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.

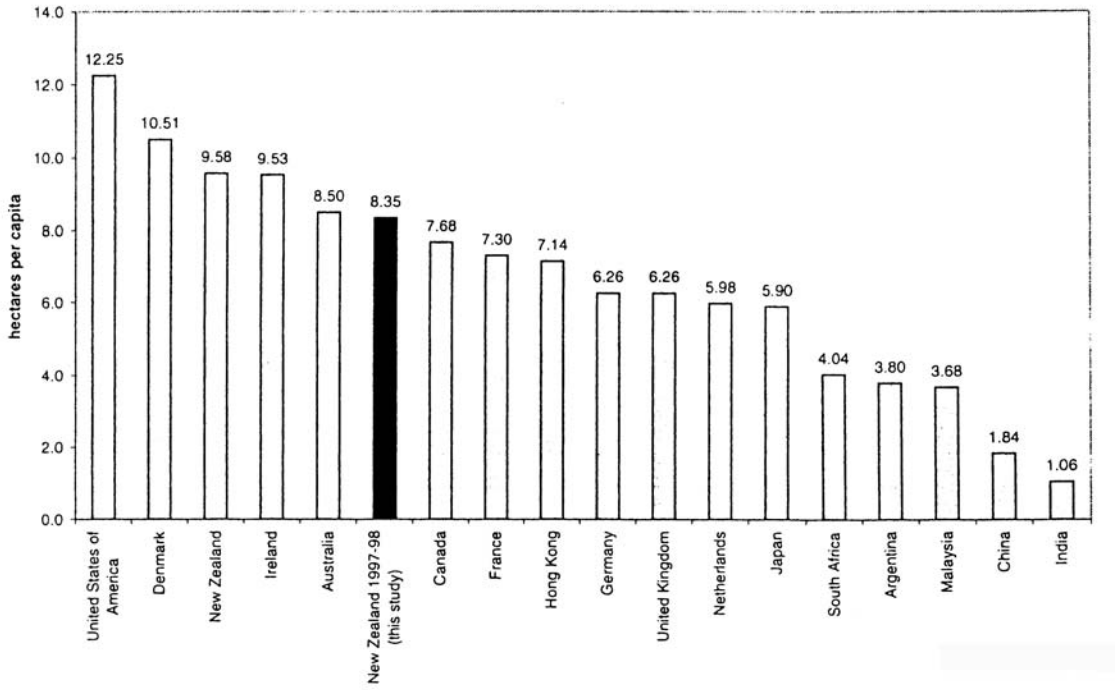
(3) *global average CO_2 sequestration factors*. Loh (2000) estimates the world average carbon absorption (including roots) to be 0.956 tonnes of carbon per hectare. In accordance with Loh (2000) oceans are also assumed to take up 35 percent of CO_2 emissions.

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

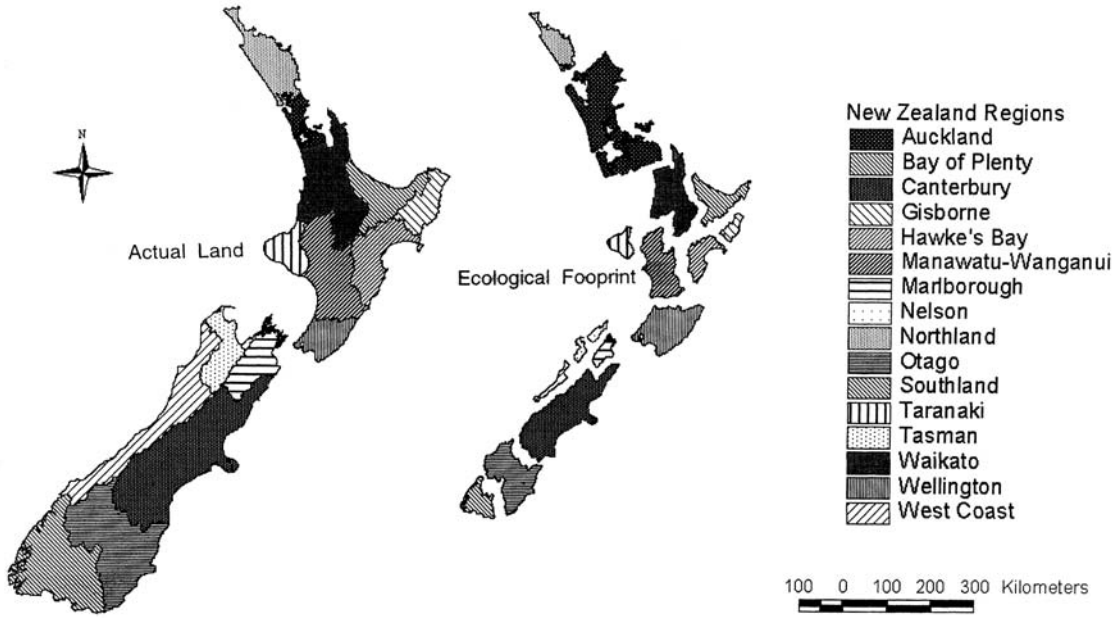
The largest regional ecological footprint was Auckland at 2,319,940 ha, which is not surprising given that it has the largest population of any region in New Zealand. Auckland makes up 21.66 percent of the New Zealand ecological footprint.[18] Canterbury is a clear second, with an ecological footprint 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

