1998j).

Situated on the east coast of the North Island, the Hawke's Bay region occupies an estimated 1,416,400 ha or 5.1 percent of New Zealand's land area. To the east the Pacific Ocean, and to the west by the Ruahine, Kaweka, Huiarau and Kaimanawa ranges bound the region. The region has a diverse topography characterised by mountains, hill country, alluvial terraces, sand dunes and swamps. The soils of the alluvial Heretaunga and Ruataniwha plains are very fertile, renewed of nutrients by seasonal flooding. The western mountains shelter the Hawke's Bay from the prevailing westerly weather. The region has a sunny temperate climate with warm summers and mild winters. As land used by horticulture and cropping has intensified, the potential for soil loss from wind erosion has also increased.

The 1997–98 GDP of the Hawke's Bay region is estimated to be 3.5 billion or 3.6 percent of the national GDP. The region's economy is an export commodity based economy and is vulnerable to commodity price changes on the world market. Sheep, beef and mixed livestock farming (LQ 1.92), horticulture (LQ 3.75) and services to agriculture (LQ 2.39) are the key primary industries in which the region has a comparative advantage. This spills over into the manufacturing sector where the region shows dominance in meat processing (LQ 3.32), manufacture of other foods (LQ 1.72) and beverage manufacture (3.01). Proximity to the central north island forests, particularly those surrounding Taupo District, has led to significant growth in paper and paper product manufacturing. At the 1 April 1998, the region had an estimated 119,200 ha of forest, or 9.9 percent of the North Island's forestry estate. The discovery of gas at the Kauhauroa-1 and Awatere-1 wells north east of Wairoa in early 1998 is expected to boost the regional economy.

The region's fertile soils and climate mean that horticulture, fruit growing, market gardening and viticulture are well established and dominant industries of the economy. In recent years there has been a significant increase in land set aside for horticulture. Pipfruit exports are the highest of any region in the country. The main fruits grown include apples, pears, nectarines and peaches. The Hawke's Bay is also the second largest grape producing region in New Zealand with local soils ideally suited to growing Chardonnay and Cabernet grapes. In 1997 the region accounted for 27.9 percent of New Zealand's total vineyard land area and since then this has increased significantly.

9.2 Overall ecological footprint and comparison with other regions

Hawke's Bay has an ecological footprint of 384,660 ha. This represents 3.58 percent of New Zealand's total ecological footprint and is the ninth highest ecological footprint of any region. The Hawke's Bay ecological footprint is comparable to Southland's (375,310 ha).

On a per capita basis, Hawke's Bay has the seventh lowest ecological footprint out of the 16 regions, at 2.63 ha per capita. This figure is relatively low compared with the national average, primarily because of the high productivity of agricultural land within the Hawke's Bay region. This means that less agricultural land per capita is required to produce agricultural products than in the nation. The highly fertile nature of the region's plains is a key influence.

The useful land area of Hawke's Bay is 1,048,480 ha, meaning that Hawke's Bay has an ecological surplus of 663,820 ha. Or, stated alternatively, the region's ecological surplus is 1.7 times its ecological footprint. In relative terms, Hawke's Bay has the fourth largest surplus of any region nationally. Overall this means that the region is self-sufficient in ecological footprint terms.

9.3 Ecological footprint disaggregated by land type

The agricultural land component of the Hawke's Bay region's ecological footprint equates to 259,850 ha (see Table 9.1). This represents 67.6 percent of the region's ecological footprint. This land is predominantly appropriated from within the region (190,830 ha). Lesser amounts of agricultural land are appropriated from other nations (57,670 ha) and from other regions (11,350) particularly from the Waikato region (9670 ha).

Table 9.1 Hawke's Bay's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	190,830	11,350	57,670	259,850	1.78	67.6
Forest land	29,300	1,190	4,900	35,390	0.24	9.2
Degraded land	16,410	3,670	3,700	23,780	0.16	6.2
Energy land	46,270	1,360	17,930	65,560	0.45	17.0
Total	282,810	17,570	84,200	384,580	2.63	100.0

The forest land component of the Hawke's Bay's ecological footprint consists of 35,390 ha or 9.2 percent of the region's footprint. This is mostly within region land (29,300 ha) although some 4900 ha is embodied in goods and services purchased from other nations. The remaining 1190 ha are appropriated from other regions, mainly Gisborne. Forest land does not include the planted forest required to sequester CO_2 emissions.

The degraded land component of the ecological footprint is 23,780 ha or 6.2 percent of the entire ecological footprint. This is mostly within region land, consisting primarily of residential properties and land embodied in goods and services purchased from local manufacturing and service sector businesses (excluding farming and forestry). Similar quantities of degraded land are imported interregionally (3670 ha) and internationally (3700 ha).

The energy land component of the region's footprint is estimated to be 65,560 ha, 17.0 percent of the region's total footprint. In relative terms, energy land embodied in the goods and services consumed by Hawke's Bay residents (0.45 ha per capita) is similar to that consumed by New Zealanders generally (0.50 ha per capita). A warmer than average climate, and hence lower energy requirement among other things explains this figure.

9.4 Ecological footprint disaggregated by goods and services purchased

9.4.1 Purchase of Hawke's Bay produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products by Hawke's Bay residents accounts for 173,310 ha (45.1 percent) of the region's ecological footprint (refer to Table 9.2). The vast majority of this land is embodied in manufactured goods produced locally (145,530 ha), in particular processed food products. Smaller quantities of land (16,840 ha) are also embodied in manufactured goods purchased by the region's residents from overseas. Overall, the land embodied in manufactured products purchased by Hawke's Bay residents (1.19 ha per capita) is only 86 percent of the New Zealand average (1.37 ha per capita).

Table 9.2 Hawke's Bay's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	34,050	70	730	34,850	0.24	9.1
Forestry	1,770	10	20	1,800	0.01	0.5
Fishing and hunting	10	0	10	20	0.00	0.0
Mining and quarrying	20	10	20	50	0.00	0.0
Manufacturing	145,530	10,940	16,840	173,310	1.19	45.1
Utilities and construction	12,530	810	3,450	16,800	0.11	4.4
Services	64,670	430	15,910	81,000	0.55	21.1
Domestic final demand	24,210	5,390	47,220	76,830	0.53	20.0
Total	282,800	17,660	84,200	384,660	2.63	100.0

Significant quantities of land (81,000 ha) are also embodied in service sector products consumed by Hawke's Bay residents. On a per capita basis, this amounts to 0.55 ha per Hawke's Bay resident. At first glance this figure appears very high, but can be explained by backward linkages to primary sectors in the economy. Thus while a service sector business may physically occupy only a small land area, the products that it purchases from other industries (such as food, paper, equipment, machinery etc) may contain substantial amounts of embodied land. A significant majority of land embodied in service sector products (64,670 ha) comes from within the region.

Land embodied in the purchases from other sectors by Hawke's Bay residents (53,520 ha) is significantly smaller than that embodied in manufactured and service sector products. Consumption of products produced by the agricultural and utility and construction sectors respectively account for 34,850 ha and 16,800 ha of the region's ecological footprint.

9.4.2 Purchase of goods and services produced outside Hawke's Bay (D_1+D_4)

Hawke's Bay residents also directly purchase products from outside the region, which accounts for 52,610 ha of the region's footprint. The bulk of this land (47,220 ha) is derived from international sources. This includes land embodied in goods purchased from local retailers that were made overseas but sold with an additional mark-up. Thus land embodied in items such as motor vehicles, computers, household appliances and imported food products is included in this figure.

9.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Hawke's Bay regional economy is 195,060 ha. In comparison, land embodied in exports from the Hawke's Bay economy equates to 1,066,330 ha. This means that the Hawke's Bay region is an overall net producer of embodied land with a positive Ecological Balance of Trade of 871,270 ha (refer to Table 9.3).

Table 9.3 Hawke's Bay's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	860	79,170	78,310
Forestry	340	10,150	9,810
Fishing and hunting	0	80	80
Mining and quarrying	30	20	-10
Manufacturing	47,940	34,850	-13,090
Utilities and construction	830	480	-350
Services	520	480	-40
Domestic final demand	5,390	0	-5,390
Interregional Balance of Trade	55,910	125,220	69,310
International trade			
Agriculture	8,800	307,130	298,330
Forestry	450	40,510	40,060
Fishing and hunting	550	1,010	460
Mining and quarrying	110	200	90
Manufacturing	59,920	577,740	517,820
Utilities and construction	3,550	70	-3,480
Services	18,550	14,460	-4,090
Domestic final demand	47,220	0	-47,220
International Balance of Trade	139,150	941,110	801,960
Total Balance of Trade	195,060	1,066,330	871,270

9.5.1 Exports and imports by economic sectors

Over half of the land embodied in imports (107,860 ha) into the Hawke's Bay region is in goods and services purchased by the manufacturing sector. Although this may appear high it is comparatively small when compared with the region's exports of land embodied in manufactured products (612,590 ha). The vast majority of this land (577,740 ha) is embodied in processed food products destined for locations offshore. These products include processed sheep and beef meat, processed horticulture and fruit produce.

The Hawke's Bay is also a net exporter of land embodied in agriculture sector products both regionally (78,310 ha) and internationally (298,330 ha). International exports encapsulate land embodied in wool, unprocessed fruit and horticulture products. Like many regions in New Zealand, the Hawke's Bay is driven by external (particularly international) demand for its primary sector products. Thus, it is not surprising that the land embodied in exported agricultural sector products outweighs imported equivalents by approximately 10.8 times.

Unlike the region's agriculture and manufacturing industries, the service sector is a net importer of embodied land (4130 ha). The vast majority of land embodied in service sector products originates from offshore (18,550 ha). While this figure may appear high, it is explained by indirect purchases of products with high embodied land contents (eg. food, paper, and equipment). All the remaining sector groups of the Hawke's Bay economy have a positive Ecological Balance of Trade with the exception of the utilities and construction sector which imports some 3850 ha of embodied land.

9.5.2 Exports and imports by type of land

The Hawke's Bay region is a very large net provider of embodied agricultural land, exporting an estimated 837,910 ha to other countries and a further 109,340 ha to other New Zealand regions (refer to Table 9.4). This represents primarily the land occupied by the region's sheep, beef and mixed livestock farms and orchards. Generally speaking, the region's agricultural land is embodied in farm products that flow onto local processing/manufacturing facilities and, in turn, leave New Zealand destined for international markets.

Table 9.4 Hawke's Bay's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	47,860	109,340	61,480
Forest land	1,910	11,800	9,890
Degraded land	3,960	620	-3,340
Energy land	2,180	3,460	1,280
Interregional Balance of Trade	55,910	125,220	69,310
International trade			
Agricultural land	103,780	837,910	734,130
Forest land	7,310	64,900	57,590
Degraded land	6,930	3,530	-3,400
Energy land	21,140	34,770	13,630
International Balance of Trade	139,160	941,110	801,950
Total Balance of Trade	195,070	1,066,330	871,260

Forest land embodied in exports is also a significant proportion of the region's large positive ecological trade balance. Forest land embodied in products sold internationally equates to 64,900 ha, while the equivalent interregional figure is 11,800 ha. The region's forest land is primarily located in the west and north. It is exported internationally from the port of Napier.

Less energy land (14,910 ha) is exported in products produced by the region's industries. In the case of degraded land, the Hawke's Bay is a net consumer both interregionally (-3340 ha) and internationally (-3400 ha). There are at least two possible reasons for this, namely:

(1) local service sector businesses are unable to meet local demand for their products

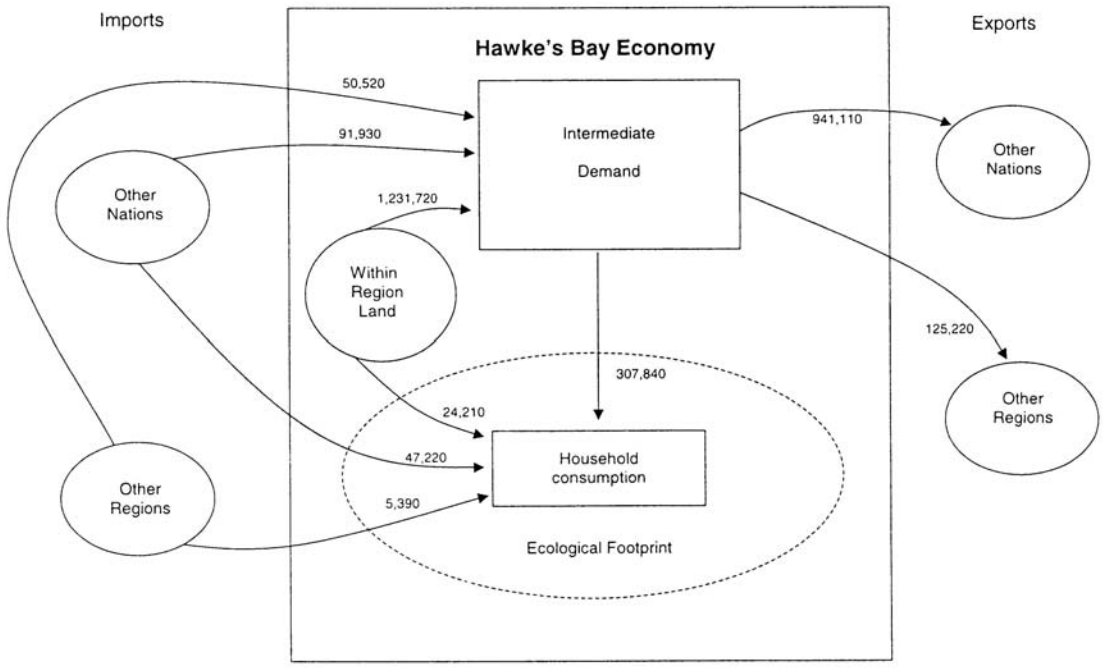
(2) critically, service sector industries are absent from the Hawke's Bay economy.

In both cases, this results in the importation of degraded land embodied in the goods and services required to fill these gaps.

9.5.3 Overall picture

Figure 9.1 provides a summary of the overall flows of embodied land through the Hawke's Bay region economy. This diagram shows that the region's ecological footprint (384,660 ha) is significant less than the land embodied in overseas exports (941,110 ha). The region is exporting most of its ecological capital overseas. Considering land embodied in both international and interregional trade, the Hawke's Bay region has an overall Balance of Trade surplus of 871,270 ha.

Figure 9.1 Flows of embodied land through the Hawke's Bay economy



10 Taranaki's Ecological Footprint

10.1 Profile of the region

On census night 2001 Taranaki's resident population was 102,858, representing 2.8 percent of the national population. In population terms Taranaki region is the second smallest region in the North Island. In the intercensal period Taranaki experienced a significant population decline of 3732 people or 3.5 percent of the population. Most of this population loss was due to internal migration, particularly to the neighbouring Manawatu–Wanganui and Waikato regions. Population projections (based on 1996 Census data) suggest that the region will continue to lose people. Significant proportions of those leaving the region are in the 15–24 year age group. Possible reasons for this include lack of access to education and employment opportunities. Almost 47 percent of the population reside in New Plymouth (47,763 people), the region's major urban area.

The region is one of New Zealand's smallest, accounting for only 727,300 ha. The Mohakatino river marks the northern boundary of the region, the Waitotara river the southern boundary and the Whanganui river the inland eastern boundary. The most prominent feature of the region is Mt Taranaki/Egmont (2518 metres), an almost perfectly symmetrical cone-shaped volcano. Mt Taranaki is a major influence on climatic conditions in the region, resulting in considerable variation throughout the region. Land quality in the region varies considerably from fertile well drained plains and terraces to steep, erosion prone mountain slopes. Most of the region's rivers, including the Waiwhakaiho River that flows through New Plymouth, fan out from Mt Taranaki.

The 1997–98 GDP of the Taranaki region is estimated to be $3.2 billion or 3.2 percent of the national GDP. The extraction, exploration and processing of fossil fuels are the region's most significant industries. Almost all of New Zealand's fossil fuels are extracted from the Kapuni, Maui, McKee, Ngatoro and Waihapa/Ngaere fields. The Maui gas field covers 76,500 ha and is the largest in New Zealand, accounting for an estimated two-thirds of economically recoverable reserves. At current extraction rates it is likely to be depleted by 2006 and possibly sooner. Gas from the field is pumped to New Plymouth before shipment to the Marsden Point refinery in the Northland region. The region also has two methanol plants located at Motunui and in the Waitara Valley. Motunui is one of the world's largest methanol production facilities. Specifically, the oil extraction and exploration industry has a location quotient of 33.06, manufacture of petroleum products 4.41 and gas treatment and distribution 4.87. Closely associated is the region's comparative advantage in basic metal manufacture (LQ 3.43).

Other major industries include dairying and energy production. Dairy farming (LQ 5.70) and the processing of dairy products (LQ 6.72) are also significant industries regionally. The fertile volcanic soils and mild climate are ideal for dairy farming and the region was the first specialised dairying area in New Zealand. Taranaki has two major power stations. The New Plymouth thermal power station is the second largest in the country with a net output capacity of 575 megawatts. Smaller gas turbine stations which utilise gas from the Maui, Waihapa/ Ngaere fields are located at Stratford.

10.2 Overall ecological footprint and comparison with other regions

The Taranaki region has an estimated ecological footprint of 233,150 ha, 2.17 percent of New Zealand's total ecological footprint. This is the sixth smallest ecological footprint of any region

in New Zealand. By comparison, Taranaki's ecological footprint is smaller than Southland's (375,310 ha) but larger than Marlborough's (163,810 ha).

In per capita terms, Taranaki's ecological footprint is the fourth lowest out of all regions at 2.19 ha per person. This means that Taranaki residents have a similar per capita ecological footprint to Tasman residents (2.08 ha). The region's per capita ecological footprint is in relative terms lower than the average New Zealander's. On a per capita basis, a Taranaki resident requires only 70.1 percent of the land required to sustain an average New Zealander annually. This is a consequence of the region's agricultural land having higher than average yields per hectare. Given the region's comparative advantage in intensive dairy farming on fertile land this comes as no surprise.

The useful land area of Taranaki is 635,250 ha, ie. Taranaki has an ecological surplus of 402,100 ha, or put alternatively, the region's ecological surplus is 1.7 times its ecological footprint. In this way, the region is similar to the Hawke's Bay region. Overall, Taranaki is self-sufficient in ecological footprint terms with a considerable ecological surplus available.

10.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 154,910 ha (refer to Table 10.1). This equates to 66.5 percent of Taranaki's ecological footprint and in relative terms is comparable with the nation's 68.8 percent. As with most of New Zealand's rural regions, the majority of the agricultural land comes from within the region, but there are significant relative differences. While an estimated 67.6 percent of agricultural land originates from within the Taranaki, this figure is significantly lower than the corresponding national figure of approximately 80.0 percent. This is explained by the higher than average amount of agricultural land embodied in interregional trade flows which, in turn, is a consequence of Taranaki's sheep, beef and mixed livestock and horticulture industries not being able to satisfy local demand. Not surprisingly, agricultural land embodied in interregional imports originate from neighbouring regions and from Canterbury and Southland which have a significant relative comparative advantage in farming types not present in Taranaki.

Table 10.1 Taranaki's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	104,770	11,070	39,070	154,910	1.45	66.5
Forest land	4,090	1,550	3,620	9,260	0.09	4.0
Degraded land	20,130	450	4,040	24,620	0.23	10.6
Energy land	28,680	1,170	14,400	44,250	0.41	19.0
Total	157,670	14,240	61,130	233,040	2.18	100.0

The forest land component of the ecological footprint consists of 9260 ha or 4.0 percent of the region's footprint. Of this figure an estimated 44.0 percent (4090 ha) of the forest land component comes from within the region, while a similar amount (39.0 percent or 3620 ha) is embodied in goods and services purchased from overseas. Lesser amounts of forest land are embodied in interregional trade products purchased from primarily the Gisborne and Waikato regions. The forest land component of the footprint does not include the hypothetical land planted to sequester CO_2 emissions.

The degraded land component of the ecological footprint makes up 10.6 percent (24,620 ha) of the Taranaki ecological footprint. Of this 81.7 percent is within-region land consisting of land occupied by residents' households and local businesses (excluding farming and forestry holdings). A further 16.4 percent or 4040 ha is degraded land embodied in goods and services purchased by Taranaki residents from other nations.

The energy land component of Taranaki ecological footprint is 44,250 ha. This represents 19.0 percent of Taranaki's ecological footprint, approximately 14 percent higher than the nation in relative terms. This suggests that Taranaki residents purchase goods and services that are slightly more energy intensive than those purchased by the average New Zealander. Some 14,400 ha of energy land is embodied in goods and services purchased from other nations.

10.4 Ecological footprint disaggregated by goods and services purchased

10.4.1 Purchase of Taranaki produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 99,120 ha of embodied land in Taranaki's ecological footprint (refer to Table 10.2). This amounts to nearly 42.5 percent of the entire ecological footprint of the Taranaki region. Most of this embodied land (75,550 ha) is in manufacturing products produced within Taranaki itself. Similar amounts of land were embodied in manufacturing products purchased from other regions (11,670 ha) and from overseas (11,900 ha). A significant component of the land embodied in manufacturing products is agricultural land.

Table 10.2 Taranaki's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	15,210	110	400	15,720	0.15	6.7
Forestry	510	580	10	1,100	0.01	0.5
Fishing and hunting	10	0	10	10	0.00	0.0
Mining and quarrying	300	0	10	310	0.00	0.1
Manufacturing	75,550	11,670	11,900	99,120	0.93	42.5
Utilities and construction	6,540	30	2,790	9,360	0.09	4.0
Services	43,610	380	11,260	55,240	0.52	23.7
Domestic final demand	15,950	1,580	34,750	52,280	0.49	22.4
Total	157,670	14,340	61,130	233,150	2.19	100.0

Land embodied in service sector products (eg. finance, business, insurance, government, education, health) accounted for 55,240 ha. This equates to 23.7 percent of the region's ecological footprint. At first glance this finding may appear extraordinarily high given the small physical land area occupied by service sector industries. This result is, however, explained by the significant quantity of land embodied in inter-industry purchases made by the service sector. Overall, a significant proportion of the land embodied in service sector products is made up of within region land (43,610 ha) with lesser amounts coming from off-shore locations (11,260 ha). The land embodied in other products consumed by Taranaki residents is

significantly smaller than for manufacturing and service sector goods and services: agriculture products (15,720 ha), utilities and construction (9360 ha), and forestry products (1100 ha).

