Forestry Expansion and the Resource Management System in New Zealand: Implication to Japan's Wood Utilization and Resource Management

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Chapter 1
Introduction

1.1 The world's requirement of sustainable resource management system

Expanding human requirements and economic activities are placing ever increasing pressures on land resources, creating competition and conflicts and resulting in sub-optimal use of both land and land resources (UN, 1992). Such important environmental problems include, for example, all kinds of pollution, climate change, the depletion of the ozone layer, excessive deforestation, desertification and land degradation, hazardous waste, and depleting biological diversity. It is almost universally accepted that our expanding technological capacity to inflict permanent damage upon the biosphere must be controlled to avoid irreversible environmental harm (Williams, 1997).

The level of international concern for the environment and conservation has been reflected first in the UN Stockholm Conference 1972. The fact that pollution does not recognize political or geographical boundaries, but affects countries, regions and people beyond its point of origin, was recognized in the conference. Over the decades following the conference, this concept was broadened to encompass environmental issues that are truly transnational in scope, requiring concerted action by all countries and all regions of the world in a universal manner. It was also recognized that environmental protection and natural resource management must be integrated with socio-economic issues. Based on those concepts, the report of the World Commission on Environment and Development (the Brundtland Report) recommended that all countries should adopt sustainable development as their overriding goal, and that national policies and international cooperation should be directed to achieving this goal (Williams, 1997). "Sustainable development" was defined by the commission (National Institute for Agro-Environmental Science, 1995; Ferguson, 1996) as " development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Williams, 1997).

The recognition of the importance of sustainable development culminated in the United Nations Conference on Environment and Development (UNCED) 1992, which is also known as the Earth Summit. Agenda 21, a thorough and broad-ranging program of actions demanding new ways of investing in our future to reach global sustainable development in the 21st century, was the main achievement together with the Framework Convention on Climate Change (FCCC) and the Convention of Biological Diversity (CBD). Because forest has the ability to stock carbon (FAO, 2000) and regulate climatic factors and is especially rich in biodiversity (Bunnell and Johnson, 1998), and because it takes many other roles such as water and soil protection, the importance of forest management was emphasized in the summit (FAO, 2000). However, the greatest emphasis was on the integrated planning and management of land resources including forests, which is the basis of Agenda 21. Examining all uses of land in an integrated manner was considered essential because it makes it possible to minimize conflicts, to make the most efficient trade-offs and to link social and economic development with environmental protection and enhancement, and thus helping to achieve the objectives of sustainable development (UN, 1992).

A number of countries have elaborated national policies and procedures for integrated land-use planning and have introduced changed in land administration (UN, 2001). Initially some plans focused on delineating areas for protection as nature reserves, critical watersheds and other environmentally important areas. Gradually the scope has expanded to encompass sustainable land-use plans in a wider geographical and a longer-term perspective. For example, the United States has started to implement the integrated resource management system so called “ecosystem management”. Germany makes an effort to connect significant natural ecosystems throughout the country (Kakizawa, 2000). However, in many countries, policies for sustainable land-use remain fragmented and incomplete, generally because of institutional barriers, conflicting mandates, and the prioritization of economic over social and environmental goals and of short-term development over long-term conservation goals (UN, 2000).

New Zealand was the country took the lead to establish the system of integrated resource management. In the late 1980s, New Zealand had decided to divide the role of natural forests and plantation forests clearly. The former was managed for environment and biodiversity conservation, and the latter for timber production. In addition, the world’s first integrated resource management policy, the Resource Management Act (RMA) was established in 1991.

1.2 History of New Zealand forestry

The decision to manage New Zealand’s forests dichotomously is a result of previous forest management system and its socio-economic background. The decision itself became one of the causes for the current prosperity of plantation forestry in New Zealand. Hence, the process reaching to the decision should be interpreted through understanding the history of forestry in New Zealand. This section provides an overview of the history of New Zealand forestry. The reason why New Zealand made the decision is also explained. Its history can roughly divided into three eras: Before world war II, After world war II till 1970's, and From 1980's up to the present.

1) Before World War II

Originally, about 75% of New Zealand's land surfaces were covered by forests that consisted of evergreen trees such as kauri (*Agathis australis*) and southern beech (*Nothofagus*) (Blaschke et al., 1992). Non-forested area was mostly distributed over alpine and coastal dune land or wetland (Blaschke et al., 1992). Polynesians who arrived about 1,000 years ago, burned about 4 million ha of the forests, particularly of the dry eastern area of New Zealand (Grant, 1996), to clear the land for farming and hunting flightless birds such as moa birds. While large section of lowland forests were deforested and transformed into the land with grass, fern, and shrub by the Polynesians, the rate of deforestation increased after the arrival of European settlers in 1840. They converted a further 8 million ha of forests to pasture by 1920 (Whyte, 1989).

From 1860, concerns about depletion of forest areas and degradation of forest quality arose and people began to show interest in afforestation of exotic trees. However, the development of plantations did not really commence until 1896, the year when the Department of Lands was set up. Subsequently, a nursery in Rotorua and 12,700 acres of plantation mainly at Whakarewarewa in the North Island and Dusky and Hanmer in the South Island, were established. These were planted mainly with eucalyptus and redwood, but also hosted many other species including radiata pine. The most appropriate species were determined in order to meet the future timber supply. "The Royal Commission on

Forestry," published in 1913, reported that radiata pine was likely to become an appropriate species for plantation and recommended expanding the area of plantation (Kininmonth, 1997).

However, in this time, Macintosh Ellis, the first director of the Forest Service which was established in 1919, had a great concern on the expensive cost to establish plantation. He was prudent to perform the plan to establish huge area of plantation while large number of forester considered that afforestation of exotic species was indispensable to meet the future demand. Ellis insisted the necessity of the extension of afforestation until the investigation of natural forests' condition, the analysis of the timber supply from State and Private forests, and the development of cheaper way to establish plantation, had finished. This made to hold the first National Forest Survey from 1920 to 1923.

The results of the first National Forest Survey indicated that the remaining natural forests could not meet New Zealand's wood demand, even if it had been managed sustainably. Therefore, an additional 120,000 ha of plantation forests were planed to be established. This target was achieved in 1931. Further afforestation was performed and 240,000 ha of plantations were established from 1925 till 1936 (Fig. 1-1), which was later recognized as the first boom of afforestation (Whyte, 1989). Although radiata pine was the primary planted species, it occupied only 40% of the total planted species in the State forests and many other species were planted. This was due to concerns about the weakness of monocultural forestry and due to the restrictions that limited each species not to occupy more than 30% of the total planted species (Horgan, 1994).

The new planting rate slowed in the late 1930s and the first boom ended with the start of World War II (Fig. 1-1).

2) After World War II

(a) Plantation

The dramatic decrease and degradation of New Zealand's forests was regarded as serious condition from aspects of timber production as well as environment and national land conservation by the second and third National Forest Survey, which were conducted from 1946 to 1956 and from 1959 to 1963, respectively. Specifically, over-cutting and over-grazing on steep lands were indicated as the most serious problems. Taking this result seriously, the Forest Service examined the necessary plantation area to meet the estimated future wood demand and planned to afforest a million ha by 2050. As a result, the rate of afforestation increased dramatically and the second boom of afforestsation began (Fig. 1-1). From the late 1960s, New Zealand Forestry became a promising industry for exportation while by then it was just for self-supporting. The target of a million ha of new plantation was easily achieved by 1984.

(b) Indigenous forests

When the serious condition of natural forest was revealed by the second National Forest Survey, the importance of indigenous forests was closed up and large numbers of National parks were demarcated (Table 1-1) and real investigation of indigenous forest management was started in the 1940s and 1950s. By then, most of the indigenous forests were left unmanaged and all the salable trees were cut down and the areas converted to pasture. However, the main objective for management in the 1940s and 1950s was to maintain the timber production, and the aims for the research were, for example, to improve the quality of logging operations, and to remove a defined percentage of timber volume (Kininmonth, 1997). Protection of the indigenous forest was still less in priority.

In 1971, the New Zealand Forest Service proposed to fell huge areas of beech forest for wood chips (WWF, 1992). This, the so-called "beech scheme", was an initiative to attempt to find an end use for the bulk of timber which was unsuitable for sawing. By this stage it was acknowledged that the key to successful silviculture and management of beech forests lay in finding markets for the non-sawlog quality or industrial wood. After logging, land management was to involve a blend of regeneration back to beech forest, some enrichment planting with eucalypts, and the conversion of substantial areas to exotic plantation forest (Halkett, 1991). However, this beech scheme proposal caused a public outcry, which criticized the forest conversion and environmental protection aspects of the scheme. This criticism resulted in one of the New Zealand's major environmental campaigns, which finally let the project put on ice.

Coinciding with the growing public concern on environmental conservation, the government acknowledged the 1970s as the "environmental decade." The first Minister for the Environment was appointed in 1972 which was followed by the formation of the Commission for the Environment (Halkett, 1991).

(c) From 1980's up to the present

The stagnation of NZ economy in the early 1980s, which was caused by the oil shock in 1970s and by the decision of England to become a member of European Community, resulted in the call for easing restriction, abolishing subsidies, privatizing state-owned corporation, and selling state-owned properties (Konohira, 1989). The fourth Labor

Government, which assumed the Treasury benches in 1984, carried out the economic reform and the Forest Service became the target of privatization. The Forest Service was taking the multiple-use approach and had a responsibility for both management of plantation and indigenous forests. The Ministry of Finance criticized the inefficiency of the work of Forest Service and its multiple-use approach was pointed out as the cause of the inefficiency (Bilek, 1994).

On the other hand, conservation groups indicated the confliction of interest of the multiple-use approach. They concerned the result of indigenous forest management which was managed by departments with major interests in commercial forestry and land development (Kirkland and Berg, 1997). In addition, the fact that neither the Minister for the Environment nor the Commission for the Environment had a clear statutory mandate to develop and to advise the Government on environment policy and environmental implications of sectoral policies, plans and projects, was also pointed out as a problem (Halkett, 1991). These problems eventually bring about a claim to establish an environmental agency which has a holistic view of the "environment" and take a role for an integrated environmental management (Minowa, 1989).

Under the pressures of economic reform and conservation movement, the New Zealand Forest Service was disbanded in 1987 in favor of Department of Conservation, a Ministry of Forestry and the New Zealand Forestry Corporation (Minowa, 1997b). The management purpose of each organization was simplified. The economic activity and non-economic activity of the Forest Services were divided clearly into different agencies. The Department of Conservation was for native forest management which goals are to protect and preserve biological, aesthetic and other natural attributes under the

Conservation Act 1987. The Ministry of Forestry took the policy and regulatory role, and the Corporation was for commercial plantation forestry.

Moreover, the government announced the plan of reducing the national debt in December 1987. The strategy to implement the plan included the sale of State's commercial forest assets. The sale was implemented under the Crown Forest Assets Act established in 1989 (Minowa, 1997b). The sale itself was structured so that the purchaser bought outright the existing trees together with buildings and other fixed assets on the land, with the land remaining in Crown ownership (Kirkland and Berg, 1997).

This dramatic changes in forestry conditions in the late 1980s resulted in reduction of the rate of afforestation (Kininmonth, 1997) shown in Fig. 1-1. In another, sudden increase, a third boom of afforestation, began because of the reversal of the taxation system in 1990 and the sudden rise of timber prices in 1993. At present, New Zealand is still in the midst of the third afforestation boom and the plantation area is still expanding.

Although publicly owned native forest was conserved under the Conservation Act 1987, the destruction of native forests on private land was not under control. It was predicted that nearly 2000 ha of privately owned native forest was felled each year at the late 1980s, especially for woodchips export (Halkett, 1991). A new policy was announced by the Prime Minister in 1990 to enhance protective opportunities for privately owned native forest and requiring any future forest logging to be undertaken in accordance with sustained yield management principles. Under the policy, a Forest Heritage Fund was established. The fund was designed to provide financial support for the protection of forest areas with high conservation values, particularly if they are under threat from logging or clearance.

The private sector also recognized the importance of the remaining native forests and a series of accords, which have agreed not to replace native forests, have been reached between various conservation groups, forest industry representatives and other forestry interests. In addition, the Forests Amendment Act 1993 established new controls on the export of indigenous timber. It assures the future of natural forest on private land by promoting sustainable forest management. The act also prohibits the export of indigenous timber from New Zealand and the milling of indigenous timber at any sawmill except in certain circumstances (Spence, 1997).

Indigenous forests currently cover 23% of New Zealand's land surface (New Zealand Ministry of Agriculture and Forestry, 1998). Only 4% of the area is used for timber production (Table 1-2) and only 0.7% of the total roundwood removal is from the indigenous forests (Fig. 1-2).

3) Current situation of New Zealand forestry

The current total plantation area is about 1.6 million ha and 90% of the species are radiata pine (Table 1-3). The plantation area is still expanding at a rate of 70,000 ha per year (New Zealand Forest Owners Association Inc., 1997). Looking at these plantations by age class in Fig. 1-3, there is a large potential for timber production increase in the future. In fact, it is predicted that the amount of timber production will be 25 million m^3 by 2003 and if the rate of afforestation averages 60,000 ha/yr, it will be approximately 60 million m^3 by 2040, a dramatic increase from the current timber production of about 16 million m^3. Most of the timber will be for exportation because the predicted future timber consumption in New Zealand is approximately 6 million m^3 (Donnelly and Whyte, 1994).

As a result of this increase of timber exportation, it is said that meat and dairy exports will be exceeded by forestry products exports by 2004 (Maclaren, 1996).

Forty-eight percent of the total exported forestry products from New Zealand are in the form of logs or poles (Fig. 1-4). However, the export amount of value added products, such as fiberboard and particleboard, have increased lately (Fig. 1-5). After the privatization of New Zealand's state-owned forests, increased resources from foreign company investment resulted in the improvement of the processing techniques of these materials.

Japan is the largest importer of New Zealand forestry products based on market value, followed by Australia, and Korea. Each country occupies 31.7%, 27.5%, and 15.2% of the total respectively at the end of 1996 (New Zealand Ministry of Forestry, 1997a).

As the forestry sector became the object of investment after the Asset sale of state-owned forests in 1990, it started to contribute to the employment opportunities to the nation and the number of employment in forestry sector began to increase (Table 1-4).

Current contribution of forestry sector to Gross Domestic Products (GDP) is 5.3% and its contribution to New Zealand total export is about 12% (New Zealand Forest Owners Association Inc, 1997). These figures indicate that forestry is a significant but not a dominant sector in New Zealand economy. However, based on all of these above factors, New Zealand forestry could be said that it is a developing and promising industry.

1.3 The Resource Management Act (RMA)

Environmental laws in New Zealand, traditionally, had been regulated addressing specific environmental and resource management problems in relative isolation. For instance, land-use and water control and management were deal with in separate legislation with different objectives. Consent and enforcement functions were also exercised by quite separate administrative bodies. However, increase awareness and understanding of environmental problems have led people to recognize that the inter-connection between various elements of the environment necessitates an integrated approach to environmental protection and resource development. In order to cope with the recognized situation, the Resource Management Act, the first statute including all laws relating to the use of land, air and water, was established in 1991 (Williams, 1997).

The purpose of the Act provided in section 5 is "to promote the sustainable management of natural and physical resources." "Sustainable management" is defined in section 5 (2) as,

"Sustainable management means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social economic and cultural well-being and for their safety and health while –

(a) Sustaining the potential of natural and physical resources to meet the reasonable foreseeable needs of future generations

(b) Safeguarding the life-supporting capacity of air, water, soil and ecosystems

(c) Avoiding, remedying or mitigating any adverse effects of activities on the environment" (Williams, 1997).

The key feature of the RMA is the focus placed upon the "effects" of activities rather than upon the activities themselves (Milne, 1992). The meaning of "effect" is defined as the following, "The term 'effect' in relation to the use, development, or protection of natural and physical resources, or in relation to the environment, includes:

(a) Any positive or adverse effect

(b) Any temporary or permanent effect,

(c) Any past, present, or future effect,

(d) Any cumulative effect which arises over time or in combination with other effects,

regardless of the scale, intensity, duration or frequency of the effect, and also includes-

(e) Any potential effect of high probability

(f) Any potential effect of low probability which has a high potential impact."

Similarly, "environment" is defined in section 2 as the following,

"(a) Ecosystems and their constituent parts, including people and communities

(b) All natural and physical resources

(c) Amenity values,

(d) The social, economic, aesthetic, and cultural conditions which affect the matters stated in (a) to (c) or which are affected by those matters" (Milne, 1992).

Comparing with the previous laws, the role of central government in the management of natural and physical resources had reduced, which implies a corresponding increase in the autonomy of regional councils to decide policy within their own regions. The principal powers retained by central government are the making of national policy statements that express national goals and objectives, the call-in procedures for projects of national significance and the making of regulations prescribing environmental standards.

In addition, the minister of conservation is responsible for substantial control over the coastal environment (Fig. 1-6).

The regional councils primary responsible for the management of water, soil, geothermal resources, pollution control, natural hazard mitigation, regional inter-relationships, and lake, riverbed, and coastal marine area management. Regional council is required to make a regional policy statement, regional plans, and regional coastal plans (Fig. 1-6). The regional policy statement provides an overview of the resource management issues of each region and integrates the regional and district management of natural and physical resources. Regional plans contain detailed provisions relating to issues identified in regional policy statements. Regional coastal plan provides a list of rules for activities that is likely to have significant or irreversible adverse effects on the coastal marine area.

At a local level, district plans, which might directly affect the actual land-use, are required to made by the district councils (Fig. 1-6). The district plans include control over land-use management, subdivision, noise control, and hazard mitigation.

District plans contain rules that define what activities can occur in all or part of the area covered by the plan. Activities are classified into 5 categories: permitted, controlled, discretionary, non-complying, and prohibited activities. The key difference between these different levels of activity is the likelihood that an application for consent will be granted. Permitted activity is allowed by the plan and no consent is necessary. Controlled activity is expressly allowed by the plan but consent has to be applied for (which has to be granted but which may have conditions attached [New Zealand Ministry of Forestry, 1995b]). Discretionary activity is an activity specified in the plan and is not prohibited. A consent is required and the decision to grant it or not is based on the criteria specified in the plan. Non-complying activity is an activity contravenes the plan. Consent cannot be granted unless the consent authority recognized that the environmental effects will be minor or if the granting will not be contrary to the objectives and policies of the plan. Prohibited activity is not allowed and no consent can be sought.

The consent applied for will vary with the type of activity. There are five possible types of resource consents: land-use consents; subdivision consents; coastal permits; water permits; and discharge permits. For relatively large-scale activities there may be more than one consents involved, for example, plan for factory establishment might requires subdivision and water consents. Activities that affect a wide range of people or have significant environmental effects should be publicly notified and a hearing will be held. Major effect on the environment by the activity will need to be supported by a detailed assessment of environmental effect.

1.4 Objectives and scope of the study

1) Objectives

The privatization and its shift to dichotomous forest management system in New Zealand helped to establish a general acceptance that commercial utilization of planted forests, by substituting for natural forest exploitation, is a method of conservation (FAO, 1997). The higher potential of export earnings of forestry than farming promoted to expand the plantation rapidly and New Zealand is experiencing a remarkable expansion that she ever had (Fig. 1-1). With the plantation forestry expansion, there was always an argument of the influences of mono-cultural plantation on the environment. Plenty of studies have been investigated the effect of plantation establishment on water yield (e.g. Dons, 1987; Fahey and Watson, 1991), water quality (e.g. Fahey and Coker, 1992; O'Loughlin, 1994), soil erosion (e.g. Marden and Rowan, 1993), soil deterioration (e.g. Hawke and O'Conner, 1993), and biodiversity (e.g. Clout and Gaze, 1984; Norton, 1989; Allen et al., 1995b). However, its influence on a landscape level has not been well investigated.

Landscape change or transformation by unplanned human activities might result in land fragmentation, breaking up of large habitat or land areas into smaller parcels, which leads to extinction and loss of biodiversity (Forman, 1995). It also can induce alteration in the integrity of a stream network system, water quality of an aquifer, the flow of nutrients, and the rate of soil erosion (Forman, 1995; Gorham, 1997). There is increasing recognition that those problems occurred by human derived land-use, need to be tackled at a landscape level and that landscape-scale considerations is required to involve in land-use planning (Hobbs, 1999). Examining the effect of forestry expansion at landscapes level is, therefore, significant not only for evaluate the influence itself but also to provide information for appropriate land-use management system. Moreover, it is useful for evaluating the new resource management policy, the RMA.

As the RMA is regulating activities adversely affect the environment, New Zealanders are showing their great interests in its influence on the land-use pattern such as pastoral farming, horticultural lands, and forestry. There are also some reports mentioning the expected influence of RMA on forestry (e.g. Novis, 1997). Japan also shows great interests in the influence and effectiveness of the RMA from a legal and forest political point of view (e.g. Hiramatu, 1996, 1997a and b, and 1999; Hirota, 1999;

Kakizawa and Nozaki, 2001). The influence of the RMA on forestry expansion might also one of the greatest interests for Japanese companies having interests in timber importation and having financial interest in establishing plantations in New Zealand.

Thus, this study aims 1) to interpret the effects of forestry expansion on land-use pattern, 2) to examine the effect of the RMA on land-use and environmental conservation, and 3) to investigate the potential of further forestry expansion.

In addition, the expansion possibility of New Zealand wood utilization in Japan was also interpreted because it may contribute to fulfill Japan's responsibility to consume environment-friendly wood resources as one of the world's largest timber consumer and timber importer.

2) The scope of the study

The Nelson region was selected as a study area to examine the land-use patterns. As the adopted data set was based on the definition or systems that is specific to New Zealand, chapter 2 provides an explanation of the data set together with the outline of the study area (Fig. 1-7).

In order to interpret the influence of forestry expansion on land-use, two steps need to be gone through. First step is to understand the current land-use pattern and the second is to interpret how the land-use was changed over a certain period. Chapter 3 investigates the current land-use pattern by understanding the relationship with the land characteristics such as rock, soil, and slopes. In chapter 4, the land-use change patterns were examined through understanding the differences of landscape structure between the 1970s and 1990s, and through interpreting the human-induced land-use changes. Factors influencing the pattern were also analyzed.

Although interpretation of land-use change patterns is useful for evaluating the land management policy (Zheng et al., 1997), this was not the case for examining the influence of the RMA. The reason for this is because the RMA has just been implemented and it was expected that no significant change would be detected from the actual land-use data. Hence, evaluation of the RMA might only be achieved by predicting the future land-use and comparing the predicted land-use with the district plan under the RMA. Chapter 4, therefore, also aims to establish a sufficient data set to predict the future land-use.

Based on the data set established in Chapter 4, future land-use change was predicted in Chapter 5. The predicted land-use changes were put into the map and those maps were compared with the Nelson Resource Management Plan Planning Map and the Tasman Resource Management Plan Planning map in order to understand whether the predicted land-use change can really occur even under the regulation of the RMA.

As one of the world's largest timber importer and consumer, Japan is responsible for using timbers which were harvested in a way of avoiding, mitigating and remedying the adverse effects on environment with high natural values. New Zealand woods might be able to meet those condition and Chapter 6, therefore, discusses the possibility of further utilization of New Zealand wood in Japan.

Based on all of the results of each chapter, Chapter 7 discusses 1) the impact of forestry expansion on landscape, 2) the effectiveness of the new resource management system, and 3) the possibility of further forestry expansion. Whether or not using New Zealand wood in Japan can contribute to fulfill Japan's responsibility to consume environment-friendly wood resources, was also examined. In addition, it searches the application possibility of the new resource management system in New Zealand to the resource management system in Japan.

Table 1-1. Protected areas administered by Department of Conservation

Protected area category	Conservation units ※1	Area (ha)
National Parks	22	2,425,884
Reserves (Includes 758277 ha) ※2 of marine reserves)	3,475	1,567,846
Conservation areas ※3	5,113	4,657,729
Wildlife areas ※4	85	10,821
Marine mammal sanctuaries	2	335,511
Protected private land	434	61,760
Total land protected area ※5		**7,965,763**
Total (includes marine protected area)		**9,059,551**
Total New Zealand land area		**27,053,400**

Source: NZ Ministry of Forestry, 1998.

※**Notes** :

1 **A Conservation unit** is a standard grouping of parcels of land which is used in the Department of Conservation's computerized National lands Register. The number of units does not necessarily correspond to the actual number of protected areas.

2 **Reserves** include national, historic, scenic, nature, scientific, wildlife purposes, wilderness areas, marine, faunistic, and others not specified, and excludes any reserve with another administering body.

3 **Conservation areas** include conservation parks, ecological areas, sanctuary areas, other specifically protected areas and stewardship lands.

4 **Wildlife areas** include refuge, sanctuary and management reserves. This does not include other Department of Conservation areas, or areas for wildlife purposes administered under the Reserves Act 1977.

5 **Total Land protected area** occupies 29.4% of the total New Zealand land area.

Table 1-2 New Zealand Natural Forest Area Estimates : State and Private

Natural forest category	**Estimated area (1,000 ha)**	**Percentage of total natural forest area**	**Percentage of total New Zealand land area**
State-owned natural forest	4,919	77.1	18.2
State-owned natural forest allocated for timber production	142	2.2	0.5
State-owned natural forest total	**5,061**	**79.3**	**18.7**
Privately owned natural forest			
Protection forest	654	10.3	2.4
Currently unavailable	545	8.5	2.0
Potentially commercially available	124	1.9	0.5
Privately owned natural forest total	**1,323**	**20.7**	**4.9**
Natural forest total	**6,384**	**100.0**	**23.6**
Total New Zealand land area	**27,053**		

Source: NZ Ministry ofAgriculture and Forestry, 1998.

Table 1-3 Planted production forest area by species

	area (1,000ha)	% of total
Radiata pine	1,396	90.5%
Douglas fir	70	4.5%
Other exotic softwoods	33	2.1%
All exotic hardwoods	43	2.8%
Total	1,542	

Source: NZ Ministry of Agriculture and Forestry,1998.

Table 1-4 Employment in forestry and processing activities.

Year	1990	1991	1992	1993	1994	1995	1996
Forestry	6,704	6,776	8,120	8,216	10,190	11,237	11,323
Sawmilling	6,499	6,199	6,405	6,915	8,107	8,368	8,320
Panels, Pulp, Paper	9,740	11,191	10,605	10,570	10,620	11,414	11,450
Total All Activities	**22,943**	**24,166**	**25,130**	**25,701**	**28,917**	**31,019**	**31,093**

Source: New Zealand Forest Owners Associations Inc., 1997

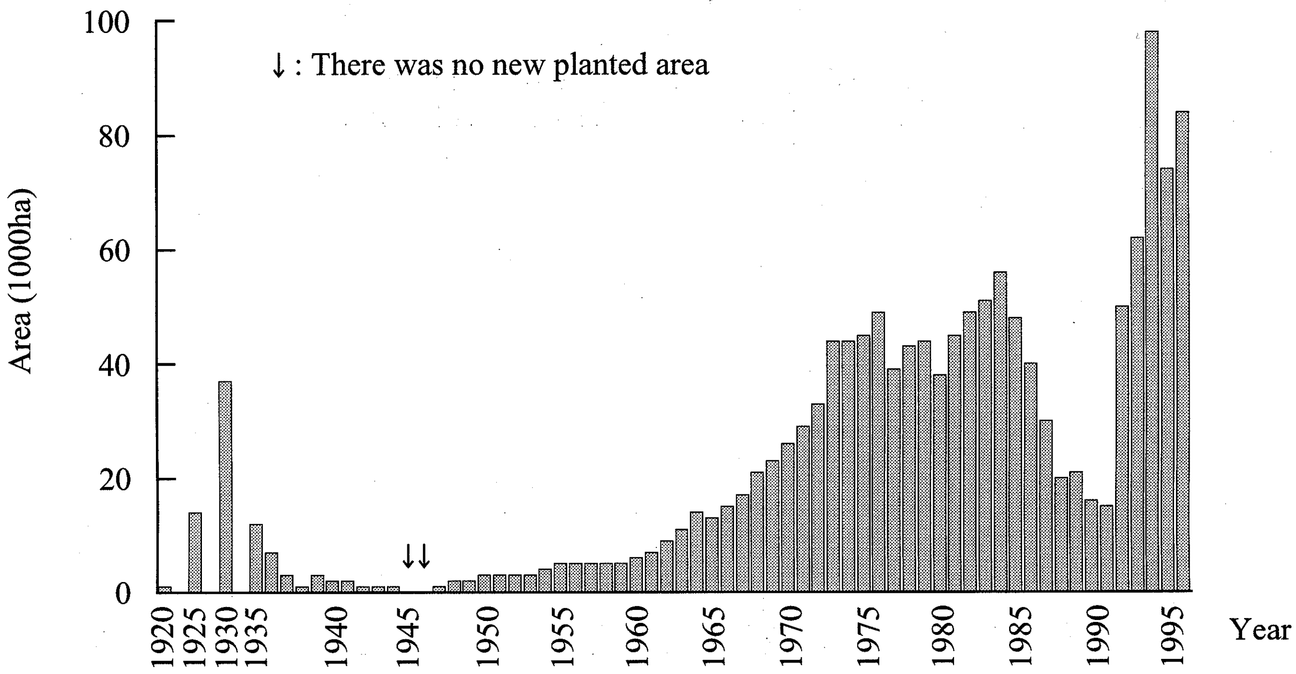


Fig. 1-1 New planted production forest in New Zealand
Source: New Zealand Ministry of Agriculture and Forestry, 1998.