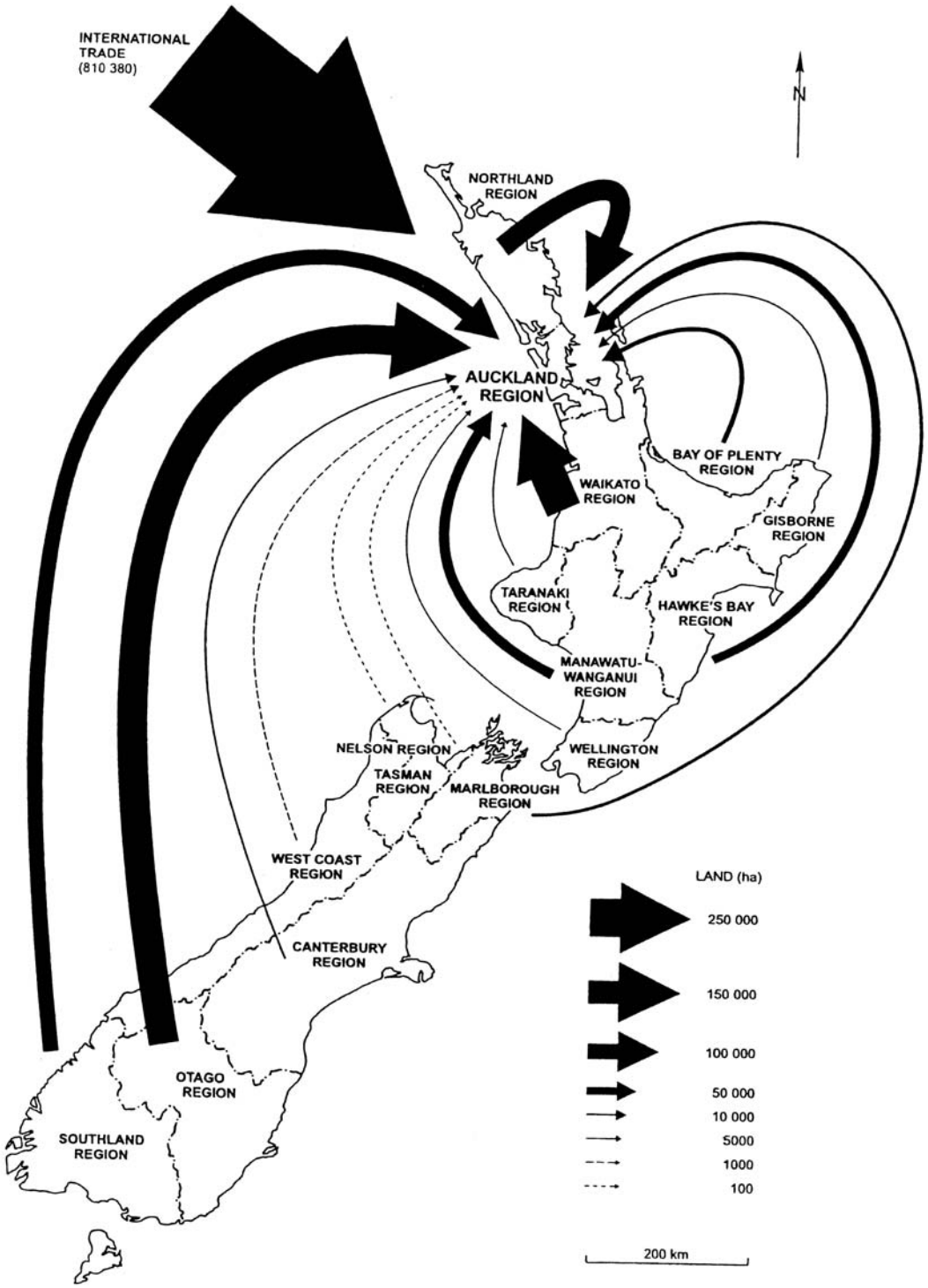
Region	Ecological footprint (ha)	Usable land area[1] (ha)	Ecological surplus/ deficit[2] (ha)	Degree of overshoot[3] (%)
Auckland	2,319,940	481,370	-1,838,570	481.9
Nelson	76,910	35,230	-41,680	218.3
Wellington	1,029,010	723,190	-305,820	142.3
Bay of Plenty	618,260	925,530	307,270	66.8
Waikato	1,048,860	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.