10.4.2 Purchase of goods and services produced outside Taranaki (D_1+D_4)

Residents directly purchase products from outside the region, an estimated 36,330 ha (1580 ha interregionally, 34,750 ha internationally). This includes direct importation of motor vehicles.

10.5 Ecological Balance of Trade and ecological interdependencies

141,570 ha of embodied land is imported into Taranaki compared to 940,900 ha embodied in exports from the Taranaki economy, making Taranaki a net exporter of embodied land, 6.6 times more embodied land is exported than it imported.

Table 10.3 Taranaki's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	1,940	224,210	222,270
Forestry	4,590	0	-4,590
Fishing and hunting	0	0	0
Mining and quarrying	0	2,010	2,010
Manufacturing	21,310	34,370	13,060
Utilities and construction	30	350	320
Services	440	270	-170
Domestic final demand	1,580	0	-1,580
Interregional Balance of Trade	29,890	261,210	231,320
International trade			
Agriculture	7,110	40,140	33,030
Forestry	90	7,580	7,490
Fishing and hunting	120	250	130
Mining and quarrying	510	10,850	10,340
Manufacturing	53,140	611,560	558,420
Utilities and construction	2,870	40	-2,830
Services	13,090	9,260	-3,830
Domestic final demand	34,750	0	-34,750
International Balance of Trade	111,680	679,690	568,010
Total Balance of Trade	141,570	940,900	799,330

10.5.1 Exports and imports by economic sectors

Over half of the land embodied in imports (74,450 ha) into the Taranaki region is encapsulated in goods and services purchased by the manufacturing sector. Although this may appear high it is comparatively small when compared with the region's exports of land embodied in manufactured products (645,930 ha). A significant proportion of the embodied land exported overseas is contained within dairy products and thus, indirectly, the land occupied by the region's dairy farms.

A significant amount of land is embodied in agricultural products that are exports from the Taranaki region (264,350 ha). This consists mainly of dairy and beef cattle and to a lesser extent sales of sheep, wool and horticultural produce processed further in other regions.

The Taranaki service sector is also a significant importer of embodied land (13,530 ha). The vast majority of this land is embodied in goods and services purchased by the service sector from international sources. This ranges from computers to specialist services required in the energy industries. The service sector also uses paper products, equipment, furniture, and other capital items that have a high embodied land content. Some of this embodied land is re-exported in products sold to other regions.

The region's comparative advantage in petroleum product manufacturing is also evident. Although not all of the land occupied by the energy fields themselves is included (as it is predominantly located in the Tasman Sea), a small but significant component is identified in embodied land exports of mining and quarrying products heading overseas (10,850 ha).

10.5.2 Exports and imports by type of land

The Taranaki region is a very large net exporter of agricultural land (see Table 10.4). Net exports of agricultural land equate to 773,970 ha or 96.8 percent of the region's Balance of Trade. Agricultural land embodied in products sold by the Taranaki economy is 9.6 times greater than agricultural land embodied in products purchased by the region.

Table 10.4 Taranaki's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	21,370	249,770	228,400
Forest land	6,300	820	-5,480
Degraded land	610	4,790	4,180
Energy land	1,600	5,820	4,220
Interregional Balance of Trade	29,880	261,200	231,320
International trade			
Agricultural land	69,110	614,680	545,570
Forest land	5,880	12,870	6,990
Degraded land	13,410	16,460	3,050
Energy land	23,280	35,680	12,400
International Balance of Trade	111,680	679,690	568,010
Total Balance of Trade	141,560	940,890	799,330

Lesser amounts of forest land (1510 ha), degraded land (7240 ha) and energy land (16,620 ha) are embodied in goods and services exported from the region. Only in forest land is Taranaki a net consumer of land (-5480 ha).

10.5.3 Overall picture

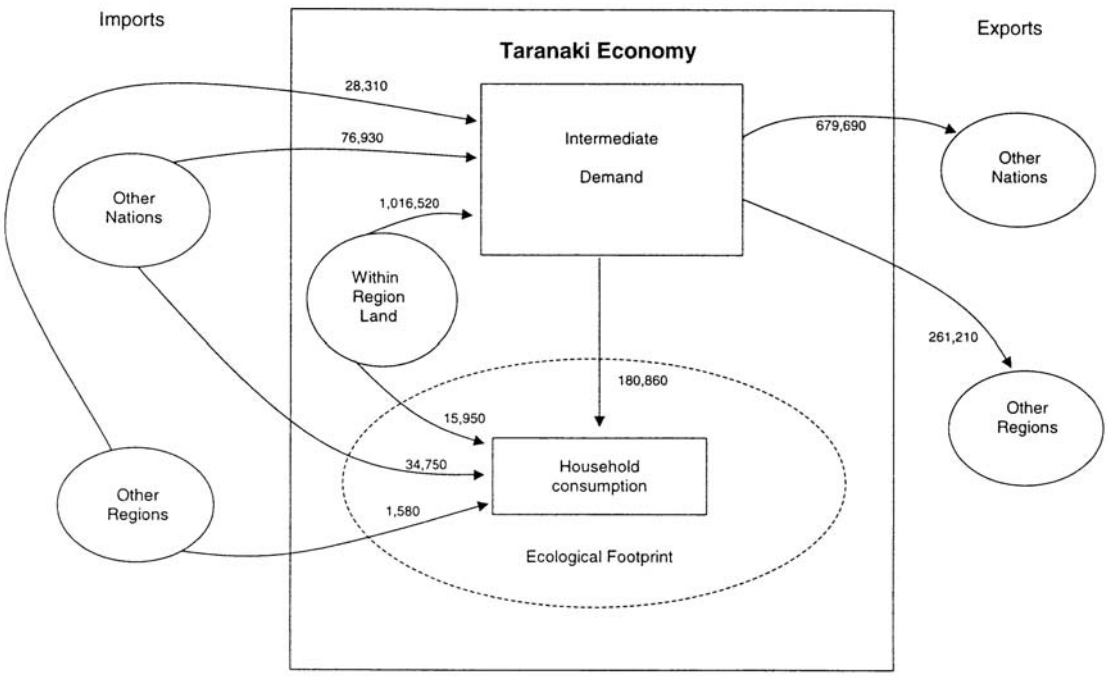
Figure 10.1 provides a summary of the overall flows of embodied land associated with the Taranaki economy. This diagram indicates that Taranaki is:

(1) comparatively self-sufficient in terms of land, with relatively few imports for local household consumption

(2) very much an internationally driven export economy.

Land embodied in international exports (679,690 ha) considerably outweigh local household requirements (233,140 ha). Overall, Taranaki exports 940,900 ha of embodied land compared with imports of only 141,570 ha, resulting in a positive Balance of Trade of 799,330 ha.

Figure 10.1 Flows of embodied land through the Taranaki economy



11 Manawatu–Wanganui's Ecological Footprint

11.1 Profile of the region

On Census night in 2001 the region had a resident population of 220,089 people, making the region the sixth-largest in terms of population nationally. Between 1996 and 2001 the region's population reduced by 8682, or 3.8 percent of the population. This represents the single largest population loss of any region in the country during this period. Most of the decline was experienced in rural parts of the region. The Palmerston North and Wanganui urban areas account for 112,104 people or 50.9 percent of the 2001 population regionally. The region's population density is estimated to be 10.43 people per square kilometre, which is below the New Zealand average in 1998 reflecting the region's rural nature.

The Manawatu–Wanganui region is the second largest by area in the North Island and, overall, the sixth largest in New Zealand. The region covers an area of 2,221,500 ha or 8.1 percent of the country. The region stretches from north of Taumarunui to just south of Levin in the west, and from Cape Turnagain to Owhanga in the east. It is bounded internally by the Waikato, Taranaki, Hawke's Bay and Wellington regions. The region has three major rivers: the Whanganui, Rangitikei and Manawatu. The Manawatu River is the only river beginning on the east coast that empties its waters on the west. The region has a variety of landforms, ranging from the rugged volcanic plateau and block faulted Tararua and Ruahine ranges to the extensive coastal sand dunes. The volcanic plateau encapsulates Mt Ruapehu (2797 metres), the tallest mountain in the North Island. Mt Ruapehu, Mt Ngauruhoe (2291 metres) and Mt Tongariro (1968 metres) dominate the volcanic plateau and are all active volcanoes. The volcanic plateau is made primarily of pumice soils that lack essential trace elements. This includes the Tongariro National Park, a designated World Heritage site.

The 1997–98 GDP of the Manawatu–Wanganui region is estimated to be $5.3 billion or 5.4 percent of New Zealand's GDP. Manawatu–Wanganui is one of the most important pastoral farming areas in New Zealand. Agriculture occupies an estimated 72.5 percent of all land in the region, significantly higher than the national average of 60.1 percent (Statistics New Zealand, 1998l). Sheep, beef and mixed livestock farming is predominant (LQ 2.32). The flat fertile soils suit intensive sheep farming and cropping (particularly potato and barley); and hill country, as exists in the Rangitikei region, suits semi-intensive sheep and beef farming. The region also has a comparative advantage in textile and apparel manufacture (LQ 1.65) with wool and semi-wool carpet manufacturing plants located at Foxton, Feilding and Dannevirke. The region has three military bases and the largest proportion of people serving in the armed forces nationally. It is not surprising therefore that the central government sector (which includes defence) has a location quotient of 2.25. Relative to the nation the region also has a comparative advantage in the education sector (LQ 1.40) mainly due to the presence of Massey University.

11.2 Overall ecological footprint and comparison with other regions

Manawatu-Wanganui has an ecological footprint of 879,520 ha. This represents 8.2 percent of New Zealand's total ecological footprint, the sixth largest ecological footprint of any region. This is higher than Bay of Plenty region (618,260 ha) but lower than Otago region (1,019,050 ha).

On a per capita basis, the Manawatu-Wanganui region's ecological footprint of 3.80 is significantly higher than the New Zealand footprint of 3.08 ha. This means that the average Manawatu-Wanganui resident requires 23.4 percent more land to sustain their lifestyle than does the average New Zealander. This figure occurs because the region has slightly lower than average agricultural productivity. The productivity of agricultural land is a significant factor in determining the region's footprint size because land embodied in food (and other agricultural products such as textiles) is a major component of a person's ecological footprint.

Manawatu-Wanganui's useful land area is 1,833,120 ha, indicating that the region has an ecological surplus of 953,600 ha. This is the fourth largest ecological surplus of any region. In per capita terms, each Manawatu-Wanganui resident has a ecological surplus of 4.1 ha.

11.3 Ecological footprint disaggregated by land type

The agricultural land component of the Manawatu-Wanganui region's ecological footprint is estimated to be 636,820 ha (refer to Table 11.1). On a per capita basis, this amounts to 2.75 ha per person or 72.4 percent of the region's footprint. An estimated 84.9 percent of this land type is made up of within region land. In relative terms, this is a slightly higher share than the New Zealand average of 79.6 percent. This is explained by lower than average agricultural yields in areas near the volcanic plateau and in the region's hill country. A further 92,930 ha of agricultural land is embodied in purchases of goods and services from overseas.

Table 11.1 Manawatu-Wanganui's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	541,220	2,670	92,930	636,820	2.75	72.4
Forest land	25,650	2,290	7,680	35,620	0.15	4.1
Degraded land	94,590	310	5,380	100,280	0.43	11.4
Energy land	76,530	1,890	28,250	106,670	0.46	12.1
Total	737,990	7,160	134,240	879,390	3.80	100.0

The forest land component of the region's ecological footprint consists of 35,620 ha or 4.1 percent of the footprint. Relative to the nation where 6.4 percent of the footprint consists of forest land, this component is significantly less. This suggests that Manawatu-Wanganui residents purchase less wood-based products than New Zealanders on average. An estimated 25,650 ha (72.0 percent) of this land originates from within the region, 7680 ha (21.5 percent) from other nations and the remaining 2290 ha (6.5 percent) from other regions. The forest land component of the footprint does not include the hypothetical land employed in sequestering CO_2 emissions.

The degraded land component of the ecological footprint accounts for 100,280 ha or 11.4 percent of the regions footprint. Of this land type an estimated 94.3 percent is within-region land. This encapsulates primarily land occupied by residential homes and local businesses (other than farming and forestry). An additional 5380 ha of degraded land is embodied in goods and services purchased from overseas by Manawatu-Wanganui residents.

The energy land component of the region's footprint consists of 106,670 ha. On a per capita basis this equates to 0.46 ha per person or 90.2 percent of the national average. Most of the energy land consists of within-region land (76,530 ha) with a lesser but significant share embodied in goods and services purchased from overseas (28,550 ha). The remaining 1890 ha are embodied in products purchased from other regions.

11.4 Ecological footprint disaggregated by goods and services purchased

11.4.1 Purchase of Manawatu-Wanganui produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products by Manawatu-Wanganui residents accounts for 426,360 ha (48.5 percent) of the region's ecological footprint (refer to Table 11.2). The vast majority of this land is embodied in manufactured goods produced locally (397,880 ha), in particular processed food products. Smaller quantities of land (24,760 ha) are also embodied in manufactured goods purchased by the region's residents from overseas.

Table 11.2 Manawatu-Wanganui's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	69,450	20	1,690	71,150	0.31	8.1
Forestry	2,190	70	30	2,290	0.01	0.3
Fishing and hunting	10	40	10	60	0.00	0.0
Mining and quarrying	60	10	30	100	0.00	0.0
Manufacturing	397,880	3,720	24,760	426,360	1.84	48.5
Utilities and construction	24,740	840	5,070	30,650	0.13	3.5
Services	206,490	1,050	27,960	235,500	1.02	26.8
Domestic final demand	37,170	1,560	74,680	113,410	0.49	12.9
Total	737,990	7,300	134,230	879,520	3.80	100.0

Significant quantities of land are also embodied in service sector products consumed by Manawatu-Wanganui residents. On a per capita basis, this amounts to 1.02 ha or 26.8 percent of the region's footprint. At a first glance, this figure appears very high but can be explained by backward linkages to the farming, forestry, and mining sectors in the economy. Thus, while a service sector business may physically occupy only a small land area, the products that it purchases from other industries (such as food, paper, equipment, machinery etc) may contain substantial amounts of embodied land. Most of this land is embodied in service sector commodities that are produced locally (206,490 ha) with smaller amounts from overseas (27,960 ha). In this way, the land embodied in service sector purchases by Manawatu-

Wanganui residents (1.02 ha per capita) is approximately 27 percent higher than the New Zealand average (0.80 ha per capita).

Purchases from other sectors by Manawatu-Wanganui residents are much smaller than for manufacturing and service sector products. Such purchases accounted for 104,250 ha or 11.9 percent of the region's ecological footprint. This figure is primarily made up of agricultural product purchases (71,150 ha) along with purchases of utility and construction products (30,650 ha).

11.4.2 Purchase of goods and services produced outside Manawatu-Wanganui (D_1+D_4)

Manawatu-Wanganui residents also purchased products imported into the region, accounting for 76,240 ha of the region's footprint. The bulk of this land is derived from international sources. This includes land embodied in goods purchased from local retailers that were made overseas but sold with an additional mark-up. In this way, land embodied in items such as motor vehicles, computers, household appliances and imported food products is included in this figure.

11.5 Ecological Balance of Trade and ecological interdependencies

Imports into the Manawatu-Wanganui region economy embody 197,510 ha of land, while exports from the region embody 1,195,810 ha (refer to Table 11.3). In this way, the region's economy has a large Ecological Balance of Trade surplus, exporting nearly 6.1 times more embodied land than it imports.

Table 11.3 Manawatu-Wanganui's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	140	239,170	239,030
Forestry	1,210	2,040	830
Fishing and hunting	200	0	-200
Mining and quarrying	50	0	-50
Manufacturing	7,000	15,230	8,230
Utilities and construction	860	790	-70
Services	1,230	27,030	25,800
Domestic final demand	1,560	0	-1,560
Interregional Balance of Trade	12,250	284,260	272,010
International trade			
Agriculture	12,920	233,810	220,890
Forestry	460	35,230	34,770
Fishing and hunting	60	250	190
Mining and quarrying	120	350	230
Manufacturing	57,820	609,740	551,920
Utilities and construction	5,190	140	-5,050
Services	34,010	32,030	-1,980
Domestic final demand	74,680	0	-74,680
International Balance of Trade	185,260	911,550	726,290
Total Balance of Trade	197,510	1,195,810	998,300

11.5.1 Exports and imports by economic sectors

Sales of manufactured products by the Manawatu-Wanganui economy were estimated to include 624,970 ha of embodied land. Land embodied in exports of manufactured products made up 62.6 percent of the region's total ecological trade surplus. The vast majority of land embodied in manufactured products (609,740 ha) is destined for other nations. This land is primarily embodied in processed agricultural products, including processed sheep and beef meat, processed horticulture produce and textiles.

The Manawatu-Wanganui region is also a significant net exporter of land embodied in agricultural products with similar quantities heading offshore (233,810 ha) as going to other New Zealand regions (239,170 ha). This includes land embodied in but not limited to wool, livestock sales and cash crops such as carrots and maize. Overall the region exports more than 36 times the embodied land in agricultural products than it imports.

Purchases by the region's service sector embody 35,240 ha of land. By comparison, service sector embodied land exports equate to 59,060 ha. This gives the region's service sector a positive Ecological Balance of Trade of 23,820 ha. All other sectors of the region's economy have close to neutral trade balances, with the exception of the utilities and construction sector which is a net importer of 5120 ha of embodied land.

11.5.2 Exports and imports by type of land

Manawatu-Wanganui is a large net producer of agricultural land (refer to Table 11.4). International exports (829,080 ha) outweigh international imports (135,640 ha) by 6.1 times. Much of the land embodied in the region's exports is associated with sheep, beef, dairy, crops produce and in wool. On an interregional basis, the region is also a significant net exporter of agricultural land (249,220 ha).

Table 11.4 Manawatu-Wanganui's Ecological Balance of Trade by land type, 1997–98

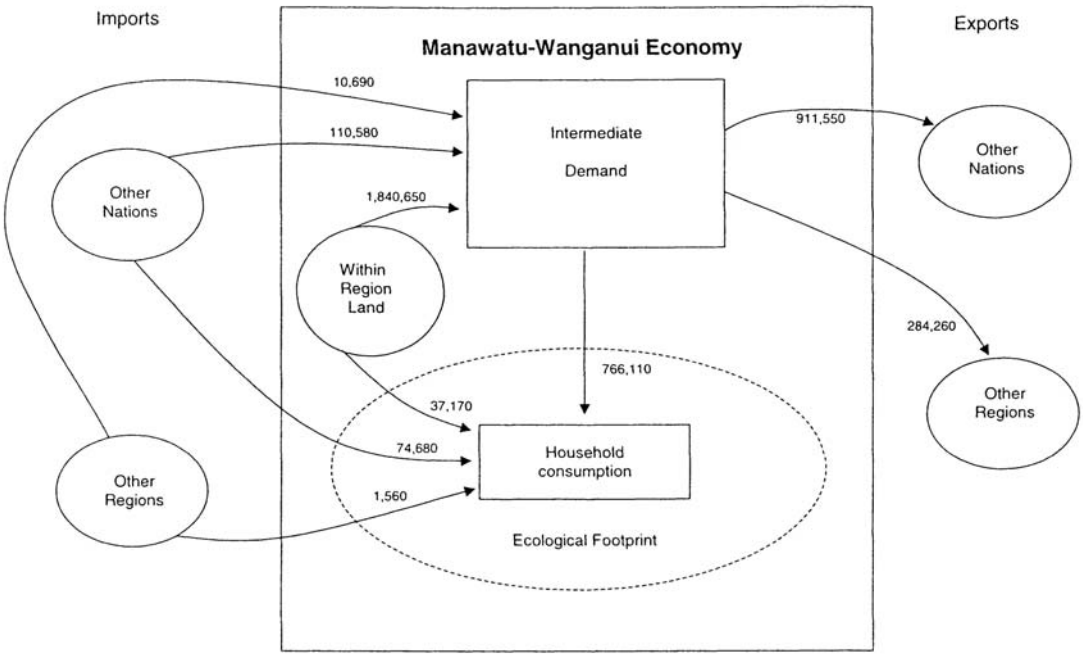
Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	5,100	254,320	249,220
Forest land	3,990	3,110	-880
Degraded land	560	20,990	20,430
Energy land	2,610	5,840	3,230
Interregional Balance of Trade	12,260	284,260	272,000
International trade			
Agricultural land	135,640	829,080	693,440
Forest land	9,500	46,690	37,190
Degraded land	9,740	7,270	-2,470
Energy land	30,370	28,520	-1,850
International Balance of Trade	185,250	911,560	726,310
Total Balance of Trade	197,510	1,195,820	998,310

The remaining land types in the Manawatu-Wanganui region all have relatively small trade surpluses compared with the agricultural land embodied in the region's exports: forest land (36,310 ha), degraded land (17,960 ha) and energy land (1380 ha). Degraded land embodied in products sold by the Manawatu-Wanganui region to other regions is however quite high (20,990 ha). This is partially explained by the region's comparative advantages in military/ defence and education/research institutions that occupy extensive land areas.

11.5.3 Overall picture

Figure 11.1 provides a summary of the overall flows of embodied land through the Manawatu-Wanganui regional economy. The production of agricultural products for international exports dominate with 911,550 ha being exported to other nations. By comparison, exports to other regions of embodied land are considerably smaller at 284,260 ha. Although the Manawatu-Wanganui region has a strong export orientation, the region's predominantly urban population also requires a considerable quantity of land to support its existence (879,520 ha). Overall, exports of embodied land (1,195,810 ha) outweigh embodied land imports (197,510 ha) by nearly 6.1 times. The Manawatu-Wanganui region is therefore a large net provider of ecological capital to other regions and countries.

Figure 11.1 Flows of embodied land through the Manawatu-Wanganui economy



12 Wellington's Ecological Footprint

12.1 Profile of the region

Wellington's population was 428,699 in 1997/98, the third most populated region behind Auckland and Canterbury. In terms of population the region is dominated by the Wellington metropolitan area (population about 335,000). The 1996 Census showed that Wellington had the second highest percentage of urban population of any region in New Zealand after Nelson. This is despite farming occupying about two-thirds of the land area in the Wellington region mainly in the Wairarapa. Over the last decade the total population in the Wellington region has remained reasonably static.