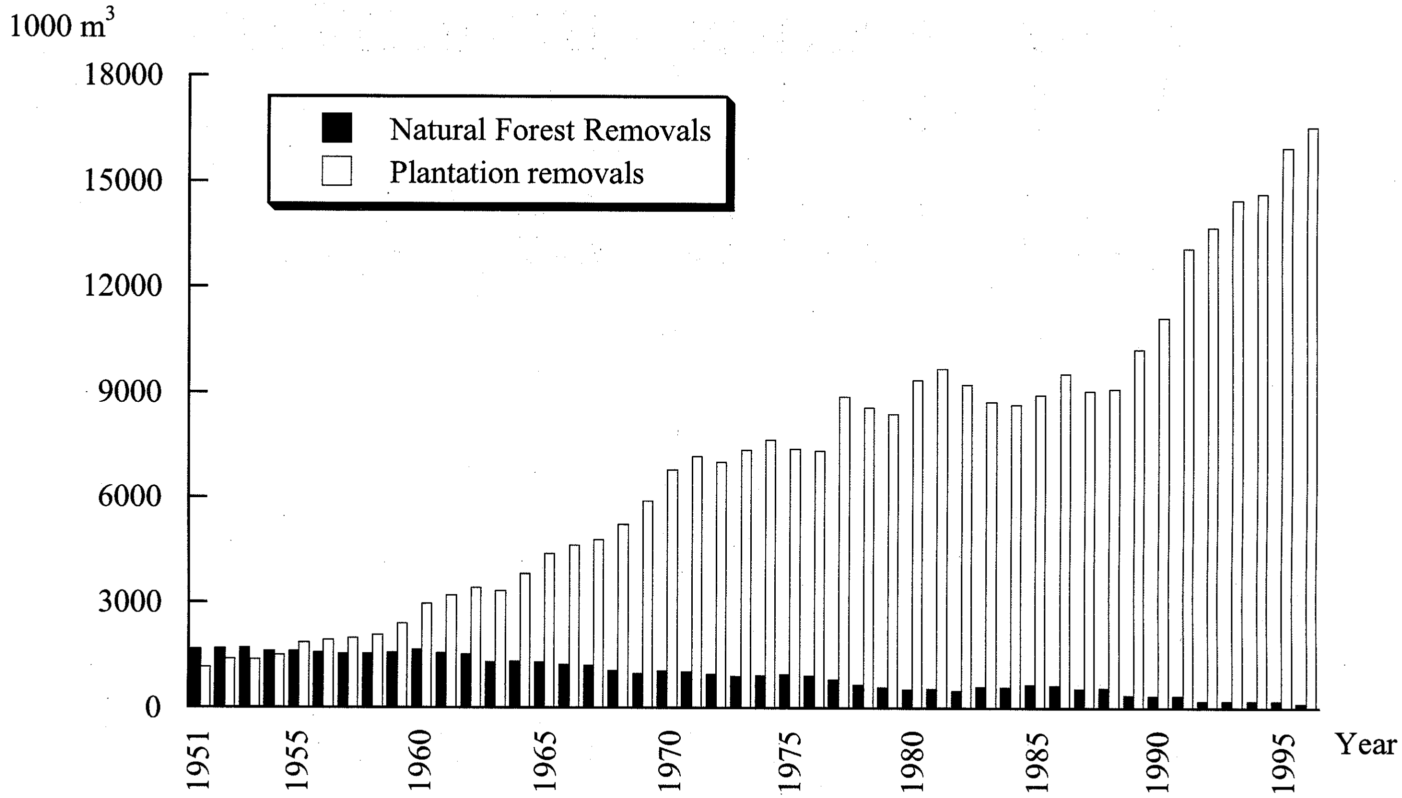


Fig. 1-2 Estimated roundwood removals from NZ forests.
Source: NZ Ministry of Agriculture and Forestry, 1998.

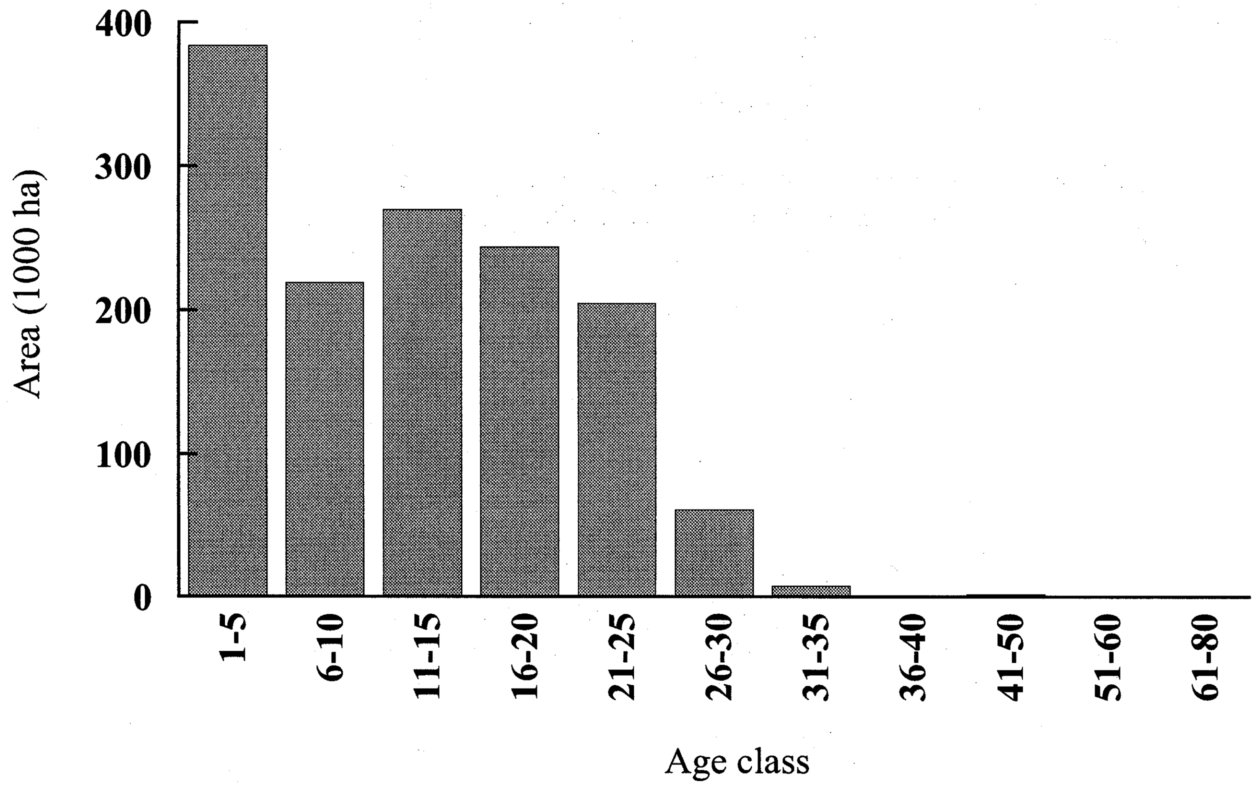


Fig. 1-3 New Zealand net stocked radiata pine planted forest area (by age class).
Source: NZ Ministry of Agriculture and Forestry, 1998.

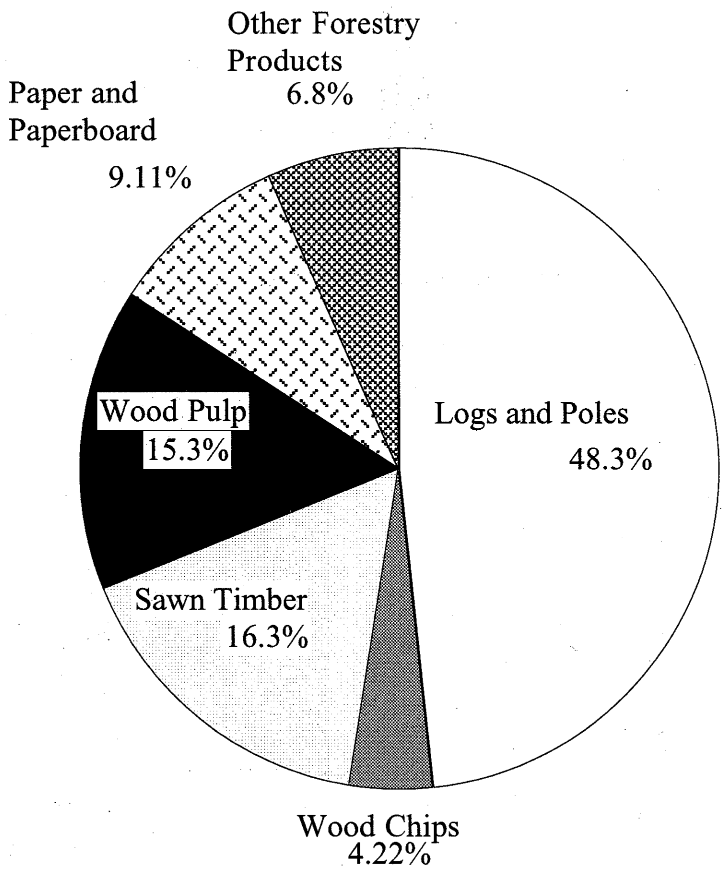


Fig. 1-4 The forms of forestry products exported from New Zealand based on quantity: roundwood equivalent.
Source: NZ Ministry of Agriculture and Forestry, 1998.

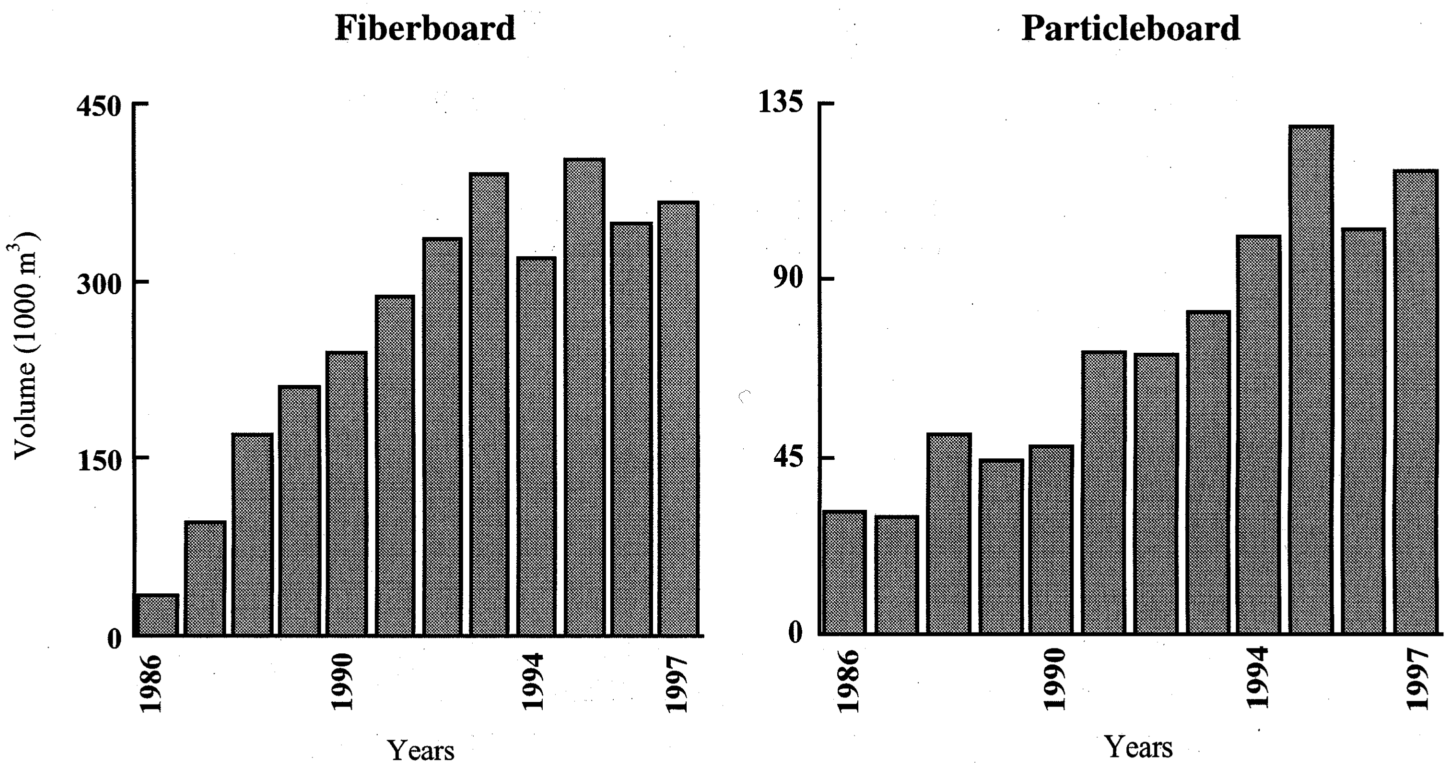


Fig. 1-5: Exportation of Fiberboard and Particleboard.
Source: NZ Ministry of Agriculture and Forestry, 1998.

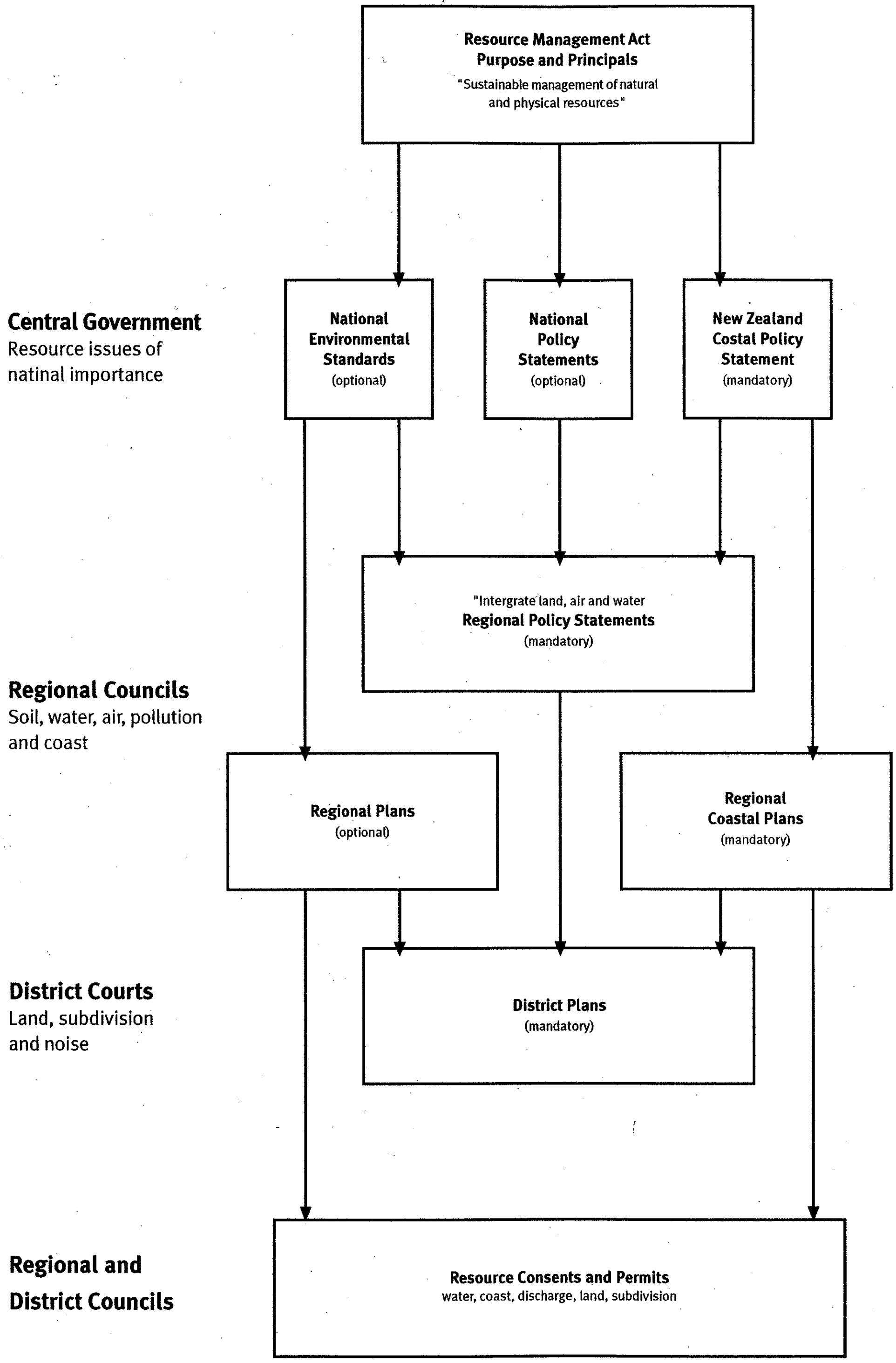


Fig. 1-6 The Resource Management Act
Source: Taylor *et al.*, 1997.

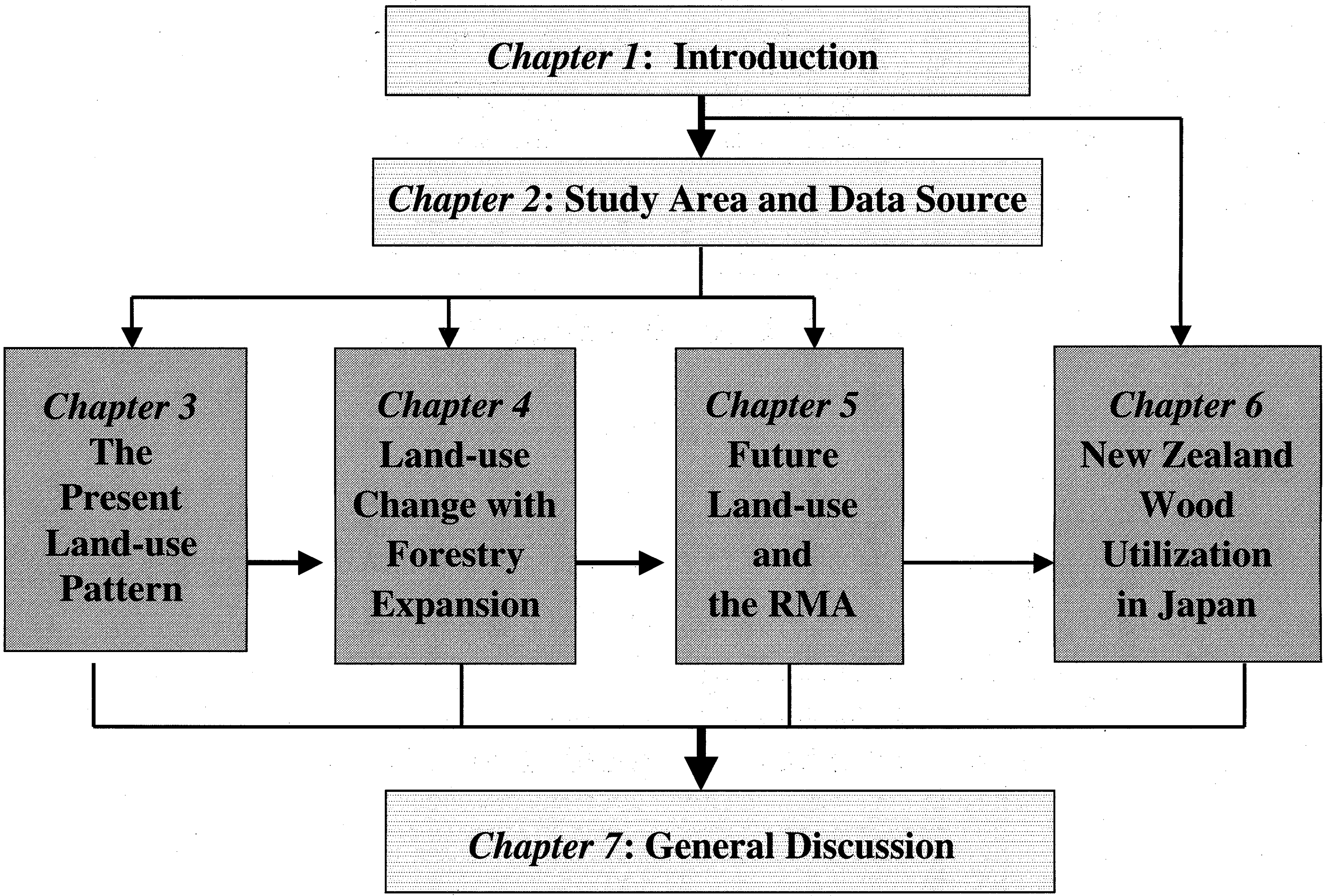


Fig. 1-7 The scope of the study.

Chapter 2

Study Area and Data Sources

2.1 Study area

The Nelson region is located at the north of the South Island of New Zealand, and consists of Nelson City (41°16'S, 173°17E') and Tasman District (Fig. 2-1). The region is bounded to the west by the Matiri Ranges, Tasman Mountains and the Tasman Sea, and to the north by the Tasman and Golden Bays. The eastern boundary extends north from Cape Soucis along the Bryant, Richmond, and St Arnaud Ranges and the Spencer Mountains. The Victoria Ranges form the southern boundary (Statistics New Zealand, 1999a and 1999b).

Much of the region is mountainous mostly covered with indigenous forest and shrub. Fifty-three percent of the land area is indigenous forest consisted of beech or podocarps forest, and further 10 % is covered by shrub composed of fern, manuka, and kanuka (Table 2-1). Most of the indigenous forests are administered by the Department of Conservation, with major areas being the Abel Tasman National Park, Nelson Lakes National Park, and Kahurangi National Park (Fig. 2-2). Abel Tasman National Park, established in 1942, is New Zealand's smallest national park (22,541 ha) and is situated along the shores of Tasman Bay. Nelson Lakes National Park (101,753 ha), established in 1956, is a rugged mountainous area situated in the southeast of the region. Kahurangi National Park (452,000 ha), established in 1996, dominates the western of Tasman and extends into the north of the West Coast Region. Together with national parks, state forests were proclaimed in the region, and Mt Richmond State Forest Park is the main state forest (Fig. 2-2).

The climate of the region is temperate, with high annual sunshine hours and mild temperatures. The sunshine hours in the Nelson Region are around 2400 per year, among the highest in the country. Annual rainfall varies from less than 1000 mm to over 2000 mm, with higher rainfall in the foothills of the major ranges and lower rainfall in the lowlands around Nelson City (New Zealand Ministry of Forestry, 1997b).

According to the 1996 census, the population of the region was 82,070 (Statistics New Zealand, 1998). Both in the Nelson City and the Tasman district show high rate of population growth, 14.5% and 11.6% respectively.

Agriculture, horticulture and forestry are the major source of employment. Agriculture has always been the major contributors to the region's economy since 1850's (New Zealand Ministry of Works, Town and Country Planning Branch, 1965). Horticulture grew rapidly since 1945 and started to make significant contributions to the local economy. The region once had a significant tobacco growing industry but international competition and the removal of tariff protection made this crop uneconomic. Today, hops, pip fruit (apple and pear), kiwi fruit, and berry fruits (boysenberries and raspberries) are the main products. Although forestry had started along with horticulture expansion in order to provide timbers for fruit cases in the early 1900s, it started to contribute to the local economy since the late 1950s when the logs planted in the first boom began to mature (McAloon, 1997).

As elsewhere in the country, there has been extensive new planting in the Nelson region since 1970. The plantation area in the region increased 51,000 ha to reach 99,138 ha (6% of the New Zealand's total plantation area) in 1998 since 1970. Radiata pine

(86%) is the dominant species followed by Douglas-fir (11%). The expansion of plantation area also coincided with an increase of sawn timber production and the amount of log exports from Nelson port. The sawn timber production increased from 159,440 m^3 in 1990 to 239,350 m^3 in 1996 and log exports increased from 212,600 m^3 in 1992 to 477,400 m^3 in 1996 (New Zealand Ministry of Forestry, 1997b). Future forest harvests in Nelson and Marlborough together are predicted to rise from 1.5 million m^3 in 1996 to 2.4 million m^3 in 2005, which should also produce significant increases in wood processing (Statistics of New Zealand, 1999b).

As it is known that forestry in New Zealand had been largely mechanized, people in Japan imagine that large area of plantations is established on flat or gentle slopes (Kai, 1989). However, New Zealand is a mountainous country, especially in the South Island where slopes steeper than 20 degrees covers 60% of the area (Wardle, 1991). Plantation can be observed on those steep slopes (Konohira, 1989). As Nelson region is one of the region where forestry is on its prosperity, and experiencing rapid plantation expansion in the last 20 year, it was considered to be sufficient as a study area that represents the situation of forestry expansion on steep areas in New Zealand. Considering forestry and the resource management systems of areas with steep slopes in New Zealand might also provide some good information for Japan on forestry and resource management.

2.2 Data sources

1) New Zealand Land Resource Inventory (NZLRI) Map

The NZLRI map was digitized between 1977 and 1980 from New Zealand Land Resource Inventory maps (National Water and Soil Conservation Organization

[NWASCO] 1975-1979) at a scale of 1: 63,360. The data were collected between 1973 and 1979 from detailed aerial photo-interpretation, large-scale resource maps and extensive fieldwork (Newsome, 1992). It contains vector polygonal data, known as Land Resource Inventory (LRI) units, representing land-use and vegetation, rock, soil, slope, and erosion. Other items were also added to the data such as stock carrying capacity and soil phosphate requirements. The basic objective of the survey was to provide a systematic physical stocktaking of New Zealand's land resource for soil conservation (Water and Soil Division, Ministry of Works, 1971). However, the physical data was also used for classifying the land by "Land Use Capability (LUC)" to promote appropriate land-use. In the NZLRI map, each LRI unit also includes information about LUC.

Land-use, rock, soil, slope, and LUC on the NZLRI map were mainly utilized in the following chapters. Explanation of the legends and the classification system are provided in the following.

(a) Land-use

Nine types of land-uses were classified based on the vegetation data: indigenous forest, horticulture, lake and rivers, pasture, plantation, shrub, tussock, urban, and other vegetation (Fig. 2-3).

Indigenous forests in the Nelson region (Fig. 2-4) is mainly consist with Beech forests. The lower altitude is covered with hard beech (*Nothofagus truncata*)(Fig. 2-5a). Black beech (*nothofagus solandri,* Fig. 2-5b) grows mainly on the lower ends of sharp spurs and on brows of alluvial terraces. Red beech (*Nothofagus fusca*, Fig. 2-5c) tends to dominate on moist colluvial slope, and silver beech on valley floors. Above the limits of hard beech, silver beech (*Nothofagus menziesii*, Fig. 2-5d) expands to occupy both gullies and spurs; red beech remains largely on the colluvial slopes up to the altitudinal limit around 1000m. With increasing altitude, mountain beech (*Nothofagus solandri var. cliffortioides*, Fig. 2-5e) increasingly dominates on shallow, leached soils. Podocarps-broad-leaved forests which is consist mainly with totara (*Podocarpus totara*, Fig. 2-6a), rimu (*Decrydium cupressinum,* Fig. 2-6b) and miro (*Prumnopitys ferruginea*, Fig. 2-6c) distributes mainly on valley floors and fertile colluvial slopes up to 640m (Wardle, 1991).

Shrub is mainly consisted of tree ferns (e.g. Black tree fern [*Cyathea nedullaris*], Soft tree fern [*Cyathea smithii*], Fig. 2-7), ferns other than tree ferns (e.g. Bracken [*Pteridium esculentum*], Crown Fern [*Blechnum discolor*],Prickly Shield Fern [*Polystichum vestitum*], Ring Fern [*Paesia scaberula*], Fig. 2-8), Manuka (*Leptospermum scoparium*, Fig. 2-9a and b) and Kanuka (*Kunzea ericoides*, Fig. 2-9c), and sometimes of Matagouri (*Discaria toumatou*, Fig 2-9d). Native shrub land associated with Gorse (*Ulex europeaus*) can be observed sometimes. However, mostly gorse invades on plantation or extensively managed pasture, and therefore is a serious weed for farmers (Hunter and Blascke, 1986)(Fig. 2-10).

Tussock is dominated by snow tussock (*Chionochloa spp.*) and red tussock (*Chionochloa rubra)* (Fig. 2-11).

(b) Rock types

The rock classification system applied on the NZLRI map is based on Lynn (1985). Although it is said that rock type classification system is different in some terms from the international standard, it is basically the same in a broad sense. Therefore, no particular explanation of rock types was added in here. The objective of this study is to understand the rock types of the main land-uses in a broad sense and not about the detail of the rock characteristics.

Rock type in the Nelson region consists mainly of plutonic rocks (20.6%), Alluvium (12.8%), and conglomerate (11.5%) (Fig. 2-12).

(c) Soil types

Although a new soil classification system, known as the New Zealand soil classification was developed in 1992, most of the soil resource information currently available in New Zealand (e.g. soil maps and bulletins) conforms to the old system, the New Zealand genetic soil classification (McLaren and Cameron, 1996). The soil classification in the NZLRI map is not an exception. Therefore, the soil classification is based on the old system and its detail is explained in Taylor and Pohlen (1970) or the Soil Bureau, Department of Scientific and Industrial Research (1968). As the classification system does not conform to the international standard of soil classification, main soil types in the Nelson region are explained briefly in the following.

(1) Alpine soil (ALP)

Alpine soils occur at high altitudes (above about 1000 m) on the main mountain ranges. The surface is bare rock, scree, and rock waster on which alpine plants are scattered.

(2) Brown granular clays (BGC)

Brown granular clays are brown soils with high structural stability, and relatively high iron and aluminum oxide content, formed on basic rocks, principally basalt and basaltic tuffs. It forms under various climatic conditions and native vegetation. It is considered as a valuable soil because of its medium to relatively high nutrient status, resistance to structural deterioration under cropping, and the ease of cultivation.

(3) Gray soil (GY)

Grey soil occurs on sites (mostly low lying swampy land) where soils receive moisture from ground water as well as from direct surface wetting by rain. It has characteristic gray horizons in which grayish, bluish, or greenish colors predominate.

(4) High-country podzolised yellow-brown earth (HCPYB) and Upland podzolised yellow-brown earth (UPYB)

The soil is formed on wide range of parent materials including schist greywacke, and granite. The topsoil is dark gray silt loam with crumb to nutty structures. It is found under various kinds of vegetation such as tussock, shrub and beech forests. Its nutrient status is low.

(5) High-country yellow-brown earth (HCYB)

It occurs under environment subject to intense ground frosts, high-velocity winds, and high rainfall. It has weakly developed fine crumb structure, low bulk density, and are highly susceptible to wind and sheet erosion. Its nutrient status is low, too.