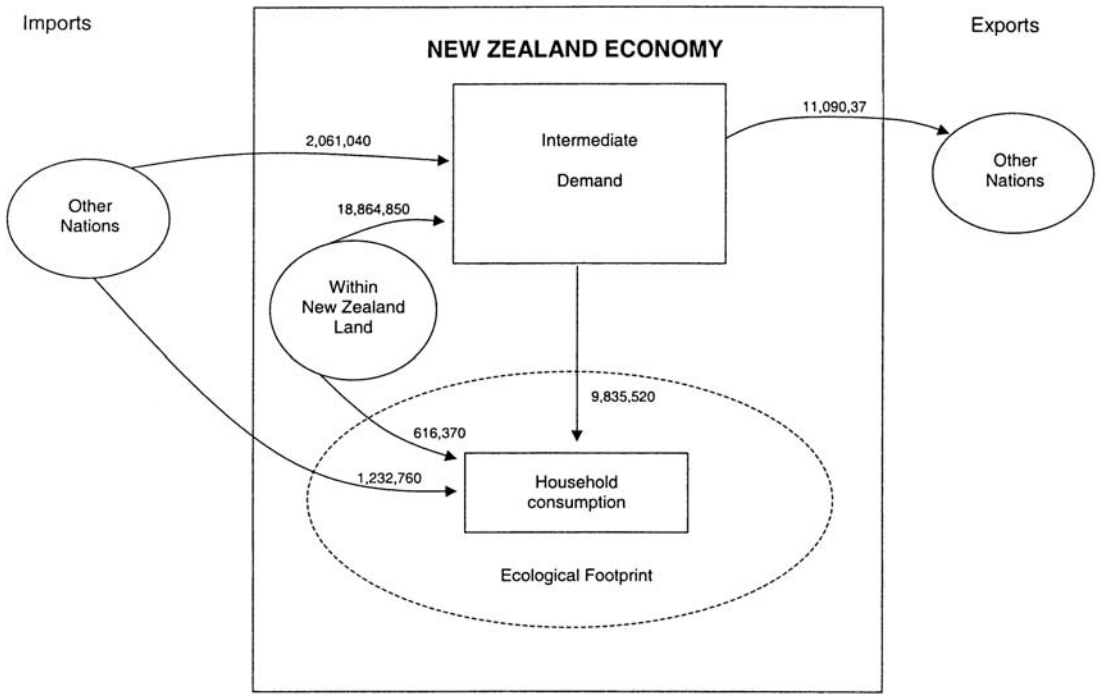
3.5 Ecological Balance of Trade

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).

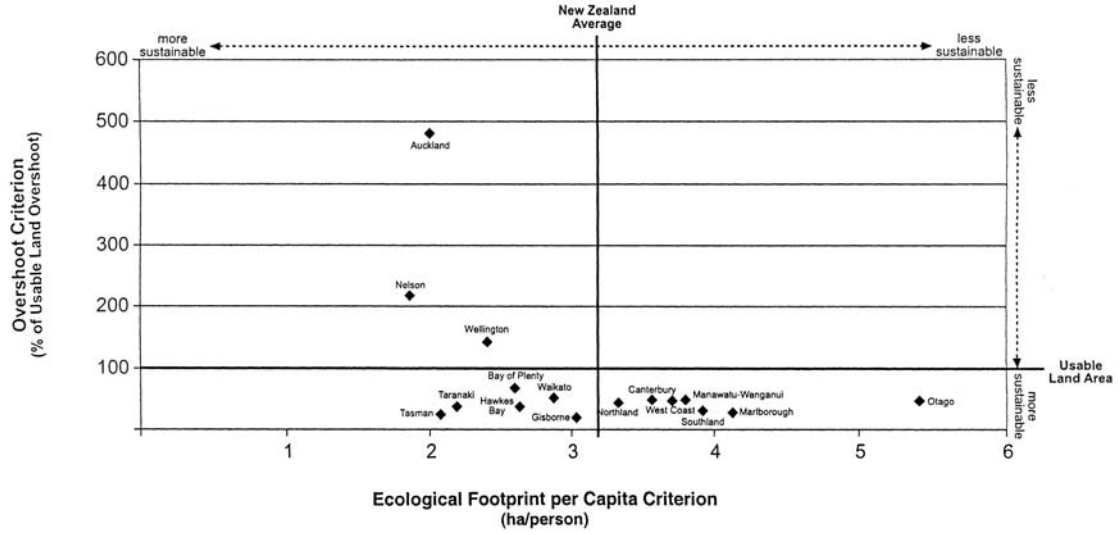
(2) *Degree of overshoot.* It is argued that to be sustainable a population (of a nation, region or city) must consume less embodied land than the amount of useful land that is available. That is, the population must live within its carrying capacity or biocapacity. If the population overshoots its carrying 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.