The land area of the Wellington region is 812,503 ha, the fourth smallest region in the country. It includes the Wellington metropolitan area, the Kapiti Coast northwards to south of Levin and most of the Wairarapa. Few energy or mineral resources exist in the region, although the Wairarapa provides Wellington with a considerable land resource suitable for pastoral farming, horticulture and forestry. The region is also relatively rich in biodiversity with three forest parks, Kapiti Island and other areas of ecological significance.

The Wellington regional economy is heavily dominated by the service sector. In a sense, the Wellington economy operates in a reverse way to many other economies – that is, it is the service sector that drives the rest of the regional economy, rather than the primary or manufacturing sector which is usually the case. Accordingly, many of the economic activities in the Wellington region exist and thrive only because they supply the service sector with intermediate goods and services. For example, specialist niches have been developed in the manufacturing sector especially to supply commercial furniture, printing supplies and computer equipment to the service sector.

Based on this picture of service sector dominance, there are relatively high location quotients for finance (2.15), services to finance and insurance (2.49), business services (1.55), health and community services (1.23), cultural and recreation services (1.26) and central government (2.02). Most of the manufacturing sectors have relatively low location quotients, reflecting a lower than average presence in the Wellington economy. The two exceptions are printing and publishing (1.12) which is higher due to the derived service sector demand for printing and publishing products; and rubber and plastic and other chemicals (1.37) which is primarily due to head office activities for these industries in the Wellington region. At below the 48 sector level, location quotient analysis reveals some specialist manufacturing activities which Wellington has a predominant role in (eg. commercial furniture, computer equipment). However, the effect of the removal of tariff barriers and the opening of the economy has led to the decline of several traditional manufacturing industries such as car assembling and textiles.

Wellington City is an important transportation hub. It is a transit point between the North and South Islands for rail, road and water traffic. It has New Zealand's busiest domestic airport. Wellington also has the most well-developed metropolitan rail network in New Zealand, providing Wellington with an efficient public transport system.

12.2 Overall ecological footprint and comparison with other regions

The Wellington ecological footprint is the fourth largest in the country at 1,029,050 ha. Only Auckland, Canterbury and Waikato have larger footprints. It makes up 9.57 percent of New Zealand's ecological footprint.

Wellington's per capita footprint is 2.40 ha/capita, below the New Zealand average of 3.08 ha/capita. It is ranked the fifth to lowest per capita footprint of any region in the country, behind Nelson, Auckland, Tasman and Taranaki. The main factor that seems to contribute to this relatively low per capita footprint is the efficiency achieved through the concentration of the urban population in the Wellington region. The Wellington region is very urban (even with the Wairarapa sub-region considered), and has relatively high population density (52.76 people/km^2) which is the third highest in the country. Urban populations can achieve relatively good resource use efficiencies and this seems a primary factor in explaining Wellington's lower per capita footprint. It's well known, for example, that the Wellington public transport and rail system is efficient which will decrease the size of its per capita footprint. The relatively small size of Wellington's per capita ecological footprint cannot be explained by land productivity factors as it can in some other regions. Wellington's land productivity is close to the New Zealand average.

Overall, the Wellington region has an ecological deficit of 305,820 ha. It is one of the only three regions in New Zealand that has an ecological deficit – that is, it uses more land (1,029,010 ha) in domestic consumption than there is available useful land (723,190 ha). The other two regions that have ecological deficits (rather than surpluses) are Auckland and Nelson. Wellington and these two regions are the most urban and most densely populated. This means, almost by necessity, they need to draw a significant amount of their ecological footprint (for food supply and other products) from outside their regions. This results in Wellington overshooting it useful land area by 1.42 times which is still far less than Auckland's overshoot of 4.82 times.

12.3 Ecological footprint disaggregated by land type

The agricultural land component of Wellington's ecological footprint consists of 705,610 ha (refer to Table 12.1). This represents 68.6 percent of Wellington's ecological footprint. The largest amount (286,350 ha) of this agricultural land is imported from other regions in New Zealand: Taranaki (122,280 ha), Canterbury (100,010 ha), Southland (48,080 ha) and all other regions (15,990 ha). Agricultural land sourced from within the Wellington region, mainly from the Wairarapa, amounts to 236,800 ha. A significant amount (182,300 ha) of agricultural land was imported from other countries, being embodied in imports such as foodstuffs and other manufactured products.

Table 12.1 Wellington's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	236,880	286,350	182,380	705,610	1.65	68.6
Forest land	10,180	11,420	18,500	40,100	0.09	3.9
Degraded land	84,270	1,420	11,400	97,090	0.23	9.4
Energy land	116,210	6,200	63,590	186,000	0.43	18.1
Total	447,540	305,390	275,870	1,028,800	2.40	100.0

The forest land component is 40,000 ha, representing 3.9 percent of Wellington's ecological footprint. Nearly half (18,500 ha) is embodied in products imported from overseas. A significant amount (11,420 ha) of the forest land is drawn from within the region mainly embodied in wood-based construction products. The remainder of the forest land is appropriated from outside the region, particularly from the Waikato, Hawke's Bay, Nelson and Marlborough.

The degraded land component of the ecological footprint is 84,270 ha. This represents 9.4 percent of the Wellington ecological footprint, significantly above the national average of 8.2 percent. Most of this degraded land is drawn from the Wellington urban area. Comparatively little degraded land is embodied in products imported into the region. The relatively high proportion of degraded land in Wellington's ecological footprint is probably explained by the large service sector and urban dominance of the Wellington economy.

The energy land component of Wellington's ecological footprint is 186,000 ha. This represents 18.1 percent of Wellington's ecological footprint, which is slightly higher than the national average but significantly lower than other largely urban areas in New Zealand such as Auckland (23.7 percent) and Nelson (27.3 percent). This is explained by Wellington's economy being relatively energy efficient, perhaps due to its efficient commuter rail system and high urban densities.

12.4 Ecological footprint disaggregated by goods and services purchased

12.4.1 Purchase of Wellington produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing products accounted for 443,990 ha of embodied land in Wellington's ecological footprint (refer to Table 12.2). This amounts to 43.1 percent of the entire ecological footprint of the Wellington region, which is slightly less than the New Zealand percentage. Most of the 443,990 ha is embodied in products imported from rural regions (282,190 ha) particularly from Taranaki, Canterbury and Southland although a significant proportion is surprisingly sourced from within the Wellington region (107,990 ha).

Table 12.2 Wellington's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	123,980	9,660	2,270	135,910	0.32	13.2

Forestry	1,830	2,330	40	4,210	0.01	0.4
Fishing and hunting	20	10	20	50	0.00	0.0
Mining and quarrying	120	30	30	180	0.00	0.0
Manufacturing	107,990	282,190	53,810	443,990	1.04	43.1
Utilities and construction	29,840	3,090	11,320	44,240	0.10	4.3
Services	108,880	3,580	67,310	179,770	0.42	17.5
Domestic final demand	74,900	4,720	141,040	220,660	0.51	21.4
Total	447,550	305,610	275,860	1,029,010	2.40	100.0

Consumption of service sector products (eg. insurance, finance, business consulting, retailing) accounts for 179,770 ha of embodied land which makes up 17.50 percent of Wellington's ecological footprint. This is significantly below the national average of 26.0 percent. This does not mean that Wellingtonians consume less service sector products rather that they consume service sector products that require less land per unit of product. Much of the service sector product is sourced within Wellington and the Wellington service sector seems to require less land per unit of product – in other words, typically service sector premises in Wellington are in multi-storeyed buildings that take up comparatively little land area per business.

The land embodied in agricultural products purchased by Wellingtonians account for 135,910 ha. This makes up 13.2 percent of the ecological footprint which is relatively high compared to the New Zealand average of 7.8 percent.

The land embodied in other products purchased by Wellingtonians is relatively small: forestry (4210 ha), fish (50 ha), mining and quarrying (180 ha) and utilities and construction (44,420 ha).

12.4.2 Purchase of goods and services produced outside Wellington (D_1+D_4)

Wellingtonians also directly purchase products outside the region, which accounted for 220,660 ha of land. Most of these imported purchases are from overseas (141,040 ha) such as the purchase of motor vehicles, computers, electronics and other household items. There is only a small amount of embodied land in direct purchases of products from other regions (4470 ha). The embodied land in these purchases is 12.04 percent of the Wellington footprint, which is above the New Zealand average of 10.55 percent.

12.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Wellington region is 770,810 ha. Whereas the land embodied in exports from the Wellington region is 385,050 ha (refer to Table 12.3). This means that the Ecological Balance of Trade of the Wellington economy is -385,760 ha, making Wellington a net consumer of land from outside the region.

Table 12.3 Wellington's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)

Interregional trade			
Agriculture	16,530	0	-16,530
Forestry	22,660	1,850	-20,810
Fishing and hunting	180	0	-180
Mining and quarrying	150	0	-150
Manufacturing	391,300	1,550	-389,750
Utilities and construction	3,100	2,000	-1,100
Services	4,920	10,360	5,440
Domestic final demand	4,720	0	-4,720
Interregional Balance of Trade	443,560	15,750	-427,810
International trade			
Agriculture	3,880	96,590	92,710
Forestry	440	34,810	34,370
Fishing and hunting	780	1,520	740
Mining and quarrying	160	660	500
Manufacturing	80,430	186,240	105,810
Utilities and construction	11,420	180	-11,240
Services	89,090	49,300	-39,790
Domestic final demand	141,040	0	-141,040
International Balance of Trade	327,240	369,300	42,060
Total Balance of Trade	770,800	385,050	-385,750

12.5.1 Exports and imports by economic sectors

A large percentage (61.20 percent) of land embodied in imports into Wellington is associated with purchases of products by the manufacturing sector. Most of these purchases by the Wellington manufacturing sector are the raw materials obtained from other regions for further processing in Wellington. Eventually, most of this land is channelled into local consumption but some is re-exported as value-added processed products. The level of further processing of products for export, however, is lower than for the Auckland urban economy.

The service sector also consumes considerable embodied land appropriated into the region (94,010 ha) particularly from international sources. For instance, the purchase of computers and professional services from overseas involves the appropriation of land from other countries – in Wellington's case, this amounts to 89,090 ha, which interestingly is more than the land embodied in international imports into the manufacturing sector in Wellington. This is not surprising given the relative size of the service sector in the Wellington economy. Although the service sector appropriates considerable amounts of land into Wellington, it also exports embodied land (59,660 ha) in the products it sells to businesses in other regions in New Zealand and overseas.

Overall, the manufacturing sector (-283,940 ha), utilities and construction (-12,340 ha), services (-34,350 ha) and domestic final demand (-145,760) sectors all have negative Balances of Trade – they consume more land than they export out of the region. The agriculture (76,180 ha), forestry (13,560 ha), fishery and hunting (560 ha) and mining and quarrying (350 ha) sectors all have positive Balance of Trades, albeit involving relatively small amounts of embodied land.

12.5.2 Exports and imports by land type

Wellington is a very large net consumer of agricultural land from outside the region (refer to Table 12.4). Wellington imports 397,580 ha of agricultural land from the regions and a further 215,320 ha of agricultural land from overseas. Although Wellington does export considerable amounts (273,260 ha) of embodied agricultural land to overseas destinations, there is virtually no (3950 ha) embodied agricultural land exported to the regions. Overall, accounting for these trade flows, the net effect is that Wellington consumed 385,760 ha of agricultural land appropriated from outside the region.

Table 12.4 Wellington's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	397,580	3,950	-393,630
Forest land	35,140	2,560	-32,580
Degraded land	2,210	3,880	1,670
Energy land	8,640	5,360	-3,280
Interregional Balance of Trade	443,570	15,750	-427,820
International trade			
Agricultural land	215,320	273,260	57,940
Forest land	22,070	43,770	21,700
Degraded land	19,760	9,270	-10,490
Energy land	70,090	43,000	-27,090
International Balance of Trade	327,240	369,300	42,060
Total Balance of Trade	770,810	385,050	-385,760

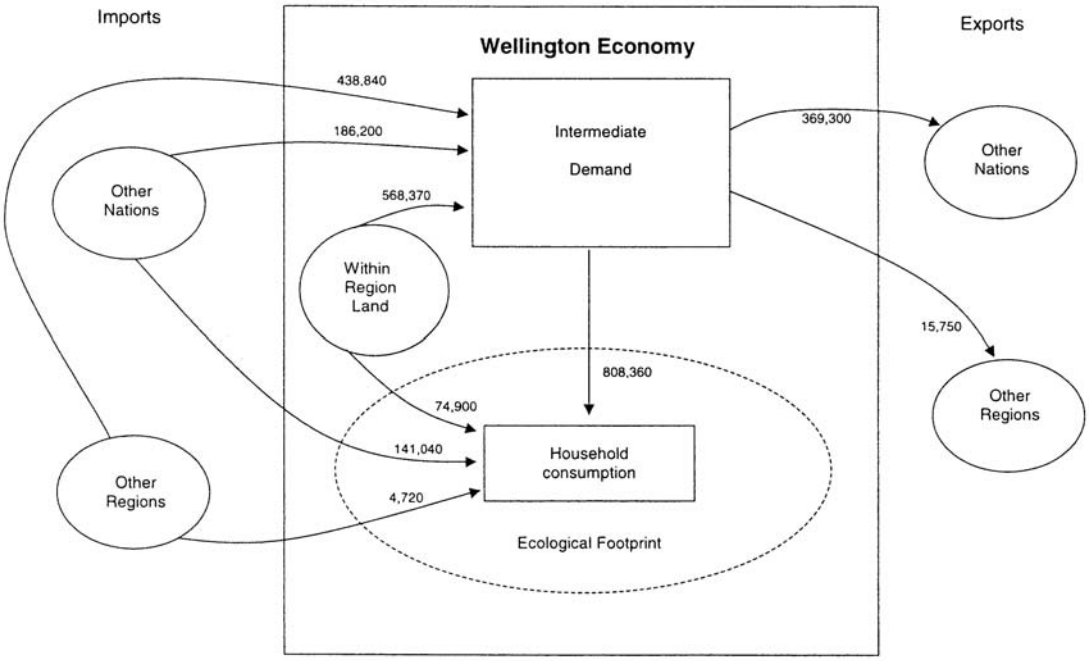
Energy land embodied in imports is the next most significant but much smaller than agricultural land imports. Imports of appropriated energy land were 78,730 ha compared to exports of energy land at 48,360 ha. Again, the net effect is that Wellington consumed 30,370 ha of energy land appropriated from outside the region.

The trade flows of forest land and degraded land in and out of the Wellington region are even of less significance. Wellington is a net consumer of -10,880 ha of forest land from outside the region (exports: 46,330 ha; imports: 57,210 ha). It is also a net consumer of degraded land (exports: 13,150 ha; imports: 21,970 ha).

12.5.3 Overall picture

Figure 12.1 presents a summary of the overall flows of embodied land through the Wellington regional economy. More than any other region apart from Auckland, the production patterns are oriented to supplying the local regional consumption with relatively light exports to both other regions and overseas. Exports of embodied land (385,050 ha) are significantly outweighed by imports of embodied land (770,880 ha). Wellington therefore has a negative Balance of Trade of 305,750 ha. Wellington is a net consumer rather than a producer of ecological capital.

Figure 12.1 Flows of embodied land through the Wellington economy



13 Marlborough's Ecological Footprint

13.1 Profile of the region

The Marlborough region covers an area of 1,248,400 ha, making it the ninth largest region in New Zealand. It covers the top north-eastern corner of the South Island and consists of three distinct areas – the Marlborough Sounds, the fertile Wairau Plains and the extensive tussock covered back country. Most (68 percent) of the population live in the Blenheim urban area.

Marlborough population is only 39,699, making it the third to smallest region in New Zealand ahead of the West Coast and Tasman. The population is not only relatively small, but widely dispersed with Marlborough having a population density of 3.18 people/km^2 which is the third-lowest of any region in New Zealand. Over the entire region, population growth has mainly been confined to the area surrounding the Marlborough Sounds.

The Marlborough economy is based on a buoyant primary sector. The location quotients for various primary sector industries indicate a real strength in these areas: horticulture (3.85), fishing and aquaculture (9.60) and forestry and logging (2.06). The region is currently the largest and fastest growing grape producing area in the country. The aquaculture industries are also important with farms specialising in production of mussels, oysters, salmon and scallops. Forestry is also a rapidly expanding industry, a reflection of the area's good climate and growing conditions.

The downstream processing of primary products is also important with the manufacturing of food (LQ 3.66) and beverages – mainly wine (LQ 6.04) having high location quotients for the region. The multiplier effects of primary production and processing also extends to the rest of the regional economy, indirectly generating jobs in the service sector.

Tourism is also an important industry for Marlborough not only because of its proximity to inter-island tourist traffic but also because of the attractions of the Marlborough Sounds, it's sunny and mild climate and tourism activities associated with primary production such as vineyards. The location quotient for the accommodation, restaurant and café sector (1.22) accordingly is above the national average.

The presence of the Woodburne Air Force Base also has an influence on the economy, making the central government sector the second highest employer next to horticulture, of any sector in Marlborough. The location quotient for central government is high at 2.92, which is actually the highest in country even exceeding Wellington's.

13.2 Overall ecological footprint and comparison with other regions

Marlborough has an ecological footprint of 163,810 ha. This represents only 1.52 percent of New Zealand's ecological footprint and ranks it 12th of 16 regions in New Zealand. Only Gisborne, West Coast, Tasman and Nelson have lower ecological footprints. The smallness of the ecological footprint of all of these regions including Marlborough is due to their low population base.

Notably, on a per capita basis, Marlborough has the second to highest ecological footprint of any region at 4.13 ha per person. The main reason for this high per capita footprint is the very

low productivity and stocking rates of Marlborough land. In comparative terms Marlborough land is of low productivity when it comes to pastoralism which is the main land use, although there may be pockets of relatively productive land used for horticultural uses. This means more land is required to produce the same amount of product. Analysis of agricultural data from Statistics New Zealand (1998c) indicates, for example, that the stocking rate for Marlborough land is 2.79 stock units per hectare compared with a national average of 7.52 stock units per hectare. This means that the per capita use of agricultural land in Marlborough is high with the per capita use of forest, degraded and energy land being around the national average.

The useful land area of Marlborough is 606,090 ha, far exceeding the ecological footprint of Marlborough's consumption at 163,810 ha. In fact, the level of Marlborough consumption would need to increase 3.70 times before there was an overshoot of useful land area. Overall, in net terms, this means that the Marlborough region is ecologically self-sufficient and has an ecological surplus of 442,280 ha. So even though Marlborough may not be an efficient user of land as indicated by the per capita footprint, it falls a long way short of reaching overshoot due to the abundance of land in Marlborough relative to its population base.

13.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 121,460 ha (refer to Table 13.1). This represents 74.2 percent of Marlborough's ecological footprint. Most of the land is agricultural land sourced from within the region (102,910 ha) with only small amounts of agricultural land drawn from other regions (2270 ha) or other nations (15,780 ha). The high proportion of agricultural land sourced from within the region is not surprising given the abundance of agricultural land in Marlborough. Most of the agricultural land drawn from other regions is embodied in dairy products imported from the Waikato and Southland, although these are relatively very small amounts compared with agricultural land obtained within the region.

Table 13.1 Marlborough's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	102,910	2,770	15,780	121,460	3.06	74.2
Forest land	8,650	180	1,320	10,150	0.26	6.2
Degraded land	12,070	210	850	13,130	0.33	8.0
Energy land	13,830	570	4,650	19,050	0.48	11.6
Total	137,460	3,730	22,600	163,790	4.13	100.0

The forest land component of the ecological footprint consists of 10,150 ha. This represents 6.2 percent of the Marlborough ecological footprint, slightly below the New Zealand average. Most (8650 ha) of the forest land is drawn from within the Marlborough region with very little (180 ha) being obtained from other regions in New Zealand. A significant amount (1320 ha) of the forest land is however appropriated from other nations.

The degraded land component of the ecological footprint consists of 13,130 ha. This represents 8.0 percent of the Marlborough footprint. Almost all this degraded land is derived from within the Marlborough region (12,070 ha). Surprisingly, only a small amount of degraded land is imported from other regions (570 ha) and other nations (850 ha).

The energy land component of the Marlborough ecological footprint is 19,050 ha. This is only 11.6 percent of Marlborough's footprint, which is low compared with the national percentage of 16.6 percent. However, on a capita basis the energy land component for Marlborough (0.48 ha/person) is close to the New Zealand average figure (0.51 ha/person). This latter figure suggests that the level of energy efficiency in Marlborough may be slightly better than the national average.

13.4 Ecological footprint disaggregated by goods and services purchased

13.4.1 Purchase of Marlborough produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 65,810 ha of embodied land (refer to Table 13.2). This amounts to 40.2 percent of the entire ecological footprint of the Marlborough region, significantly below the national average of 44.5 percent. Almost all of land embodied in these manufacturing products is sourced within the region (60,120 ha).

Table 13.2 Marlborough's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	20,010	10	260	20,270	0.51	12.4
Forestry	460	0	0	470	0.01	0.3
Fishing and hunting	10	0	0	10	0.00	0.0
Mining and quarrying	10	0	10	20	0.00	0.0
Manufacturing	60,120	2,680	3,000	65,810	1.66	40.2
Utilities and construction	9,640	100	1,110	10,840	0.27	6.6
Services	39,430	220	5,250	44,900	1.13	27.4
Domestic final demand	7,780	740	12,960	21,480	0.54	13.1
Total	137,460	3,760	22,590	163,810	4.13	100.0

The purchase of agricultural sector products accounts for 20,270 ha, 12.4 percent of the ecological footprint of the Marlborough region. This figure for land embodied in agricultural products is considerably higher than the national average of 7.8 percent. Also, on a per capita basis, the land embodied in agricultural products consumption in Marlborough at 0.51 ha/capita is more than double the national figure of 0.24 ha/capita.

It therefore appears that Marlborough residents are purchasing more agricultural products (fresh fruit and vegetables, vineyard products) directly from the agricultural sector, and these are substituting for goods usually bought as purchases from the manufacturing sector. This explains both the comparatively low embodied land in manufacturing products and high embodied land in agricultural products.