(6) Intergrade between rendzina and yellow-brown earth (IRENYB)

Rendzinas are soils with black or very dark gray topsoil with strongly developed crumb, nutty, or granular structure overlying limestone or highly calcareous rocks. Subsoil would be absent or weakly developed. IRENYB have browner color than the rendzinas, have less free lime and are commonly unsaturated. It mainly observed under podocarp/broadleaved forest.

(7) Intergrade between yellow-gray and yellow-brown earth (IYGYB)

It occurs throughout the South Island from Nelson to Southland in patches and strips between the yellow-gray earths and the yellow-brown earths. It is formed on loess or loess-like fine textured sediments. The principal profile features for the soil are: dark grayish brown topsoil with weakly to moderately developed nutty or crumb structure; a distinct worm-mixed transition horizon; yellowish brown subsoil with weakly to moderately compact fragipan. The soil indicates low to medium nutrient status.

(8) Podzolised yellow-brown earth (PYB)

In wetter districts of the South Island such as western Nelson where annual rainfall is more than 1250 mm and where mor-forming forest vegetation occurs, yellow-brown earths grade into podzolised yellow-brown earth. Between 1250 mm to 2500 mm per annum it occupies an increasing area of the total. The litters from mor-forming trees accumulate less than 24 cm thick. Litters may be extremely acid, with pH less than 4 and in some cases as low as 3.3. Its nutrient status is very low.

(9) Recent soil (RE) and Integrated between yellow-brown earth and recent soil (IYBRE)

Recent soils from alluvium are widespread on the flood plains and low terraces of rivers in the South Island. Together with recent soil intergrades to adjacent soils, it is among the most important soils of the country because it is highly favored for intensive mixed farming and is well suited to a wide range of crops. However, because many of them have weakly developed structure, they cannot be used for a long-term cropping without structure deterioration.

(10) Yellow-brown earth (YB) and Yellow-brown shallow and stony soil (YBST)

It is formed on a variety of unconsolidated deposits derived from graywackes, schist, granite, sandstones, mudstones and so on. The principle profile features are: grayish brown to dark grayish brown silt loam topsoil, friable with nutty or nutty and crumb structure; yellowish brown to brownish yellow silt loam to heavy silt loam subsoil with nutty or fine blocky structure. The nutrient status is low to medium. The YBST is observed on hills and steeper slopes than the YB occurs. It is commonly on stony silt loam texture and the soil is shallow with some rock outcrops.

(11) Yellow-brown sands (YBS)

Yellow-brown sand is formed on small strips of sand dunes along the coastline of the South Island. The sands are derived from a wide range of rocks and consequently vary greatly in mineralogical composition. It is low in organic matter and clay, and also in nutrient status.

Soil type in the Nelson region consists mainly of yellow-brown earths (YB: 31.6%) and high country podzolized yellow-brown earths (HCPYB: 25.1%)(Fig. 2-13).

(d) Slope type

The Nelson region has 51.5% of its land categorized as “steep: 26-35 degrees” and 14.4% as “very steep: more than 35 degrees” (Fig. 2-14). This confirms the fact that the region is mountainous. The slope classification used in the figure is explained in Table2-2.

(e) Land Use Capability

The Land Use Capability (LUC) classification is “a systematic arrangement of different kinds of land according to those properties that determine its capacity for permanent sustained production". "Capacity" is defined here as "suitability for productive use" (Water and Soil Division, Ministry of Works, 1971). The LUC is derived from five physical factors (rock, soil, slope, vegetation, and erosion) together with climate. The classification has three components: a class, a subclass, and a unit (Water and Soil Division, New Zealand Ministry of Works and Development, 1979) (Fig.2-15). The LUC class is the broadest grouping that delimits land characteristics together with suitability for general land-use such as cropping and pasture (Fig.2-16). The LUC subclass disaggregates the land within each class according to the major kind of limitation or hazard such as erosion and wetness. The LUC unit is a group of LRI units with similar management and conservation treatments (Fig.2-15).

The LUC has been used by local territorial authorities (e.g. regional councils, government departments and private companies) as a standard for land-use planning (Agriculture New Zealand Richmond, 1994; Harmsworth, 1996). It may also be useful for district or regional planning under the RMA. Although LUC is a planning standard and not a plan, it could assist in understanding whether or not the land-use planning was applied appropriately in determining the actual land-use.

The region has 47.9% of its land classified as "8e," which is "catchment protection land" (Fig. 2-16) with the dominant limitation of the land being "erosion" (Fig. 2-17). Another 27.6% of the land is classified as "7e," "pastoral or forestry" with the dominant limitation of the land being "erosion." Thus, 75% of the land is not suitable for cropping and even the suitability for pasture or forestry is low.

2) Land Cover Data Base (LCDB)

Land Cover Data Base is a land-use map made and digitized by the Ministry of Forestry based on the SPOT satellite image. The mapped land-uses were bare ground, horticulture, indigenous forest, lakes and rivers, pasture, plantation, shrub, tussock and urban sites (Fig. 2-18). Plantation is placed into four sub-categories based on their ages: less than 3 years, 3 to 10 years, 10 to 20 years, and more than 20 years.

2.3 The Regional and District Plan under the RMA in the Nelson region.

1) The Nelson Resource Management Plan (NRMP)

The Nelson City Council operates as a unitary authority, which is the district with the responsibilities of regional councils. This implies that the City Council needs to make both the regional plan and the district plan. The City Council decided to combine those two because they considered it is the best way to achieve the objective of the plan: integrated management of the natural and physical resources of the city.

The plan introduced a zoning system to define the different environmental qualities sought for different areas and to control the actual and potential adverse effects of development within them. The zones cover all of the land area of the District without overlapping (Fig. 2-19), and each zone contain rules to avoid, remedy or mitigate the adverse effects of activities. A brief explanation of each zone (based on Nelson City Council, 1999a) is as follows:

a. Residential zone: A quality residential environment that provides a choice of living styles, a high level of amenity, and a minimal occurrence of nuisances.
b. Inner City zone: A city center which provides a strong and vibrant focus to the

city, together with a city fringe which supports and complements the city center.

c. Suburban Commercial zone: Suburban commercial centers which enable community needs to be met, while minimizing their impacts on surrounding areas.

d. Industrial zone: An environment within which there are opportunities for the needs of industry to be met and where the actual and potential effects of industrial activity are contained.

e. Open Space and Recreation zone: Area for the present and planned open space and recreation land.

f. Rural zone: An environment within which soil, water and land resources are managed in a sustainable manner, and the rural character of the district (including water works catchments) and the surroundings of urban Nelson are maintained or enhanced. It contains much of the districts lands used for productive purposes, mainly for forestry and farming and hence it is important for the local economy.

g. Conservation zone: An environment where natural character and landscape values are preserved and enhanced. The land is largely under some form of protection, being forest park and other reserve land administered by the Department of Conservation, and the waterworks reserves areas and other reserves administered by the Nelson City Council. The Council's approach to the management of this area is to maintain it as far as possible in its natural state.

h. Coastal Marine area: where the natural character is preserved and enhanced and inappropriate subdivision, use, and development do not occur.

In addition to the zones, areas with particular issues arising in the district were designated as overlays. Overlays that particularly relate to land-use change might be Landscape overlay and Conservation overlay (Fig. 2-20), although there are totally 14 overlays defined in the NRMP. Adverse visual effects on the remote backdrop to the district through structures, tracking, land clearance, and planting technique is one of the issues arising in the City. In order to protect this key landscapes, Landscape overlays cover areas adjacent to the city, coast, and main traffic routes that are highly sensitive to development. They comprise mainly the ridge tops together with sensitive shoulder slopes. Conservation overlay covers areas of significant conservation value outside the Conservation zone. This is to recognize and provide for the protection of outstanding natural features and landscapes from inappropriate subdivision, use, and development, and the protection of significant indigenous vegetation and habitats of indigenous fauna.

2) The Tasman Resource Management Plan (TRMP)

As a unitary authority, the Tasman District had also made a combined district and regional plan named "The Tasman Resource Management Plan (TRMP)." The TRMP uses the technique of zones and areas in conjunction with rules to manage adverse environmental effects of resource use activities in promoting sustainable management.

A zone is any mapped part of the District in which there are common resources or resource values that may be adversely affected in certain ways by certain activities and where common restrictions on activities and effects are specified by rules. Zones always cover separate parts of the District and do not overlap in space. The zones are Residential zone, Central Business, commercial and tourist service zone, Industrial zone, Rural 1 and 2 zone, Rural residential zone, Rural industrial zone, Open space zone, Recreation zone, and Conservation zone (Fig. 2-21). A brief definition for each zone (Tasman District Council, 2000) is provided as follows:

a. Residential zone: is an area for residential activity which means the use of land and buildings by people for the purpose of living accommodation.

b. Central business, commercial and tourist service zone: Central business and commercial zone is an area for using land and buildings for the display, offering, provision, sale or hire of goods, equipment, or services and includes shops, markets, showrooms restaurants, service stations and so on. The tourist service zone means the use of land and buildings for short-term, commercial or recreational living accommodation, where the length of stay for any one visitor is not greater than three months at any one time. It includes some centralized services or facilities such as food preparation, dining, sanitary, conference, recreation, and bar facilities, and associated parking areas.

c. Industrial zone: is an area of land and building use for the primary purpose of manufacturing, fabricating, processing, packing, or associated storage of goods, but does not include home occupations.

d. Rural 1 zone: comprises the most inherently productive and versatile land and largely used for horticultural purpose, pastoral farming and forestry.

e. Rural 2 zone: comprises land of more limited inherent productive and versatile values compared with Rural 1 zone.

f. Rural residential zone: is a rural site using for residential purposes, with any farming or other rural activity being ancillary.

g. Rural industrial zone: is composed with lands for industry that depends on the direct handling or processing of produce harvested from farming, forestry, or the sea or any other land-derived product. It includes, for instance, sawmill, timber treatment plant, stockyard, rural transport depot, and the processing of minerals and quarry products.

h. Open space zone: indicates playgrounds, picnic facility or public shelter, a public garden and accessory buildings, and a walkway or cycleway.

i. Recreational zone: is an area for recreation or entertainment by members of more than one household unit. It includes lands for indoor or outdoor sporting and recreational activity including craft fair and gala, public gardens, playground, picnic facilities, public car park, walkway or cycleway.

j. Conservation zone: is an area for protecting and enhancing the land's natural characteristics in the region. It is administered by the Department of Conservation and includes the Abel Tasman, Kahurangi, and Nelson Lakes National Parks and numerous scenic reserves.

An area is any mapped part of the District with further specific resource values that may be adversely affected in certain ways by certain activities and where common restrictions on activities and effects apply in addition to the zone rules. Areas which were considered to affect the land-use significantly, were Groundwater Recharge Protection Area (GRPA), Landscape Priority Areas (LSPA), Natural Heritage Areas (NHA), and Slope Stability Hazard Areas (SSHA)(Fig. 2-22). The GRPA is an area for dealing with the water yield effects of plantations on life-supporting capacity of surface water resources and on existing and potential water supplies for abstraction. Changing the vegetation cover from short to tall vegetation, like establishment of plantation on pasture, can cause a decline on both groundwater and surface water yields. The instream values and opportunities for continuing or new abstractions of water for irrigation or other purposes will be adversely affected by such declines. In order to avoid, remedy, and mitigate of reductions in water availability for sustainable water uses, plantation establishment is regulated by the rules in the area. The LSPA contains landscapes and natural features outside the conservation estate that are outstanding or of regional significance on the basis of their character, quality, and visibility. The NHA was designated for protecting areas of significant indigenous vegetation and habitats for indigenous fauna and outstanding natural features in the region. The indigenous vegetation outside of the conservation zone have been extensively modified over the years through human activity and is limited and largely fragmented, especially on lowlands. While the NHA includes some of the lands under formal protection, it also focuses on protection of those remaining fragmented indigenous vegetation from human activities. Slope instability is a general hazard affecting wide area of the Tasman District. In particular, on slopes greater than 20 degrees. The SSHA is an area with high risk of instability if vegetation or soils are disturbed. Thus, it limits activities that accompany vegetation removal and soil disturbance.

Table 2-1 Land use in Nelson region in 1996.

	Proportion(%)	Area (ha)
Indigenous forest	52.8	531,959
New Planting <3	0.6	5,843
Planted forest <10	2.9	29,231
Planted forest 10-20	3.3	32,838
Planted forest >20	4.0	40,815
Total plantation	10.8	108,727
Primary horticulture	0.6	5,589
Primary pastoral	15.3	153,985
Shrub	9.8	98,527
Tussock	6.1	61,472
Bare ground	3.4	34,146
Urban	0.3	3,255
Urban open space	0.1	892
Others	0.9	9,337
Total	100.0	1,007,890

Horticultural land

Pasture and Plantation

Table 2-2 Slope classification.

Class	Angle of inclination
Flat to gently undulating	0-3 degrees
Intermediate: F and U	Intermediate of "Flat to gentle undulating" and "Undulating"
Undulating	4-7 degrees
Intermediate: U and R	Intermediate of "Undulating" and "Rolling"
Rolling	8-15 degrees
Intermediate: R and S	Intermediate of "Rolling" and "Strongly rolling"
Strongly rolling	16-20 degrees
Intermediate: S and M	Intermediate of "Strongly rolling" and "Moderately steep"
Moderately steep	21-25 degrees
Intermediate: M and St	Intermediate of "Moderately steep" and "Steep"
Steep	26-35 degrees
Intermediate: St and V	Intermediate of "Steep" and "very steep"
Very Steep	> 35 degrees

Source: Newsome, 1992.

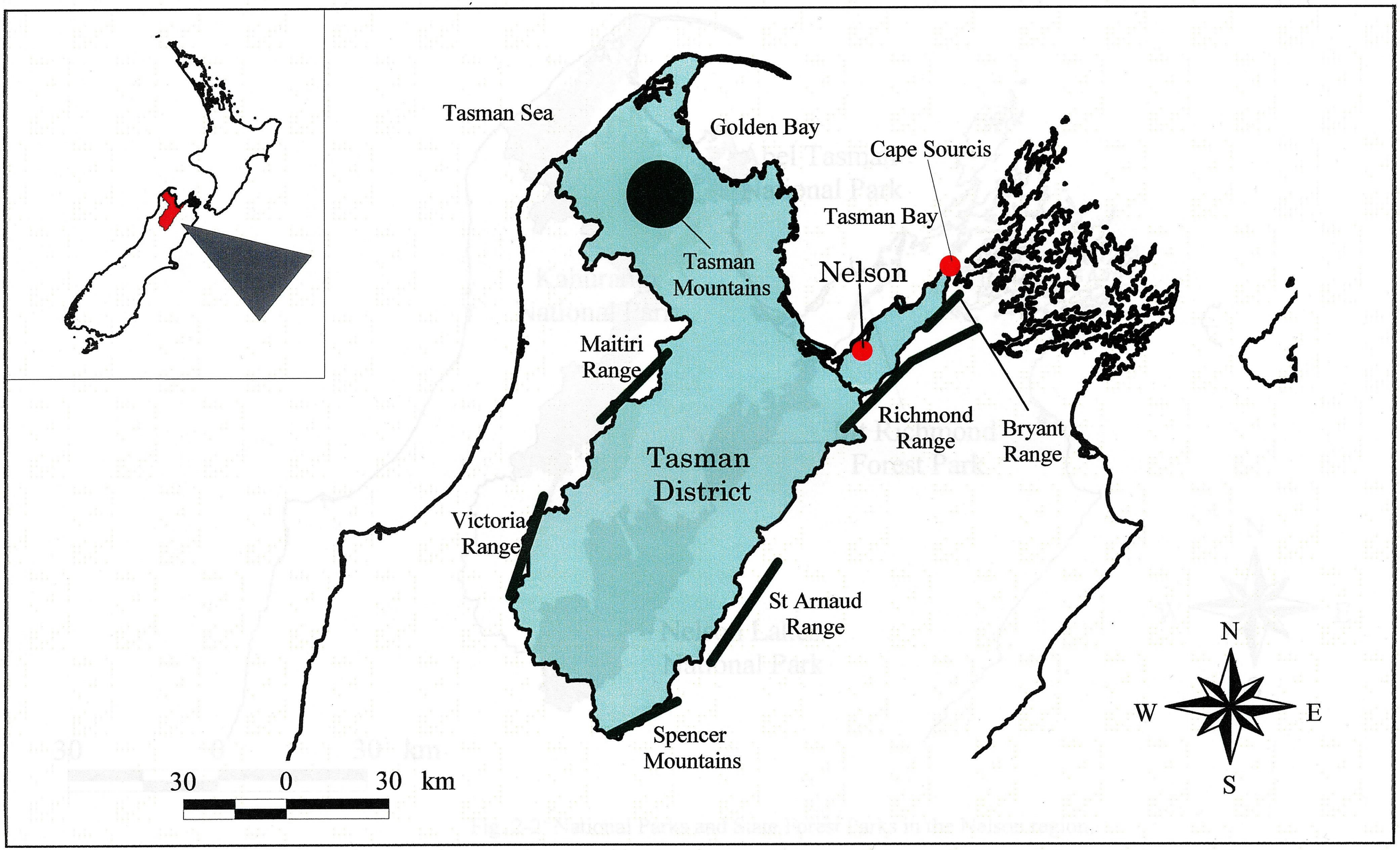


Fig. 2-1 Study Area.

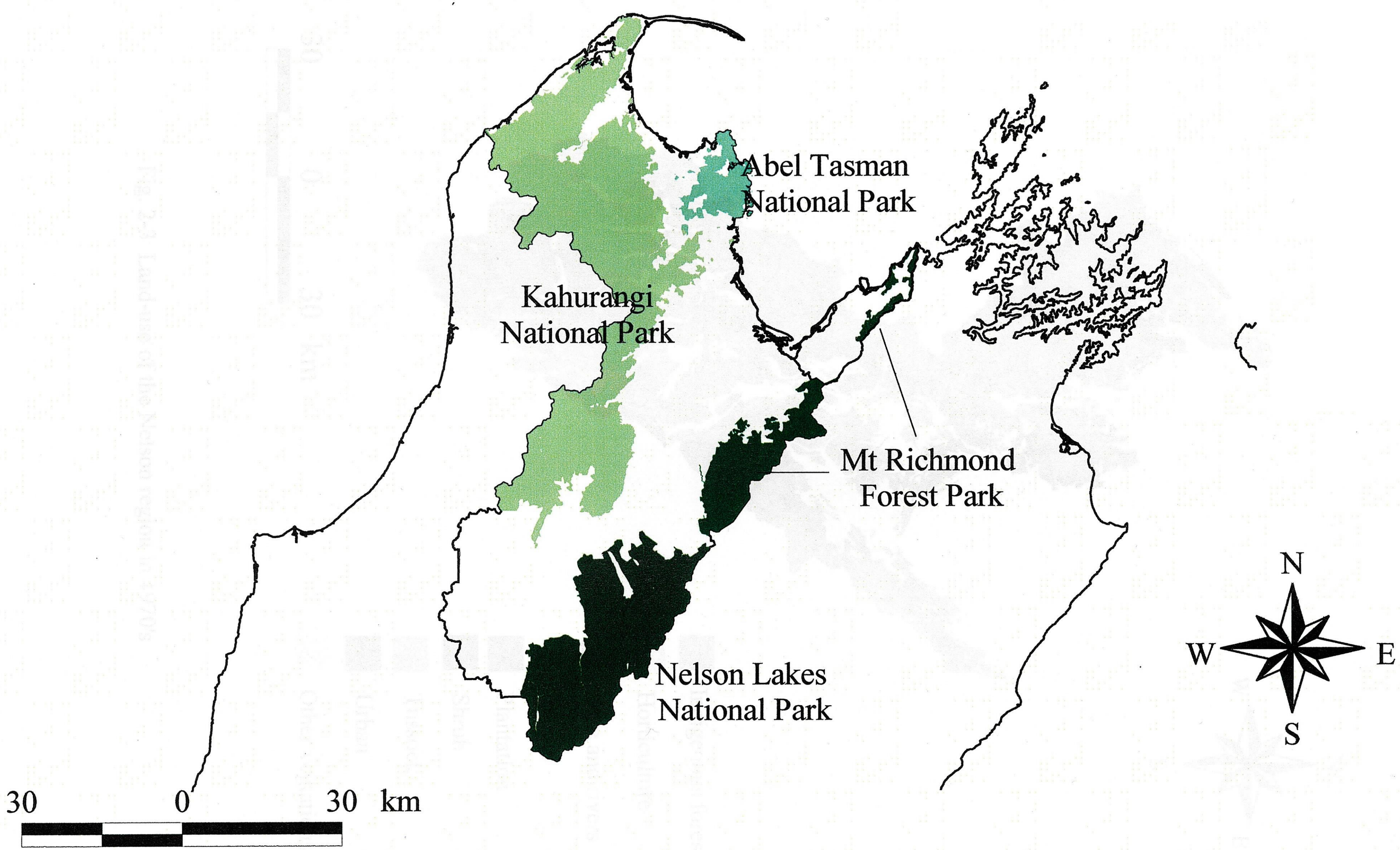


Fig. 2-2 National Parks and State Forest Parks in the Nelson region.

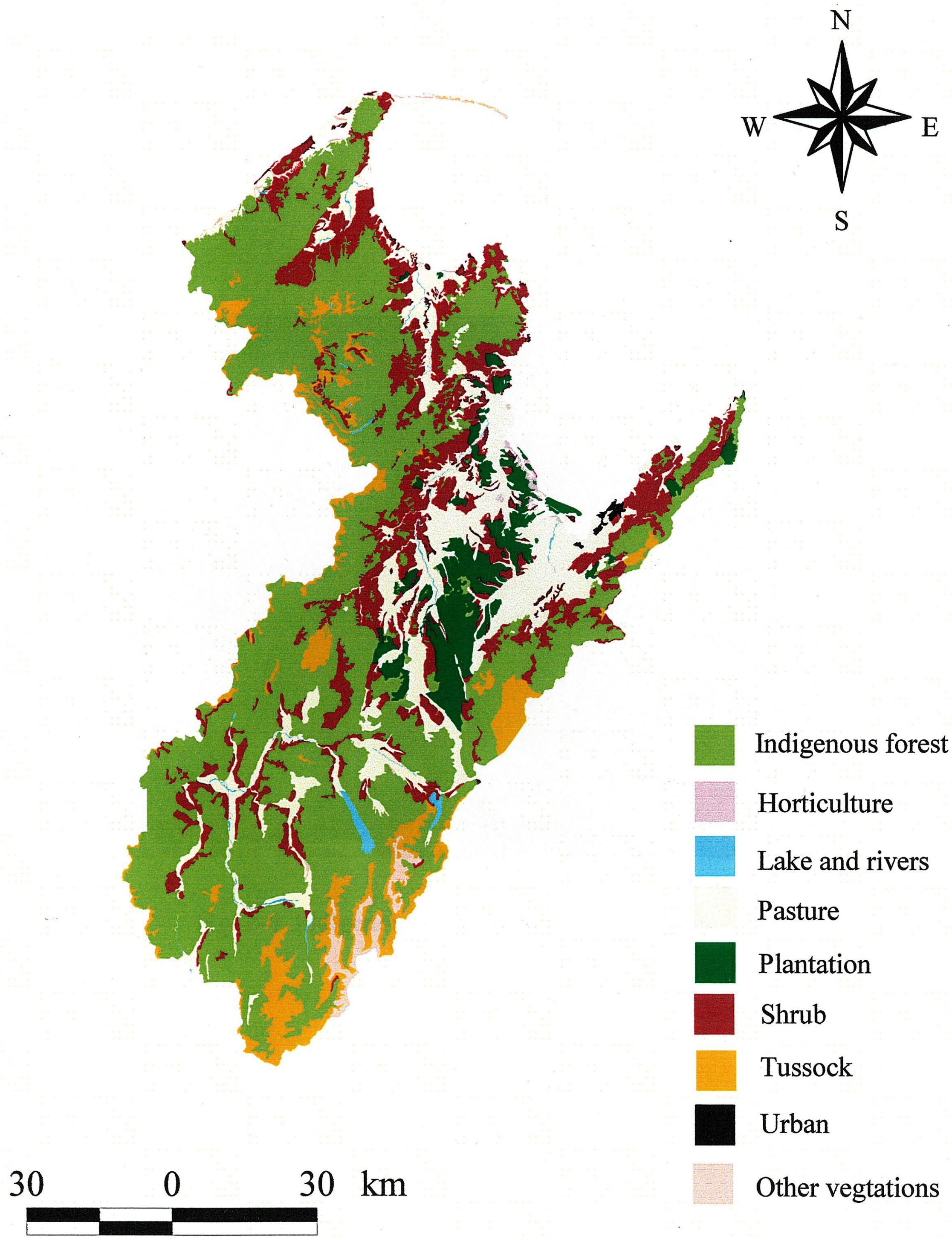
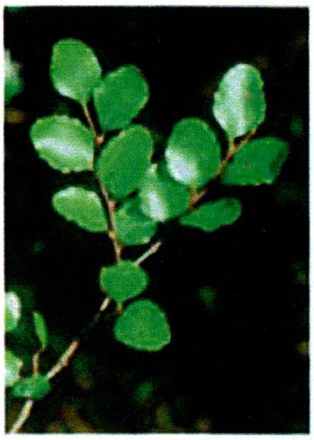
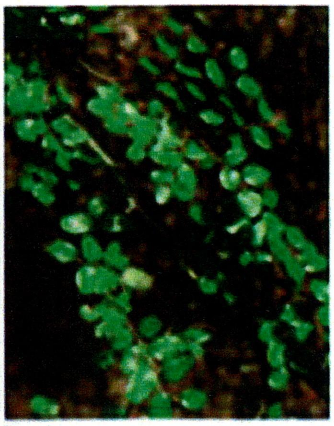


Fig. 2-3 Land-use of the Nelson region in 1970's

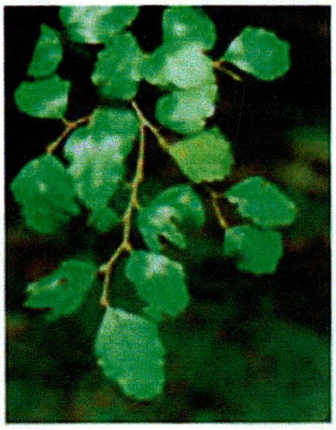
Fig. 2-4 Indigenous forest in the Nelson region.



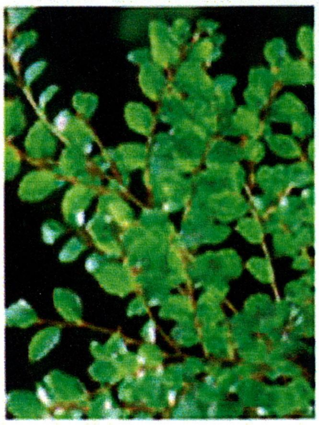
a. Hard beech



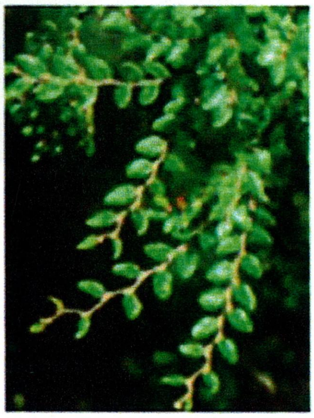
b. Black beech



c. Red beech



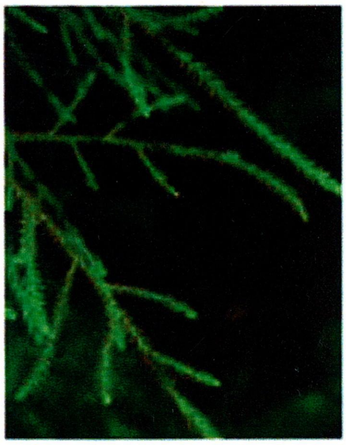
d. Silver beech



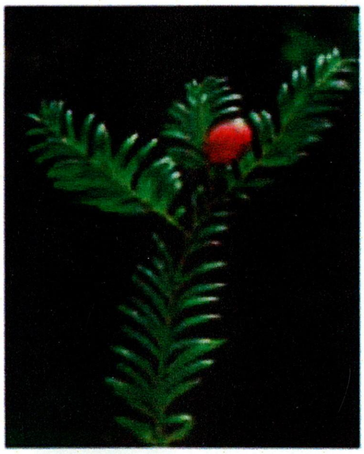
e. Mountain beech

Fig. 2-5 Beech species.
Note: Photos from Crowe, 1992.

a. Totara



b. Rimu



c. Miro

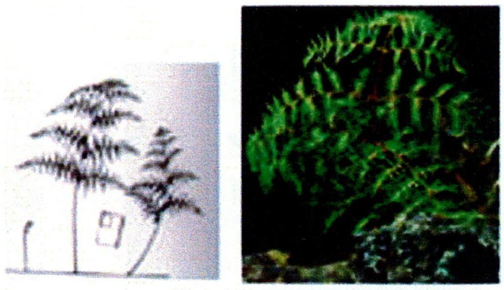
Fig. 2-6 Plant species in Podocarps/broad-leaved forest.
Note: Photos from Crowe, 1992.

a. Black tree fern
Size: trunk up to 20 m tall. fronds up to 5 m long.

b. Soft tree fern.
Size: trunk up to 8 m tall. fronds up to 2.5 m long.

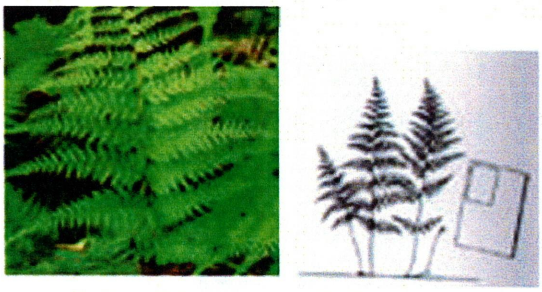
Fig. 2-7 Tree fern species.
Note: Photos from Crowe, 1994.

a. Bracken.
Size: Fronds 20-400 cm long.