The purchase of service sector products accounted for 44,900 ha of the embodied land in the Marlborough ecological footprint. This amounts to 27.4 percent of the entire ecological footprint of the Marlborough region. Most of these service sector products (insurance, finance, retail margin) directly and indirectly draw on land from within the Marlborough region (39,430 ha). Only a very insignificant amount of land (220 ha) is embodied in service sector products appropriated from other regions. On the other hand, the amount of overseas land embodied in purchases by the service sector is relatively high at 5250 ha.

The land embodied in other products used by Marlborough consumers is much smaller for the other sectors: forestry (470 ha), fishing and hunting (10 ha), mining and quarrying (20 ha), and utilities and construction (10,840 ha).

13.4.2 Purchase of goods and services produced outside Marlborough (D_1+D_4)

Marlborough residents purchased products imported from outside the region, which accounted for 13,700 ha. Most of these purchases are of overseas products (12,960 ha) including imported motor vehicles, computers, foodstuffs and various household items. There is only a relatively small amount of land embodied in products imported from other regions (740 ha).

13.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Marlborough regional economy is 47,650 ha. Whereas, the land embodied in exports from the Marlborough economy is a massive 529,680 ha (refer to Table 13.3). The Ecological Balance of Trade of the Marlborough economy is therefore 482,680 ha, making it a big net provider of land to other regions and countries.

Table 13.3 Marlborough's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	80	39,150	39,070
Forestry	150	9,320	9,170
Fishing and hunting	0	1,510	1,510
Mining and quarrying	10	40	30
Manufacturing	9,200	6,080	-3,120
Utilities and construction	110	550	440
Services	260	2,680	2,420
Domestic final demand	740	0	-740
Interregional Balance of Trade	10,550	59,320	48,770
International trade			
Agriculture	3,230	196,170	192,940
Forestry	220	17,490	17,270
Fishing and hunting	770	3,300	2,530
Mining and quarrying	70	110	40
Manufacturing	11,720	243,210	231,490
Utilities and construction	1,150	40	-1,110
Services	6,980	10,050	3,070
Domestic final demand	12,960	0	-12,960
International Balance of Trade	37,100	470,360	433,260
Total Balance of Trade	47,650	529,680	482,030

13.5.1 Exports and imports by economic sector

Exports of embodied land from Marlborough (529,680 ha) far outweigh imports of embodied land (47,650 ha). The ratio of exports (of embodied land) to imports (of embodied land) is the second highest of any region in New Zealand, indicating the strong orientation of the Marlborough economy to the exporting of land-based products.

The export of agricultural products (horticultural produce, wool) and manufacturing products (processed land based products) is high, respectively accounting for 235,320 ha and 249,290 ha of embodied land. The embodied land associated with either the agricultural (233,320 ha) or manufacturing (249,290 ha) sector products, both exceed the land appropriated for local consumption as indicated by Marlborough's ecological footprint (163,810 ha).

In comparison, the imports into Marlborough are very light with only imports purchased by the manufacturing (20,920 ha), service (7240 ha), domestic final demand (13,700 ha) sectors having any real significance.

13.5.2 Exports and imports by type of land

The Marlborough region is a very large net provider of agricultural land to other regions but far more importantly, internationally to other countries. A massive 477,420 ha of agricultural land is exported internationally out of the Marlborough region (refer to Table 13.4). This is primarily land embodied in sheep and beef products as well as horticultural products. The extensive nature of pastoral farming in Marlborough means that there are comparatively large land multipliers associated with sheep products (eg. wool) exported from the region which in part accounts for the large exports of embodied land.

Table 13.4 Marlborough's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	9,090	46,520	37,430
Forest land	380	9,380	9,000
Degraded land	290	1,060	770
Energy land	790	2,350	1,560
Interregional Balance of Trade	10,550	59,310	48,760
International trade			
Agricultural land	27,730	430,720	402,990
Forest land	1,940	21,200	19,260
Degraded land	1,690	3,920	2,230
Energy land	5,740	14,530	8,790
International Balance of Trade	37,100	470,370	433,270
Total Balance of Trade	47,650	529,680	482,030

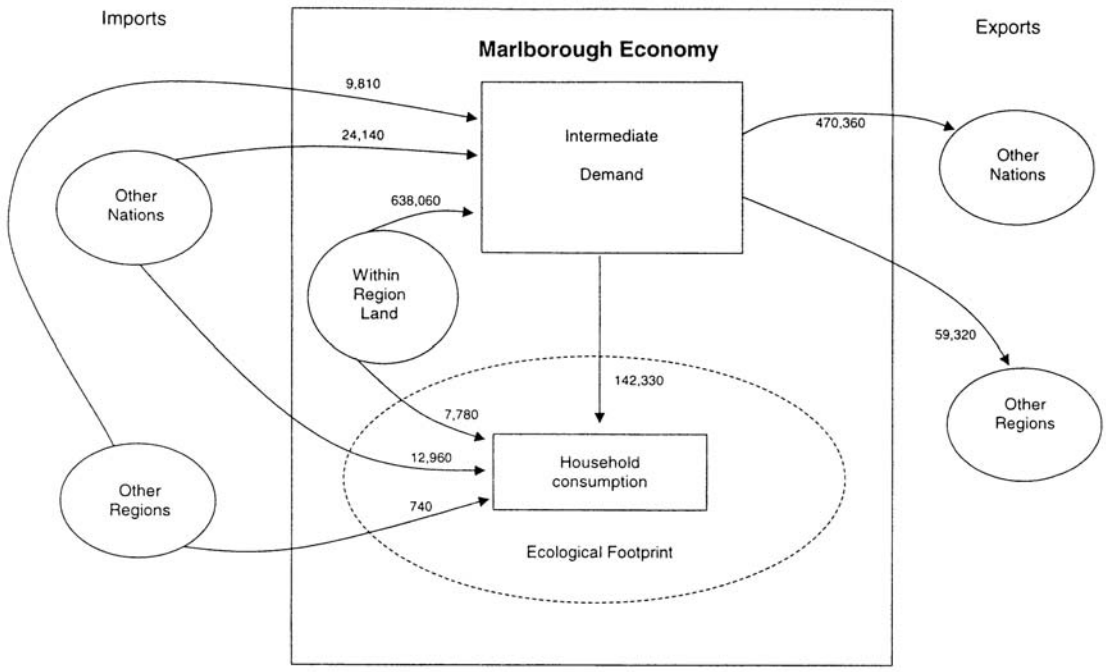
The region is also a significant net exporter of forest land (28,260 ha) although this nowhere near approaches the quantity of agricultural land exported. This may significantly increase overtime with increased conversion of farmland to forestry.

Degraded and energy land is more associated with domestic (particularly urban) uses in Marlborough which are relatively insignificant compared with the export-oriented pastoral sector. It is therefore not surprising that the net Ecological Balance of Trade for degraded land (3000 ha) and energy land (10,350 ha) are both relatively insignificant.

13.5.3 Overall picture

Figure 13.1 provides a summary of the overall flows of embodied land of the Marlborough economy. This diagram indicates that firstly Marlborough is very self-sufficient in terms of land with relatively few imports for local household consumption. Secondly, the diagram indicates that Marlborough is very much orientated to international exports with these flows (470,360 ha) outweighing the flows in to local household consumption within the Marlborough region (168,810 ha). Overall, Marlborough exports 529,680 ha of embodied land compared with imports of only 47,650 ha. This gives Marlborough a positive Balance of Trade of 482,030 ha. Marlborough is therefore a very significant provider of ecological capital to outside regions and more particularly to overseas consumers.

Figure 13.1 Flows of embodied land through the Marlborough economy



14 Tasman's Ecological Footprint

14.1 Profile of the region

The Tasman region covers the top northwest corner of the South Island. The total land area of the Tasman region is 969,120 ha, making it the 11th largest region in New Zealand. Much of the region is mountainous with large parts inaccessible. Abel Tasman (22,541 ha) and Nelson Lakes (101,753 ha) national parks are found within the region with part of the Kahurangi National Park also within the region. The coastal areas of the Tasman region have high annual sunshine hours and are fertile, making them suitable for horticultural activities.

The population of the Tasman region was only 39,599, making it the second lowest of all regions. Only the West Coast has fewer people. The population is much more rural than other regions – the March 1996 Census recorded 43.1 percent of the population as rural. The main urban populations are small, including the townships of Motueka, Takaka, Richmond and Collingwood, all of which have population below 10,000. Tasman consequently has the fourth lowest population density at 4.09 people/km^2.

Horticulture is the key industry in the region. It includes the growing of apples, pears, berry fruit and specialty crops such as hops. The intensive use of land for horticulture has resulted in smaller than average farm sizes in the region. The location quotient for horticulture is very high at 8.16. Other land uses such as dairying (LQ 1.60), sheep and beef farming (LQ 1.82) and forestry and logging (LQ 4.94) are also above the national average as reflected in their location quotients.

Fishing also makes an important contribution to the local economy. A large fish processing plant is located at Port Motueka and Golden Bay's port is located at Tarakohoe which houses a fish processing plant.

The manufacturing sector, although small by national standards, is also relatively strong in the Tasman economy and is based on the further processing of primary products. The region contains the world's largest single-site medium-density fibreboard mill, located in Richmond. Cement manufacturing in Golden Bay as well as food manufacturing, are also important. As a result, the location quotients for many manufacturing sectors are above the national average: other food manufacturing (LQ 2.29), beverage, malt and tobacco manufacturing (LQ 1.66), wood and wood products (LQ 3.08) and non-metallic minerals (LQ 2.13). The region's Cobb River power station complex also makes a significant contribution to the regional economy.

The level of employment in the service sector is notably well below the national average with services tending to be provided by businesses in Nelson City which is outside the region.

14.2 Overall ecological footprint and comparison with other regions

Tasman has an ecological footprint of 82,180 ha, only 0.76 percent of New Zealand's ecological footprint. It is the second smallest of any region in New Zealand; only neighbouring Nelson City has a lower ecological footprint.

On a per capita basis, Tasman has the second lowest ecological footprint of all of the regions, at 2.08 ha per person. It is marginally larger than Auckland's per capita ecological footprint which

is the lowest. This low per capita footprint is partly explained by the relatively productive land in the Tasman area. This means that less agricultural and horticultural land is required to produce the same amount of product, thus lowering the numerical magnitude of Tasman's ecological footprint. This particularly applies to horticultural land required for food production in Tasman. There is also some evidence to suggest that the per capita energy use is lower in this region thereby reducing the energy component of the footprint.

According to the ecological footprint calculation, 82,180 ha of land is required to produce commodities that the Tasman population consumes. There are in contrast 332,906 ha of useful land available, meaning that the Tasman region has more than enough land to sustain it current level of consumption. In fact, the Tasman region would need to increase its consumption, 4.05 times before it would overshoot the availability of useful land. Overall, in net terms, Tasman region is ecologically self-sufficient and actually has an ecological surplus of 250,730 ha of useful land. This situation is to be anticipated as Tasman is the most rural of all New Zealand regions.

14.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 13,110 ha (refer to Table 14.1). This represents 49.8 percent of Tasman's ecological footprint. Most (25,550 ha) of this land is sourced within the Tasman region. A considerable amount of agricultural land (13,110 ha) is however embodied in international goods imported to the Tasman area. Some (2230 ha) agricultural land is also embodied in goods imported from other regions in New Zealand particularly those in the South Island. Overall, the Tasman region's appropriation of agricultural land is low, both on a percentage and per capita basis, compared with the national average. This appears to be primarily because the land is relatively productive in Tasman, meaning less is required.

Table 14.1 Tasman's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	25,550	2,230	13,110	40,890	1.03	49.8
Forest land	9,640	240	1,140	11,020	0.28	13.4
Degraded land	11,990	640	850	13,480	0.34	16.4
Energy land	11,820	760	4,170	16,750	0.42	20.4
Total	59,000	3,870	19,270	82,140	2.07	100.0

The forest land component of the ecological footprint consists of 11,020 ha. This represents 3.4 percent of Tasman's ecological footprint, significantly above the national average of 6.4 percent. Not surprisingly, most (9640 ha) of the forest land is appropriated from within the Tasman area. Because of Tasman's abundant forestry stocks, there is little need to appropriate forest land from outside the region. Nevertheless, inevitably some forest land (1140 ha) is embodied in products imported from overseas.

The degraded land component of the ecological footprint consists of 13,480 ha. This represents 16.4 percent of Tasman's ecological footprint. This is significantly higher than the national average of 8.2 percent. Most of this degraded land (11,990 ha) is sourced within the Tasman region. The largest amount of degraded land imported from other regions is the degraded land embodied (430 ha) in the imported mineral products from the West Coast region.

The energy land component of the Tasman ecological footprint is 16,750 ha. This represents 20.4 percent of Tasman's ecological footprint. On a per capita basis (0.42 ha energy land/ person) it is below the national average (0.50 ha energy land/person). This indicates that because Tasman has a lower than average per capita energy land, the region is relatively energy efficient.

14.4 Ecological footprint disaggregated by goods and services purchased

14.4.1 Purchase of Tasman produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing products accounted for 72,180 ha of embodied land in Tasman's ecological footprint (refer to Table 14.2). This amounts to 27.1 percent of the entire ecological footprint of the Tasman region. Most (18,930 ha) of the land embodied in these manufacturing products comes directly from within the Tasman region. That is, these manufacturing products are made in the Tasman region using land from within the region. The outside-region land embodied in these manufacturing products is relatively small.

Table 14.2 Tasman's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	6,360	20	200	6,580	0.17	8.0
Forestry	620	0	10	630	0.02	0.8
Fishing and hunting	0	0	0	0	0.00	0.0
Mining and quarrying	20	0	10	20	0.00	0.0
Manufacturing	18,930	1,670	1,680	22,280	0.56	27.1
Utilities and construction	7,390	40	870	8,300	0.21	10.1
Services	19,730	360	3,850	23,940	0.60	29.1
Domestic final demand	5,930	1,820	12,670	20,430	0.52	24.9
Total	58,990	3,910	19,280	82,180	2.08	100.0

There is a much lower percentage (27.1 percent) of land embodied in manufacturing products in this region compared with the national average (44.5 percent). The reason is that Tasman residents directly purchase a considerable amount of manufacturing products from outside the region – most notably from Nelson City. Tasman residents will shop in Nelson, technically outside the region, and purchase products from there.

The purchase of service sector products accounts for 23,940 ha of the embodied land in the Tasman ecological footprint. Most of these service sector products (insurance, finance, retail margin) are directly and indirectly drawn from land from within the Tasman region. Much smaller amounts of land which are associated with the purchase of service sector products are appropriated from other regions (360 ha) and other nations (3850 ha).

The land embodied in other products purchased by Tasman residents is much smaller than that for manufacturing and service sector products: agricultural products (6580 ha), forestry products (630 ha), mining and quarrying (20 ha) and utilities and construction products (8300 ha).

14.4.2 Purchase of goods and services produced outside Tasman (D_1+D_4)

Tasman residents also purchased products made outside the region, which account for 14,410 ha of land. Most of these purchases are of overseas products such as imported motor vehicles, computers, foodstuffs and various household items (12,670 ha). There is also 1820 ha of land embodied in purchases of products imported from other regions (13,370 ha).

14.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Tasman economy is 37,730 ha (refer to Table 14.3) whereas, the land embodied in exports from the Tasman economy is 242,510 ha. This results in the Ecological Balance of Trade of the Tasman economy of 208,780 ha, meaning it is an overall provider of land to other regions and nations.

Table 14.3 Tasman's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	390	20,830	20,440
Forestry	0	18,200	18,200
Fishing and hunting	20	700	680
Mining and quarrying	10	30	20
Manufacturing	3,370	3,650	280
Utilities and construction	40	630	590
Services	410	40	-370
Domestic final demand	1,820	0	-1,820
Interregional Balance of Trade	6,060	44,090	38,030
International trade			
Agriculture	3,820	97,910	94,090
Forestry	500	39,630	39,130
Fishing and hunting	620	1,050	430
Mining and quarrying	50	150	100
Manufacturing	4,560	56,710	52,150
Utilities and construction	930	30	-900
Services	4,520	2,930	-1,590
Domestic final demand	12,670	0	-12,670
International Balance of Trade	27,670	198,420	170,750
Total Balance of Trade	33,730	242,510	208,780

14.5.1 Exports and imports by economic sectors

Measured in terms of embodied land, imports of products into the regions are very low, amounting to only 37,730 ha. The low population base results in comparatively few consumer products being imported into the region as well as the small number of secondary and tertiary sector industries means that there are also comparatively few imports by these industries.

Overall, the most important sectors for appropriating land through these purchases of imports are: domestic final demand (14,490 ha), manufacturing (7930 ha), services (4930 ha) and agriculture (4210 ha).

The Tasman region is oriented towards exports particularly to international markets. The embodied land of exports (242,510 ha) outweighs the embodied land of imports (33,730 ha) by a factor of 7.19 times. This is the fifth largest ratio of any region in New Zealand. Exports by the agriculture sector (114,530 ha) are the largest with most embodied land (94,070 ha) being exported overseas – particularly in the form of exported apples. The export of forestry sector products (57,330 ha) is also important, again with the exports to international markets (39,130 ha) dominating. The exports of further processed forestry and agricultural products is also critical, resulting in 52,430 ha of manufacturing sector product being exported out of the region almost entirely to overseas markets.

14.5.2 Exports and imports by land type

Tasman is a significant net exporter of agricultural land to other regions (17,080 ha) and more importantly to other countries (117,000 ha) (refer to Table 14.4). In overall terms, 134,080 ha of Tasman's agricultural land is appropriated by other regions and countries. This is in the form of agricultural land embodied in primary sector products (eg. apples) or primary sector products that have been further processed (eg. foodstuffs).

Table 14.4 Tasman's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	4,220	21,300	17,080
Forest land	250	20,710	20,460
Degraded land	710	500	-210
Energy land	890	1,580	690
Interregional Balance of Trade	6,070	44,090	38,020
International trade			
Agricultural land	19,000	136,000	117,000
Forest land	2,140	51,740	49,600
Degraded land	1,680	1,450	-230
Energy land	4,840	9,230	4,390
International Balance of Trade	27,660	198,420	170,760
Total Balance of Trade	33,730	242,510	208,780

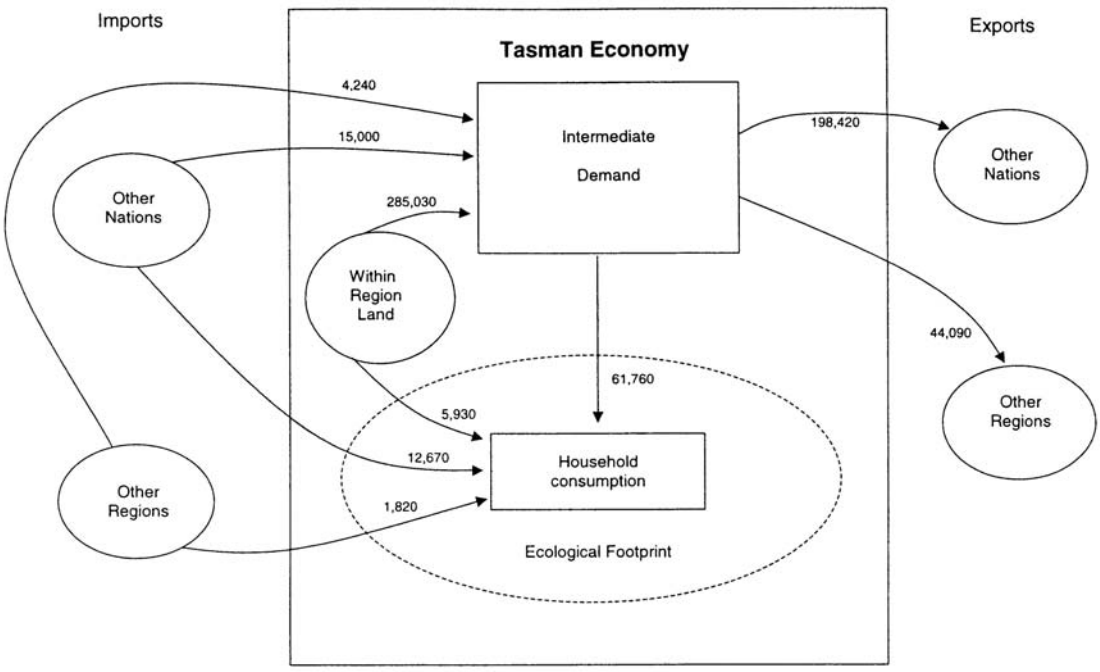
Tasman is also a net provider of forest land to other regions and countries amounting to 70,000 ha. The net exports of forest land to other regions is 20,460 ha and to other countries 49,600 ha. This land is embodied both in the export of logs and processed factory products (eg. fibreboard).

The Ecological Balance of Trade for degraded land (-440 ha) and energy land (5080 ha) is in comparison small.

14.5.3 Overall picture

Figure 14.1 provides a summary of the overall flows of embodied land through the Tasman economy. This diagram indicates that the Tasman economy is very much dominated by the exports of Agricultural and forest land. This is far greater than land channelled into household consumption within Tasman. Exports of embodied land (242,510 ha) is far outweighed by imports of embodied land (33,730 ha). This gives Tasman a positive Ecological Balance of Trade of 208,780 ha. Tasman is therefore a net provider of ecological capital to other nations and to a lesser extent other regions within New Zealand.

Figure 14.1 Flows of embodied land through the Tasman economy



15 Nelson's Ecological Footprint

15.1 Profile of the region

Nelson is by far New Zealand's smallest region covering only 44,430 ha. In terms of land coverage, it is 11.7 times smaller than Auckland, the next smallest region. A significantly large proportion of the region is covered by Nelson City urban area. As a result the Nelson region has the second largest population density of any region, at 93.18 people/km^2. The population of Nelson was 44,430 in 1997/98, making it the fourth to lowest of out of the 16 regions. Nelson's population growth over recent years has been among the highest in the country. A favourable sunny climate amongst other factors has made it a popular retirement destination as well attracting people and businesses to the region.

Nelson's port plays an important role in the regional economy. It is one of the country's busiest ports in terms of ship arrivals and departures. Significant amounts of primary products are exported through the port including forestry and horticultural products. The port is also a significant fishing port. It caters for more than 100 fishing boats and there are around 20 seafood operations based in Nelson. This is reflected in the high location quotients for fishing and hunting (LQ 11.65) and other food manufacturing, including fish processing (LQ 5.15).

The close proximity of three natural parks, beaches, craft industry and other tourist attractions, coupled with a sunny temperate climate, makes Nelson a popular tourist destination. The number of jobs and income generated through tourism is significant and is dramatically increasing. This is seen in the higher than average location quotients for tourism related sectors such as accommodation, restaurants and cafés (LQ 1.16) and air transport (LQ 2.73).

The relative level of agricultural and horticultural activity is the lowest in the country due to Nelson high urban population. There is however some processing of agricultural and horticultural products imported from outside the region (mainly from the Tasman region) in Nelson City. This leads to relatively high employment in the food processing industry of 2115 jobs in 1997/98 out of a total regional workforce of 18,087.

15.2 Overall ecological footprint and comparison with other regions

Nelson has the smallest ecological footprint of any region in New Zealand at 76,910 ha. This represents only 0.72 percent of New Zealand ecological footprint.

Nelson also has the lowest ecological footprint, on a per capita basis, at 1.86 ha per person. This low per capita ecological footprint appears to be mainly due to two factors although further research is required. Firstly, there are indications that Nelson although small, does have pockets of highly productive land that will reduce the size of its ecological footprint as less land will be required to produce the same amount of product. Secondly, there could be significant land-use efficiencies achieved in Nelson as it is New Zealand's most urban region. Urban regions through higher population and housing densities can considerably reduce the land-use per resident and this may be a factor in the Nelson case.

The useful land area of Nelson is 35,230 ha, giving Nelson an ecological deficit of 41,680 ha, Nelson overshoots it useful land area by 2.18 times. This means Nelson is not self-sufficient

and ecologically depends on land appropriated from other regions and from overseas. The ratio of ecological footprint to useful land (degree of overshoot) for Nelson is second only to Auckland. Only Nelson, Auckland and Wellington (New Zealand's most urban areas), overshoot their useful land areas.

15.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 36,720 ha (refer to Table 15.1). This represents 47.2 percent of Nelson's ecological footprint. Just under half (17,470 ha) of this agricultural land is embodied in products imported from overseas with about a third (12,910 ha) embodied in products imported from other regions in New Zealand. The agricultural land embodied in products imported from neighbouring Tasman (4600 ha) is the most significant. Only a relatively small amount of agricultural land is appropriated from within the region (5910 ha), not surprising given the urban nature of the region.

Table 15.1 Nelson's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	5,910	12,910	17,470	36,290	0.88	47.2
Forest land	3,140	790	1,950	5,880	0.14	7.6
Degraded land	11,950	600	1,160	13,710	0.33	17.8
Energy land	13,980	620	6,420	21,020	0.51	27.3
Total	34,980	14,920	27,000	76,900	1.86	100.0

The forest land component of the ecological footprint consists of 5800 ha. This represents 7.6 percent of Nelson's ecological footprint. Most (3140 ha) of this forest land is appropriated from within the region.

The degraded land component of the ecological footprint consists of 13,710 ha. This represents 17.8 percent of Nelson's ecological footprint. On a per capita basis Nelson residents consume 0.33 ha degraded land per person, more than the New Zealand average of 0.25 ha degraded land per person. This is not surprising given the urban character of Nelson. Where there is a choice there will be tendency to use urban (degraded) land rather than agricultural land.

The energy land component of the ecological footprint consists of 21,020 ha. This represents 27.3 percent of Nelson ecological footprint. On a per capita basis the energy land consumption is the same as the New Zealand average, indicating that Nelson has an energy efficiency at about the national average.

15.4 Ecological footprint disaggregated by goods and services purchased

15.4.1 Purchase of Nelson produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing products accounted for 23,180 ha of embodied land in Nelson's ecological footprint (refer to Table 15.2). This amounts to 31.0 percent of the entire ecological

footprint of the Nelson region. Nearly half (12,210 ha) of the embodied land is in manufacturing products imported from other regions, most notably food and agricultural products from: Tasman (4550 ha), Taranaki (2820 ha) and Southland (4550 ha). Significant amounts of overseas land (5660 ha) is also embodied in the manufacturing products purchased. Only a relatively small amount of land compared with other regions is appropriated by manufactured goods from within the region (5940 ha).

Table 15.2 Nelson's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	4,430	1,120	110	5,660	0.14	7.4
Forestry	270	180	0	460	0.01	0.6
Fishing and hunting	0	0	0	10	0.00	0.0
Mining and quarrying	10	10	0	20	0.00	0.0
Manufacturing	5,940	12,210	5,660	23,810	0.58	31.0
Utilities and construction	9,090	330	1,230	10,650	0.26	13.8
Services	8,000	220	6,350	14,570	0.35	18.9
Domestic final demand	7,220	870	13,640	21,730	0.52	28.3
Total	34,970	14,930	27,000	76,910	1.86	100.0

The purchase of service sector products accounted for 14,570 ha of embodied land in the Nelson ecological footprint. This accounts for 18.9 percent of the entire ecological footprint of the Nelson region. On a per capita basis, the land embodied in the purchase of service sector products is 0.35 ha/person, which is significantly below the national average of 0.51 ha per person. It is unlikely that Nelson residents consume significantly less service sector products and more likely that the land intensity per dollar of service product is lower than the national average. This could be a result of the urban nature of the Nelson economy.

The land embodied in other products purchased by Nelson residents is smaller than for manufacturing and service sector products: agricultural products (5660 ha), forestry products (460 ha), fishing and hunting products (10 ha), mining and quarrying products (20 ha) and utilities and construction products (10,650 ha).

15.4.2 Purchase of goods and services produced outside Nelson (D_1+D_4)

Nelson residents purchased products imported from outside the region, amounting to 14,510 ha of land. Most of these purchases appropriate land directly from overseas (13,640 ha). The amount of land appropriated by these purchases from other regions is small (870 ha).

15.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into Nelson is 81,550 ha. Whereas, the land embodied in exports from Nelson is 68,600 ha (refer to Table 15.3). This results in the Ecological Balance of Trade of the Nelson economy being negative 12,950 ha, making it overall a net consumer of land from outside the region. This makes Nelson along with Auckland and Wellington the only regions

that are net consumers of land. This is to be expected as they are the three most urban regions in New Zealand.

Table 15.3 Nelson's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	1,730	10	-1,720
Forestry	2,440	420	-2,020
Fishing and hunting	0	2,330	2,330
Mining and quarrying	20	0	-20
Manufacturing	38,260	910	-37,350
Utilities and construction	330	50	-280
Services	300	370	70
Domestic final demand	870	0	-870
Interregional Balance of Trade	43,950	4,090	-39,860
International trade			
Agriculture	180	3,110	2,930
Forestry	60	5,350	5,290
Fishing and hunting	2,280	2,990	710
Mining and quarrying	10	30	20
Manufacturing	11,080	45,630	34,550
Utilities and construction	1,250	30	-1,220
Services	9,100	7,370	-1,730
Domestic final demand	13,640	0	-13,640
International Balance of Trade	37,600	64,510	26,910
Total Balance of Trade	81,550	68,600	-12,950

15.5.1 Exports and imports by economic sectors

A large percentage (60.50 percent) of the land embodied in imports into Nelson is associated with purchases of products by the manufacturing sector (49,430 ha). Most of these purchases by the Nelson manufacturing sector are the raw materials purchased from other regions (particularly from Tasman) for further processing. Most of the land embodied in these imported materials is eventually re-exported from Nelson in the form of value-added products that are destined for overseas markets.

The imports purchased by the other sectors in the Nelson economy are smaller in terms of their appropriated land: domestic final demand (14,510 ha), services (9400 ha), fishing and hunting (2280 ha), forestry (2500 ha), agriculture (1910 ha), utilities and construction (1580 ha) and mining and quarrying (30 ha).

The exports are again dominated by those from the manufacturing sector (46,540 ha). Quite simply, raw materials are imported by the manufacturing sector then processed and almost all of them are then exported out of the region. The land embodied in exports from the forestry sector (5770 ha) and the fishing sector (5770 ha) are also significant. Notably, the figure for the fishing sector would be much higher if the 'marine area' were included in the ecological footprint calculations.

15.5.2 Exports and imports by land type

Nelson is a significant net consumer of agricultural land from outside the region (refer to Table 15.4). Nelson imports 63,770 ha of agricultural land both from New Zealand (38,760 ha) and international (25,010 ha) sources. A significant amount of this imported agricultural land is consumed within the Nelson economy. Overall, however Nelson does have a negative Ecological Balance of Trade for agricultural land of -24,790 ha.

Table 15.4 Nelson's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	38,760	1,080	-37,680
Forest land	3,510	640	-2,870
Degraded land	680	210	-470
Energy land	1,000	2,160	1,160
Interregional Balance of Trade	43,950	4,090	-39,860
International trade			
Agricultural land	25,010	37,900	12,890
Forest land	2,520	7,830	5,310
Degraded land	2,070	2,430	360
Energy land	8,000	16,350	8,350
International Balance of Trade	37,600	64,510	26,910
Total Balance of Trade	81,550	68,600	-12,950

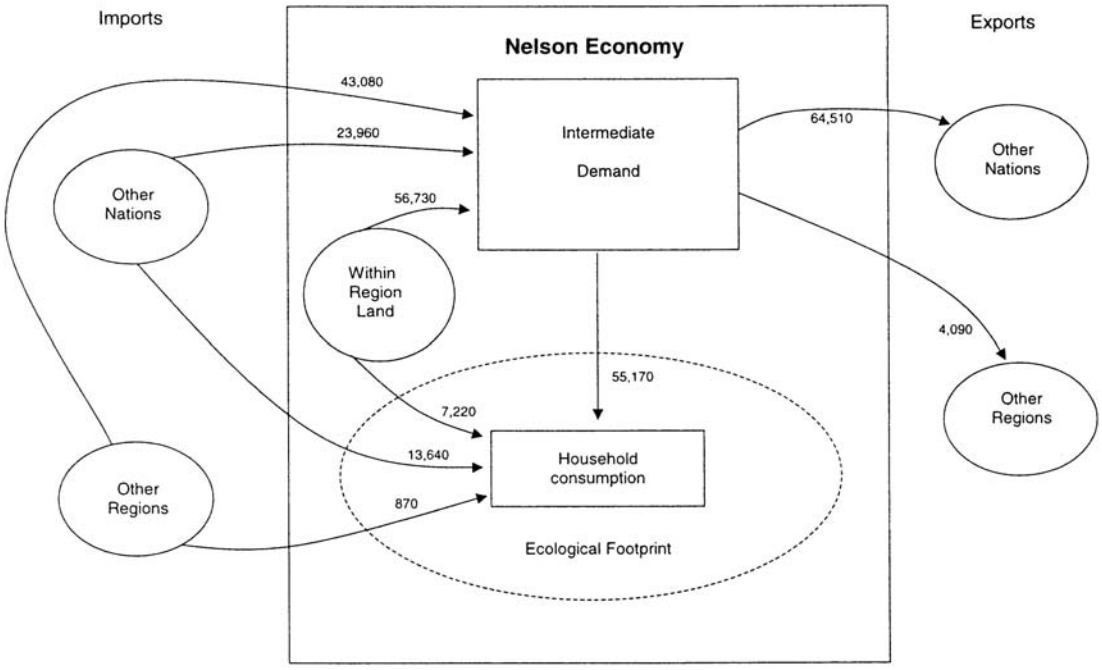
There are significant imports (6030 ha) and exports (8470 ha) of forest land. Although Nelson does import considerable forest land, most of this is just re-exported out of the region which, combined with the export of within region forest land, leads to a positive Ecological Balance of Trade for forest land (2440 ha).

There is also a significant net export of energy land. Value-added manufacturing industries in Nelson are energy intensive, which means when agricultural and forest raw materials are purchased and then processed for re-exporting out of the region, an energy land component is essentially added to them.

15.5.3 Overall picture

Figure 15.1 provides a summary of the overall flows of embodied land through the Nelson economy. This diagram indicates that the Nelson economy has two foci of about equal importance with 76,910 ha of land is channelled into household consumption and 64,510 ha being used to make products for exports to international markets. The exports to other regions (4090 ha) are very much a subsidiary function of the Nelson economy. Exports of embodied land (68,600 ha) are outweighed by imports of embodied land (81,550 ha). This gives Nelson a negative Ecological Balance of Trade of -12,950 ha. Nelson is therefore a net consumer rather than provider of ecological capital.

Figure 15.1 Flows of embodied land through the Nelson economy



16 West Coast's Ecological Footprint

16.1 Profile of the West Coast region

The resident West Coast population at the 2001 Census was estimated to be 30,303 people. In the period between censuses the region experienced the greatest percentage decline (6.8 percent) in population of any region in the country, equating to 2211 people. The West Coast has New Zealand's smallest population, making up less than 1 percent of the national population. While more than 85 percent of the nation's population lives in urban areas, only an estimated 56.9 percent of West Coasters are urban dwellers. The most significant urban area is Greymouth with a usually resident population of 9525 people, 31.4 percent of the region's population in 2001. The West Coast has a population density of only 1.41 people per square kilometre, compared with the national average of 13.97 per square kilometre in 1998. This makes it the most sparsely populated region in New Zealand.

The West Coast has an estimated land area of 2,333,600 ha, 8.5 percent of New Zealand's land area. The region is elongated extending more than 600 kilometres from Kahurangi in the north to Awarua Point in the south. The Southern Alps separate the West Coast from Canterbury while the Tasman Sea marks the western boundary. The West Coast region is the fifth largest in New Zealand. Te Waipounamu (one of the country's two World Heritage sites) traverses the region and it includes four national parks: namely Fiordland, Mt Aspiring, Mt Cook and Westland. The Southern Alps act as a barrier to the predominantly westerly weather, which in turn, ensures that the region experiences the highest annual rainfall of any region nationally. Poor climatic conditions coupled with the region's inaccessible mountainous nature result in the region experiencing regular flooding, landslides and earthquakes. The region's soils are generally infertile as a result of constant water leaching. These factors make most of the region's land unsuitable for farming.

The West Coast's GDP in 1997–98 was estimated to be $0.8 billion or 0.8 percent of the national GDP. Mining, forestry, fishing and dairy farming are significant industries. In recent years tourism has also established a strong foothold in the economy. The West Coast has an estimated 260 million tonnes of recoverable coal reserves with between 1 and 1.5 million tonnes annually extracted and exported overseas for steel production. Gold mining is still a significant industry, although not as large as in the past. The contribution made by mining to the local economy is reflected in the high location quotients for the mining and quarrying industry (LQ 21.95) and in the processing of non-metallic minerals (LQ 3.08).

Until recently, indigenous forests formed the basis of a significant wood felling and logging industry (LQ 4.41). This included harvesting of beech and podocarps such as rimu. Planted exotic forest is now becoming the mainstay of the industry. As at 1 April 1998 exotic forest plantations accounted for 32,607 ha. Other industries with a comparative advantage relative to the nation include dairy farming (LQ 2.88), dairy processing (LQ 2.25) and fishing and hunting (LQ 3.93). The transportation of mining and forestry products has resulted in a high location quotient for the water transport industry (LQ 2.70). The growing emphasis on tourism is reflected in the accommodation, restaurant and cafés sector location quotient of 1.95.

16.2 Overall ecological footprint and comparison with other regions

The West Coast has an ecological footprint of 121,890 ha. This represents 1.1 percent of New Zealand's total ecological footprint and is the third lowest of any region. It is slightly higher than the Tasman region (82,180 ha) but lower than Marlborough (163,810 ha). The West Coast region's footprint is only 7.0 percent of Canterbury's.

The West Coast region's ecological footprint per capita is 3.70 ha. This is similar to the per capita footprints of Manawatu–Wanganui region (3.80 ha) and Canterbury (3.57 ha) but is 20.1 percent higher than the New Zealand average of 3.08 ha. This figure is higher relative to the nation primarily because of the low productivity of the land on the West Coast. Susceptibility to flooding, landslips and the like, irrespective of land fertility, has meant that farming is often conducted on marginal land that produces variable yields over time. It is estimated that lower than average productivity exists across the entire agriculture industry, including sheep, beef and mixed livestock, dairying, horticulture and fruit growing.

The useful land area of the West Coast is estimated to be 266,250 ha, meaning that West Coast has an ecological surplus of 144,360 ha. In ecological footprint terms this means that the West Coast is largely self-sufficient.

16.3 Ecological footprint disaggregated by land type

The agricultural land component of the West Coast region's ecological footprint consists of 78,440 ha (refer to Table 16.1). In this way, agricultural land comprises 64.4 percent of the region's footprint. Like most rural regions in New Zealand, this land is predominantly located within the region. Some 6100 ha (5.0 percent of the region's footprint), however, is embodied in goods and services imported interregionally with a significant proportion originating from Southland. This includes land embodied in purchases of sheep and beef related food products. West Coast industries are unable to met local demand for these products and hence the importation from Southland.

Table 16.1 West Coast's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	59,800	6,100	12,540	78,440	2.38	64.4
Forest land	3,030	160	980	4,170	0.13	3.4
Degraded land	22,710	110	700	23,520	0.71	19.3
Energy land	11,630	440	3,640	15,710	0.48	12.9
Total	97,170	6,810	17,860	121,840	3.70	100.0

The forest land component of the ecological footprint consists of 4170 ha. This represents only 3.4 percent of the West Coast's ecological footprint and in relative terms is among the lowest of any region. By comparison, the average West Coast resident appropriates 0.13 ha annually while the average New Zealand appropriates nearly 1.7 times this figure (0.2 ha per person). One possible reason for this difference is a declining population, resulting in a depressed housing market which in turn leads to fewer new houses being built. Overall, an estimated 3030 ha of forest land is embodied in local goods and services purchased by West Coast residents annually. This component of the footprint does not include the hypothetical land area occupied by trees planted to sequester CO_2 emissions.

The degraded land component makes up 19.3 percent (23,520 ha) of the West Coast's ecological footprint. This figure is substantially higher than the comparable figure nationally (8.2 percent). Two key explanations are:

(1) significantly larger residential section sizes

(2) similarly, significantly larger manufacturing/commercial section sizes.

This component is almost entirely (96.6 percent) made up of within-region land.

The energy land component of the region's footprint is estimated to be 15,710 ha. Whilst the relative share of the energy footprint (12.9 percent) differs greatly from its national equivalent (16.6 percent), in per capita terms the two are similar. Most of this land is appropriated from within the region (11,630 ha) although an additional 3640 ha is embodied in goods and services purchased from overseas.

16.4 Ecological footprint disaggregated by goods and services purchased

16.4.1 Purchase of West Coast produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 42,290 ha of embodied land in the West Coast's ecological footprint (refer to Table 16.2). Over 80 percent of this figure, 34,840 ha, comes from within the region. It is also predominantly made up of agricultural land. A further 5930 ha is embodied in manufactured products purchased from other regions in particular Southland.

Table 16.2 West Coast's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	10,380	100	160	10,630	0.32	8.7
Forestry	270	0	0	270	0.01	0.2
Fishing and hunting	0	0	0	0	0.00	0.0
Mining and quarrying	120	0	0	120	0.00	0.1
Manufacturing	34,840	5,930	1,520	42,290	1.29	34.7
Utilities and construction	7,070	50	720	7,840	0.24	6.4
Services	38,570	180	4,880	43,630	1.33	35.8
Domestic final demand	5,930	580	10,580	17,090	0.52	14.0
Total	97,170	6,850	17,870	121,890	3.70	100.0

Land embodied in the purchase of service sector products required to support West Coast residents constitutes 35.8 percent of the region's footprint. In this way, land embodied in service sector purchases (43,630 ha) is slightly greater than land embodied in manufactured goods (42,290 ha). Backward linkages from the service sector to the farming sector on the West Coast economy partially explain why this figure is so high. The actual physical space occupied by the region's service sector also contributes to this finding. Unlike the manufacturing sector, a significant proportion of land embodied in service sector products consumed by West Coast residents comes from other nations (4880 ha).

Of the land embodied in purchases from other sectors by West Coast residents, agriculture products contribute 10,630 ha while utility and construction purchases make up 7840 ha of the region's ecological footprint. Once again, these figures are made up of almost entirely within-region land.

16.4.2 Purchase of goods and services produced outside the West Coast (D_1+D_4)

West Coast residents also purchase products that are made outside of the region. The vast majority of land embodied in these purchases (10,580 ha) comes from abroad. This includes land embodied in goods purchased from overseas by retailers that are on-sold to West Coast households within an additional margin. Thus, land embodied in purchases of motor vehicles, computers, many household appliances and furniture is included in this figure.

16.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the West Coast economy is 36,030 ha, while exports into the region embody 235,910 ha of land (refer to Table 16.3). This means that the West Coast is a net provider of land to other regions and nations, having a positive Ecological Balance of Trade of 199,880 ha.

Table 16.3 West Coast's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	770	56,140	55,370
Forestry	130	6,500	6,370
Fishing and hunting	0	630	630
Mining and quarrying	10	380	370
Manufacturing	9,030	3,800	-5,230
Utilities and construction	60	1,120	1,060
Services	230	1,080	850
Domestic final demand	580	0	-580
Interregional Balance of Trade	10,810	69,650	58,840
International trade			
Agriculture	1,230	16,450	15,220
Forestry	410	16,860	16,450
Fishing and hunting	470	970	500
Mining and quarrying	220	7,180	6,960
Manufacturing	4,750	112,710	107,960
Utilities and construction	790	40	-750
Services	6,770	12,050	5,280
Domestic final demand	10,580	0	-10,580
International Balance of Trade	25,220	166,260	141,040
Total Balance of Trade	36,030	235,910	199,880

16.5.1 Exports and imports by economic sectors

Sales of manufactured products from the West Coast embody an estimated 116,510 ha of land. This represents approximately half of the region's embodied land exports. Like many regions in New Zealand this land consists of Agricultural and forest land destined for other countries. Small quantities of land associated with mining are also included. On an interregional basis, however, the region is a significant net importer of land embodied in manufactured products (5230 ha). This occurs because either:

(1) base manufacturers are not present (ie. goods are imported non-competitively) or

(2) local supply is unable to met local demand for many manufactured products.