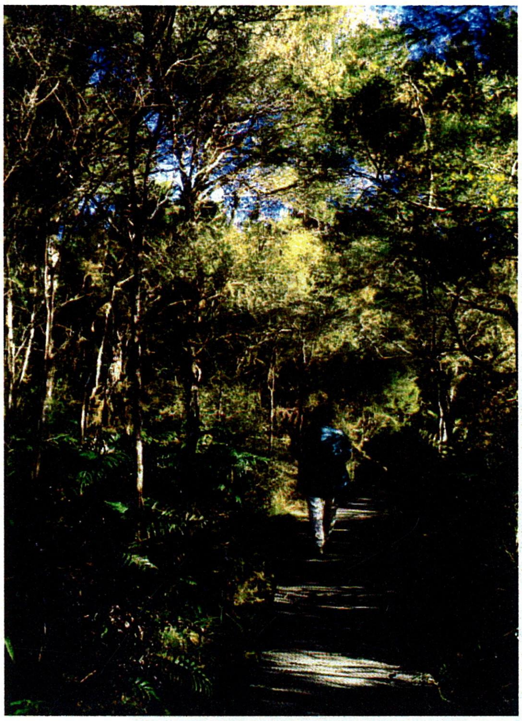
b. Crown Fern.
Size: Trunk up to waist-high; fronds 25-120 cm.

c. Prickly Shield fern
Size: Trunk up to waist-high; fronds 30-150 cm long.



d. Ring fern
Size: Fronds 20-115 cm long.

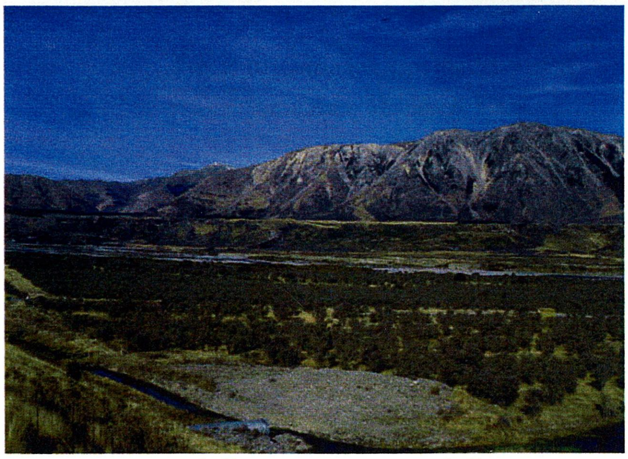
Fig. 2-8 Fern species other than tree ferns.
Note: Photos from Crowe,1994.



b. Manuka

a. Manuka-Kanuka shrub.

c. Kanuka



d. Matagouri

Fig. 2-9 Shrub species.

Fig. 2-10 Gorse invaded into plantation.
Note: Photo from Maclaren, 1996.

a. Snow tussock.

b. Red tussock

Fig. 2-11 Tussock species.
Note: Photos from Salmon, 1992.

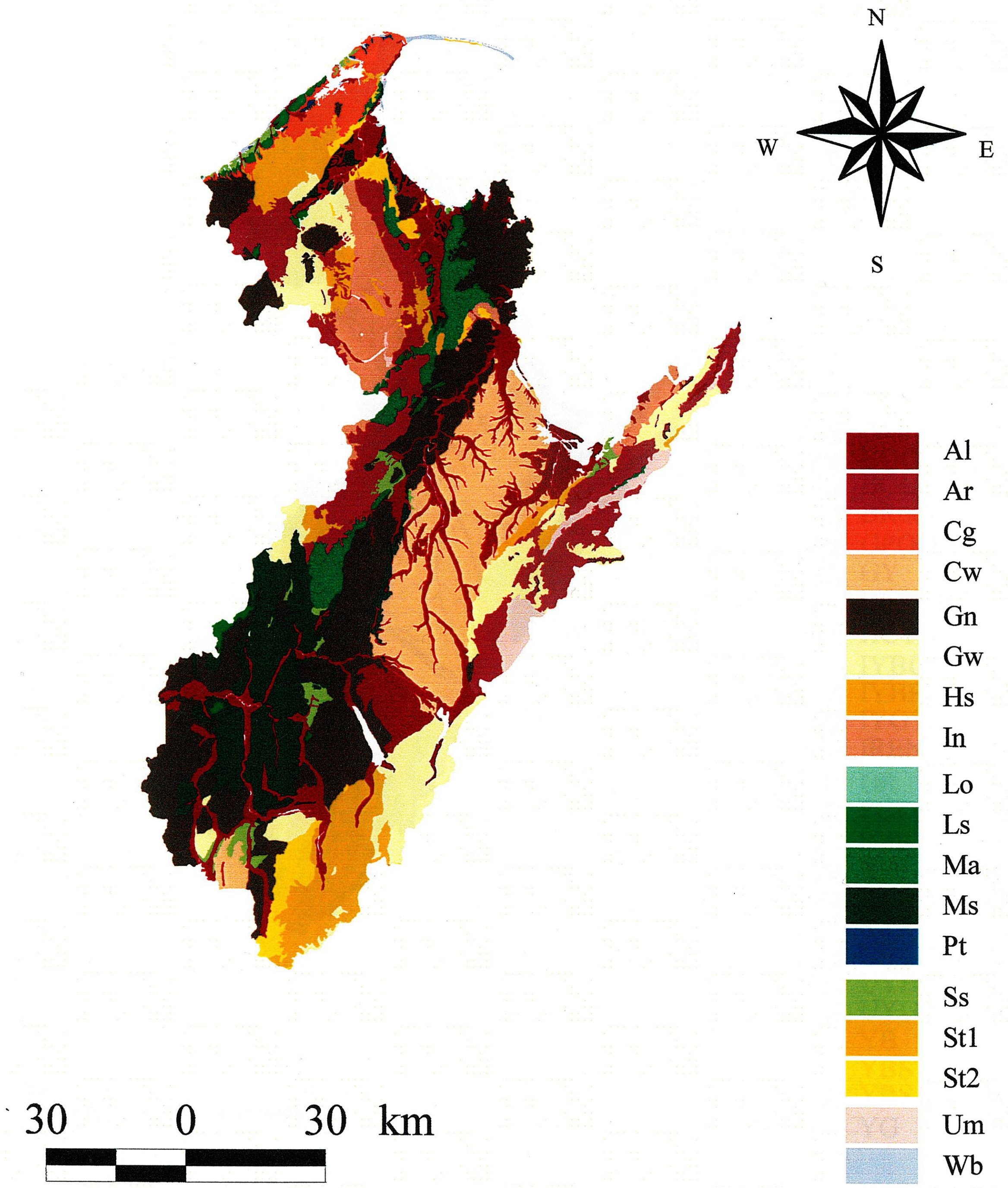


Fig. 2-12 Rock types of the Nelson Region.

Note: Al (Alluvium, colluvium, glacial drift); Ar (Argillite); Cg and Cw (Conglomerate); Gn (Plutonics); Gw (Graywacke); Hs and Ss (Sandstone); In (Ancient volcanoes, minor intrusives); Lo (Loess); Ls (Limestone); Ma (Marble); Ms (Mudstone); Pt (Peat); St1 (Semi-schist); St2 (Schist);Um (Ultramafics); Wb (Windblown sand).

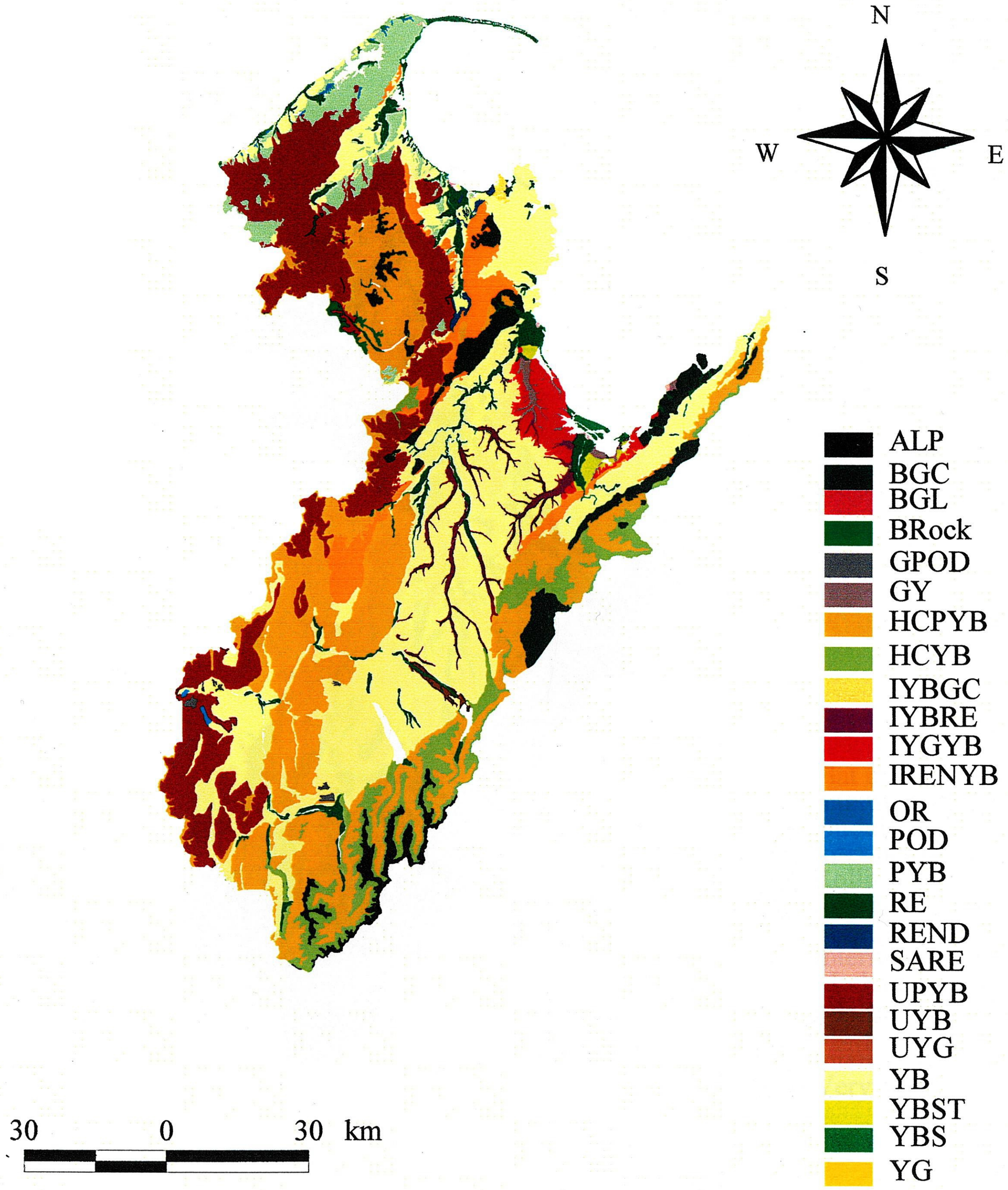


Fig. 2-13 Soil types of the Nelson region.

Note: ALP (Alpine soil); BGC (Brown granular clay); BGL (Brown granular loam); BRock (Bare rock); GPOD (Gray podzol); GY (Gray soil); HCPYB (High country podzolised yellow-brown earth); HCYB (High country yellow-brown earth); IYBGC (Intergrade between yellow-brown earth and granular clay); IYBRE (Intergrade between yellow-brown earth and recent soil; IYGYB (Intergrade between yellow-gray and yellow-brown earth; IRENYB (Intergrade between rendzina and yellow-brown earth); OR (Organic soil); POD (Podzol); PYB (Podzolised yellow-brown earth); RE (Recent soil); REND (Rendzina); SARE (Saline recent soil); UPYB (Upland podzolised yellow-brown earth); UYB (Upland yellow-brown earth); UYG (Upland yellow-gray earth) ; YB (Yellow-brown earth); YBST (Yellow-brown shallow and stony soil); YBS (Yellow-brown sand); YG (Yellow-gray earth).

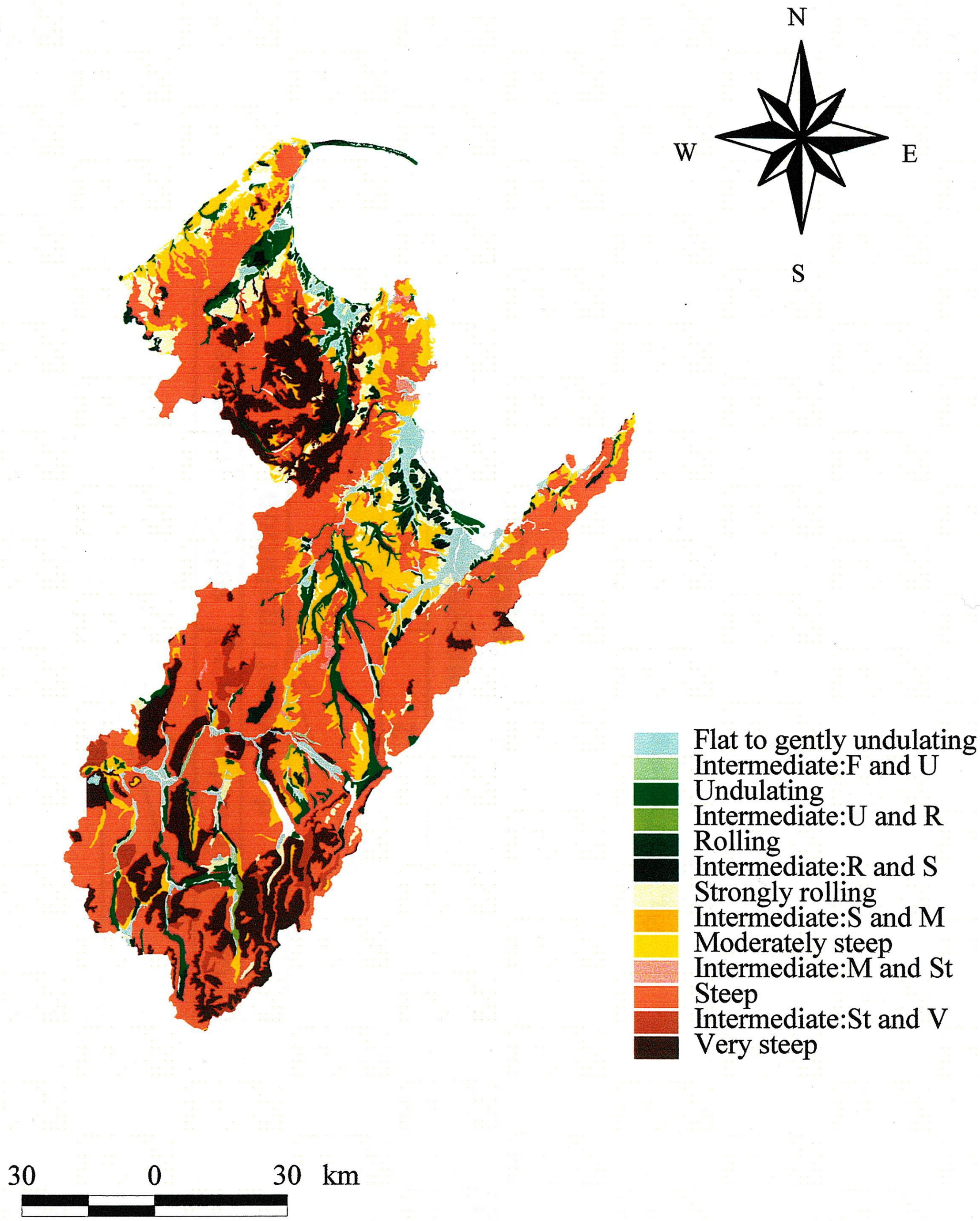


Fig. 2-14 Slope types of the Nelson region.

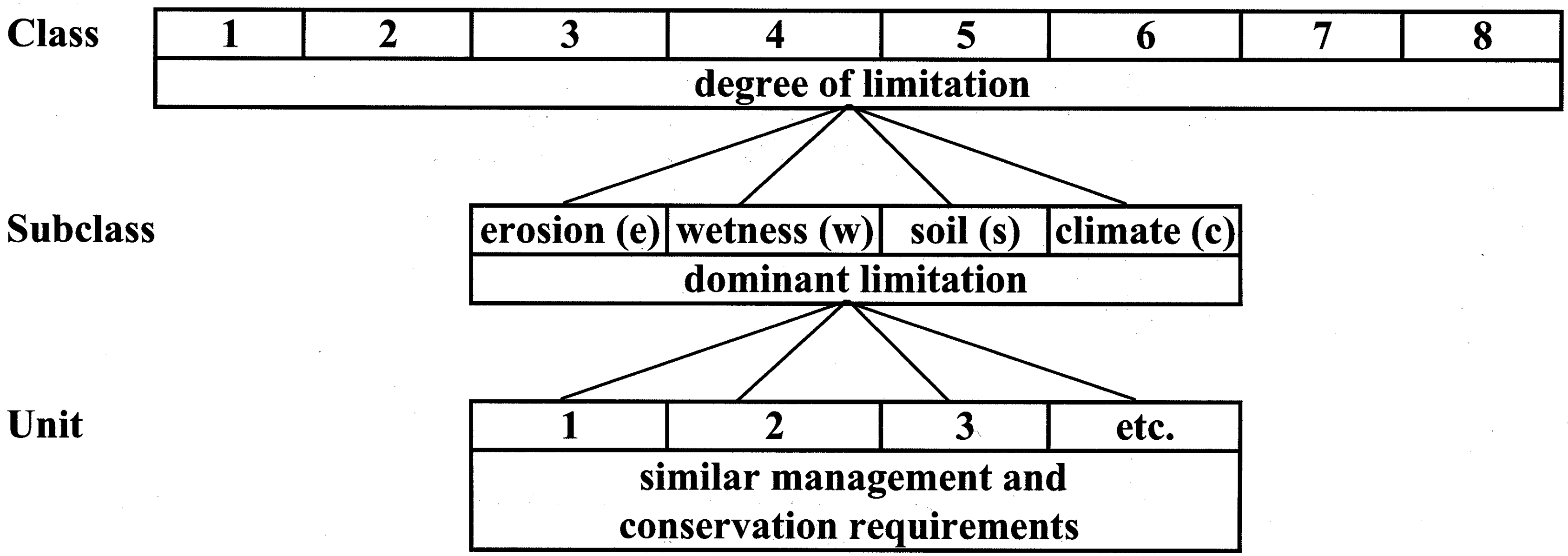


Fig. 2-15 The categories of Land Use Capability (LUC).
Source: Water and Soil Division, New Zealand Ministry of Works, 1979.

Increasing limitation to use

Decreasing versatility

<table>
<tr><th>Class</th><th>Cropping Suitability</th><th>General Pastoral & Production Forestry Suitability</th><th>General Suitability</th></tr>
<tr><td>1</td><td rowspan="2">High</td><td rowspan="5">High</td><td rowspan="4">Multiple use</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td>Medium</td></tr>
<tr><td>4</td><td>Low</td></tr>
<tr><td>5</td><td rowspan="4">Unsuitable</td><td rowspan="3">Pastoral or Forestry</td></tr>
<tr><td>6</td><td>Medium</td></tr>
<tr><td>7</td><td>Low</td></tr>
<tr><td>8</td><td>Unsuitable</td><td>Catchment Protection</td></tr>
</table>

Fig. 2-16 Relationship between the land-use and the LUC class.
Source: Water and Soil Division, New Zealand Ministry of Works, 1979.

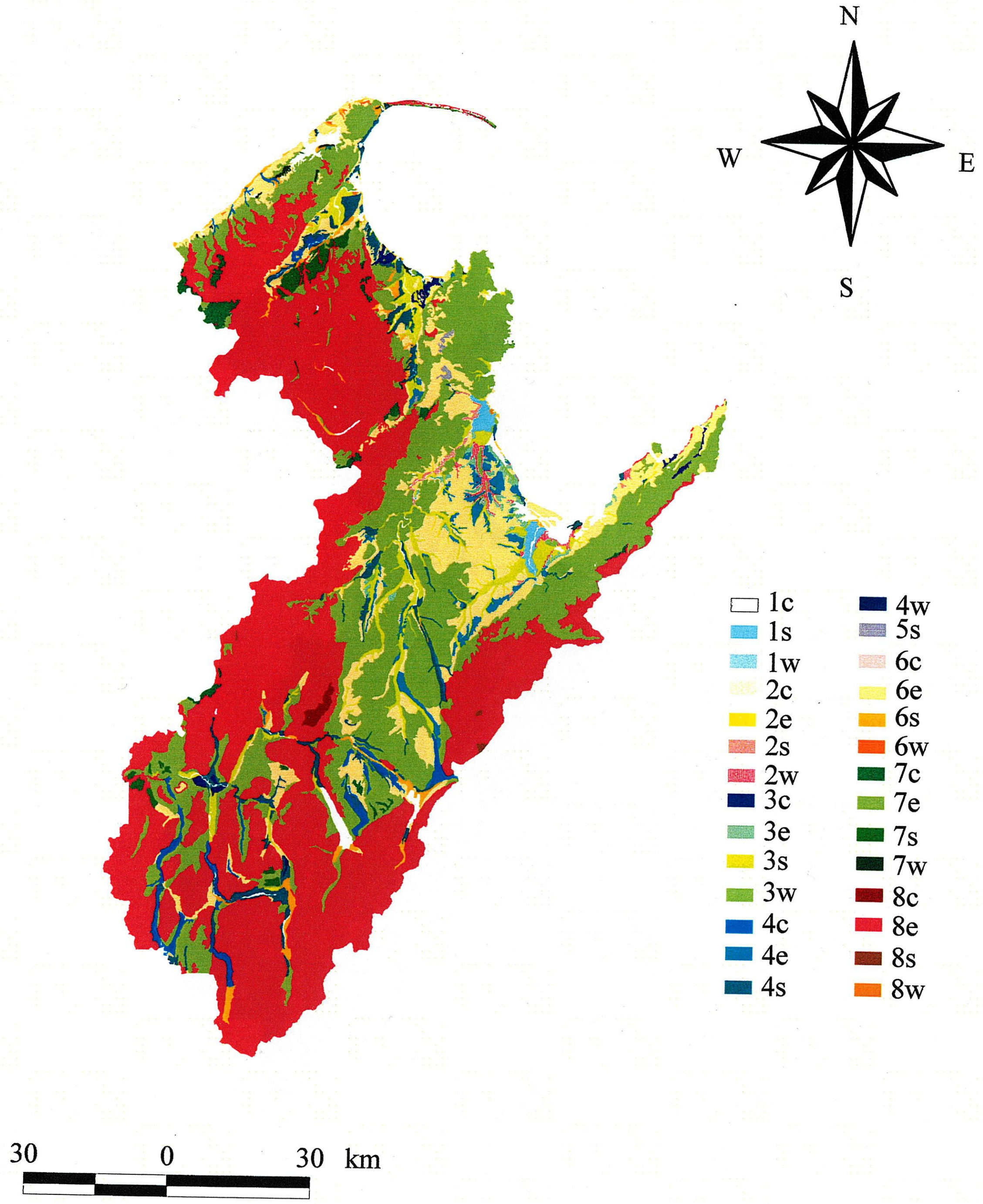


Fig. 2-17 LUC of the Nelson region.

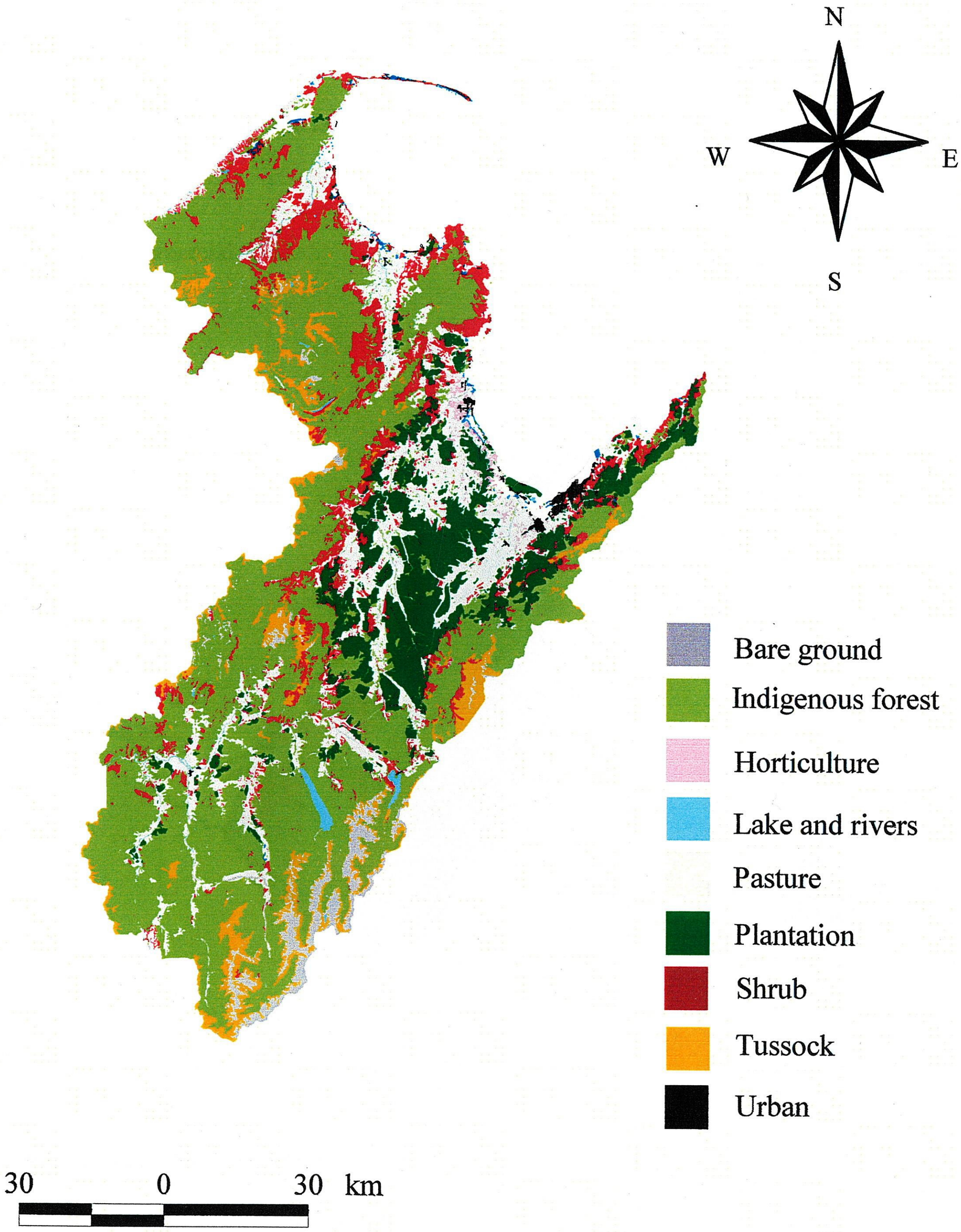


Fig. 2-18 The Land Cover Data Base (LCDB) map.

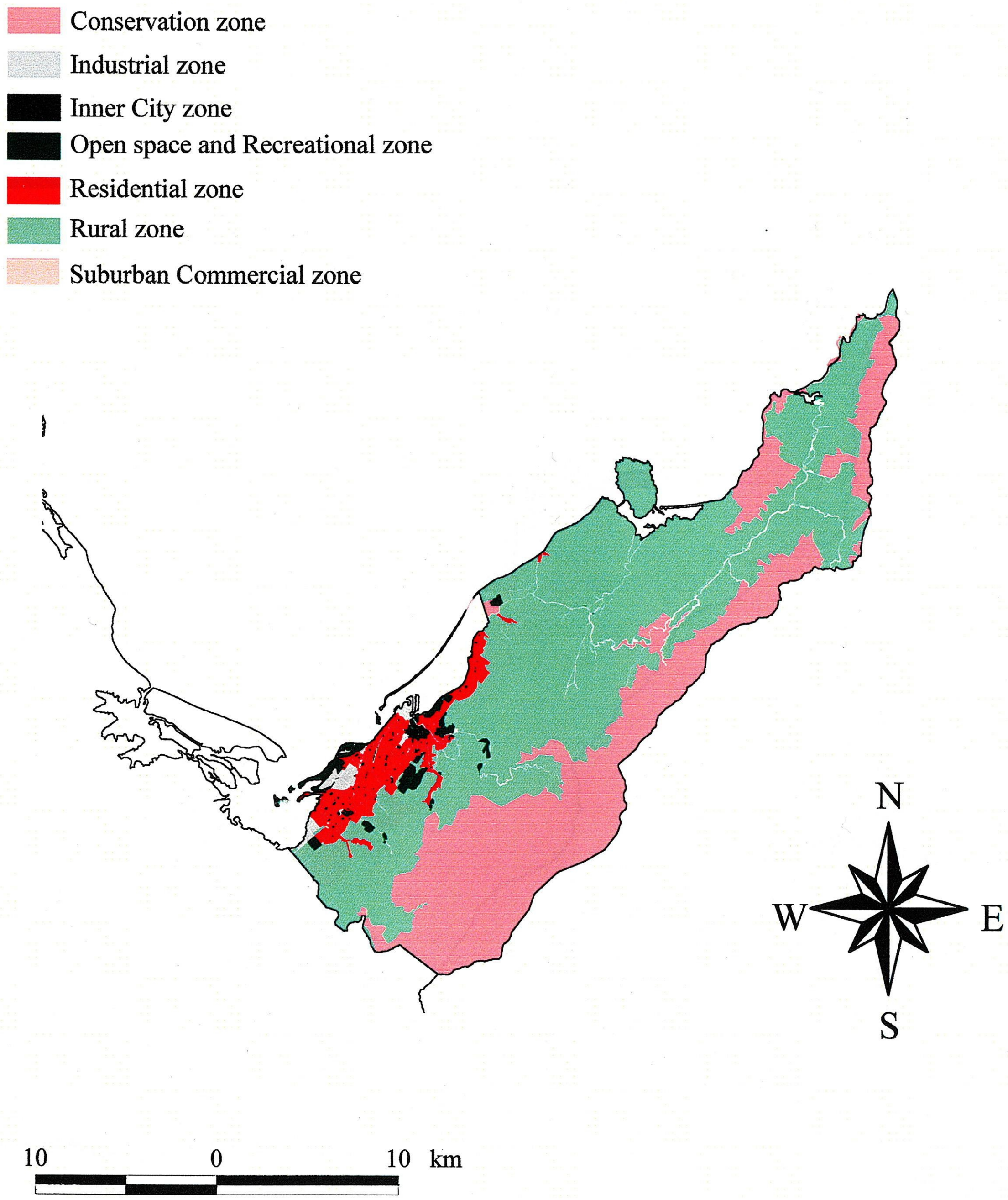


Fig. 2-19 Zone in the Nelson City.

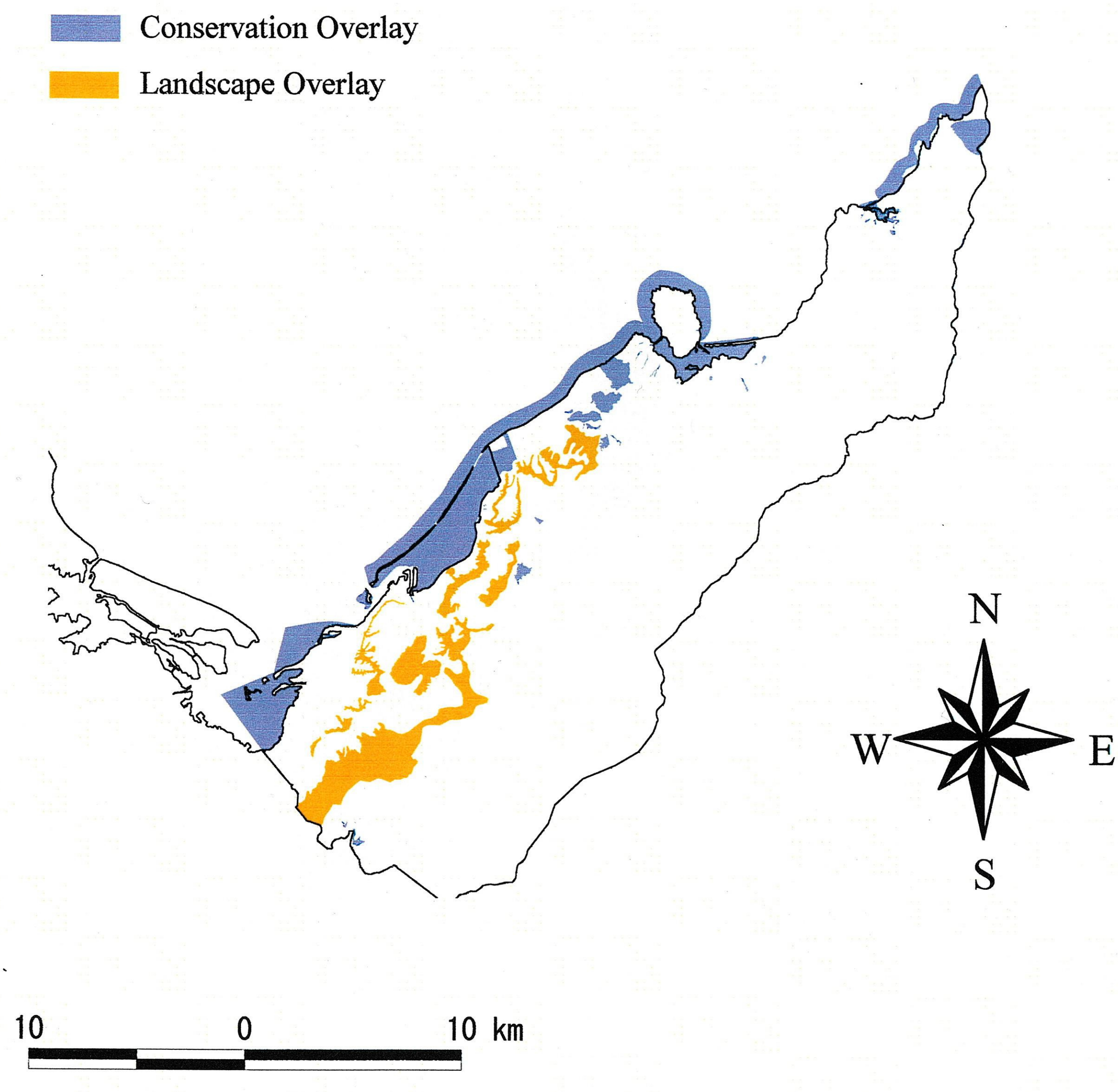


Fig. 2-20 Conservation and Landscape Overlays in the Nelson City.

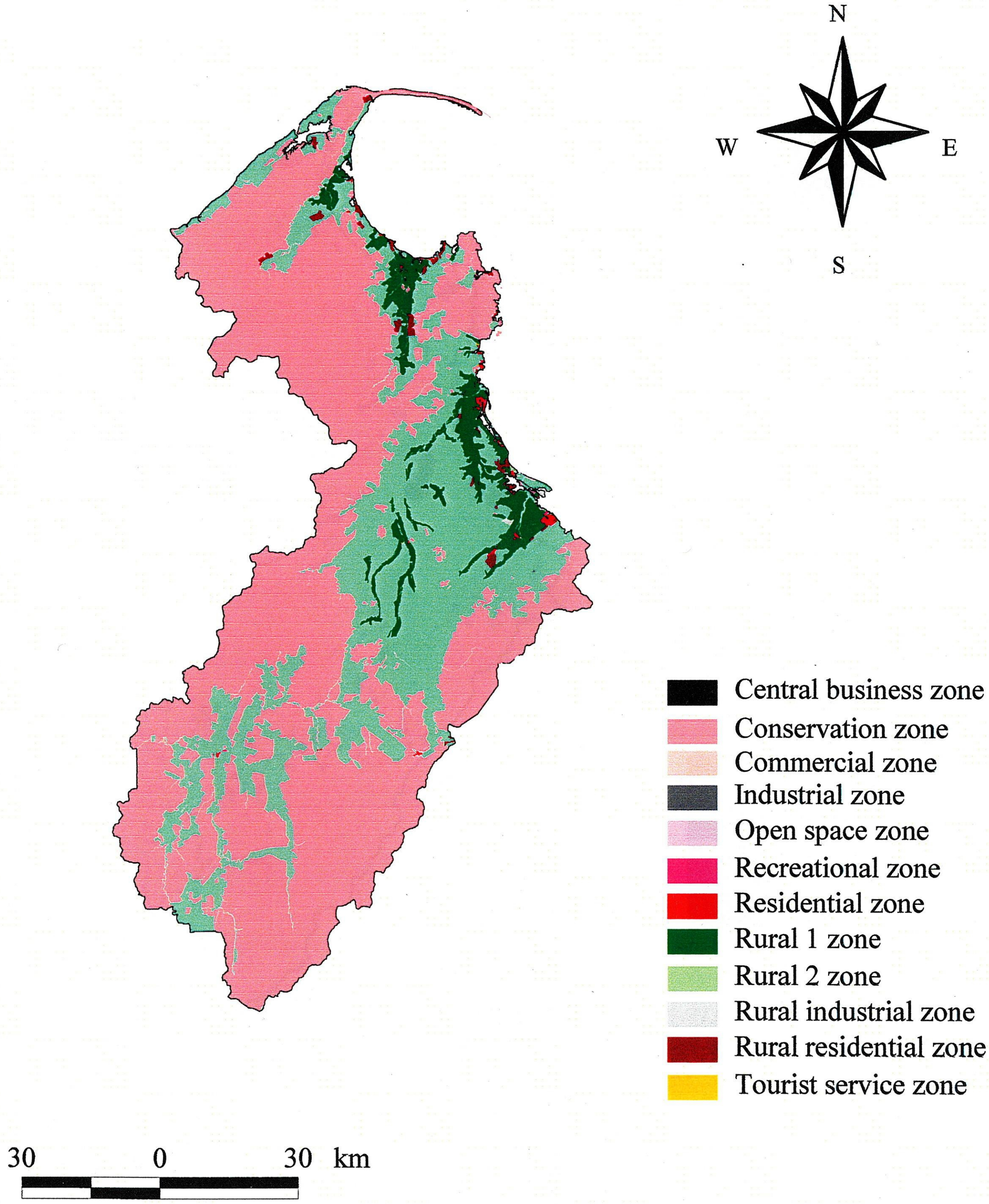


Fig. 2-21 Zones in the Tasman District under the TRMP.

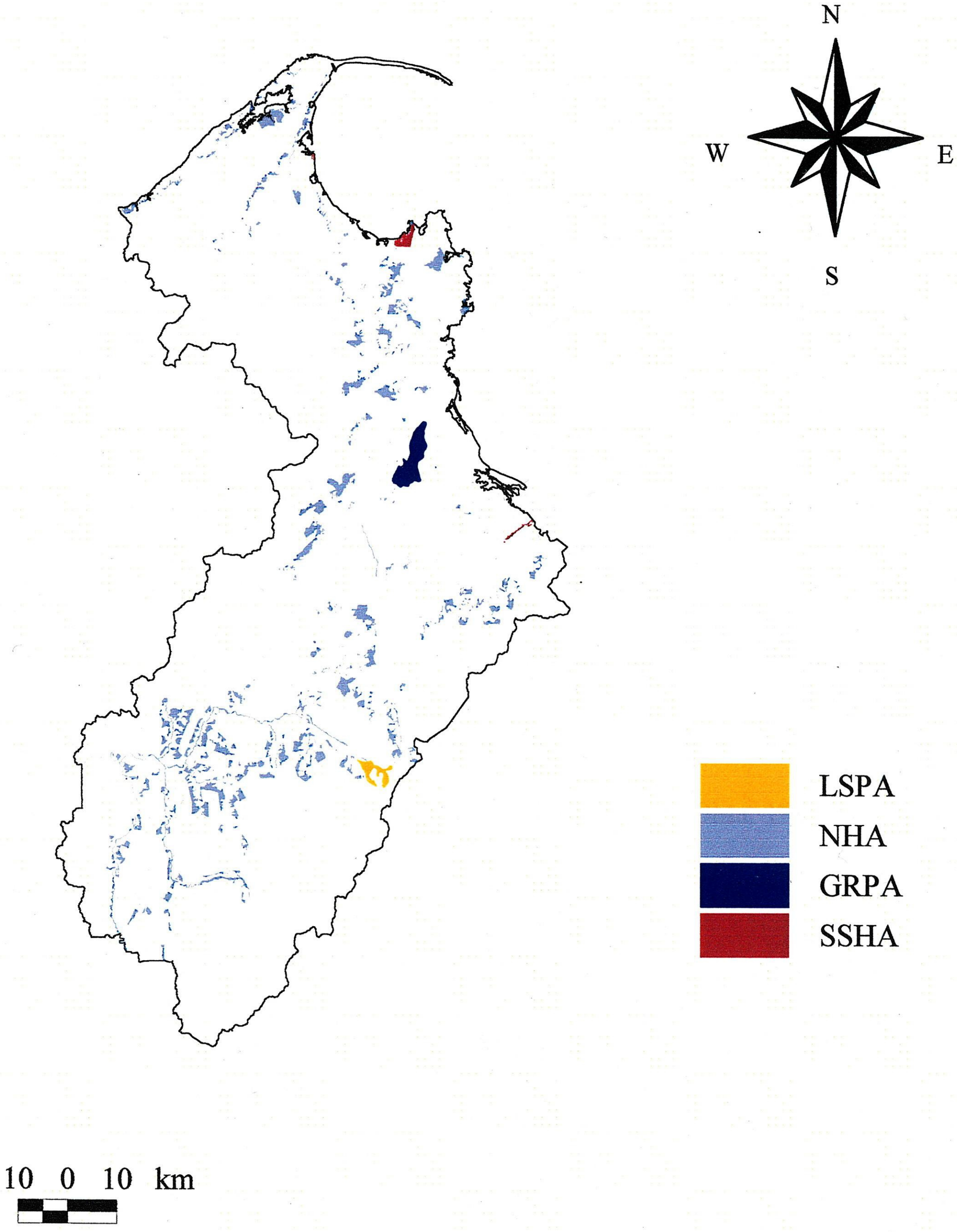


Fig. 2-22 Special Areas under the TRMP.

Chapter 3

The Present Land-use Pattern

3.1 Introduction

Complex interaction of physical, biological, and social forces determines the pattern of land-use developed over time (Urban et al., 1987; Odum and Turner, 1990; Forman, 1995). Physical attributes such as soil, topography, and climate play the main role in determining development of natural vegetation (Ales et al., 1992). These attributes are also important in determining the land use selected by humans because people consider the natural advantages of the land for specific uses such as agriculture. However, humans also can develop specific land uses having no relationship with natural attributes (Iverson, 1988). The human activities which modify landscape patterns are strongly related to socio-economic environments (Kamada et al., 1991; Nakagoshi and Ohta, 1992).

As explained in chapter 1, the socio-economic situation in New Zealand has changed greatly over the last 20 years. Farming subsidies have been largely eliminated and forestry now competes nearly equally with agriculture. Rapid expansion of plantation forest greatly modified the traditional farming landscapes in New Zealand. Although there are various studies examining the influence of forestry expansion (e.g. Bull, 1981; Goh and Phillips, 1991; Maclaren, 1996), assessing its effect at the landscape level is rare.

Interpretation of current land-use pattern is a first step to examine the influence of forestry expansion at landscape level because analyzing the present land-use pattern offers a present day baseline for evaluating the previous land-use consequence. It also provides a baseline for assessing future landscape patterns (Zheng et al., 1997), which suggests its effectiveness on evaluating the new land-use management policy, the RMA.

Picking up Nelson region as an area for case study, this chapter aims 1) to understand the general distribution patterns of land use from the center of the city based on economic theory; 2) to interpret the land characteristics of each land use by analyzing the relationship with physical attributes, LUC, and distance from the city center; 3) to understand the factors affecting the distribution pattern of each land use type. In addition, land characteristics of plantation were analyzed based on age classes in order to interpret whether or not there were any changes on its distribution pattern over time.

3.2 Methods

The general land use distribution pattern was analyzed by overlaying the LCDB map (the land-use map of 1990s) on the NZLRI map (including information of physical attributes and LUC) and by drawing buffers on the overlaid map at intervals of 5 km out from the polygon representing the center of Nelson City. The distribution pattern was interpreted by principal component analysis (PCA) and *post hoc* values. Patches smaller than 10 ha arising from the overlaying were considered to have a high chance of error due to superimposition and were excluded from all of the analysis.

The *post hoc* value is a statistic related to the Chi square test based on a contingency table. It indicates the difference of the observed frequency of each land-use between the actual distribution and the expected value (SAS Institute Inc., 1998). Thus, *post hoc* values are appropriate to examine what kind of land-use is concentrated at what distance. The formula for the *post hoc* value (p) is,

$$p = \frac{Oij - Eij}{\sqrt{Eij\left(1 - \frac{Rj}{N}\right)\left(1 - \frac{Ci}{N}\right)}}$$

Where Oij is the area of land-use type i within the buffer zone j. Eij is the expected value of land-use type i within buffer zone j. Rj is the total area of buffer zone j and Ci indicates the total area of land-use type i. N is the total area of the whole land-use type (= total area of whole buffer zone). Each expected value (Eij) is calculated considering the difference of the total area of each buffer zone and of each land-use type as shown in the following,

$$Eij = \frac{Ci \times Rj}{N}$$

The land characteristics of each land use were interpreted based on the information of rock, soil, slope, and LUC, and the distance from the city center on the overlaid map. The combination of these five land characteristics need to be considered to understand which factors had greater influence on determining the distribution patterns of each land use type because trade-off was considered to exist among factors. Conjoint analysis was utilized to satisfy this condition. Conjoint analysis has been used extensively in marketing and transportation studies to examine individual preferences for private and public goods which have multiple attributes. Recently, conjoint analysis has also been used to value the watershed ecosystem (Griner and Farber, 1996), and to value environmental damages from electric utility plants (Johnson et al., 1995). The advantage of conjoint analysis is that it is able to detect the important attribute while regarding the trade-off between all attributes (SPSS Inc., 1997). As land-use distribution pattern is the result of interaction of many physical and socio-economic factors, conjoint analysis is appropriate for evaluating which factor has more influence on determining the land-use distribution pattern.

Information on the ranking of preferred land characteristics combinations was required to conduct the analysis (SPSS Inc., 1997). We assumed that the preferred land characteristic combination had the larger area. Because the numbers of combinations of land characteristics for each land-use type were too large to implement the conjoint analysis, the numbers of combinations were reduced to the number that could explain 80% of the total area of each land-use. Factors highly correlated to other factors for each type of land-use were excluded from the conjoint analysis.

The PCA and Chi square test were utilized to examine whether or not the land characteristics of plantation were different by age class.

3.3 Results

1) General land-use distribution pattern

The distribution pattern of each land use type based on the proportion of its area to the total area of each buffer zone is shown in Fig. 3-1. Using the distance from the city center as the explanatory variate, the PCA was conducted to comprehend the features of the land use distribution pattern. However, because only a rough tendency could be deduced from this analysis, *post hoc* values were calculated based on the area of each land use type at each distance to interpret the tendency in more detail.

The distribution pattern was divided roughly into three groups by PCA: the dominant land-use within 40 km from the center, the dominant land-use from 40 to 130 km from the center, and a group of other minor land-uses. Pasture and plantation were the dominant land uses within 40 km. Indigenous forest was the dominant beyond 40 km (Fig.3-2).

The large *post hoc* values within 5 km of the city polygon showed that urban areas were concentrated within 5 km of the city. However, some areas were observed at 5-10 km and 25-30 km (Table 3-1). Horticulture was concentrated from 5 to 30 km whereas the pasture and plantation were concentrated from 5 to 40 km. Although the range from 40 to 65 km was included in the range dominated by indigenous forest, plantation, shrub and tussock had a positive value. Particularly, the value for plantation was positive up to 55 km away. On the other hand, the value for indigenous forest in this range changed to positive from 55 km and its value increased greatly after 65 km. Thus, it could be said that the range from 40 to 65 km was a transitional area from a plantation-dominant area to an indigenous forest-dominant area. Bare ground was concentrated at 65 to 120 km together with indigenous forest. Tussock was concentrated mainly from 110 to 130 km.

These results are summarized in Fig. 3-3. Agriculture, pasture, and forestry were adjacent to urban. There was a transitional zone from plantation-dominant area to indigenous forest area around the agricultural area. The remaining land was dominated by indigenous forest.

2) Land characteristics of each land-use type

(a) Urban

Urban areas were distributed on gentle slopes relatively close to the city center: 92% within 40 km from the city center. Among the urban areas distributed within 40 km, more than half were within 10 km (43% were within 5 km and 21% from 5-10 km), which implies its strong relationship with the central city (Fig. 3-4a). Soil types were diverse: ranged from low to high fertility. Nonetheless, most of the LUC class was less than class 4 which is suitable for cropping.

When examining the relationship of land characteristics of urban areas, rock was strongly correlated with soil and slope (correlation coefficient [Cramer's V statistics (V)] = 0.79 and 0.71, respectively [SPSS Inc., 1999]), and soil also showed a high correlation with LUC (V= 0.68). Therefore, conjoint analysis was implemented excluding rock and soil types. Consequently, LUC and slope showed relatively high importance as a factor determining its distribution pattern (importance score [IS] for LUC: 39.52, for slope: 37.43). Distance from the city center was less important (IS= 23.05) but had some influence on its distribution pattern.

(b) Horticulture

Horticulture was concentrated within 40 km from the city center (Fig. 3-4b). The land characteristics were gentle slopes, soil with middle (e.g. IYGYB) to high fertility, and LUC class suitable for cropping. Conjoint analysis excluding rock type that showed a high correlation with soil (V=0.9), suggested that the distance from the city center and the LUC were the most important factors (IS for both: 40.36). Soil was of lesser importance (IS: 19.27).

(c) Pasture

The land characteristics of pasture were diverse. Some were distributed on low lands with high fertility soil (e.g. RE) and LUC class suitable for cropping (Fig. 3-4c). Others were on steep lands with low fertility soil (e.g. YB) and LUC class suitable for grazing. Pasture was scattered all over the region but was mainly distributed within 65 km from the city center. Rock and slope type was highly correlated with soil (V=0.58) and LUC

(V=0.63), respectively, and therefore excluded from the conjoint analysis. The result indicated that soil and LUC (IS: 50.0) were both important for determining the distribution pattern of pasture.

(d) Plantation

Plantation was on conglomerate with low fertility soil, steep slopes, and LUC class suitable for forestry (Fig. 3-4d). As with pasture, plantation was mainly distributed within 65 km from the city center but was also established beyond 65km. Conjoint analysis was conducted excluding slope from the analysis because it was correlated both to soil (V=0.75) and LUC (V=0.84). Soil and LUC were equally important (IS: 50.0) for determining the distribution pattern of plantation.

(e) Shrub

Shrub was on relatively steep slopes with low fertility soil (e.g. HCPYB and YB) and on land suitable for catchment protection and pasture or forestry (Fig.3-4e). Shrub was scattered all over the region but was mainly observed at 40 to 65km from the city center. Excluding rock that had a high correlation with soil (V=0.615) from the conjoint analysis, LUC (IS: 34.15) had the greatest influence on determining the shrub distribution pattern followed by slope (IS: 31.15) and soil (IS: 29.36).

(f) Indigenous forest

Indigenous forest was mainly distributed beyond 65 km from the city center (Fig. 3-4f). Most indigenous forest was on steep land with plutonic or argillitic rocks, low fertility soils, and LUC classes suitable for protection and for pasture or forestry. Rock type and slope type were correlated with soil (V=0.67) and LUC (V=0.84), respectively, and therefore excluded from conjoint analysis. LUC (IS: 52.17) was the most important factor determining the distribution pattern followed by soil (IS: 41.06).

(g) Tussock

Tussock was concentrated in mountainous areas with low fertility soil and on land evaluated for protection (Fig. 3-4g). Mostly, tussock was distributed far away from the city center. Soil, LUC (IS for both: 34.60), and slope (IS: 30.79) were the main factors influencing the distribution pattern.

(h) Bare ground

The land characteristics of bare ground were similar to tussock. It was concentrated beyond 65 km from the city center, on steep land with soil of low fertility, and on land evaluated for protection (Fig. 3-4h). However, the factors influencing the distribution pattern were different to tussock. Soil (IS: 50.45) and slope (IS: 40.13) were the main factors influencing the distribution of bare ground and the influence of LUC (IS: 2.49) was small.

3) Land characteristics of plantation by age class

The general difference or similarity of land characteristics between age classes could be observed in figure 3-5. Although the minor categories are combined to one category named “others” in figure 3-5, the PCA and Chi square test were conducted using all categories (including all minor categories that classified to "others") in order to reflect the difference of the minor categories on the result of the analysis. Consequently, the result of PCA suggested that all land characteristics for each age class are basically the same. In other words, all age classes were classified into one group by the PCA. The obtained group for rock type was characterized by "Ar," "Cw," "Gn," and "Gw" according to the principal component score (Table 3-2a), "HCPYB" and "YB" for soil (Table 3-2b), "Moderately steep" and "steep" for slope (Table 3-2c), "6e" and "7e" for the LUC (Table 3-2d), and "0-40 km" for the distance (Table 3-2f). On the contrary, the Chi square test showed some difference in all land characteristics (p value for all land characteristic was less than 0.0001).

3.4. Discussion

Considering the general distribution pattern (Fig. 3-3) together with physical attributes, urban areas were located on flatlands close to the city center. Gentle slopes with high fertile soil surrounding the urban area were utilized for horticulture. Remaining low lands and some hill countries with less fertile soil were utilized for grazing. Plantation was also established on hill country with low fertility soil. Pasture and plantation were both mainly distributed within 40 km from the city center defined as "agriculture, pastoral, and forestry area". However, they also expanded to the uplands from 40-65 km from the city center on land that was suitable for grazing or forestry. Lands evaluated as areas worth protecting within this range were covered by shrub or tussock. The surrounding mountainous areas of low soil fertility and unsuitable for utilization, were occupied by indigenous forest. The tendency for forested areas (including plantation and indigenous forest) to be distributed on steeper land and soils poorly suited for agriculture, was also observed in other studies such as LaGro Jr. and DeGloria (1992).

It is interesting that the result of PCA indicated the land characteristics of plantation between age classes are basically the same but the Chi square test suggested some differences. Presumably, the differences detected by Chi square test were based on the detail proportion of each category. As this study aims to interpret whether or not the main characteristics were changed, the rough tendency as detected by the PCA is more important than the differences in detailed proportion. Hence, it could be said that the main land characteristics of the plantation had not changed while the socio-economic situation had changed in the late 1980's such as dissolution of the Forest Services, the sale of large proportion of State forest, and economic stagnation of pastoral farming.

An early analysis of the relationship between differences in spatial location and land-use patterns was developed by Johann Heinrich von Thunen (Forman and Godron, 1986), a German landowner and economist, in his book *Der isolierte Staat*, written in 1826 (Hall, 1966). He considered that the differences in land-use could be attributed directly to variations in transportation costs when assuming the case of a single European-type village which was isolated, the physical attributes of which were uniform, and where most families lived in the central city rather than in the open country. He concluded that land-use would occur in the following order from the city: (i) city; (ii) gardens; (iii) plantations; (iv) land for intensively cultivated field crops such as potatoes, root crops, and hay which are heavy and bulky; (v) land planted with cereal or used for fallow or pasture; (vi) land for grazing purposes, and finally, (vii) wilderness areas (Fig. 3-6). It might seem unusual to place plantations in position (iii). However, this was because he assumed that the products would be carried to the market in horse- or ox-drawn wagons or by humans, because railroads and superhighways were not yet known. Thus, the area producing more bulky and heavier production would be established closer to the city when considering the transportation costs.

Plenty of studies have discussed von Thunen's concept such as Ely and Wehrwein (1940), Dunn Jr. (1954), and Stevens (1968). Particularly, Chisholm (1966) discussed the current application of von Thunen's concept in different part of the world. Alfred Weber is another important contributor who presented the location theory of industries (Friedrich, 1929).

Based on all of these studies, Barlowe (1986) presented a simple model, which considered the improvement of transportation systems such as railroads and highways. He considered the land-use pattern assuming the example of an isolated state with a major city located in the valley at the foot of the mountains, which is similar to the situation in the Nelson region. According to his model, the city would be located on flatlands and highly accessible sites that offer transportation facilities. The next zone surrounding the city would be the residential zone mostly on sites of gentle terrain. Bottomlands near the residential zone would be used for intensive agriculture. The remaining bottomlands together with some of the more accessible uplands would be used for less intensive crops. Some upland areas would be used for producing grain and hay crops, but higher and rougher lands would be used for grazing and forestry. The surrounding mountainous areas would be reserved mostly for forest recreation and wildlife uses (Fig. 3-7).

The land-use distribution pattern observed in the Nelson region is quite similar to the model developed by Barlowe. However, one difference was the indistinct boundary between the agricultural zone and the pasture and forestry zone, even though the former is distributed on more fertile soils and gentler slopes than the latter as Barlowe's model represents. This might be because only 6% of the total land was evaluated as suitable for agriculture by LUC classification (class from 1 to 3), and its use is therefore restricted.

LUC was the factor determining most of the land-use. Not only the land-use developed by humans but also the land-use derived from natural processes such as indigenous forest and shrub, were well suited to the LUC classification. This implies the appropriate utilization of LUC as a standard for land-use planning or determination.

In addition to the LUC, the distance from the city center affected the distribution pattern of horticulture. Because more intensive land-use tends to be distributed on land closer to the city center (Chisholm, 1966; Barlowe, 1986), it is understandable that distance showed a high importance score. However, the distance from the city center was not so important for extensive land-use. Instead, soil was more important. This might be because low fertility soil occupied a large area of the region even on land relatively close to the city, and pasture or plantation was established to use this land effectively. Consequently, pasture and plantation are scattered all over the region and therefore no relation with distance was found. This process of pasture or plantation establishment might also be the cause for the obscure boundary between the agricultural zone and the pasture and forestry zone. Even though extensive land-use was distributed within a large range from the city center, there might be no problem from an economic sense according to the maximum economic distance that is between 80 and 120 km (New Zealand Ministry of Forestry, 1994).

As most of the urban area were distributed close to the city, mainly within 5 km or 5-10 km, the distance were expected as a significant factor determining its distribution pattern. However, the result of conjoint analysis indicated that LUC and slope are more important than the distance. This result might strongly relate to the development history of suburban site in the Nelson region. When the European colonization had started in the 1840s, Nelson City was the base for the settlement. For settlement to progress beyond subsistence, farmland had to be allocated and developed. People started to explore lands available for agriculture but the region had not enough good land for farming. The best land was the terrace along the lower reaches of the Waimea and Motueka rivers (McAloon, 1997). Consequently, those two areas became the target for development as a suburban sections and Richmond on Waimea plain and Motueka were formed. At the present, Richmond and Motueka are taking their roles as centers of commercial activities in the region (New Zealand Ministry of Forestry, 1994). Although Richmond is near to the city center (within 10 km), Motueka is approximately 30 km away. This location of Motueka could weaken the importance of the distance as a factor determining the distribution pattern of urban area. In other words, it could be said that the LUC or the slopes were detected as important factors because the suburban sites were first developed based on its suitability for agriculture.

Perhaps the reason why shrub, indigenous forest, tussock, and bare ground are 'undeveloped' is because of difficulty of access, unsuitability for any land-use, or reservation for protection. Some areas of indigenous forest or shrub would be suitable for conversion to pasture or plantation based on their physical attributes and LUC class. However, further conversion of indigenous forest probably will not happen because most of the indigenous forest is on steep land defined as "protection forests: forests that stabilize the soil, provide good water and protect human investments in the lowlands" (McKelvey, 1995), or otherwise is reserved as national parks (McAloon, 1997). Also the major plantation owners in New Zealand have agreed not to convert land containing indigenous species to plantations (Forest Accord 1992) and this includes shrub land containing indigenous species. The definition, though, of indigenous shrub land remains open to interpretation. Further conversion of shrub land could occur for pasture and plantation, but presumably not for plantation by signatories of the Accord on shrub land considered to be indigenous. The application of the RMA will determine which areas of shrub may be converted.