The region's export-driven focus is also apparent in the quantity of land embodied in forestry products. On an annual basis some 23,360 ha of land embodied in forestry products leaves the region with slightly more than two-thirds heading offshore. Similarly, the region's export focus on mining is also highlighted. It is estimated that 7180 ha of embodied land is exported annually in mining sector products.

Of the remaining sectors in the West Coast economy the following have fairly small and close to neutral Ecological Balance of Trade results: fishing and hunting (1600 ha) and utilities and construction (310 ha). The exception is the region's service sector, which has an Ecological Balance of Trade surplus of 6130 ha – this finding is explained by backward linkages to forestry and mining.

16.5.2 Exports and imports by type of land

The West Coast is a net producer of agricultural land (refer to Table 16.4). Agricultural land embodied in international exports (128,520 ha) outweighs that embodied in international imports (17,550 ha) by 7.3 times. This land is sourced from all farming types but more so from dairying and less so from horticulture crops and fruit.

Table 16.4 West Coast's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	9,790	58,330	48,540
Forest land	320	6,530	6,210
Degraded land	160	2,310	2,150
Energy land	540	2,480	1,940
Interregional Balance of Trade	10,810	69,650	58,840
International trade			
Agricultural land	17,550	128,520	110,970
Forest land	1,620	18,360	16,740
Degraded land	1,580	9,000	7,420
Energy land	4,480	10,380	5,900
International Balance of Trade	25,230	166,260	141,030
Total Balance of Trade	36,040	235,910	199,870

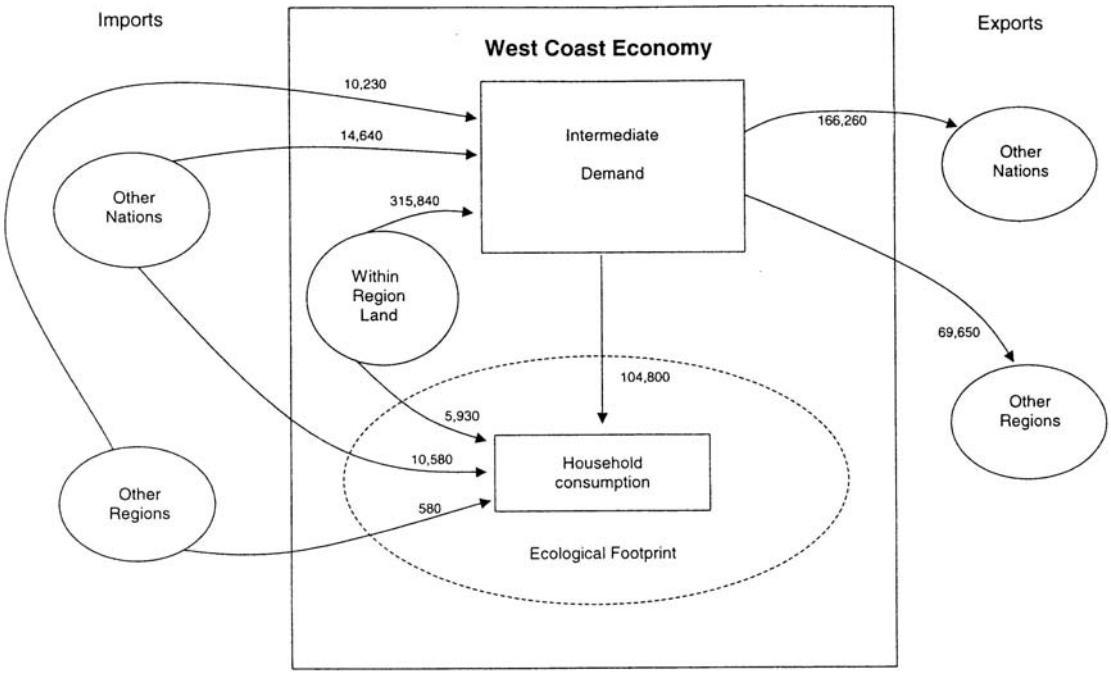
The West Coast's comparative advantage in forestry products is clearly highlighted. In Balance of Trade terms, forest land embodied in products sold (24,890 ha) by the West Coast economy outweigh equivalent purchases from both other regions (320 ha) and nations (1620 ha).

The trade flows of both degraded land and energy land for the West Coast economy show a positive net Balance of Trade. Specifically, in net terms degraded and energy land embodied in the exports out of the region respectively accounts for 9570 ha and 7840 ha of land. The region's net outflow of embodied degraded land, particularly to international locations, is linked with the region's large precious metal and coal mining operations.

16.5.3 Overall picture

Figure 16.1 provides a summary of the overall flows of embodied land of the West Coast economy. This diagram indicates that the West Coast is self-sufficient in embodied land with relatively few imports required to support local households. In addition, the diagram indicates that the West Coast's economy is export orientated. Embodied land flows out of the region equates to 235,910 ha, 6.5 times greater than flows into the region. In this way, the West Coast is has positive Balance of Trade of 199,880 ha.

Figure 16.1 Flows of embodied land through the West Coast economy



17 Canterbury's Ecological Footprint

17.1 Profile of the region

At 4,553,681 ha, Canterbury is New Zealand's largest region in terms of land coverage. In terms of population and GDP output it ranks second behind Auckland and marginally ahead of the Wellington region.

Geographically, the region is expansive and diverse with perhaps four distinctive landscapes: the Southern Alps on the western flank, rolling foothills of the Alps, the Canterbury Plains based on alluvial fans and Banks Peninsula which has volcanic origins. This physical endowment provides the basis for much of the economic activity of Canterbury, ranging from farming activity through to downstream manufacturing and nature-based tourism.

Over half (52 percent) of the South Island population lives in Canterbury, mostly in the Christchurch metropolitan area. Over the last two census periods (from 1991-2001) Canterbury has experienced steady population growth, reaching 481,131 in the 2001 Census. Current projections estimate that the population will increase to 533,600 by 2021 (15.6 percent increase). The population density of 10.75 people per square kilometre is close to the New Zealand average, reflecting the urban-rural mix of Canterbury which is a microcosm of the New Zealand situation.

Canterbury has a strong agricultural base particularly in sheep and beef farming (LQ 1.37), and other farming (LQ 5.11) ie. cropping, deer, pig and other livestock. It has the largest number of sheep of any region in New Zealand and a dominance in pig farming in part due to Canterbury being a major grain producing region.

The manufacturing base in Canterbury is also strong and diverse, (70 percent) based mainly in urban Christchurch but with significant pockets of activity in Ashburton (5 percent) and Timaru (8 percent). Much of this strength is derived from the further processing of raw materials from the primary sector, including meat and meat product manufacturing (LQ 1.40), manufacturing of food (LQ 1.24), textile and apparel manufacturing (LQ 1.59), and wood and wood products (LQ 1.06). Light manufacturing industries with a technological focus, such as machinery and equipment manufacture (LQ 1.37), transport equipment (LQ 1.26) and chemical products (LQ 1.20) also record activities above the national average.

Canterbury is an important region in terms of electricity generation, producing 24 percent of New Zealand's electricity from hydroelectric plants in the Waitaki Basin, Lake Coleridge and Highbank.

Tourism is also important to the Canterbury economy with Christchurch being the main gateway for international tourists into the South Island. Beyond Christchurch, the Southern Alps with Mt Cook and Arthur's Pass National Parks are significant tourism attractions. International tourists made 800,000 trips to the Canterbury region, spending $724 million in 2002 (McDermott Fairgray Group Ltd, 2001). This makes Canterbury the second most important tourism region behind Auckland.

17.2 Overall ecological footprint and comparison with other regions

Canterbury has an ecological footprint of 1,737,840 ha, 16.16 percent of New Zealand ecological footprint. It is the second highest ecological footprint of any region in New Zealand behind Auckland.

On a per capita basis, Canterbury has an ecological footprint of 3.75 ha per person. On this basis, it is the sixth largest ecological footprint of any region in New Zealand and above the New Zealand average of 3.08 ha per person. Canterbury, in overall terms, has slightly less productive land than the New Zealand average, which pushes its ecological footprint just above the New Zealand average. The urban-rural mix (and resultant population density) in Canterbury is similar to the national average, which means that any urban efficiencies (and their effects on the ecological footprint) will probably be the same as the national average.

According to the ecological footprint calculation, 1,737,840 ha of land is required to produce the commodities which the Canterbury population consumes. These are in contrast 3,636,071 ha of useful land available, meaning that Canterbury has more than enough land to sustain its current level of consumption. In fact, Canterbury would need to increase its consumption, 2.09 times before it would overshoot the availability of useful land. Overall, in net terms, this means that Canterbury is self-sufficient and actually has an ecological surplus of 1,898,230 ha of useful land. This is the largest ecological surplus of any region in New Zealand.

17.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 1,302,510 ha (refer to Table 17.1), 75.0 percent of the Canterbury ecological footprint. Most (1,028,480 ha) of this agricultural land is appropriated from within the region, not surprising given the abundance of agricultural land in the Canterbury region. Only a relatively small amount (59,270 ha) of agricultural land is appropriated from other regions in New Zealand. Agricultural land appropriated from overseas (214,400 ha) is more significant than obtained from other regions in New Zealand.

Table 17.1 Canterbury's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	1,028,840	59,270	214,400	1,302,510	2.67	75.0
Forest land	26,890	4,650	18,630	50,170	0.10	2.9
Degraded land	143,820	1,580	12,470	157,870	0.32	9.1
Energy land	157,040	3,920	66,240	227,200	0.47	13.1
Total	1,356,590	69,420	311,740	1,737,750	3.57	100.0

The forest land component of the ecological footprint consists of 50,170 ha, only 2.9 percent of the total Canterbury footprint. On a per capita basis, this forest land appropriation is 0.10 ha per person for Canterbury, half of the national average of 0.20 ha per person. The low use of forest land in Canterbury and comparatively high use of agricultural land is suggestive of some substitution effect involving agricultural land displacing forest land for some uses.

The degraded land component of the ecological footprint consists of 157,870 ha. This represents 9.1 percent of Canterbury's ecological footprint. Most of degraded land is appropriated from urban Christchurch and to a lesser extent from urban centres such as Timaru and Ashburton. Comparatively little degraded land is appropriated from other regions (1580 ha) or from overseas (12,470 ha).

The energy land component of the ecological footprint is 227,200 ha. This represents 13.1 percent of Canterbury's ecological footprint. On a per capita basis, this amounts to 0.47 ha energy land per person, compared with a national average of 0.51 ha energy land per person. The fact that most of this energy land is appropriated within the region combined with the fact that Canterbury's per capita energy land is below the national average indicates that Canterbury is slightly more energy efficient than the national average.

17.4 Ecological footprint disaggregated by goods and services purchased

17.4.1 Purchase of Canterbury produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 822,940 ha of embodied land in Canterbury's ecological footprint (refer to Table 17.2). Most of this land was drawn from within the region. Canterbury manufacturers only appropriated relatively small amounts of land from other regions (64,350 ha) and other nations (63,760 ha) in providing these products. The land embodied in manufacturing products purchased by Cantabrians represents 47.4 percent of Canterbury's ecological footprint.

Table 17.2 Canterbury's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	160,380	360	9,110	169,850	0.35	9.8
Forestry	2,680	520	60	3,260	0.01	0.2
Fishing and hunting	30	0	30	60	0.00	0.0
Mining and quarrying	220	70	90	370	0.00	0.0
Manufacturing	694,830	64,350	63,760	822,940	1.69	47.4
Utilities and construction	53,540	1,570	12,990	68,090	0.14	3.9
Services	354,330	860	67,240	422,430	0.87	24.3
Domestic final demand	90,580	1,780	158,480	250,840	0.51	14.4
Total	1,356,590	69,510	311,740	1,737,840	3.57	100.0

The purchase of service sector products accounted for 422,430 ha of the embodied land in the Canterbury ecological footprint. This amounts to 24.3 percent of the entire ecological footprint of the Canterbury region. Most of these service sector products (insurance, finance, retail margin) are drawn from land within the Canterbury region (354,330 ha). Very little (860 ha) land from other regions is embodied in service sector products purchased by Cantabrians although there is a significant amount of overseas land (67,260 ha) involved.

The land embodied in other products consumed by Cantabrians is much smaller than that for manufacturing and service sector products: agricultural products (169,580 ha), forestry products (3200 ha) fishing and hunting products (60 ha), mining and quarrying products (370 ha) and utilities and construction products (10,096 ha).

17.4.2 Purchase of goods and services produced outside Canterbury (D_1+D_4)

Cantabrians purchase products from outside the region, accounting for 160,260 ha of appropriated land. Most of these purchases appropriate land from overseas (158,480 ha) such as householders purchasing products such as imported motor vehicles, computers, foodstuffs and various household items. There is only a small amount of appropriated land from other regions in these purchases (1780 ha).

17.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Canterbury regional economy is 653,620 ha. Whereas, the land embodied in exports from the Canterbury economy is 2,559,420 ha (refer to Table 17.3). This results in the Ecological Balance of Trade of the Canterbury economy being 1,905,780 ha, ie. it is overall a net provider of land to other regions and nations.

Table 17.3 Canterbury's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	2,200	217,960	215,760
Forestry	6,510	0	-6,510
Fishing and hunting	10	0	-10
Mining and quarrying	180	0	-180
Manufacturing	164,490	36,440	-128,050
Utilities and construction	1,580	700	-880
Services	1,060	2,600	1,540
Domestic final demand	1,780	0	-1,780
Interregional Balance of Trade	177,810	257,700	79,890
International trade			
Agriculture	55,380	644,690	589,310
Forestry	690	37,160	36,470
Fishing and hunting	1,350	2,850	1,500
Mining and quarrying	240	670	430
Manufacturing	159,610	1,506,590	1,346,980
Utilities and construction	13,190	260	-12,930
Services	86,870	109,490	22,620
Domestic final demand	158,480	0	-158,480
International Balance of Trade	475,810	2,301,720	1,825,910
Total Balance of Trade	653,620	2,559,420	1,905,800

17.5.1 Exports and imports by economic sectors

In net terms, Canterbury exports a massive amount (1,905,800 ha) of land outside the region. In fact, it is a net exporter of more land than any other region in New Zealand.

The Canterbury agricultural sector exports 862,650 ha of land in agricultural products (wool, live animals, horticultural produce) destined for regional markets (215,760 ha) and for international markets (589,310 ha). The manufacturing sector exports even more embodied land (1,543,030 ha) although there are also significant imports of land into the manufacturing sector (324,100 ha). Many of the agricultural products are further processed and then exported in a value-added form from the region. The strongest outward flow of these manufactured goods is internationally with only relatively small flows to other regions in New Zealand.

Apart from the agricultural and manufacturing sector, the other trade flows to and from the Canterbury economy are relatively small and tend not to be driven by export markets.

17.5.2 Exports and imports by land type

Canterbury is a very large net provider of agricultural land to other regions and nations. Even though it appropriates 507,870 ha of agricultural land through imports, it exports a massive 2,383,730 ha of appropriated agricultural land (refer to Table 17.4). The overall effect, is the net export of 1,875,860 ha of agricultural land. Much of the prosperity of the Canterbury economy is indeed based on this ability to produce from its land resources, large volumes of agricultural products for export to international markets.

Table 17.4 Canterbury's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	157,220	251,770	94,550
Forest land	12,270	550	-11,720
Degraded land	2,260	2,090	-170
Energy land	6,080	3,290	-2,790
Interregional Balance of Trade	177,830	257,700	79,870
International trade			
Agricultural land	350,650	2,131,960	1,781,310
Forest land	24,020	54,550	30,530
Degraded land	23,080	22,450	-630
Energy land	78,050	92,750	14,700
International Balance of Trade	475,800	2,301,710	1,825,910
Total Balance of Trade	653,630	2,559,410	1,905,780

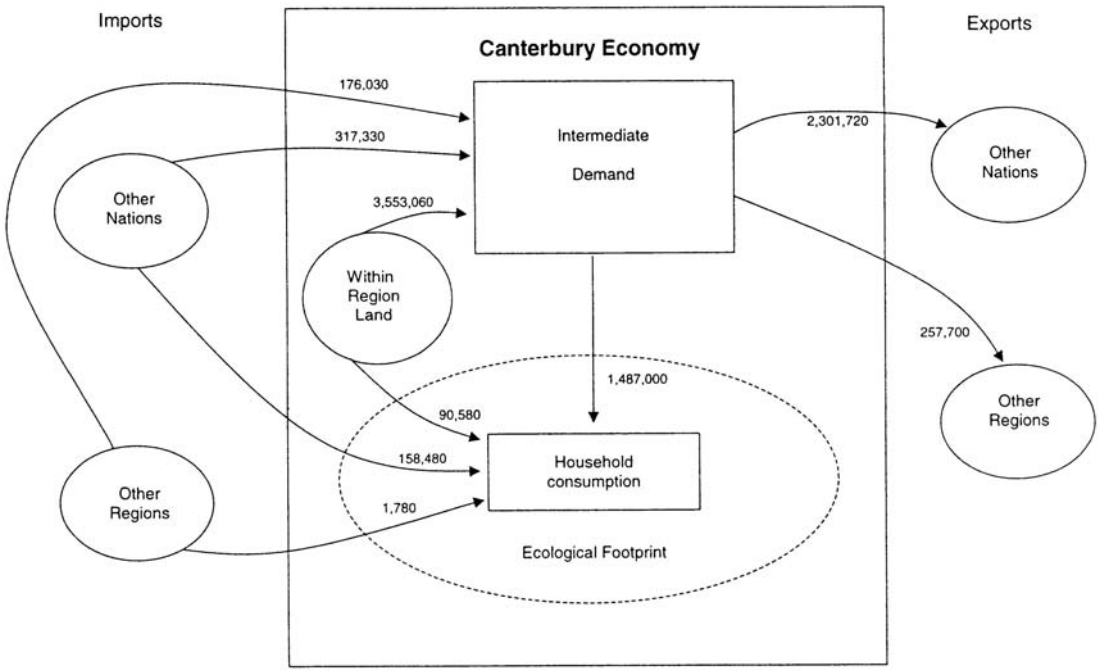
The trade flow patterns for forest land, degraded land and energy land tend on the other hand to be driven by local demand within the Canterbury economy. There are significant imports of consumer and intermediate consumption goods which appropriate forest land (36,290 ha), degraded land (25,340 ha) and energy land (84,130 ha). On the export side, some forest land (55,100 ha), degraded land (24,540 ha) and energy land (90,040 ha) is embodied in the export of products from the Canterbury economy.

17.5.3 Overall picture

Figure 17.1 provides a summary of the overall flows of embodied land through the Canterbury regional economy. The production of agricultural products for international exports dominates with 2,301,720 ha being exported to other nations. The export to other regions is in comparison much smaller at 257,700 ha. Even though the Canterbury economy has a strong export orientation, there is a considerable population base particularly in urban Christchurch, which means that the flows of embodied land required for household consumption are also high at 1,737,840 ha. Given the coincidence of these two strong drivers (international exports and household consumption) in one region, Canterbury has the largest flux of embodied land of any region in New Zealand.

Exports of embodied land (2,559,420 ha) outweigh imports of embodied land (653,620 ha). This gives Canterbury the largest positive Ecological Balance of Trade of any region in New Zealand at 1,905,800 ha. Canterbury is therefore New Zealand's largest net provider of ecological capital to other regions and nations.

Figure 17.1 Flows of embodied land through the Canterbury economy



18 Otago's Ecological Footprint

18.1 Profile of the region

The Otago region has the second-largest population of any region in the South Island. On census night 2001, the resident population was estimated to be 181,542 or 4.9 percent of the national population. In the period between the 1996 and 2001 census the Otago region experienced a decline of 3540 people or 1.9 percent of the population. Dunedin is the region's largest urban area, accounting for 107,088 residents, or 59.0 percent of the region's population. The region is relatively sparsely populated with an estimated population density of 5.8 people per square kilometre (Statistics New Zealand, 1998s).

The Otago region is the third largest in New Zealand. It occupies an estimated 3,199,000 ha or 11.6 percent of New Zealand's total land area. It is bounded to the west and south by the West Coast and Southland regions respectively with the Pacific Ocean forming the eastern boundary. The Canterbury region forms the northern boundary. The region's highest mountain is Mt Earnslaw (2819 metres); the largest lake is Lake Wakatipu (29,300 ha); and the Clutha river (322 kilometres) is the region's longest. The Clutha river carries the largest volume of water of any nationally. The topography of the Otago region varies considerably. Loess soils cover the river plains and basins with numerous waterways interwoven. The Taieri and Clutha areas are particularly fertile. However, the Central Otago soils are less fertile and a significant proportion of the region's high country is extremely susceptible to erosion. The Southern Alps greatly influence climatic conditions with Central Otago having a semi-arid continental climate. This area is the driest in summer and amongst the coldest in winter, making it one of the most climatically extreme areas nationally. Introduced animal pests such as rabbits, hares, and possums have also ravaged it. Although pastoral farming accounts for 92 percent of land use in the Otago region, this is only made sustainable through human intervention.

The 1997–98 GDP of the Otago region is 4.4 billion or 4.4 percent of the nation's GDP for that year. Sheep, beef and mixed livestock farming (LQ 2.01), mining and quarrying (LQ 1.51), meat processing (LQ 2.26) and accommodation, restaurants and cafés (LQ 1.48) all make sizeable contributions to the region's economy. Sheep and beef farms are among the largest in the country. This reflects their low biological productivity (or production yield per ha). Stocking rates per ha are among the lowest nationally. In 1996 the average Otago farm size was 656 ha, almost 2.6 times the national average.

Mining is another major industry. The Otago region has huge coal reserves, second only to the West Coast region in the South Island. Tourism, particularly in Queenstown, is a substantial and growing industry. The proportion of businesses engaged in cultural and recreational services is among the highest nationally. Central Otago is a significant producer of summerfruit in particular, apricots, nectarines and cherries. A small but growing viticulture industry also exists.

18.2 Overall ecological footprint and comparison with other regions

The Otago region has an estimated ecological footprint of 1,019,050 ha, 9.47 percent of New Zealand's total ecological footprint. This is the fifth-largest ecological footprint of any region in New Zealand. By comparison, Otago's ecological footprint is similar in size to that of the Waikato (1,048,860 ha) and Wellington (1,029,010 ha) regions.