Table 3-1 *Post hoc* values

	Bareground	Indigenous forest	Plantation	Horticulture	Pasture	Shrub	Tussock	Urban
0-5	-19.2	-77.3	35.1	1.1	15.8	39.5	-26.2	**331.4**
5-10	-23.7	-90.0	**77.0**	**59.1**	33.5	0.5	21.5	60.8
10-15	-24.5	-103.3	**63.8**	**85.2**	**83.6**	16.1	-21.6	6.7
15-20	-29.4	-115.7	**143.6**	**64.9**	**79.4**	-25.9	-30.3	-1.2
20-25	-31.8	-112.1	**144.9**	**32.0**	**88.5**	-24.7	-41.0	-9.1
25-30	-27.9	-123.1	**138.2**	**91.1**	**104.3**	-36.8	-47.2	23.1
30-35	-32.3	-113.4	**180.1**	19.3	41.9	-0.4	-39.0	-8.8
35-40	-20.5	-138.1	**138.1**	-14.3	30.5	**66.7**	4.6	-11.7
40-45	-31.8	-63.6	**39.5**	-15.8	28.7	**63.3**	-6.7	-14.1
45-50	-13.7	-34.2	**40.3**	-17.2	-18.7	**61.9**	-8.6	-14.8
50-55	-44.0	-12.1	**16.9**	-17.3	-18.7	**56.3**	5.4	-14.9
55-60	-18.9	18.5	-49.1	-16.2	-8.6	**38.4**	12.3	-6.9
60-65	-13.8	36.8	-65.7	-15.7	-21.0	-2.3	**60.8**	-11.3
65-70	-25.8	**78.5**	-66.8	-15.9	-30.6	-32.2	35.0	-10.1
70-75	7.2	**91.3**	-71.6	-15.9	-46.0	-18.7	-2.4	-13.7
75-80	30.3	**54.0**	-70.4	-16.4	-43.1	47.9	-28.7	-14.2
80-85	9.8	**63.3**	-77.0	-16.0	14.7	-20.3	-29.2	-13.1
85-90	5.7	**99.1**	-69.0	-16.7	-40.5	-47.0	5.2	-14.4
90-95	14.9	**79.2**	-72.1	-16.9	-31.5	-0.7	-27.1	-9.0
95-100	**47.8**	**29.0**	-69.1	-15.9	18.8	-7.7	-17.8	-13.7
100-105	**53.8**	**58.3**	-58.1	-12.5	-17.2	-35.1	-11.7	-10.8
105-110	**46.3**	**74.7**	-55.2	-12.4	-50.0	-39.7	11.2	-10.7
110-115	33.7	**62.8**	-53.7	-12.0	-46.4	-52.4	**53.2**	-10.4
115-120	37.2	**78.4**	-57.5	-11.7	-49.5	-49.7	**24.3**	-10.1
120-125	**66.5**	31.2	-49.3	-10.1	-35.4	-37.4	**53.0**	-8.7
125-130	**45.0**	-16.0	-28.9	-5.9	-35.3	-26.7	**125.5**	-5.1

Note: The lines in the table represents the boundary of each zone characterised by dominant land-use. Bold figures represent land-uses most concenterated in the zone.

Table 3-2 Principal component score for the land chatacteristics of plantation based on age class.

a. rock

Al	-0.041
Ar	**0.697**
Cg	-0.874
Cw	**5.389**
Gn	**1.295**
Gw	**0.197**
Hs	-0.733
In	-0.686
Ls	-0.872
Ma	-0.834
Ms	-0.381
Ss	-0.829
St1	-0.854
St2	-0.82
Um	-0.652

b. soil

BGC	-0.246
GY	-0.599
HCPYB	**0.518**
HCYB	-0.557
IRENYB	-0.54
IYBGC	-0.576
IYBRE	-0.483
IYGYB	-0.24
PYB	-0.584
RE	-0.566
REND	-0.598
UPYB	-0.576
UYB	-0.598
YB	**6.155**
YBS	-0.51

c. slope

Flat to gently undulating	-0.694
Intermediate:F and U	-0.802
Undulating	-0.620
Intermediate:U and R	-0.802
Rolling	-0.524
Intermediate:R and S	-0.757
Strongly rolling	-0.413
Moderately steep	1.724
Intermediate:M and St	-0.637
Steep	5.004
Intermediate:St and V	-0.767
Very steep	-0.710

d. LUC

2s	-0.712
2w	-0.713
3c	-0.694
3e	-0.693
3s	-0.646
3w	-0.713
4c	-0.705
4e	-0.448
4s	-0.606
6e	**1.958**
7e	**5.173**
7s	-0.711
8e	-0.490

e.distance

0-40	**1.892**
40-65	-0.426
65-130	-1.466

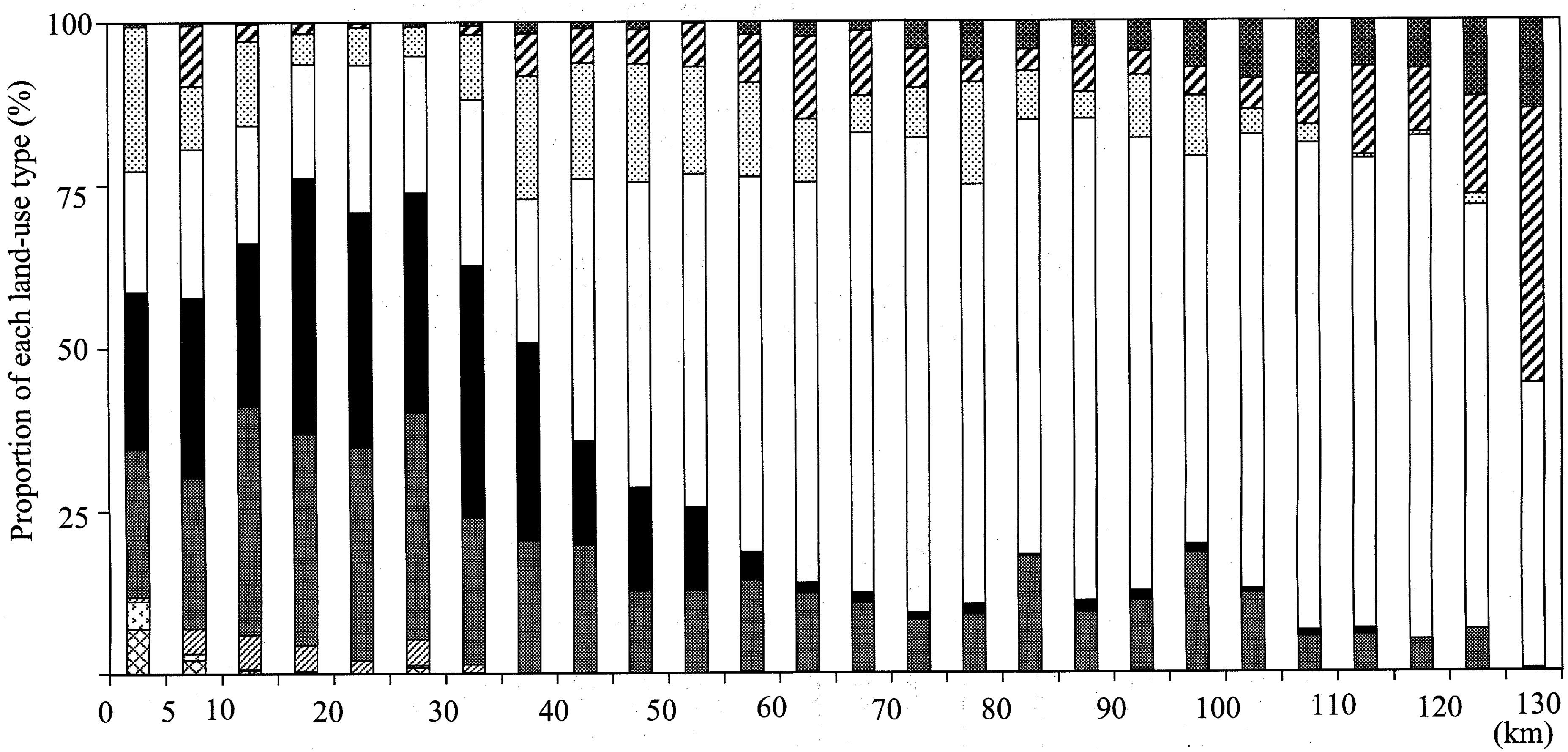


Fig. 3-1 Land-use distribution pattern in the Nelson region.
Note: : Urban; : Urban open space; :Horticulture; : Pasture; : Plantation;
: Indigenous forest; :Shrub; : Tussock; : Bare ground.

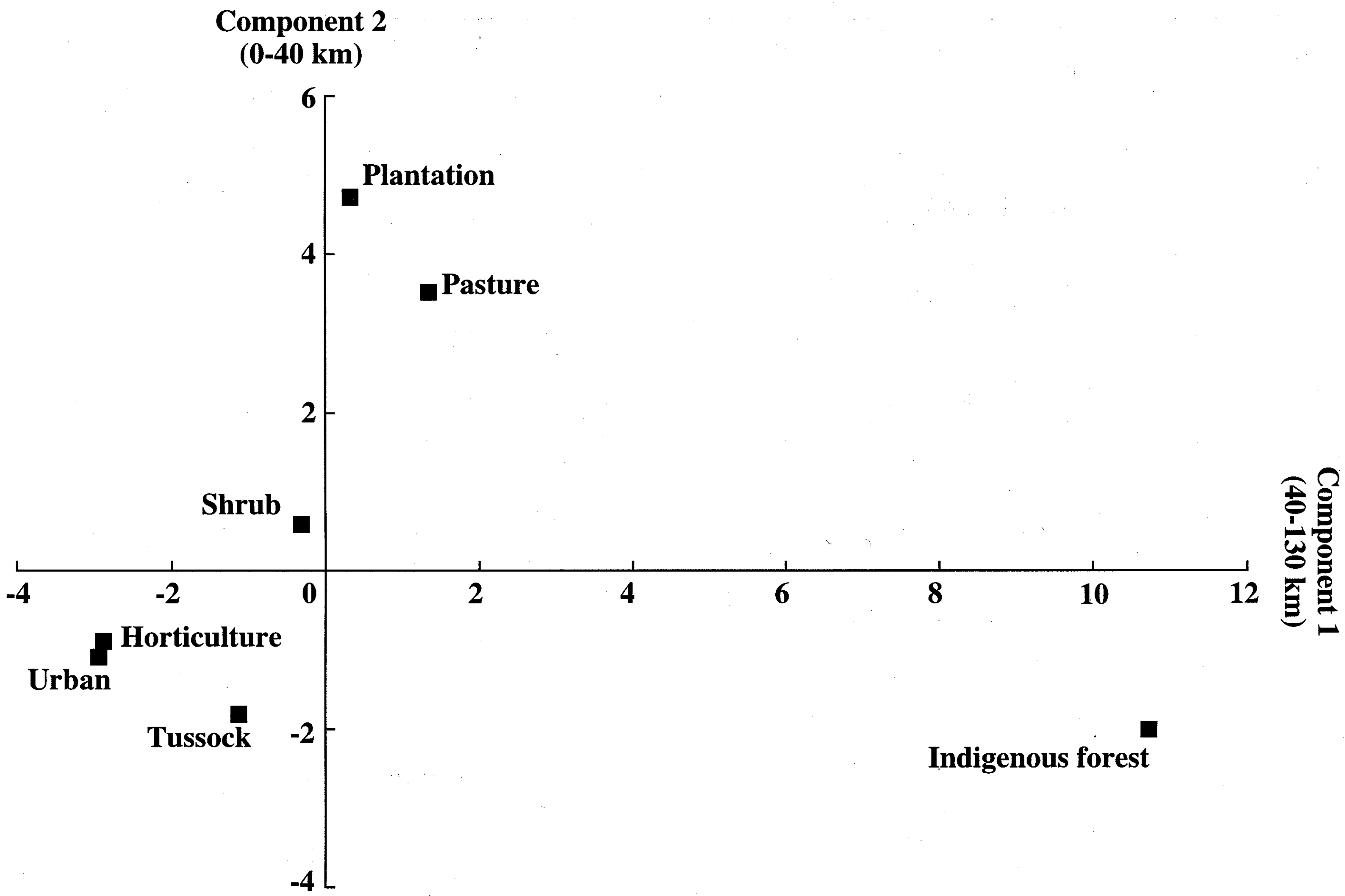


Fig. 3-2 Result of PCA on analyzing the distribution pattern.

1. **Urban**
2. **Agricultural, pastoral, and forestry area**
3. **Transitional zone from plantation dominant area to indigenous forest area**
4. **Indigenous forest area**

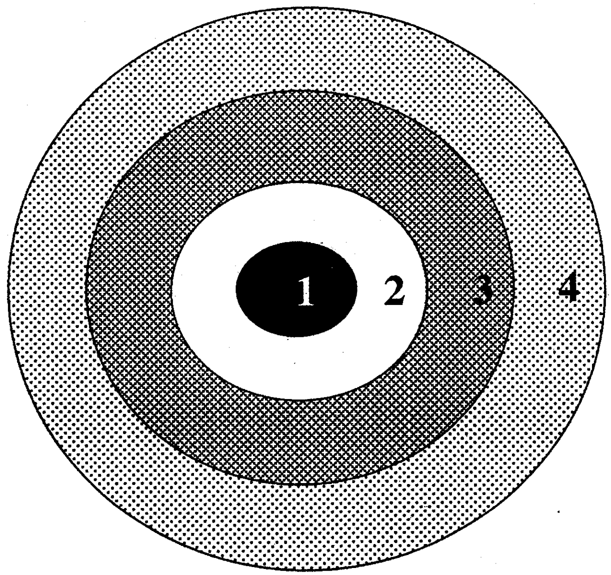


Fig. 3-3 Summarized land-use distribution pattern in the Nelson region.

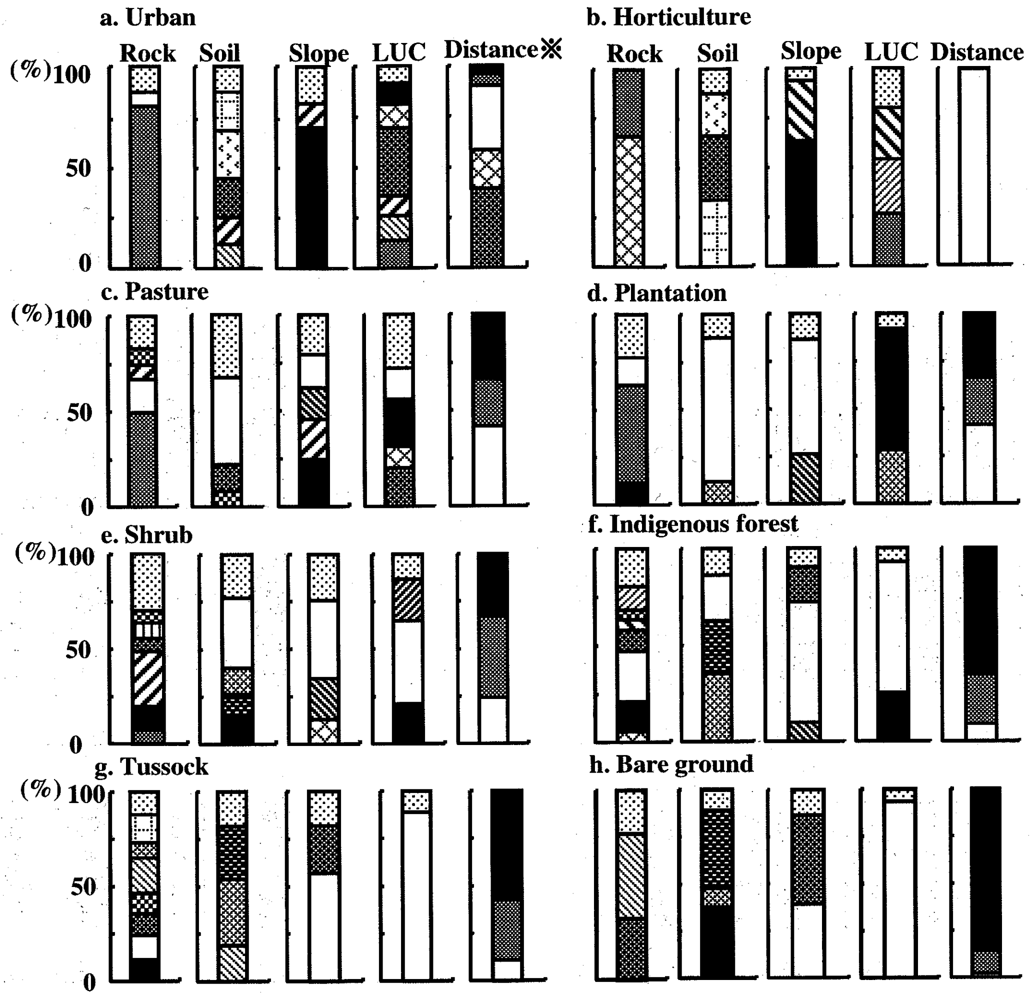


Fig.3-4 Land characteristics of each land-use type.

Note: Rock type-: Al; ■: Ar; : Cw; □: Gn; : Gw; : Hs; : In; : Ma; : Ms; : St1; : St2; : Um; : others. Soil type-■: ALP; : BGC; : GY; : HCPYB; : HCYB; : IYBRE; : IYGYB; : PYB; : RE; : UPYB; □: YB; : YBS; : YBST; : Others. Slope type- ■: Flat to gently undulating; : Undulating; : Rolling; :Strongly rolling; : Moderately steep; □: Steep; : Very steep; : Others. LUC- : 1s; : 3e; : 3s; : 4s; : 6e; ■: 7e; □: 8e; : Others. Distance - □: 0-40 km; : 40-65 km; ■: 65-130 km.

※The legend of 0-40 km were divided to : 0-5 km, : 5-10km, and □: 10-40 km in order to interpret the distribution tendency because urban area were tended to distribute close to the city center.

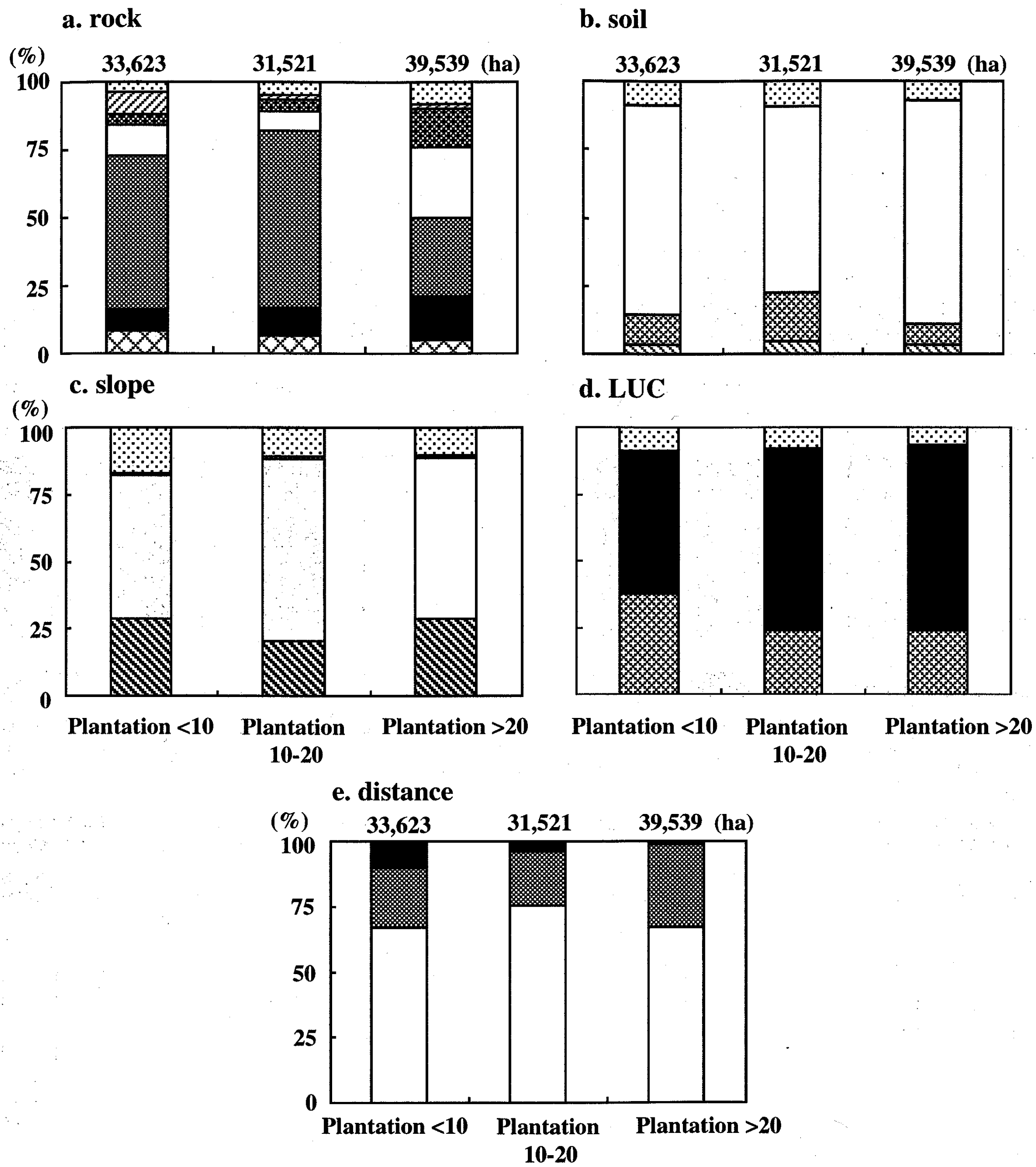


Fig. 3-5 Land characteristics of plantation forest by age classes.

Note: In order to simplify the graph, categories less than 10% were included in “Others”. All categories included in “others” were utilized under their own category name in the analysis.

Rock type- ⊠: Al; ■:Ar; ▩ : Cw; □: Gn; ▩: Gw; ▨ : Ms; ⊡: Others. Soil type-▧ : BGC; ▩ : HCPYB; □ : YB; ⊡ : Others. Slope type-▧: Moderately Steep; □ : Steep; ▩ : Very steep; ⊡ : Others. LUC- ▩ : 6e; ■ : 7e; ⊡: Others. Distance- □ : 0-40 km; ▩ :40-65 km; ■: 65-130 km.

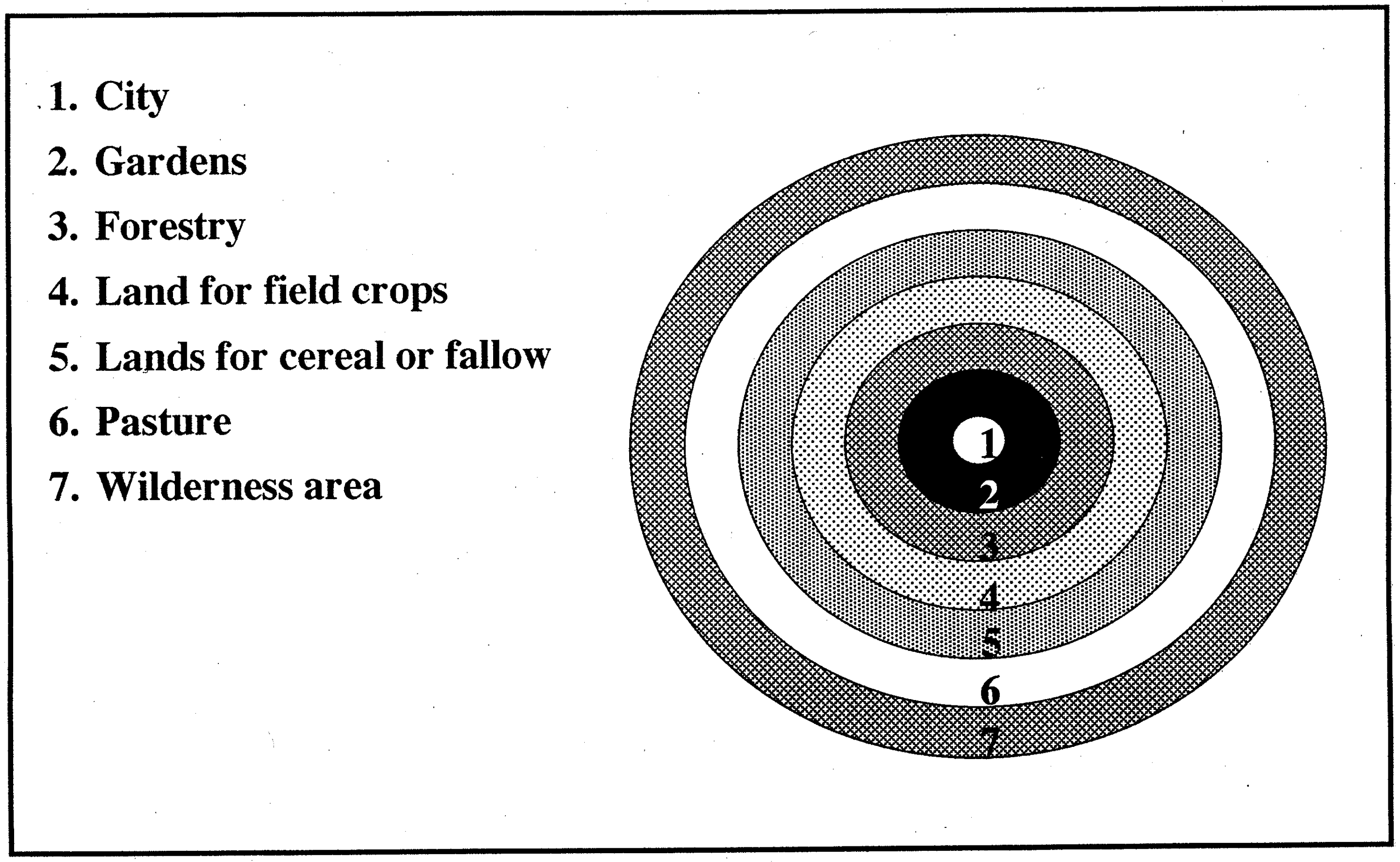


Fig. 3-6 von Thunen's model.

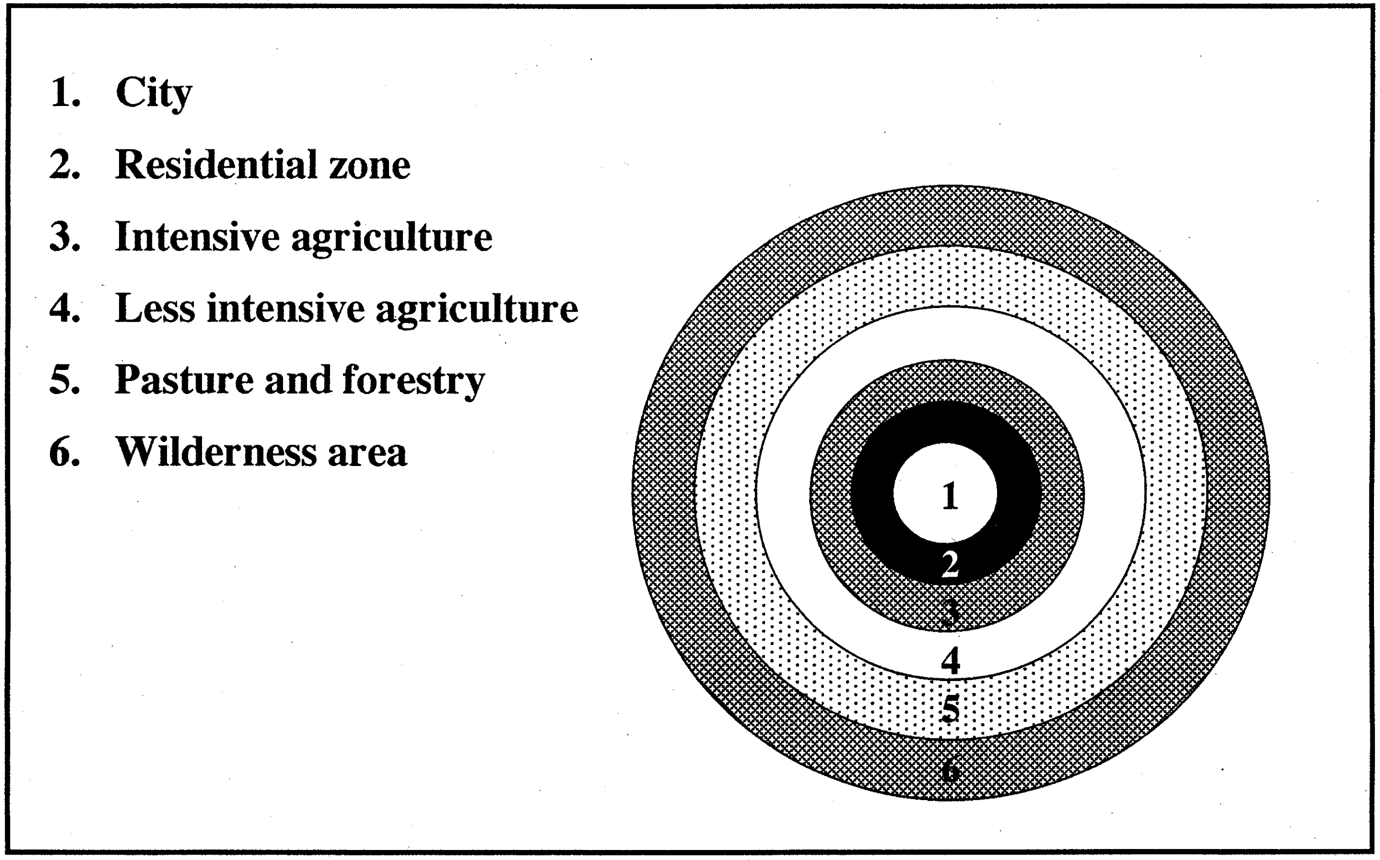


Fig. 3-7 Barlowe's model.

Chapter 4

Land-use Change with Forestry Expansion

4.1 Introduction

Although the land-use distribution pattern and its relation with site conditions were understood in chapter 3, it only provides limited information on how the current land-use pattern was formed. Interpreting the land-use change pattern and its factors may provide more detail and adequate information on this point.

As Le Heron and Roche (1985) mention, land-use change is strongly related to socio-economic environment because profitability is a great concern for the landowners. From a socio-economic sense, it is said that factors affecting the land-use are 1) natural endowment, 2) favorable production combinations, 3) transportation considerations, 4) institutional advantages, and 5) amenity factors (Barlowe, 1986). Natural endowment indicates the appropriate physical attributes for a certain land-use. For example, the relatively frost-free climate might suitable for fruit growing. Rich soils favor agricultural productions. Fields on lowlands will provide distinct advantages for mechanized farming. The favorable production combination would be decided by the profitability of the production. The location and the transportation consideration is another important factor on determining the land-use. Given an example, local producers may benefit from ability to move products to market at lower cost, in less time, and in fresher condition than more distant competitors. Institutional controls include the national or local government policy such as taxation policy, subsidy policy, and zoning ordinance. Amenity considerations had been often ignored when significant economic advantages are associated with particular site. However, local people are now more conscious of it than before as people become to pay more attention on the quality of the surrounding environment.

It is said that plantation expansion in New Zealand, have been caused by converting pasture in recent times because of the low returns from sheep farming (Fletcher, 1984; Le Heron and Roche, 1985; Maclaren, 1996; Masui, 1996; Taylor *et al.*, 1997). This suggests that plantation expansion is mainly due to the consideration of the favorable production combination. However, most studies reporting the tendency are based on statistical data and not on map overlays. Hence, it is notable to examine the actual pattern of land-use change using the geographic information systems (GIS).

As mentioned in chapter 1, there was a shift in land-use management policy in 1991 when the Resource Management Act (RMA) was enacted. The resource control at the local level is based on the district plan, which is now being implemented and expected to directly influence the actual land-use. Although interpreting the land-use change pattern is also useful for evaluating the land management policy (Zheng et al., 1997), it is too early to evaluate the effect of the RMA based on the actual land-use change data because only a few years had passed since it was enacted. Hence, the effect of the RMA only can be evaluated by examining its influence on the predicted future land-use. The obtained data set by analyzing the land-use change would be useful to predict the future land-use if all factors sufficiently explaining the land-use change pattern were deduced.

Using the Nelson region as a case study, this study aims 1) to understand the differences of landscape structure between the 1970s and 1990s, 2) to understand the human-induced changes in land-use patterns and the factors influencing them, and 3) to establish a basic data source to predict the future land-use. Based on the economic factors mentioned above (Barlowe, 1986), we included the physical attributes (rock, soil, and slope) as an indicator for the natural endowment, distance from the city center as a transportation consideration, and the LUC as an institutional advantage. Favorable production combinations and amenity factors were not included as indicators because the scale of the map was not appropriate to evaluate them. However, the production combination was discussed based on published papers. Instead of the two socio-economic factors, the potential stock carrying capacity of the land (Ccpo) (Newsome, 1992) was included as an indicator of land productivity.

4.2 Methods

The differences in landscape structures were interpreted by comparing the area, patch number, patch size and land-use distribution patterns from the city center in the 1970s and 1990s. The same method applied to interpret the current distribution pattern in chapter 3 was adopted to analyze the distribution pattern of 1970s on NZLRI map: Drawing buffers at intervals of 5 km out from the polygon representing the center of Nelson City and using principal component analysis (PCA) and *post hoc* values to understand the pattern in detail.

The NZLRI and LCDB maps were overlaid to interpret the pattern of land-use change and the factors influencing the change. Seven main land-use changes related to main industries in the region were selected and relationships with factors affecting the land-use change were interpreted. The physical attributes (rock, soil, slope), the LUC, and the potential stock carrying capacity (Ccpo) included in the NZLRI map were utilized as factors. Buffers were also drawn at intervals of 5 km out from the city center on the overlaid map and the distance from the city was also utilized as one of the factors. Discriminant analysis was utilized to understand which factors had greater influence on determining the land-use change pattern and whether the data would be sufficient to predict the future land-use.

Because of the varying scale of the original maps and the superimposition of maps, the overlaid map had operational errors. We minimized these errors by confirming the data with available aerial photos and excluding patches smaller than 10 ha, which were considered to have a high chance of error, from the analysis. The objective was to understand general land-use changes over a large area and not about individual small parcels of land.

4.3 Results

1) Difference of landscape structure

Indigenous forest occupies more than 50 % of the Nelson region (Table 4-1). Its area increased slightly over the 20 years, but individual patches became smaller and more fragmented. Shrub, which was the second dominant land-use in 1970s, decreased its area by 42%. By contrast, horticulture, exotic forest and urban areas expanded by factors of 3, 2 and 2 respectively. The reduction of mean patch size for horticulture and exotic forest along with their expansion is also noticeable. The total area of pasture, the first dominant human derived land-use, was unchanged. However, patches coalesced and therefore patch sizes got larger while patch numbers reduced.

PCA using distance from the city center as the explanatory variable, was conducted to comprehend features of the land-use distribution pattern (Fig. 4-1). However, because only a rough tendency could be deduced from this analysis, *post hoc* values calculated from the area of each land-use were also used to interpret the tendency in more detail (Table 4-2).

The distribution patterns in both 1970s and 1990s were divided roughly into three groups by PCA: the dominant land-use within 40 km from the center, the dominant land-use from 40 to 130 km from the center, and a group of other minor land-uses (Fig. 4-1). Pasture and shrub were the dominant land-uses within 40 km in the 1970s whereas pasture and plantation were the dominant in the 1990s. Indigenous forest was the dominant beyond 40 km in both the 1970s and 1990s. *Post hoc* values distinguished some differences in details between the 1970s and 1990s (Table 4-2). Large positive values represent a concentration of land-use. Horticulture was mainly distributed from 10 to 30 km from the city center in the 1970s but expanded its main distribution area from 5 to 35 km in the 1990s. Exotic forest expanded its area from 5 to 50 km in the 1970s to 0 to 55 km in the 1990s. Pasture was distributed mainly within 45 km and showed little change. However, pasture had positive values from 80 to 85 km and 95 to 100 km in the 1990s, whereas only 95 to 100 km was positive in the 1970s. Shrub was distributed at 0 to 65 and 75 to 80 km in the 1970s. The area of shrub was reduced and fragmented in the 1990s. Indigenous forest, which mainly distributed beyond 55 km, did not change over the period.

2) Land-use change

Conversion of shrub was the major change in land-use over the period (Table 4-3). More than half of the shrub area in 1970s was converted to other land-uses. Conversion from indigenous forest was the second largest change (38,509 ha) followed by conversion from pasture (38,188 ha) (Table 4-3). Nevertheless, there were no changes in the total areas of indigenous forest and pasture because conversion losses were balanced by conversion gains (Table 4-1).

The observed main land-use change were as follows in order of area: 1) shrub to plantation, 2) shrub to pasture, 3) shrub to indigenous forest, 4) indigenous forest to shrub, 5) tussock to bare ground, and 6) pasture to plantation. The other land-use changes related to human activity (e.g. indigenous forest to pasture, indigenous forest to plantation, and pasture to horticulture) was smaller but still more than 3,000 ha.

Table 4-4 shows where people have induced land-use changes. Sixty-four percent of the new plantation was established on shrub land and 28 % on pasture. The remaining 8 % was converted from indigenous forests. Most of the new horticultural land was developed on pasture (95 %) and pasture was converted from shrub (79 %) and indigenous forest (14 %).

3) Human derived land-use change

Agriculture, horticulture and forestry are the main industries contributing to the local economy and likely to remain so in the future, and therefore land-use change related to those industries were chosen and their factors examined. The selected land-use changes were 1) shrub to plantation, 2) shrub to pasture, 3) pasture to horticulture, 4) pasture to plantation, 5) pasture to shrub, 6) indigenous forest to pasture, and 7) indigenous forest to plantation. The physical attributes (rock, soil, and slope), the LUC, potential stock carrying capacity (Ccpo), and distance from the city center were used as the factors that might influence the land-use change. As the same in chapter 3, the rock type classification used is based on Lynn (1985). The New Zealand genetic soil classification (Taylor and Pohlen, 1970; Soil Bureau Department of Scientific and Industrial Research, 1968) was used even though this is not the most recent system of classification (McLaren and Cameron, 1996), because this was the system used in the NZLRI maps. The Ccpo is a carrying capacity in stock units per hectare to one decimal place. A stock unit is defined as a breeding ewe (Newsome, 1992).

(a) Shrub to plantation

Conversion from shrub to plantation was the largest change observed within the region, which demonstrates considerable expansion of forestry. Thirty-seven thousand ha of shrub land were converted to plantation (Table 4-3), most of which was distributed on steep land with low fertile soil (e. g. YB and HCPYB) and LUC categories suit for pasture and plantation (Fig. 4-2a). The productivity of the land was low to medium based on the Ccpo. The new plantations are distributed mostly within 40 km of the city center and between 40 and 65km in a lesser proportion. This is consistent with the observation that their main distribution area shifted from 5-50 km in 1970s to 0-55 km in 1990s.

(b) Shrub to pasture

Approximately 34,000 ha of the shrub land were converted to pasture which was the second largest conversion in the region (Table 4-3). This change occurred mainly on steep slopes, on low fertile soils formed on various kinds of rock types (Fig. 4-2b). LUC classes showed a satisfactory change in terms of land use capability. However, 3,000 ha (9% of the area) occurred on "8e" where there was a high possibility of erosion as a result of conversion. The Ccpo indicates that low to medium capacity land was converted to pasture. Although the main distribution area of pasture was within 45 km from the city center, most shrubs converted to pasture was distributed beyond 40 km, especially beyond 65 km (49% of the area).

(c) Pasture to horticulture

Most new horticulture area (3,793 ha) was derived from pasture (3,740 ha) (Table 4-3 and 4-4). The change was mainly on gentle slopes, on relatively high fertile soils (RE and YBST) formed on alluvium and conglomerate (Fig. 4-3a). The LUC classes indicated the medium to high cropping suitability of the land and therefore it seems the conversion took place on appropriate lands. The Ccpo showed medium to high productivity. Ninety-nine percent of the conversion occurred within 40 km of the city center.

(d) Pasture to plantation

More than 16,000 ha were converted to plantation from pasture (Table 4-3) which is 28% of the total area of conversion to plantation (Table 4-4). Similar to plantation converted from shrub, plantation derived from pasture also took place on relatively steep lands with low fertile soil, low to medium productivity, and lands suitable for grazing or forestry (Fig. 4-3b). The land-use change from pasture to plantation occurred within 65 km, especially within 40 km. This again confirms the expansion of main plantation distribution area within those 20 years.

(e) Pasture to shrub

This land-use change occurred when the landowner abandoned grazing. Approximately 10,000 ha of pasture regenerated in shrub (Table 4-3). The change was scattered evenly over the region and observed on lands with diverse characteristics (Fig. 4-3c). Rock types were various and soils with low fertility were the dominant except "RE" which is high in fertility. Most of the conversion took place on hill country which is suitable for grazing but some on gentler slopes. Half of the lands regenerated to shrub showed medium productivity. The remaining half was evenly distributed on land with lower and higher productivity.

(f) Indigenous forest to pasture

Indigenous forest was on more than 50% of the area and was marginally greater in 1996 than 1970 (Table 4-1). However, 38,509 ha of indigenous forest was converted to other land-uses of which 6,000 ha was changed to pasture (Table 4-3). Forests converted to pasture were distributed on steep slope with low fertile soil and various kinds of rock types (e.g. Ms, Al and Gn)(Fig. 4-4a). The dominant LUC was "7e" followed by "8e" and "6e". The productivity of the land based on the Ccpo was low. Most conversion occurred beyond 65 km from the city center.

(g) Indigenous forest to plantation

The area converted from indigenous forest to plantation (4,553 ha) was a little smaller than that area changed to pasture (5,965 ha)(Table 4-3). Comparing aerial photos in the 1970s, 1980s, and 1990s, it showed that in some areas (more than 1000 ha) conversion was from indigenous forest to pasture first and then to plantation. Because of this, the characteristics of lands converted to plantation from indigenous forest were similar to the lands converted to pasture; steep land with soils low in fertility and with the LUC class "7e", followed by "8e", and "6e". Nevertheless, some differences also observed. The proportion of medium productivity land was larger. "Cw", "Gw", and "Ar" were the main rock type and the area changed to plantation tended to distribute within 65 km whereas the areas changed to pasture were beyond 65 km (Fig. 4-4b).

4) Main factors determining land-use change

(a) Indigenous forest to pasture and plantation

Discriminant analysis using all factors (rock, soil, slope, LUC, Ccpo, and distance from the city center) revealed that conversion from indigenous forest to pasture and to plantation were different ($p < 0.001$). The contribution of each factor to distinguish the differences can be understood by the coefficient of the standardized discriminant function. The factor with larger absolute value of the coefficient indicates that there is a great difference between the distribution patterns and thus contributed largely to determine the land-use change pattern. In case of the land-use change from indigenous forest to pasture and plantation, the distance from the city center (Dcc) and LUC showed large absolute values (Table 4-5). In other words, Dcc and the LUC were the factors distinguished the land-use change pattern from indigenous forest to pasture and to plantation. The discriminant function for conversion from indigenous forest was calculated as follows:

$$Z=0.176*[Dcc]-0.084*[Ccpo]-0.654*[LUC]+0.016*[rock]+0.309*[slope]+0.07 \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The correct discrimination of this function was 84%, which means it is possible to utilize it for predicting the areas that might be converted into pasture or plantation.

(b) Shrub to pasture or plantation

Discriminant analysis showed that conversion from shrub to pasture and plantation is different ($p<0.001$) where the distinguishing factors were Dcc and Ccpo (Table 4-5). The discriminant function for conversion from shrub to pasture or plantation was calculated as:

$$Z=0.153*[Dcc]+0.118*[Ccpo]+0.014*[LUC]+0.036*[rock]-0.017*[soil]+0.009*[slope]-2.844 \quad \ldots\ldots.(2)$$

This function also had a high percentage of correct discrimination (67.9%).

(c) Pasture to shrub, plantation and horticulture

Because there are three land-use changes, two discriminant functions were calculated:

$$Z=0.106*[Dcc]+0.043*[Ccpo]+0.426*[LUC]-0.008*[rock]-0.013*[soil]-0.054*[slope]-5.401 \ldots\ldots\ldots.(3)$$

and

$$Z=-0.154*[Dcc]+0.032*[Ccpo]+0.11*[LUC]-0.055*[rock]+0.082*[soil]+0.135*[slope]-1.55 \ldots\ldots\ldots..(4)$$

The discriminant functions indicated that change from pasture to shrub, plantation, and horticulture are all different ($p<0.001$) with Dcc and LUC being the discriminating factors (Table 4-5). Using both functions, the percentage of correct discrimination was 66.2%.

4.4 Discussion

The net area of indigenous forest has not changed. However, some areas were converted to shrub, pasture or plantation while some areas regenerated to indigenous forest from pasture or shrub. Thus the indigenous forests are now more fragmented than in 1970s, which means that conservation of biodiversity could be more difficult and threatened species could be more vulnerable. Nonetheless, the Nelson region is still rich in indigenous forest where it has been reserved and precluded from clearing. Establishment of national parks began in 1942 in the region. Currently, the region has three national parks: Abel Tasman (22,541 ha), Nelson Lakes National Park (101,753 ha), and Kahurangi National Park (452,000 ha) which extends into the north of the West Coast region. Most of the remaining indigenous forests are distributed within the national parks and therefore, it could be said that National parks largely contributed for protecting indigenous forest. However, some indigenous forest outside of reserved areas was converted to pasture or plantation on steep, low fertility land with LUC class from 6 to 8. This is probably undesirable, especially on LUC class "8e" which could result in significant erosion. However, the likelihood of undesirable conversions has now been reduced because of the Resource Management Act 1991 which promotes sustainable land-use management. In addition, the conversion to plantation would also decrease due to the New Zealand Forest Accord 1992 in which the main forestry companies have agreed not to replace native forest and other significant natural habitats with exotic forests (Taylor *et* *al.*, 1997).

The sunny and warm climate of the Nelson region is advantageous for horticulture. Horticulture expanded in the region and contributed to the regional economy from 1945, particularly because of fruit growing and also because it was the only region producing tobacco and hops. By the end of 1950s, Nelson accounted for 40 % of the national pip fruit crop. Fruit growing steadily expanded in the 1960s, which was promoted by the establishment of the fruit juice plant at Stoke in 1962. Hops and tobacco picking became largely mechanized from the early 1960s, but fruit picking remained manual because it was difficult to mechanize. When the connection of smoking with disease became obvious in the 1970s, scientists and the government warned that the tobacco would not remain profitable and plans were made to replace tobacco with other crops. The government protected tobacco industries until 1981 and finally the last tobacco was harvested in 1994. Other new crops gradually replaced the tobacco. Kiwi fruit was the most common. There were 10 ha of kiwi fruit in 1977, 80 ha by 1981 and 1,100 ha by 1986. As a result, the Nelson region became second to the Bay of Plenty in cultivation of kiwi fruit. Other export crops such as boysenberries and blueberries also replaced tobacco (McAloon, 1997).

Considering those social backgrounds, the reason why the patch size became smaller in 1990s than in 1970s, might be because of replacement of tobacco by fruits. In 1970s when tobacco was still in its prosperity, tobacco was cultivated by machine and therefore it was possible to manage a huge area. However, once it was converted to fruit, the size of each farm was reduced because those fruits were picked by hand. It seems pasture was converted to horticulture because horticulture had a high export potential and a higher return than grazing sheep or dairy farming. Fletcher (1984) indicated that the gross margins varied from upwards of $4,000 (for pip fruit, stone fruit and grapes) per ha to as much as $30,000 per ha (for kiwi fruit) in 1982 compared with $590 for dairying.

Expansion of horticulture occurred within 40 km from the city center and most converted from pasture. The converted pastures were distributed on low lands, fertile soil with high productivity, and with an LUC class suitable for cropping. Thus, pastures that had appropriate site conditions for horticulture were converted. Because more intensive land-use is tends to be distributed on land closer to the city center (Chisholm, 1966; Barlowe, 1986), it is understandable that the lands converted to horticulture were close to the city center.

The area of pasture was almost unchanged over the 20 years. However, 27 % of the pasture area was converted to horticulture, plantation, or shrub and this was compensated by conversion of shrub to pasture. Pasture converted to plantation was distributed on steep land with relatively low fertile soil, and an LUC class suitable for grazing or forestry. The site conditions were very similar to the land regenerated to shrub except there were additional site conditions probably corresponding to land abandoned following overgrazing.

The conversion of pasture to plantation and shrub on the hilly country is also related to the social background. The Nelson region was developed into pasture from a very early stage in late 1980s. However, pasture development was difficult in this region. The natural fertility of most of the hill soils was low and although the initial responses with surface sown pastures were promising, deterioration was soon apparent (The Town and Country Planning Branch, Ministry of Works, 1965). Thus, establishment of good quality pasture was restricted to the lowland. Technical improvement such as aerial topdressing and oversowing in the 1960s allowed redevelopment of the hill country into pasture. Therefore, pasture started expanding into the hills. The observed conversion from shrub to pasture on steep lands might be the result of this. The technical improvement and mechanization also allowed managing larger areas and therefore the patch size of the pasture increased. However, there were also some lands that were unprofitable due to the low return from sheep grazing, and therefore were abandoned or converted to plantation.

Forestry began to make an impact on the local economy after 1950. By the mid-1950s, Nelson's plantations covered 70,000 acres and were second only to the great plantations of the central North Island. The Nelson region experienced further expansion of plantation from 1960 when the second planting boom started. The region was identified as one of the priority planting regions and the Golden Downs Forest was well placed to contribute to the government's new national expansion plans (Ward and Cooper, 1997). However, because plantations started to intrude onto traditional pastureland, the land-use competition between sheep grazing and forestry became a problem in the mid- 1970s. Consequently, losses from pastoral land to plantations became directed to LUC classes 6 or 7 in shrub or fern (Fletcher, 1984). Kirkland (1981) considered that 1.8 million ha of this kind of land is available in the whole country. Hence, there was a large area of shrub converted to plantations, which subsequently became the dominant land-use within 40 km from the city.

Some publications report that plantations are now established predominantly on pasture (Fletcher, 1984; Le Heron and Roche, 1985; Maclaren, 1996; Taylor *et al.*, 1997). However the study reported here shows that more shrub than pasture was converted to plantation over the period from 1970s to 1990s. Taylor *et al.* (1997) mentions that conversion of pasture became popular after the third planting boom and was assisted in the 1990s by the high export earnings from forestry and low returns from sheep. This can not be confirmed in this study because no data in the 1980s was available. However, it is possible that this phenomenon occurred in the 1990s because the main forestry companies agreed not to replace regenerating shrub with plantation under the Forest Accord 1992.

To achieve the annual plantation targets in the late second planting boom, the importance of small growers such as farmers was recognized. Currently forest owners with less than 1,000 ha account for 15% of the total area together with the adjacent Marlborough region (New Zealand Ministry of Forestry, 1994). This is considered the reason for the reduction in patch size of plantations within the 20 years.

The land converted to plantation was mainly within 65 km and particularly 40 km of the city center, whereas land converted to pasture was mainly beyond 65 km. More intensive and higher demand land-use tends to be closer to the city center (Chisholm, 1966) and accordingly forestry appears to have a priority over pasture as a land-use in this region. Currently the main distribution area both of pasture and plantation are within 40 km, and the order of main land-use from the city could be summarized as 1) city, 2) horticulture, pasture and plantation, 3) transitional zone from a plantation dominant area to indigenous forest, 4) indigenous forest (Fig.4-5). However, with the current tendency of pasture closer to the city center being converted to plantation and new pasture being developed further away from the city, there is a possibility the distribution pattern may change to 1) city center, 2) horticulture and plantation, 4) pasture, and 5) indigenous forest (Fig. 4-5).

Shrub was the first land-use type converted to other land-use. Shrub considered marginal for agriculture or forestry was brought into production using current technology. Shrub considered not appropriate for cultivation was left undeveloped. Shrub is important not only as an area regenerate to indigenous forest (Bergin and Kimberley, 1995) but also because it has high biodivesity (Dickinson *et al*, 1998; Mark *et al*, 1989). Shrub land is also important as a habitat for threatened species. Fifteen percent (22 species) of threatened plants are distributed on shrub (Taylor *et al*, 1997). Even though the main forestry companies agreed not to replace shrubs under the Forest Accord, it is still important to monitor the dynamics of shrub in the future.

Discriminant analysis showed that the distance from the city center, and Ccpo or LUC influenced the land-use change related to the main business in the region. Distance from the city center was the main factor for all land-use change, which reflects the importance of transportation cost. The Ccpo, which is used as an indicator of land productivity, was the main factor for the land-use change from shrub. This indicates that when the uncultivated land is to be 'developed', productivity is the important factor. However, the LUC was one of the factors when the indigenous forest, another kind of uncultivated land, was developed. The land-use suitability, which integrates many factors, could be more important than the productivity (Ccpo) because the indigenous forests distribute on hill country and because the development could result in significant soil erosion. Most of the land-change was well suited to the LUC classification which demonstrates the usefulness of LUC in determining and predicting changes in land-use. The discriminant function was very promising for predicting the future land-use. Thus, the objective to establish a data set for future prediction of future land-use was achieved.

Table 4-1 Main land-use in the Nelson region in the1970's and the1990's

	1970's				1990's			
	Area (ha)	%	Patch Number	Mean Patch size	Area (ha)	%	Patch Number	Mean Patch size
Horticulture	1,887	0.19	17	111	5,589	0.55	141	40
Pasture	152,854	15.22	754	203	153,985	15.28	436	353
Indigenous forest	531,933	52.95	721	738	531,959	52.78	926	574
Exotic forest	53,328	5.31	101	528	108,727	10.79	810	134
Scrub	167,035	16.63	693	241	98,527	9.78	1339	74
Tussock	74,928	7.46	176	426	61,472	6.10	415	148
Urban	1,444	0.14	2	722	3,255	0.32	46	71
Others	21,180	2.11	-	-	44,376	4.40	-	-

Table 4-2 *Post hoc* values for various distances from the city center of land-uses in the Nelson region in the 1970's and the 1990's

	1970's					1990's				
Distance (km)	Horticulture	Pasture	Exotic forest	Indigenous forest	Shrub	Horticulture	Pasture	Exotic forest	Indigenous forest	Shrub
0-5	-4.7	**75.3**	-17.3	-89.2	**79.7**	0.5	**20.7**	**43.3**	-70.9	**41.9**
5-10	-6.7	**71.9**	**14.0**	-98.7	**60.5**	**65.0**	**32.6**	**78.3**	-90.6	-1.2
10-15	**77.0**	**127.5**	**33.1**	-89.0	**1.7**	**92.3**	**80.7**	**66.7**	-104.2	**14.8**
15-20	**104.3**	**70.6**	**127.6**	-121.8	**42.0**	**74.0**	**77.3**	**146.5**	-116.6	-27.9
20-25	**49.5**	**112.2**	**103.4**	-114.2	**19.1**	**34.9**	**86.9**	**146.4**	-111.9	-25.0
25-30	**8.7**	**114.7**	**145.6**	-118.3	**3.0**	**87.1**	**102.2**	**138.4**	-123.0	-34.0
30-35	-8.8	**81.9**	**159.3**	-133.6	**43.3**	**18.6**	**40.2**	**179.3**	-112.7	0.9
35-40	-9.4	**27.7**	**126.0**	-155.4	**105.4**	-13.7	**29.3**	**136.0**	-136.5	**65.2**
40-45	-10.3	**21.3**	**40.2**	-68.4	**63.8**	-16.9	**28.0**	**38.3**	-62.1	**62.3**
45-50	-10.8	-7.9	**35.5**	-21.2	**43.3**	-18.0	-19.2	**39.8**	-32.4	**68.7**
50-55	-10.7	-23.8	-21.3	**34.8**	**14.3**	-18.5	-18.6	**15.1**	-10.9	**54.3**
55-60	-10.2	-2.0	-53.3	**36.6**	-3.4	-17.4	-8.0	-49.7	**19.5**	**35.7**
60-65	-9.8	-5.7	-49.1	**0.9**	**8.7**	-16.8	-21.1	-66.5	**36.7**	-1.4
65-70	-10.0	-44.0	-54.4	**94.1**	-52.2	-17.0	-30.5	-67.8	**78.5**	-31.7
70-75	-10.0	-51.8	-54.8	**95.0**	-52.1	-17.1	-46.1	-72.5	**89.9**	-17.4
75-80	-10.2	-68.0	-55.8	**76.5**	**6.4**	-17.7	-42.9	-70.8	**52.9**	**45.0**
80-85	-10.1	-25.4	-54.9	**60.9**	-20.2	-16.9	**14.5**	-78.5	**61.8**	-18.4
85-90	-10.4	-68.0	-56.7	**82.7**	-23.7	-17.8	-40.6	-70.3	**98.6**	-46.5
90-95	-10.5	-50.2	-57.5	**76.9**	-27.5	-18.1	-30.9	-72.8	**78.2**	-2.0
95-100	-9.9	**5.0**	-54.1	**28.1**	-27.7	-17.1	**18.9**	-71.1	**28.1**	-4.2
100-105	-7.9	-46.8	-42.9	**62.4**	-35.0	-13.4	-16.3	-59.0	**58.8**	-36.2
105-110	-7.6	-49.6	-41.6	**76.6**	-62.7	-13.3	-49.0	-56.2	**75.7**	-41.3
110-115	-7.3	-53.5	-40.1	**67.0**	-52.5	-12.8	-46.2	-54.1	**64.3**	-54.1
115-120	-7.2	-59.7	-39.1	**69.4**	-65.7	-12.5	-48.5	-58.1	**79.9**	-51.7
120-125	-5.4	-26.0	-29.4	**15.6**	-53.7	-10.7	-35.4	-49.8	**33.6**	-39.3
125-130	-2.7	-26.6	-14.9	-16.2	-28.1	-6.3	-35.3	-29.6	-16.1	-28.0

Note: Positive values are represeted by bold figures.

Table 4-3 Land-use changes in the Nelson region between the 1970's and the 1990's.

	Land-use in 1990's (ha)								Area changed
Land use in 1970's	Horticulture	Pasture	Plantation	Indigenous forest	Shrub	Tussock	Bare ground	Urban	to other land-use
Horticulture	913	772	0	0	0	0	0	0	772
Pasture	3,740	104,001	16,338	5,438	9,876	314	915	1,568	38,188
Plantation	108	2,416	45,501	1,773	1,292	0	131	0	5,720
Indigenous forest	0	5,965	4,553	486,552	21,368	5,111	1,512	0	38,509
Shrub	75	34,634	37,629	24,471	53,755	7,145	1,294	89	105,336
Tussock	0	126	0	6,721	2,564	45,449	18,114	0	27,526

Table 4-4 The origin of horticulture, pasture and plantation in the 1990's.

	Land-use in 1990's (%)		
Land use in 1970's	Horticulture	Pasture	Plantation
Horticulture	-	1.8	-
Pasture	95.3	-	27.9
Plantation	2.8	5.5	-
Indigenous forest	-	13.6	7.8
Shrub	1.9	78.9	64.3
Tussock	-	0.3	-

Note: the percentage was calculated from Table 3.