In per capita terms, Otago's ecological footprint is the largest of all regions at 5.41 ha per person. An Otago resident requires 1.8 times more land than the average New Zealander. This is explained by the Otago region's agricultural land being far less productive than the New Zealand average. It is estimated that sheep, beef and mixed livestock farming has the second lowest yield per ha of any region in the country, only higher than the Marlborough region. The fact that the average Otago farm size is the largest of any region at 656 ha or 2.6 times the national average reinforces this finding. Significantly lower than average agricultural productivity is a result of the harsh and rugged hill country, extreme climatic conditions in Central Otago and the presence of introduced animals and weedy plants.

The total useful land available in the Otago region is estimated to be 2,155,440 ha. Otago has an ecological surplus of 1,136,390 ha. This is the second largest surplus of any region and equates to 6.0 ha per Otago resident. This ecological surplus is second only to Canterbury's with an estimated 1,898,230 ha surplus. In this way, the region is self-sufficient in ecological footprint terms.

18.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 859,880 ha (refer to Table 18.1). This represents 84.4 percent of Otago's ecological footprint. On a per capita basis, the average Otago resident appropriates 4.57 ha of agricultural land, 2.2 times the national average of 2.12 ha per person. This is a consequence of the region's farms being among the lowest yielding per ha of any in the country. Overall, an estimated 87.6 percent of agricultural land is within region land, while another 9.0 percent is embodied in goods and services purchased by Otago residents from overseas.

Table 18.1 Otago's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	753,530	28,980	77,370	859,880	4.57	84.4
Forest land	23,400	1,220	6,190	30,810	0.16	3.0
Degraded land	38,700	480	4,320	43,500	0.23	4.3
Energy land	60,270	1,800	22,660	84,730	0.45	8.3
Total	875,900	32,480	110,540	1,018,920	5.41	100.0

The forest land component of the Otago region's footprint consists of 30,810 ha, 3.0 percent of the footprint. While this is a lower share of the total footprint relative to the nation, in per capita terms it is similar. The Otago region's per capita forest land component is 0.16 ha while the national figure is 0.20 ha. This land is predominantly made up of within region land (23,400 ha), but lesser amounts of forest land are embodied in goods and services purchased from other regions (1220 ha) and from abroad (6190 ha). This component does not include the hypothetical land planted in trees used to sequester CO_2 emissions.

The degraded land component makes up 4.3 percent of the region's ecological footprint (43,500 ha). Most of this degraded land (38,700 ha) is derived from within the region, primarily land occupied by residential homes and businesses (excluding farms and forestry holdings). A further 4320 ha, or 10 percent of all forest land, is embodied in goods and services that Otago residents import from overseas.

Otago region's energy land component of the ecological footprint is 84,700 ha. This represents 8.3 percent of Otago's ecological footprint, significantly lower than the national average of 16.6 percent. Nevertheless, in per capita terms the region and nation are similar, requiring respectively per person 0.45 ha and 0.51 ha. An estimated 26.7 percent of the energy land is embodied in international imports consumed by Otago residents.

18.4 Ecological footprint disaggregated by goods and services purchased

18.4.1 Purchase of Otago produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 556,910 ha of embodied land in Otago's ecological footprint (refer to Table 18.2). This amounts to 54.6 percent of the entire ecological footprint of the Otago region. Most of this is appropriated from products created within the region (509,410 ha) with small amounts appropriated from other regions (29,020 ha) and other nations (18,480 ha). This constitutes largely agricultural land embodied in food products consumed by Otago residents.

Table 18.2 Otago's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	100,050	220	1,100	101,370	0.54	9.9
Forestry	1,720	10	20	1,750	0.01	0.2
Fishing and hunting	20	0	10	30	0.00	0.0
Mining and quarrying	610	0	30	640	0.00	0.1
Manufacturing	509,410	29,020	18,480	556,910	2.96	54.6
Utilities and construction	33,560	320	4,610	38,490	0.20	3.8
Services	197,930	670	25,510	224,110	1.19	22.0
Domestic final demand	32,600	2,370	60,780	95,750	0.51	9.4
Total	875,900	32,620	110,540	1,019,050	5.41	100.0

The consumption of land embodied in service sector products (224,110 ha) is also considerable, accounting for 22.0 percent of the entire footprint. The vast majority of this land is appropriated from within the region (197,930 ha), although some 25,510 ha are embodied in service sector goods purchased from international sources. At a first glance the land embodied in service sector products may appear high, particularly given that the physical space occupied by the service sector is relatively low. A close inspection, however, reveals that this is a consequence of significant indirect upstream linkages, each of which appropriates embodied land, and cumulatively is substantial.

The land embodied in the products of other sectors consumed by Otago residents is low by comparison. An estimated 101,370 ha is embodied in agricultural products, a further 33,560 ha is embodied in utility and construction products and a very small amount in forestry products (1750 ha).

18.4.2 Purchase of goods and services produced outside Otago (D_1+D_4)

Otago residents also purchase products made outside the region. In embodied land terms, this equates to 63,150 ha and is mostly appropriated from overseas (60,780 ha). This includes land embodied in goods purchased from retailers that are made overseas but sold locally with an additional mark-up. In this way, land embodied in items such as motor cars and computers purchased by households is included in this figure.

18.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Otago regional economy is 244,190 ha (refer to Table 18.3). Land embodied in imports is, however, small in comparison with land embodied in the region's exports which equates to 1,636,610 ha. Overall, this means that in Ecological Balance of Trade terms the Otago region is a substantial net exporter, exporting 1,737,550 ha of embodied land annually.

Table 18.3 Otago's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	1,660	275,610	273,950
Forestry	280	7,080	6,800
Fishing and hunting	20	10	-10
Mining and quarrying	40	280	240
Manufacturing	83,160	57,840	-25,320
Utilities and construction	340	2,420	2,080
Services	830	1,890	1,060
Domestic final demand	2,370	0	-2,370
Interregional Balance of Trade	88,700	345,130	256,430
International trade			
Agriculture	8,250	382,640	374,390
Forestry	470	33,560	33,090
Fishing and hunting	500	1,160	660
Mining and quarrying	260	4,190	3,930
Manufacturing	49,110	1,159,430	1,110,320
Utilities and construction	4,760	150	-4,610
Services	31,360	55,480	24,120
Domestic final demand	60,780	0	-60,780
International Balance of Trade	155,490	1,636,610	1,481,120
Total Balance of Trade	244,190	1,981,740	1,737,550

18.5.1 Exports and imports by economic sectors

Sales of manufactured products by the Otago economy were estimated to include 1,217,270 ha of embodied land, ie. land embodied in exports of manufactured products made up 62.4 percent

of the region's total ecological trade surplus. The majority of this land (1,159,430 ha) is embodied in sales of processed agricultural products to overseas nations. By comparison, purchases by the region's manufacturing sector accounted for 132,270 ha of embodied land or 54.2 percent of imports. On an interregional basis, land embodied in manufacturing sector purchases (83,160 ha) is greater than the land embodied in sales of manufactured goods (57,840 ha).

Land embodied in agricultural products that are exported from the Otago region (658,250 ha) is also significant. Sales of stock and horticultural produce most likely account for the embodied agricultural land exported interregionally (275,610 ha) while sales of wool and horticultural produce account for the land embodied in agricultural products heading offshore (382,640 ha).

All other sectors in the Otago economy are minor net exports with the exception of the utilities and construction sector which imports more land in product purchases (5100 ha), than it exports in products (2570 ha). The service sector in the Otago economy imports significantly less embodied land (32,190 ha) than it exports (57,370 ha). The vast majority of imported embodied land is encapsulated in goods and services purchased from abroad (31,360 ha). Backward linkages to farming from the service sector in the Otago economy explains why the land embodied in service sector products heading offshore is so high (55,480 ha).

18.5.2 Exports and imports by type of land

The Otago region is a very large net provider of embodied agricultural land, exporting an estimated 1,551,150 ha to other countries and a further 332,120 ha to other New Zealand regions (refer to Table 18.4). This represents primarily the land occupied by the region's sheep, beef and mixed livestock farms. Generally speaking, the region's agricultural land is embodied in farm products that flow onto local processing/manufacturing facilities and, in turn, leave New Zealand destined for international markets.

Table 18.4 Otago's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	83,510	332,120	248,610
Forest land	1,790	7,230	5,440
Degraded land	850	2,720	1,870
Energy land	2,550	3,070	520
Interregional Balance of Trade	88,700	345,140	256,440
International trade			
Agricultural land	115,070	1,551,150	1,436,080
Forest land	7,850	43,610	35,760
Degraded land	7,810	10,030	2,220
Energy land	24,770	31,820	7,050
International Balance of Trade	155,500	1,636,610	1,481,110
Total Balance of Trade	244,200	1,981,750	1,737,550

Of the remaining land types, an estimated 50,840 ha of forest land, 12,750 ha of degraded land and 34,890 ha of energy land is embodied in products exported from the region. The region is a net exporter of all land types both interregionally as well as internationally.

18.5.3 Overall picture

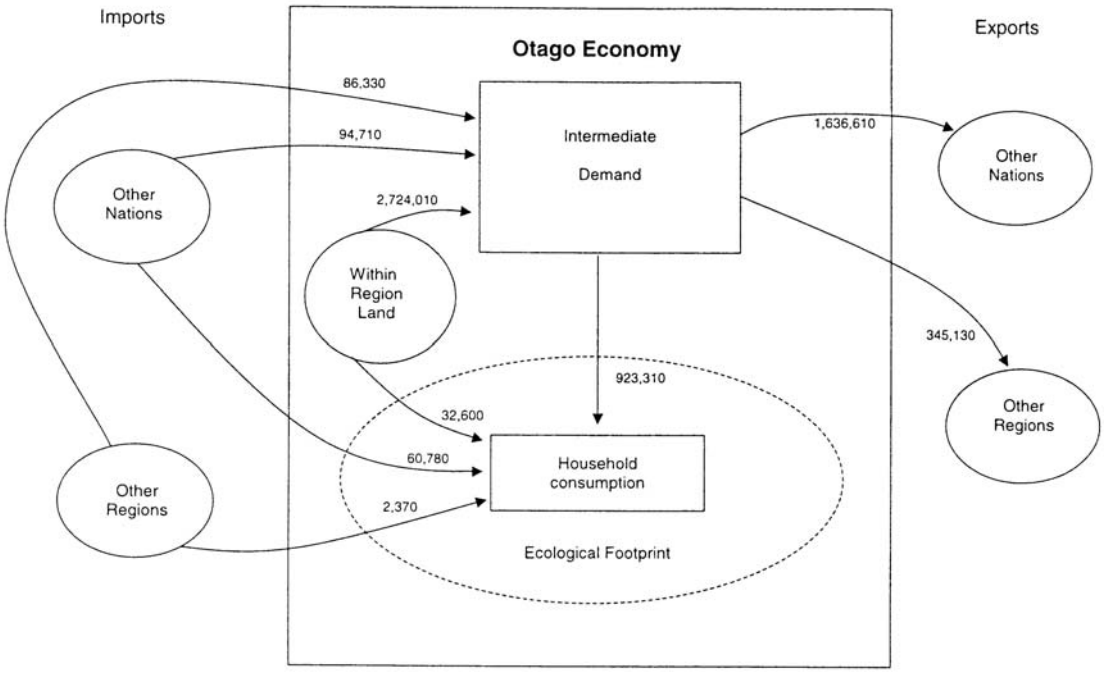
The embodied land flows associated with the Otago economy are shown in Figure 18.1. This diagram indicates that the Otago region is:

(1) self-sufficient in terms of land, with a relatively small embodied land area associated with household consumption

(2) very much an internationally driven export economy.

Land embodied in international exports (1,636,610 ha) outweighs embodied land used in meeting local household demand (1,019,060 ha). Overall, the Otago region exports 1,981,740 ha of embodied land compared with imports of only 244,190 ha resulting in a positive Balance of Trade of 1,737,550 ha.

Figure 18.1 Flows of embodied land through the Otago economy



19 Southland's Ecological Footprint

19.1 Profile of the region

At the 2001 Census Southland had a resident population of 91,005, 10.0 percent of the South Island's population. Southland has continued to experience population decline, reducing by 6.3 percent between the 1996 and 2001 census (6093 people). This represents a dramatic decline and equates roughly to the 6.9 percent decline of the preceding 10 years (1986–96). The majority of Southland's population loss is through internal migration to neighbouring regions. Particularly severe is the loss of people aged between 15 and 24 to Otago and Canterbury regions, reflecting greater employment and education opportunities offered by these regions. Invercargill is the region's largest urban area accounting for 54.3 percent of the region's population (46,305 people). Southland has an estimated population density of 2.91 people per square kilometre, making it the second most sparsely populated region in the country in 1998.

Southland is the southernmost region in New Zealand. It occupies an estimated land area of 3,400,000 ha, making it the second largest region nationally. Southland occupies 12.5 percent of New Zealand's total land area. The region extends from Awarua Point (Tasman Sea) on the west coast to Brothers Point (Pacific Ocean) on the east coast. The Foveaux Strait forms Southland's southern coastline. Much of Southland is a natural, unspoiled landscape free of human intervention. Fiordland, located in the southwest corner of the region, is characterised by rugged remoteness, fiords and extensive indigenous temperate forest. By contrast, the remainder of the Southland region is pastoral land on fertile alluvial plains with small towns and numerous rivers. Southland has the lowest mean annual temperatures and lowest average sunshine hours of any region nationally.

The Southland region accounted for 2.7 percent of New Zealand's 1997–98 GDP, or $2.6 billion. Important industries in the region's economy include agriculture, fishing, manufacturing and tourism. Agriculture is the most important industry in the Southland economy. The region has strong comparative advantage in sheep and beef farming (LQ 4.30), dairy farming (LQ 1.29), services to agriculture (LQ 2.23), meat processing (LQ 4.84) and dairy processing (LQ 1.65). Southland's fertile land is ideally suited to farming. Sheep are the predominant stock although in recent years conversion to beef and dairy farms has occurred rapidly. The region has a number of meat and dairy processing plants, including one of the world's largest meat processing facilities located at Lorneville. Fishing is an important industry within the region's economy. The comparative advantage to the region of fishing is captured in the location quotients for fishing (2.66) and water transport (1.73). The main species of fish caught are blue cod and crayfish. Shellfish such as oysters from the beds of Foveaux Strait and mussel farms are also significant industries in the region.

Basic metals manufacture (LQ 6.26) is another major industry in Southland. Given that New Zealand's only aluminium smelter is located at Tiwai Point, near Bluff, this is not surprising. This plant is powered by the large underground power station at Lake Manapouri. Most of the smelter's output is exported to Japan and other Asian countries, however, a small proportion is used for fabrication and foil products locally. Southland is also the country's third-largest coal-producing region in New Zealand (LQ 2.11).

19.2 Overall ecological footprint and comparison with other regions

Southland has an ecological footprint of 375,310 ha, 3.49 percent of New Zealand's total ecological footprint. It is the seventh largest nationally and the third largest in the South Island. Southland's ecological footprint is similar in size to that of the Hawke's Bay region (384,660 ha).

On a per capita basis, Southland region's ecological footprint is 3.92 ha per person, the third highest of any region in the country. There are several possible explanations for this finding. Relative to the nation Southland:

(1) may have lower than average agricultural yields per hectare

(2) manufacturing and service industries may occupy more land per dollar of output

(3) have larger property sizes.

Southland region's useful land area is 1,257,430 ha. This is an ecological surplus of 882,120 ha. The region's surplus is 2.4 times greater than its footprint and is the fifth-largest surplus of any region. In per capita terms, each Southland resident has a surplus of 9.2 ha. In ecological footprint terms, the region is self-sufficient and with a considerable ecological surplus.

19.3 Ecological footprint disaggregated by land type

The agricultural land component of the ecological footprint consists of 269,120 ha (refer to Table 19.1). This represents 71.7 percent of Southland's ecological footprint. Approximately 85 percent of this agricultural land is embodied in goods and services produced locally. A further 36,850 ha of agricultural land is embodied in products purchased from overseas.

Table 19.1 Southland's ecological footprint by land type, 1997–98

Land type	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agricultural land	229,390	2,880	36,850	269,120	2.81	71.7
Forest land	24,880	510	3,110	28,500	0.30	7.6
Degraded land	23,650	480	2,470	26,600	0.28	7.1
Energy land	38,040	1,060	11,800	50,980	0.53	13.6
Total	315,960	4,930	54,310	375,200	3.92	100.0

The forest land component of the region's footprint equates to 28,500 ha. On a per capita basis Southland residents require 0.30 ha annually to support their lifestyles. In relative terms, this figure is significantly higher than the New Zealand average of 0.20 ha per person. Heating based on wood fires is one possible explanation for this finding. The Southland forest land component is, like most rural regions in the country, appropriated from within the region (24,880 ha). Lesser, but significant, amounts of forest land are also embodied in wood-based products purchased from other nations. This component of the ecological footprint does not include the hypothetical land on which trees are planted to absorb CO_2 emissions.

The degraded land component of Southland's ecological footprint makes up 7.1 percent (26,600 ha) of the region's total footprint. Most of this is degraded land which is derived from within the Southland region. This consists primarily of the land occupied by residential

properties along with a significant proportion of the land on which local businesses occupy. A smaller share of the degraded land total (2470 ha) is embodied in imported products purchased by Southland residents from overseas.

Energy land constitutes 50,980 ha of the Southland footprint. While energy land is smaller as a share of the total footprint than in the nation (respectively 13.6 percent regionally versus 16.6 percent nationally), in per capita terms it is slightly greater. The region's colder climate which in turn means greater household and workplace heating requirements could account for this difference. While 74.6 percent (38,040 ha) of the energy land required by Southland residents comes from within the region and an additional 23.3 percent (11,880 ha) is embodied in products purchased from aboard.

19.4 Ecological footprint disaggregated by goods and services purchased

19.4.1 Purchase of Southland produced goods and services (P_1+P_2 ... P_n)

The purchase of manufacturing sector products accounted for 181,590 ha of Southland's ecological footprint (refer to Table 19.2). This amounts to 48.4 percent of the entire ecological footprint of the Southland region. Most of this embodied land is contained in manufactured goods produced locally (171,990 ha), in particular food products grown on the region's farmland. Small quantities of land (8570 ha) are also embodied in manufactured goods purchased from overseas.

Table 19.2 Southland's ecological footprint by economic products, 1997–98

Economic products consumed	Within region land (ha)	Land from other New Zealand regions (ha)	Land from other nations (ha)	Total land (ha)	Total land (ha per capita)	Total land (% of total)
Agriculture	28,450	20	480	28,960	0.30	7.7
Forestry	1,370	20	10	1,410	0.01	0.4
Fishing and hunting	10	0	0	10	0.00	0.0
Mining and quarrying	70	0	10	80	0.00	0.0
Manufacturing	171,990	1,030	8,570	181,590	1.90	48.4
Utilities and construction	15,340	370	2,290	18,000	0.19	4.8
Services	77,980	550	11,600	90,140	0.94	24.0
Domestic final demand	20,740	3,040	31,340	55,120	0.58	14.7
Total	315,960	5,040	54,310	375,310	3.92	100.0

Significant quantities of land are also embodied in the service sector products consumed by Southland residents. This equates to 90,140 ha or 24.0 percent of the region's footprint. At a first glance, this figure appears very high but can be explained by backward linkages to the farming, forestry and mining sectors in the economy. Thus, while a service sector business may physically occupy only a small land area, the products that it purchases from other industries (such as paper, equipment, machinery, food etc) may contain high amounts of embodied land. The vast majority of land embodied in service sector commodities originates from within the region (77,980 ha), with smaller amounts from overseas (11,600 ha).

Other industry purchases by Southland account for 19,500 ha of embodied land – 18,000 ha embodied in utility and construction products and 1410 ha embodied in forestry sector products.

19.4.2 Purchase of goods and services produced outside Southland (D_1+D_4)

Southland residents also purchase products made outside the region which accounts for 34,380 ha of land. Most of these purchases are from overseas (31,340 ha) and include land embodied in goods purchased from local retailers that are made overseas but sold with an additional margin. In this way, land embodied in items such as motor vehicles, computers, household appliances and imported food products are included in this figure.

19.5 Ecological Balance of Trade and ecological interdependencies

The land embodied in imports into the Southland regional economy is 112,860 ha (refer to Table 19.3). Land embodied in imports is, however, substantially smaller in comparison to the 1,574,870 ha of land embodied in the region's exports. Overall, this means that in Ecological Balance of Trade terms, the Southland region is a substantial net exporter, exporting 1,462,010 ha of embodied land annually.

Table 19.3 Southland's Ecological Balance of Trade by economic sector, 1997–98

Economic sector	Imports purchased by the economic sector (embodied ha)	Exports sold by the economic sector (embodied ha)	Balance of Trade (embodied ha)
Interregional trade			
Agriculture	360	283,640	283,280
Forestry	440	0	-440
Fishing and hunting	0	1,630	1,630
Mining and quarrying	20	50	30
Manufacturing	5,370	64,380	59,010
Utilities and construction	380	400	20
Services	700	660	-40
Domestic final demand	3,040	0	-3,040
Interregional Balance of Trade	10,310	350,760	340,450
International trade			
Agriculture	7,940	162,730	154,790
Forestry	230	25,110	24,880
Fishing and hunting	1,390	2,610	1,220
Mining and quarrying	140	860	720
Manufacturing	45,030	1,013,460	968,430
Utilities and construction	2,350	90	-2,260
Services	14,130	19,240	5,110
Domestic final demand	31,340	0	-31,340
International Balance of Trade	102,550	1,224,110	1,121,560
Total Balance of Trade	112,860	1,574,870	1,462,010

19.5.1 Exports and imports by economic sectors

Over half of the land embodied in imports (50,400 ha) into the Southland region is encapsulated in goods and services purchased by the manufacturing sector. Although at a first glance this may appear very high, it is minor when compared with the region's export of land embodied in manufactured products (1,077,840 ha). Most of this land is embodied in processed food products, including sheep and beef meat and dairy products all most entirely heading for international markets.

The emphasis on primary based exporting is also highlighted in the amount of land embodied in agriculture products leaving the region. An estimated 446,370 ha of land is embodied in agriculture product exports such as livestock sales, wool and horticulture produce – this is a massive 53.7 times greater than the land embodied in agriculture products entering the region.

The Southland economy's comparative advantage in fishing is also evident. The region's fishing industries has a net positive Ecological Balance of Trade both in terms of embodied land destined for other regions (1630 ha) and overseas (1220 ha). Although this may seem small these figures only include terrestrial land associated with fishing operations; they do not include sea space. If sea space were added then land embodied in fishery products would be substantially higher.

The remaining sectors of the Southland economy have the following net Ecological Balance of Trade results: forestry (24,440 ha), mining and quarrying (750 ha), services (5070 ha) and utilities and construction (-2240 ha).

19.5.2 Exports and imports by type of land

Southland is a massive net producer of agricultural land both internationally and interregionally (see Table 19.4). Agricultural land embodied in international exports (1,108,910 ha) outweigh international imports (74,450 ha) by slightly more than 14.8 times. Much of the land embodied in the region's exports includes sheep, beef and dairy products produced within the region.

Table 19.4 Southland's Ecological Balance of Trade by land type, 1997–98

Economic sector	Land embodied in imports (ha)	Land embodied in exports (ha)	Balance of Trade (ha)
Interregional trade			
Agricultural land	7,370	341,230	333,860
Forest land	1,080	1,860	780
Degraded land	640	1,140	500
Energy land	1,240	6,530	5,290
Interregional Balance of Trade	10,330	350,760	340,430
International trade			
Agricultural land	74,450	1,108,910	1,034,460
Forest land	4,720	45,760	41,040
Degraded land	5,040	6,060	1,020
Energy land	18,320	63,380	45,060
International Balance of Trade	102,530	1,224,110	1,121,580
Total Balance of Trade	112,860	1,574,870	1,462,010

Lesser amounts of forest land (41,820 ha), degraded land (1520 ha) and energy land (50,350 ha) are in net terms produced by Southland. Overall, across all land types and both internationally and interregionally, the Southland economy is a net provider of embodied land.

19.5.3 Overall picture

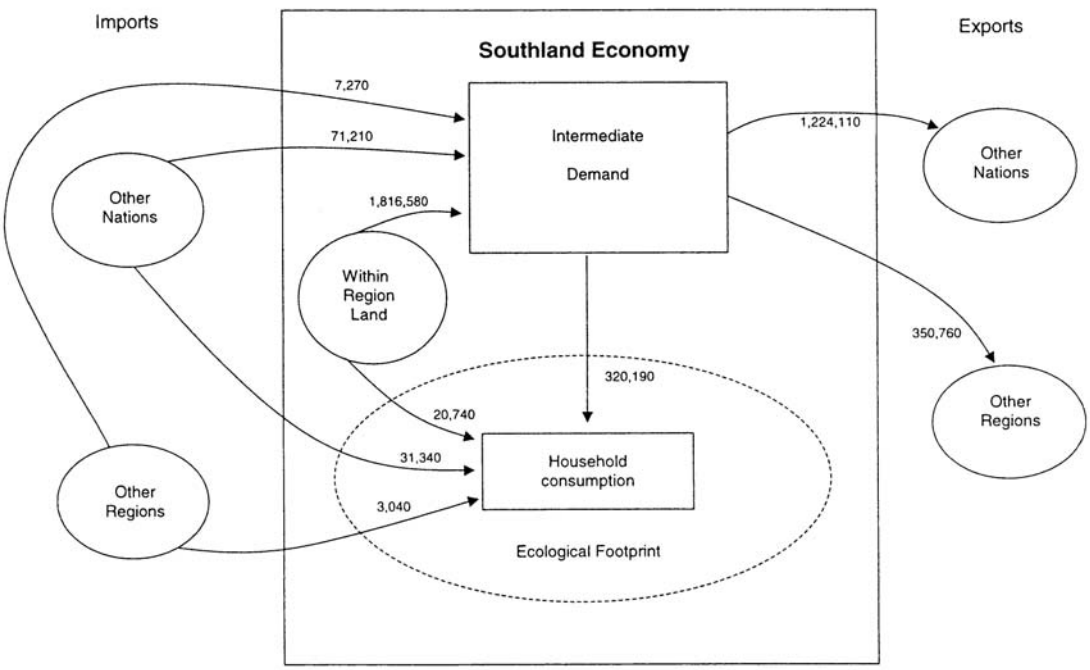
The embodied land flows associated with the Southland economy are shown in Figure 19.1. This diagram indicates that the Southland region:

(1) is self-sufficient in terms of land, with a relatively low embodied land area supporting local household consumption

(2) is strongly export driven, particularly by international demand for its products.

Thus, land embodied in international exports (1,224,110 ha) outweighs land embodied in international imports (102,550 ha) by more than 11.9 times. Similarly, the region is also a substantial net exporter with the land embodied in interregional exports 34 times greater than that embodied in interregional imports. Overall, the region has a substantial positive Ecological Balance of Trade of 1,462,010 ha – the vast majority of which is used to support citizens of other countries.

Figure 19.1 Flows of embodied land through the Southland economy



20 Further Research and Refinements to the Ecological Footprint Analysis

This report represents the first comprehensive attempt to estimate the ecological footprints of New Zealand regions although Bicknell et al (1998) estimated the national ecological footprint for New Zealand. In the process of undertaking these estimations it became apparent that further extensions and refinements to this analysis should be undertaken. These however are beyond the immediate scope of this current project.

20.1 Improving the relevance of the analysis for individuals

In this report the ecological footprint was calculated using input–output analysis. This has a number of advantages that have already been outlined in Section 2 (more comprehensive than the 'bottom up' methods, avoids double counting, deals with complicated networks of indirect flows and so forth). However, although arguably more methodologically rigorous than the 'bottom up' methods such as the 'best foot forward' Ecoindex™ method, the input–output methodology is more difficult to understand for the layperson.

It has been suggested that a 'bottom up' component analysis be utilised to estimate regional and personal ecological footprints. It is often argued that such 'bottom up' analyses are expressed in terms that are more easily understood by end-users – personal energy use, eating (food consumption), shopping behaviour (purchases of goods and services), travel behaviour, recycling and use of materials, and water usage. One reviewer commented that 'bottom up' footprint analyses are 'more intuitive and meaningful for individual action'. This can help individuals to decide how and where to make improvements in their lifestyles. It is therefore recommended that further studies of the ecological footprint for New Zealand regions focus on refining the input–output analysis to reflect individual-level behaviours and purchasing patterns. This could be achieved by integrating input–output results with a 'bottom up' analysis or probably (more expeditiously) by using a sector-by-commodity matrix in the input–output analysis. The latter would at least express the results in terms of purchases of commodities that individuals would recognise rather than the current sector-based analysis.

A hybrid of 'bottom up' component analysis and 'top down' input–output analysis would probably provide the best outcome, enabling the results to be presented in terms understood by the individual whilst retaining the methodological rigour and accuracy of the input–output approach. Such hybrid approaches have been widely used in related Lifecycle Assessment methods, but seemingly have not been applied in ecological footprinting (eg. refer to IFIAS (1975) and Patterson and Earle (1985)).

Another way of improving the accessibility and usefulness of the ecological footprinting exercise for individuals, is to construct a personal ecological footprint calculator. Several of these ecological footprint calculators appear on the web, eg. Redefining Progress (www.progress.org/programs/sustainability/ef) and Best Foot Forward's (www.bestfootforward.com) calculators.

Indeed from October 2002 such an ecological footprint calculator has appeared on the Ministry for the Environment website (www.environment.govt.nz). This footprint calculator is designed for New Zealand conditions based on the national-level analysis contained in this report. The next step would be to develop such a web-based ecological footprint calculator for every region in New Zealand.

Diagrammatic and graphical depiction of ecological footprints would also be useful in communicating the results, to individuals and a lay audience. In this respect, the Lifecycle Assessment diagrams, as presented in Patterson and McDonald's (2002) report *How Clean and Green is New Zealand Tourism: Lifecycle and Future Impacts* could be useful. They explicitly show all of the direct and indirect inputs of embodied land into the ecological footprint.

20.2 Improving the relevance of the analysis for policymakers and planners

The ecological footprint has been widely promoted as a sustainability indicator that will assist policymakers and government planners to make better decisions. It provides a broad measure of the direct and indirect environmental impacts of countries, regions and cities which is of relevance to policy development and planning.

The ecological footprint analysis presented in this report, and for that matter footprint analysis in general, needs to be fine-tuned for planning and policy analysis purposes. Firstly, a number of strategic issues directly arise from the footprint analysis and need to be addressed. In this respect, the following policy questions emerge from our analysis:

- What happens to New Zealand's footprint and its underlying function, when New Zealand's petroleum resources deplete and the country has to rely on imported transport fuels?
- What happens to New Zealand's export potential from about 2020 when the mid-point of the world oil reserves is passed and major flows of materials between countries might become constrained?
- What does economic growth and population growth mean for the New Zealand footprint from 2020 and even to 2050?
- Will population growth in our main international trading partners confer a maintenance of trade demand for each region's traded products?
- How do we break the link between an increasing per capita affluence and standard of living and an increasing footprint?

It would be informative for policy development to deal with these questions in any further ecological footprint study of New Zealand and its regions. It could be argued that the current static analysis, without answering such questions about the future, promotes a false sense of security. In this respect, although most regions do not currently overshoot their carrying capacity, within 20–30 years they could do so if current trends and structural patterns persist. A dynamic analysis focusing on such policy issues would be useful to the policy and planning community.

The current study emphasises the land footprint, which is useful in understanding land constraints and thresholds as they relate to sustainability. However, in understanding sustainability and the limits to economic growth, it is critical that other resources and pollutants be considered. For this reason, in order to better inform the policy debate, it would be useful to calculate water, carbon, energy and other footprints. These footprints would measure the direct and indirect resources/emissions required by a nation, region or city. The calculation of these footprints will undoubtedly deliver different messages to policy makers to the land footprint, and a combined study of all of these footprints would provide a richer analysis of the sustainability issue.

The ecological footprint analysis initiated in this report needs to be further developed for setting priorities for action towards sustainability including setting specific targets. Particularly if the 'bottom up' component approach was used (possibly in conjunction with the 'top down' approach), then the footprint analysis would give guidance as to what behaviours would need to be changed to reduce the ecological footprint. In this way, the ecological footprint analysis can provide guidance on how to reduce environmental impacts and improve sustainability.

In so far as the Ministry for the Environment has already implemented the first recommendation of the publication *Headline Indicators for Tracking Progress to Sustainability in New Zealand*, the place of the ecological footprint as a national sustainability indicator has been established. However, there is arguably a need to go further to establish national and regional targets for the ecological footprint indicator in the same way that the Dutch government does for their national policy performance indicators.

20.3 Methodological and accuracy improvements

Although carried out at the 23 sector level (instead of 80 sectors), as well as using a different base year of 1997/98 (instead of 1991) and using different land-use data, our study arrived at a very similar estimate for New Zealand's ecological footprint to Bicknell et al's (1998) previous study. Despite the close correspondence between the two studies, there are definite ways in which both the methodology and application could be improved in future studies.

Firstly, the current input–output model should be extended from 23 sectors to at least 50 sectors. This in particular would improve the differentiation of the agricultural sectors, enabling a better estimate of the food components of the footprint. This disaggregation of the agricultural sector should be able to be readily achieved for the land use data by utilising data available from Statistics New Zealand. The disaggregation of CO_2 emission data for the agricultural sector is however more problematic, meaning that the energy component of the ecological footprint may not be able to be accurately calculated at this level of disaggregation.

Besides the agricultural sector, in particular more accurate results would be obtained by disaggregating the transport sector into air, road, water and sea transport. Unlike the agricultural sector, we foresee few problems in doing this as good CO_2 emissions, land and economic data exist for these transport sub-sectors.[19]

In general terms, the estimation of land use data for the manufacturing and service sector below the 23 sector level becomes problematic and difficult. It would take a great deal of research effort and interagency co-operation to derive greater disaggregation of the land use data for these sectors of the economy.

Secondly, no allowance has been made for land quality factors in the regional analysis of ecological footprints. To a significant extent, this limits the ability to meaningfully compare the ecological footprint performance across regions. For example, the average quality (productivity) of land in Otago is much lower than that of the Bay of Plenty and therefore it is not strictly valid to directly compare the ecological footprint of both regions. Some adjustment needs to be made to convert land to a common unit of measurement (numeraire).

[19] The regional economic data (regional input–output matrices) required for the calculation of ecological footprints at the 50 sector level can reasonably reliably be generated by using the GRIT method. National level input–output matrices disaggregated down to about the 160 sector level are routinely produced by Statistics New Zealand.

Commensuration of land quality in terms of their net primary productivity seems to have logical appeal — in other words, three hectares of Class A land could be deemed to be equivalent to 1 hectare of Class C land because it produces three times as much in terms of its productivity. Very crude global adjustments for land quality using net primary productivity have been implemented by Wackernagel and Rees (1996) but because they are very crude and because they are of dubious applicability to New Zealand they were not utilised in our study.[20] It is therefore recommended that major research effort be put into developing the land quality factors for New Zealand conditions. This will require significant methodological and scientific research to derive such factors, probably to be funded through the Foundation of Research, Science and Technology.

Thirdly, as one reviewer pointed out, the accuracy of the results depends on accurate regional input–output matrices as well as an accurate model of interregional flows. In New Zealand, survey-based regional input–output matrices do not exist, instead estimated regional input–output matrices have been developed by Hubbard and Brown (1981), Butcher (1986) and more recently by McDonald and Patterson (1999b) using the GRIT method. Although this technique of generating regional input–output matrices is widely regarded as providing reasonable results, there is no doubt that survey-based regional input–output matrices would be more accurate. Statistics New Zealand is currently investigating the feasibility of constructing survey-based regional level input–output matrices in New Zealand.

Similarly, the interregional flows which proved to be significant in most regional footprints, could only be estimated in our study by using a minimisation of travel time method. This method needs to be checked where possible against existing data and adjusted if need be. Given the complexity of interregional flows in New Zealand and the lack of data, there is little likelihood of the interregional trade flows model being built up from survey data. However, the introduction of any superior data into the interregional flow model would be helpful in eventually improving the accuracy of the regional ecological footprints.

Fourthly, given the large amount of coastal and marine 'land' in New Zealand, and the ecological and economic importance of this 'land', it could be argued that it should be included in the footprint calculations. It wasn't included in our current analysis primarily because it would unreasonably 'distort' the size of our footprint. There would also be methodological difficulties in allocating marine and coastal areas to economic sectors and to regions. For example, although the fishing sector uses the marine area, there are other economic and ecological functions provided by the marine area. Therefore, some decision-rules would be needed to ascertain what proportion of the marine area should be allocated to the fishing sector – justifying such decision rules is likely to be quite difficult.

20.4 Updating the ecological footprint analysis

The current analysis was undertaken for the 1997/98 March year, based on the data availability. It is recommended that the analysis be updated on a biennial basis at the 23 sector level (ie. for

[20] Murray and Lenzen (2002) suggested that 'land disturbance' factors be used to measure land quality in ecological footprinting, instead of the 'productivity' based approach. They argue that the 'disturbance' factors 'better reflect the image of the footprint on the land because it describes the effects of human land use on ecosystems'. It is difficult to see how such an approach could be operationalised in New Zealand due to the lack of data and due to methodological issues concerning the interpretation of the 'disturbance concept'.

1999/2000, 2001/2002 and so on). It is unlikely that there will be sufficient movement in the ecological footprints, to justify an annual update.

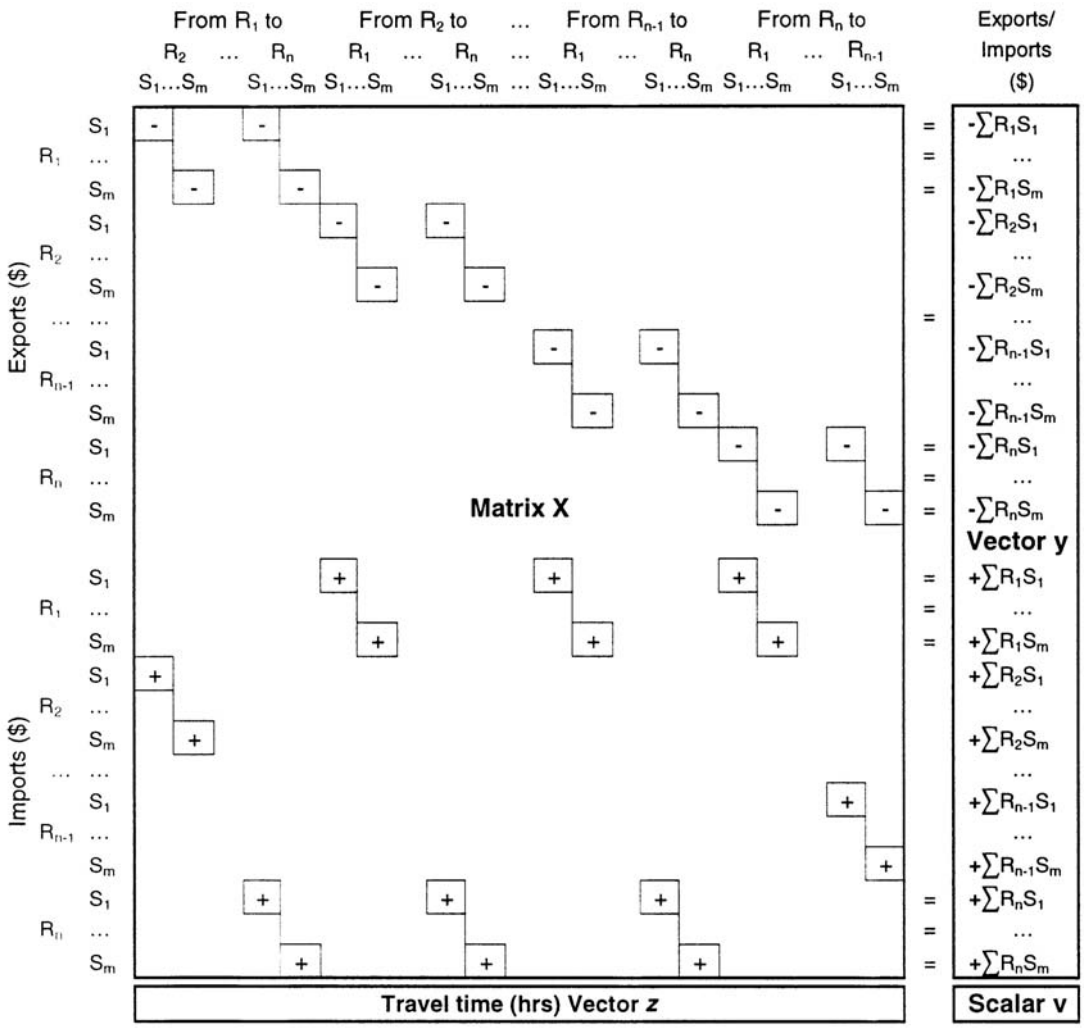
There are however data problems that will limit the accuracy of these updates:

- Over recent years agricultural statistics has been produced every three years. More up-to-date agricultural land information may be obtained from Agribase, but for a nationwide analysis this may be prohibitively expensive. If Agribase data proves to be too expensive we would need to use an estimation method that would be less accurate.
- Estimates of CO_2 emissions were obtained from our update of the EECA database. These give reasonably accurate sector level estimates of CO_2 emissions for 1997/98. However, with the last update of the EECA database being for 1994, to validly use it for 2002 (even with the use of the most sophisticated estimation methods) would be very questionable. Fundamentally, a survey-based update of the EECA database is required.

Appendix A: Description of the Interregional Flows Optimisation

This appendix describes the optimisation approach used in this report to define the level of interregional trade between the study region and its trading partners. The optimisation problem is portrayed diagrammatically in Figure A.1 and described mathematically below.

Figure A.1 Structure of the interregional trade flows optimisation problem



The capital letters *R* and *S* are used to respectively denote regions and sectors (ie. R_1S_1 denotes sector 1 in region 1. The letter *n* represents the number of regions, while the letter *m* represents the number of sectors. A total of 16 regions (Auckland inclusive), covering all 16 regional councils in New Zealand, were used in the Auckland region empirical analysis. This analysis was performed for all 23 sectors.

Matrix **X** ($n \times m \times 2$, $(n \times n - n) \times m$). This matrix describes the flow of trade between regions. A negative sign (-) denotes exports, while a positive sign (+) denotes imports. Column 1, for example, describes the trade flows between region 1, R_1, and region 2, R_2.

Vector **y** (n x m x 2, 1). This column vector describes imports to, and exports from, each region by sector. The element in row 1, for example, represents the sum of all sector 1 exports originating from region 1, $-\sum R_1 S_1$. The elements in this vector are used as binding constraints in the optimisation. This information is taken directly from the input–output tables generated by the GRIT system.

Vector **z** (1, (n x n – n) x m). This row vector denotes 'freight haulage times' between regions per dollar of trade flow. Freight haulage times were calculated using an origin/destination matrix. The major city/town in each region was used as the point of origin/destination. Haulage times between the North and South Islands were adjusted for the Cook Strait crossing.

Scalar **v** (1, 1). This scalar is the sum of row vector **z**. It represents the total freight travel time needed to move goods and services between all permutations of regions and sectors. Minimisation of this scalar is the objective function.

The optimisation is solved as follows:

Min:	**zw = v**
subject to:	**Xw = y**
	w >= 0

where: **w** = column vector ((n x n – n) x m, 1) describing the flow ($) of m sector commodities between n regions, to be solved for.

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About the Ministry for the Environment

The Ministry for the Environment works with others to identify New Zealand's environmental problems and get action on solutions. Our focus is on the effects people's everyday activities have on the environment, so our work programmes cover both the natural world and the places where people live and work.

We advise the Government on New Zealand's environmental laws, policies, standards and guidelines, monitor how they are working in practice and take any action needed to improve them. Through reporting on the state of our environment, we help raise community awareness and provide the information needed by decision makers. We also play our part in international action on global environmental issues.

On behalf of the Minister for the Environment, who has duties under various laws, we report on local government performance on environmental matters and on the work of the Environmental Risk Management Authority and the Energy Efficiency and Conservation Authority.

Besides the Environment Act 1986 under which it was set up, the Ministry is responsible for administering the Soil Conservation and Rivers Control act 1941, the Resource Management Act 1991, the Ozone Layer Protection Act 1996, and the Hazardous Substances and New Organisms Act 1996.

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