Table 4-5 Coefficients of the standardized discriminant functions

	From indigenous forest	From shrub	From pasture	
	equation 1	equation 2	equation 3	equation 4
Distance from city (Dcc)	0.892	0.816	0.533	-0.772
Ccpo	-0.472	0.601	0.200	0.151
LUC	-0.940	0.021	1.147	0.297
Rock type	0.058	0.129	-0.029	-0.199
Soil type	0.000	-0.086	-0.050	0.326
Slope type	0.586	0.020	-0.164	0.411

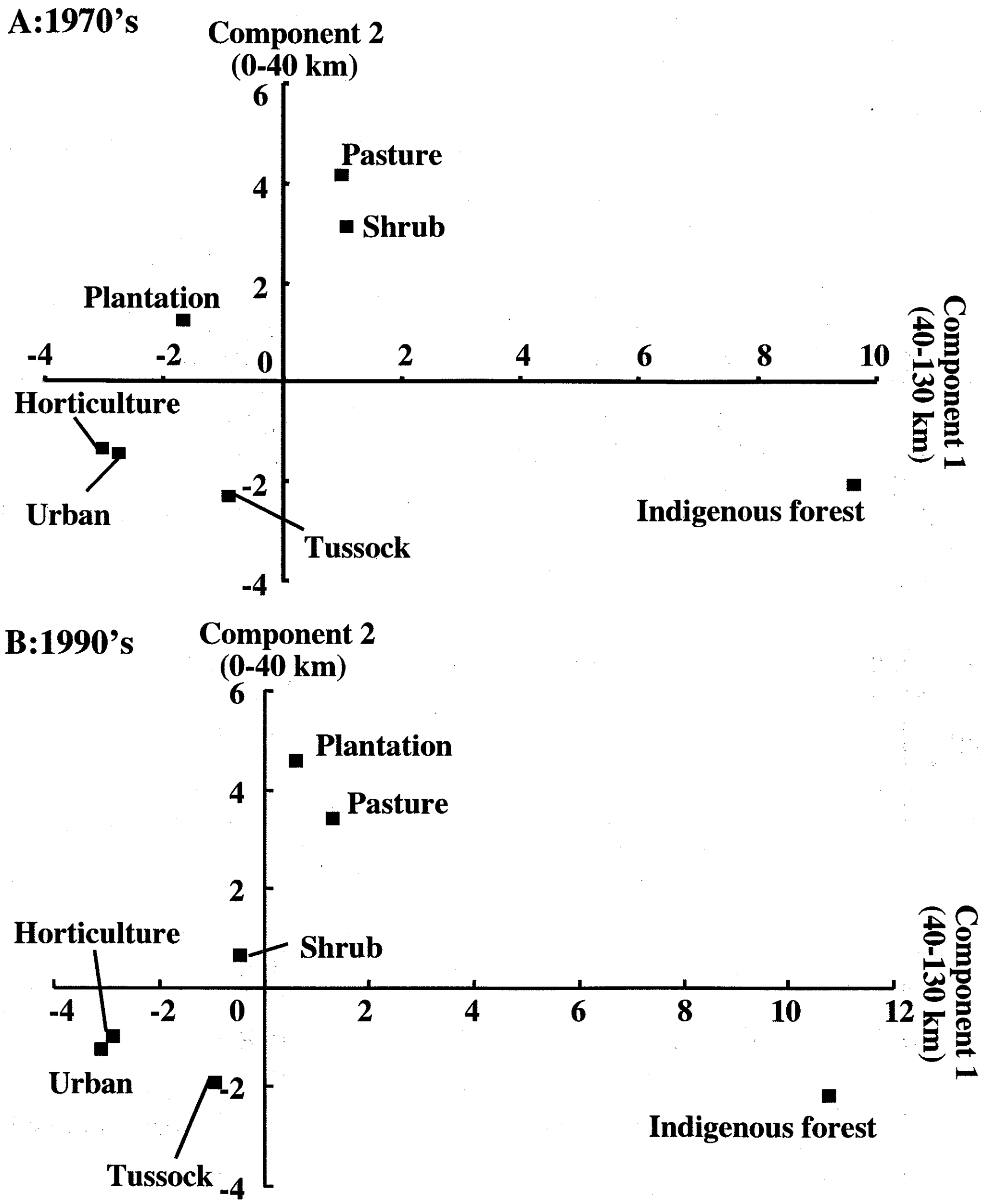


Fig. 4-1 Result of PCA on analyzing distribution pattern.

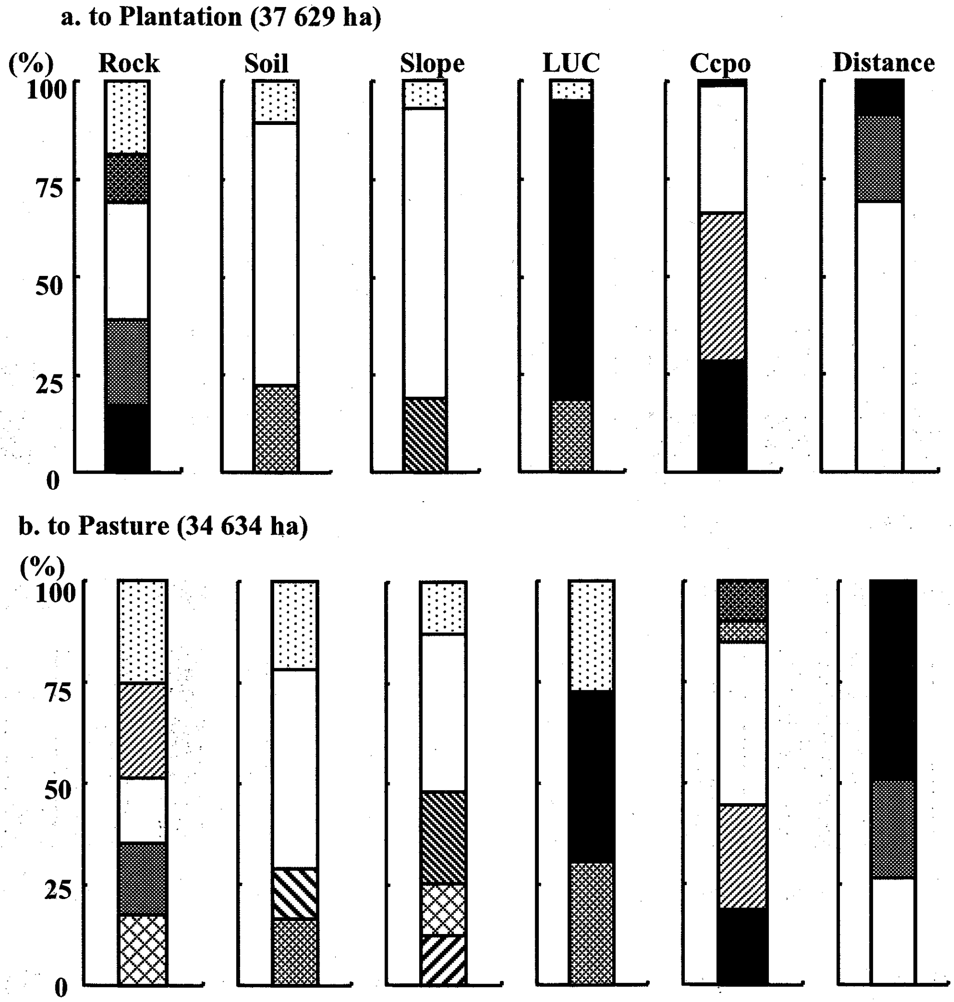


Fig. 4-2 Characteristics of land changed from shrub.

Note: Rock type - : Al; : Ar; : Cw; : Gn; : Gw; : Ms; : Others. Soil type - : HCPYB; : PYB; : YB; : Others. slope type - : Undulating; : Strongly rolling; : Moderately steep; : Steep; : Others. LUC - : 6e; : 7e; : Othres. Ccpo - : 0-5; : 6-10; : 11-15; : 16-20; : 21-25. Distance - : 0-40; : 40-65; : 65-130.

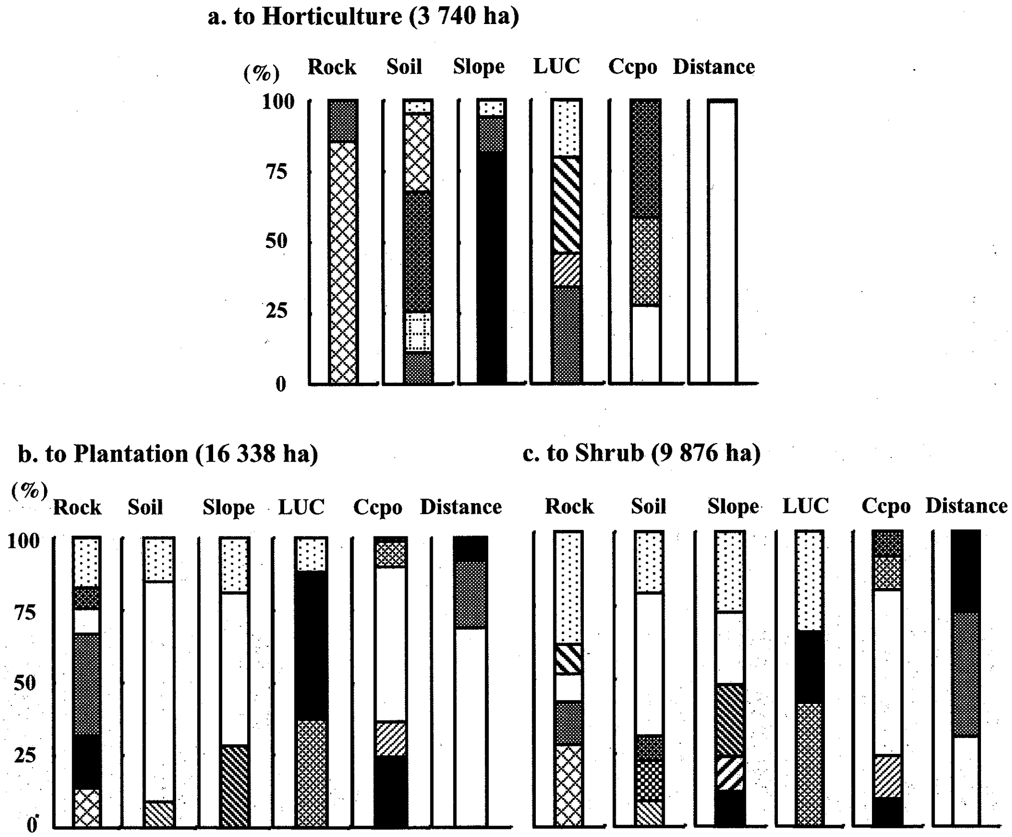


Fig. 4-3 Characteristics of land changed from pasture.

Note: Rock type - : Al; : Ar; : Cw; : Gn; : Gw; : Ma; : Others. soil type - : BGC; : GY; : IRENYB; : IYGYB; : RE; : YB; : YBST; : Others. Slope type - : Flat to gently undulating ; : Undulating; : Rolling; : Moderately steep; : Steep; : Others. LUC - : 1s; : 3e; : 3s; : 6e; : 7e; : Others. Ccpo - : 0-5; : 6-10; : 11-15; : 16-20; : 21-25. Distance - : 0-40; : 40-65; : 65-130.

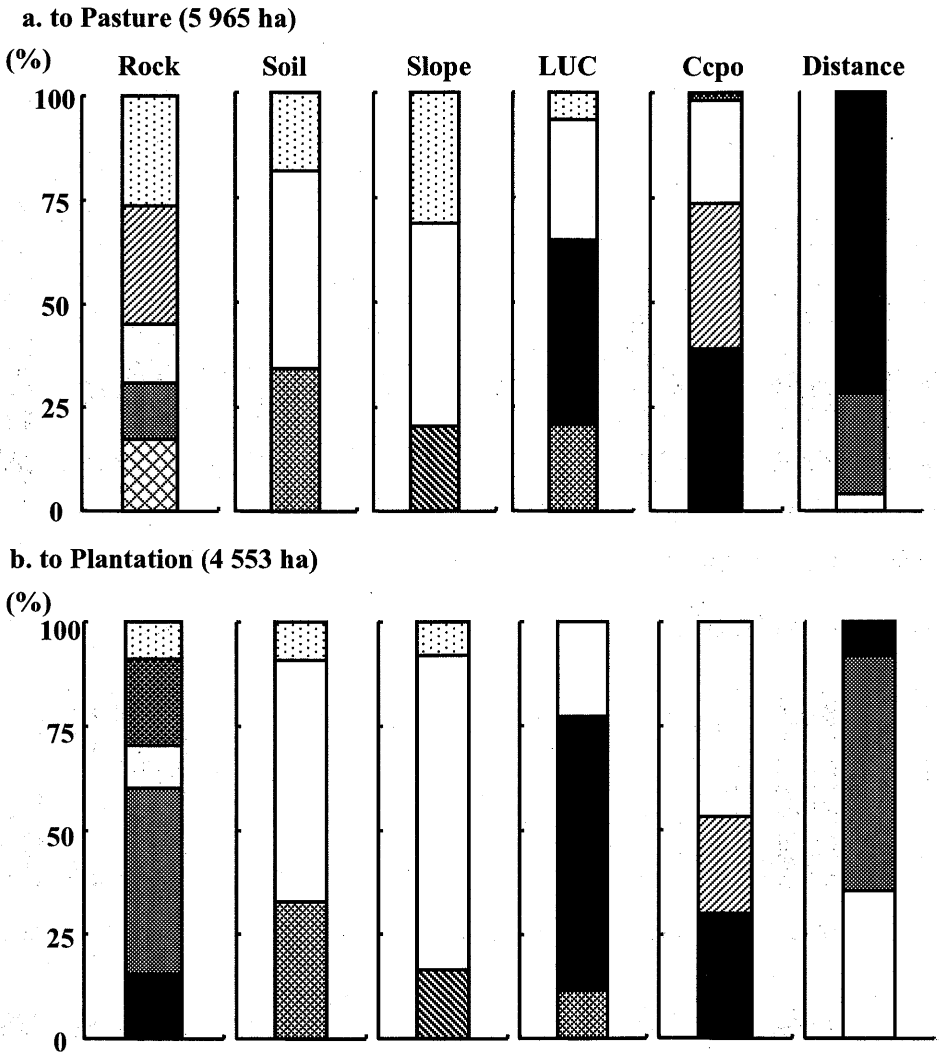
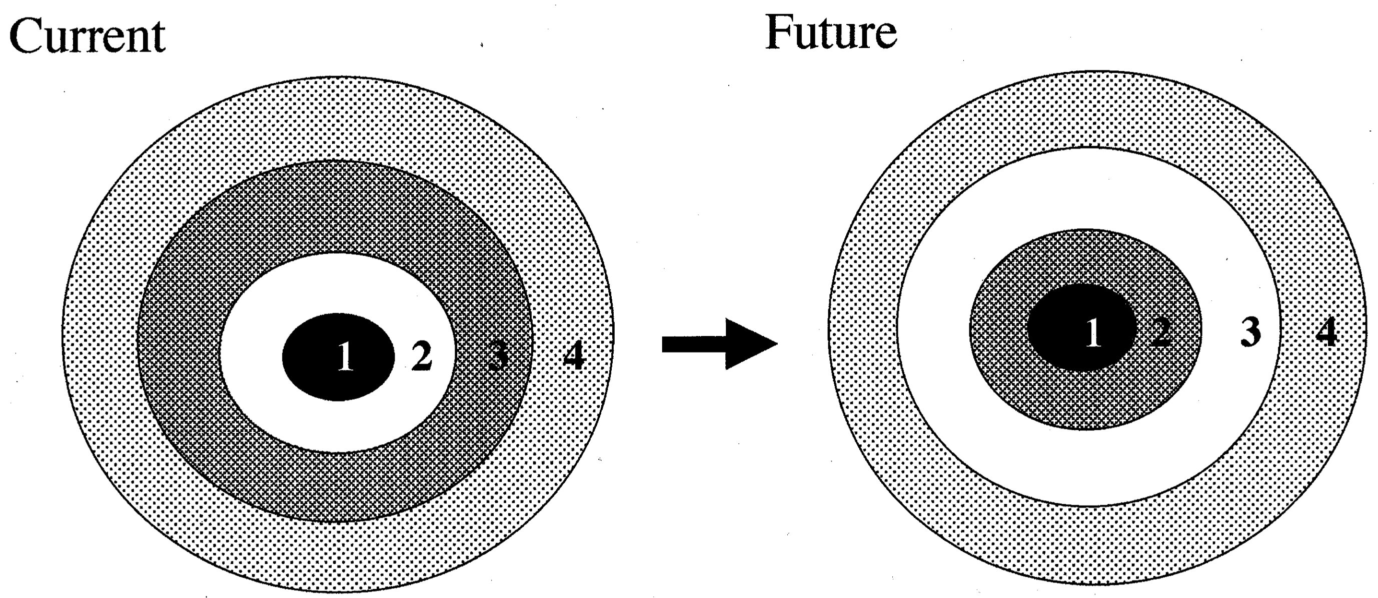


Fig. 4-4 Characteristics of land changed from indigenous forest.

Note: Rock type - ◩ : Al; ■ : Ar; ▩ : Cw; □ : Gn; ▩ : Gw; ▨ : Ms; ⛆ : Others. Soil type - ▩ : HCPYB; □ : YB; ⛆ : Others. Slope type - ▧ : Moderately steep; □ :Steep ; ⛆ : Others. LUC - ▩ : 6e; ■ : 7e; □ : 8e; ⛆ : Others. Ccpo - ■ : 0-5; ▨ : 6-10; □ : 11-15; ▩ : 21-25. Distance - □ : 0-40; ▩ : 40-65; ■ : 65-130.



- City
- Horticulture, Pasture and Plantation area
- Transitional zone from plantation dominant area to indigenous forest area
- Indigenous forest area

- City
- Horticulture and Plantation area
- Pasture
- Indigenous forest area

Fig. 4-5 Current and future land-use distribution pattern.

Chapter 5

Future Land-use and the Resource Management Act

5.1. Introduction

Predicting the future land-use change and comparing it with regional and district plans under the Resource Management Act (RMA) are essential for interpreting how the RMA affects the land-use dynamics.

Development of Models is a common method for simulating and exploring land-use change. A large numbers of studies have developed models predicting land-use dynamics (review are given in Baker, 1989; Sklar and Costanza, 1991). In general, there are two kinds of models; one developed to design alternatives for present land-use (e.g. Schipper, 1996, cited by Verburg *et al.*, 1999) and the other developed to explore possible changes in land-use in the near future as a function of driving forces (e.g. Costanza et al., 1990; Zuidema et al, 1994; Hall et al., 1995; Veldkamp and Fresco, 1996). The models belonging to the latter group provide information about the scope and impact of land-use change. Therefore, it is useful for land-use planners or managers to identify areas that require priority attention (Verburg *et al.*, 1999).

Models based on discriminant analysis (e.g. Tappeiner et al., 1998) belong to the latter group mentioned above, which are proper for predicting the possible land-use change in the near future. However, it is noticeable that the derived discriminant models can only be assumed stable for short time periods (e.g. ～20 years) because there is no principal causal dependency between the land-use change patterns and its determining socio-economic and biophysical factors. In other words, the land-use change patterns would change if the socio-economic factors determining the land-use change pattern altered.

The discriminant model derived in chapter 4 showed a high suitability for predicting future land-use. Assuming that the 7 land-use change patterns and their factors explained in chapter 4 will not change, this chapter aims to predict on which specific area the 7 land-use patterns would occur in the Nelson region. The predicted land-use changeable area was then compared to the Nelson and Tasman Resource Management Plan (RMP) Planning Maps to interpret the effect of the RMA on future land-use change. The expansion possibility of plantation forestry, horticulture, and pastoral farming, were also discussed.

5.2. Method

Using the Fisher's classification function derived from the discriminant analysis in chapter 4, the convertible area of indigenous forest, shrub, and pasture to other land-use on the LCDB map were predicted. Those land-use changeable areas were mapped individually.

Areas with high conversion possibility might be restricted by the regional or district RMPs for the purpose of sustainable resource management. Thus, each predicted land-use change map was overlaid to the Nelson and Tasman RMP Planning Maps and the area with high limitation was calculated to interpret the effect of the Plan. Patches less than 10 ha arose from overlaying were again excluded from the calculation because of their high possibility of errors.

5.3 Areas with high conversion possibility

1) From indigenous forest

The Fisher's classification function derived from the discriminant analysis can utilize in order to understand to which group a certain data (in this case, a certain patch) would belong.

As there were two land-use change patterns from indigenous forest, to pasture and to plantation, two classification functions had calculated. The function for pasture was,

$$X=0.761*[Dcc]+1.991*[Ccpo]+8.416*[LUC]+3.492*10^{-3}*[rock]+0.253*[soil]+0.887*[slope]-40.216$$

The function for plantation was,

$$X=0.412*[Dcc]+2.156*[Ccpo]+9.710*[LUC]-0.028*[rock]+0.253*[soil]+0.276*[slope]-40.758$$

Comparing the values obtained by substituting each explanatory variable for each function, the data (patch) belongs to the group that showed the largest value. For instance, if it is assumed that land characteristics of patch A is "Dcc" 30-35 km, "Ccpo" 11.0, "LUC" 6e, "rock" argillite (Ar), "soil" YB, and "slope" moderately steep, the value calculated from the function of pasture would be 26.380. The value calculated from the function of plantation would be 27.618. As the value for plantation is larger than that of pasture, patch A has the greater possibility to be converted to plantation.

Predicting all patches of current indigenous forest in this way, 129,016 ha of the total (525,043 ha) showed a higher conversion possibility to plantation and 382,543 ha to pasture (Table 5-1and Fig. 5-1). "Not predictable" showed in table 5-1 is a group of patches which could not classify because no conversion had observed on their site conditions in the past.

2) From shrub

Shrub land was developed intensely over those 20 years and converted mainly to pasture and plantation. The classification function for pasture was,

X=-0.094*[Dcc]+4.811*[Ccpo]+13.882*[LUC]+0.697*[rock]+1.051*[soil]+3.661*[slope]-109.102

And the function for plantation was,

X=-0.235*[Dcc]+4.702*[Ccpo]+13.870*[LUC]+0.664*[rock]+1.066*[soil]+3.653*[slope]-106.515

The result of the calculation indicated that approximately 45,600 ha would convert to plantation and 41,700 ha to pasture (Table 5-2 and Fig. 5-2). The change of remained 2 400 ha was not predicable.

3) From pasture

The classification functions for land-use change from pasture were as the following,

(a) to shrub

X=-0.074*[Dcc]+2.504*[Ccpo]+4.787*[LUC]+0.189*[rock]+0.452*[soil]-0.349*[slope]-45.503

(b) to plantation

X=-0.264*[Dcc]+2.512*[Ccpo]+4.681*[LUC]+0.144*[rock]+0.531*[soil]-0.201*[slope]-44.179

(c) to horticulture

X=-0.425*[Dcc]+2.376*[Ccpo]+3.482*[LUC]+0.207*[rock]+0.502*[soil]-0.162*[slope]-31.855

The result of comparing the three values calculated from those functions showed that 67,621 ha would change to shrub, 42,372 ha to plantation, and 33,288 ha to horticulture (Table 5-3, Fig. 5-3). The remaining 5,659 ha were not predictable.

5.4 The effect of the Nelson Resource Management Plan

As mentioned in chapter 2, all lands in the Nelson City are divided into one of the zones: Residential, Inner City, Suburban Commercial, Industrial, Open Space and Recreation, Rural, and Conservation zone. The rules stated in each zone are the method to achieve the objectives for each zone and have a force to prohibit, regulate, or allow the activities. This implies that the Nelson Resource Management Plan (NRMP) might be able to restrict a certain predicted land-use change. The Overlays representing the areas with particular issues also include rules that have a great influence on activities. In particular, the Conservation Overlay and Landscape Overlay can largely affect the land-use change pattern.

For those reasons, understanding the relationship between the possible land-use changes and the rules of each zone or overlays is essential for interpreting the effect of the Resource Management Act on land-use change. Overlaying the predicted land-use change areas and the maps showing the zones or the two overlays, this section discusses in what extent the NRMP would restrict the predicted land-use change.

1) Indigenous forests convertible to plantation

Approximately 84% (8,500 ha) of the indigenous forest convertible into plantation in the Nelson City (10,090 ha) belonged to the Conservation Zone (Table 5-4 and Fig. 5-4). The Conservation Zone is a zone including significant portions of conservation estate and is managed to maintain its natural state as far as possible. Activities damage the natural features and harm or introduce change which may harm the natural ecosystems, are restricted. Therefore, the conversion of indigenous forest to plantation is not likely to happen in this zone. The zone rule notes even of the effect of plantation forestry close to the zone because it might result in wilding exotic vegetation taking over from native vegetation. In fact examples have already been reported in the Red hills damaging the appearance and native vegetation (Nelson City Council, 1999a; Ledgard, 2001). In order to avoid this kind of damage, the NRMP states that forestry close to this zone needs to be considered deeply and avoid "take-off" sites where local wind conditions are likely to favor wide or long distribution of seed.

The remaining 16% of the predicted area was parted to the Rural zone (Table 5-4 and Fig. 5-4). Farming and forestry are recognized as important elements characterized the rural landscape and therefore, establishing plantation forests is basically a permitted activity in the zone. However, clearance of indigenous forest is strongly restricted and it is only permitted if the total cleared area on any one certificate of title in any three years period does not exceed 0.2 ha. Hence, the conversion of indigenous forest to plantation hardly occurs in this zone.

No area changeable to plantation was distributed in the landscape overlay. However, about 200 ha were distributed within the Conservation Overlay (Table 5-4 and Fig. 5-5). The Conservation Overlay is the area with significant conservation values out of Conservation zone. As activities in the area will restricted by the rules both of Rural zone and Conservation Overlay, the indigenous forest might be reserved more strictly than areas only adopted by the Rural zone rules.

2) Shrub convertible to plantation

The areas convertible from shrub to plantation, belonged to four zones: Conservation, Open Space and Recreation, Residential, and Rural zone. Most of the area was in the Rural zone (5,143 ha, 72%) where vegetation clearance other than indigenous forest is only restricted in the area within 5 m from the riverbanks or 20 m from the Coastal Marine Area. This suggests the low restriction potential on land-use conversion in the Rural zone. The Conservation zone occupied 20% (1,488 ha) of the total, where conversion is restricted. The Residential zone and the Open Space and Recreation zone occupied 264 ha and 136 ha, respectively (Table 5-5 and Fig. 5-6). Conversion to plantation in those two zones is discretionary or non-complying activity and therefore, needs a resource consent.

Landscape overlay is an area with significant scenery value and with high sensitivity to development, such as areas adjacent to city, coast, or main traffic routs. The overlay covered about 900 ha of the predicted area of which 640 ha were in the Rural zone. In addition, 110 ha of the area in the Rural zone were also covered by the Conservation

Overlay (Table 5-5 and Fig. 5-7). Consequently, in total, 750 ha of the predicted area in the Rural zone were expected to be restricted to establish plantation forests.

3) Shrub convertible to pasture

Only 16 ha of the shrub were predicted to change to pasture, which whole area was included in the Rural zone (Table 5-6 and Fig. 5-8). As farming is a permitted activity in the zone and no area was under either the Conservation Overlay or Landscape Overlay, no restriction is imposed on the area.

4) Pasture convertible to plantation

Pastures convertible to plantation distributed on Conservation, Residential, Open Space and Recreation, and Rural zone. Rural zone was the dominant and occupied 3,930 ha (93%). The second dominant zone was Residential zone (5%) followed by Open Space and Recreation zone (1%) and Conservation zone (1%) (Table 5-7 and Fig. 5-9). As mentioned before, establishment of plantation in the latter three zones had some regulation whereas it is permitted activity within the Rural zone.

Eighteen hector of the area belonged to the Rural zone were under the Conservation Overlay and 728 ha were under the Landscape Overlay. Hence, 746 ha of the area within the Rural zone were presumed not changeable (Table 5-7 and Fig. 5-10).

5) Pasture convertible to horticulture

The majority of the area belonged to Rural zone (80%) followed by Residential (13%), Industrial (4%) and Open Space and Recreation zone (3%)(Table 5-8 and Fig. 5-11). Horticulture is also one of the activity characterize the Rural zone and thus, it is a permitted activity. The Industrial zone was established for supplying industrial lands and the use for non-industrial activities is limited. For example, car assembly plants, timber yards, and processing plants occupy the zone. Although no specific statement regulating horticultural use was found, it was considered to be difficult to convert the pasture to horticultural land. The reason for this is because the land for industry is becoming scarce these days due to high rates of growth and is lacking for suitable alternative areas (Nelson City Council, 1999a). Horticulture is taking place at the Horticulture Parks within the Open Space and Recreation zone, but establishing a new horticulture land in other areas in this zone is a non-complying activity. As well as establishment of plantation forests, conversion to horticulture land within the Residential Zone is a discretionary activity and thus needs a resource consent.

Landscape Overlay covered 15 ha of the predicted area within the Rural zone, which limits its conversion (Table 5-8 and Fig. 5-12).

5.5 The influence of the Tasman District Resource Management Plan

As the NRMP, the Tasman District Resource Management Plan (TRMP) is taking a zoning approach. The Zones are Central Business, Commercial and Tourist Services zone, Conservation zone, Industrial zone, Residential zone, Rural Industrial zone, Rural 1 zone, Rural 2 zone, Rural Residential zone, Recreation zone, and Open Space zone. The rules for each zone limit the activities which might adversely affects the environment. The rules for special areas such as Natural Heritage Areas and Landscape Priority Areas are applied in addition to the zone rules, which means the land-use change would be restricted more strictly.

In order to understand the actual influence of the rules for zones and special areas on future land-use change in the Tasman District, each zone or area map was overlaid on the predicted land-use change maps and areas with high restriction possibility were examined. Special areas discussed in here are Groundwater Recharge Protection Area (GRPA), Landscape Priority Areas (LSPA), Natural Heritage Areas (NHA), and Slope Stability Hazard Area (SSHA), which were strongly related to the land-use changes.

1) Indigenous forests convertible to plantation

Eighty-seven percent (103,962 ha) of the area belonged to the Conservation zone where no land-use can carry out if it is not approved by the conservation management strategy proposed for the area under the Conservation act 1987 or Reserves Act 1977. This represents the district's high priority on protecting the remaining indigenous forest. The remaining areas out of conservation zone (14,924 ha) were observed mainly in Rural 2 zone (14,756 ha) followed by Rural 1 (100 ha) and Rural Residential Zone (68 ha)(Table 5-9 and Fig. 5-13). Although forestry is a permitted activity within those three zones, the rules regulate activities destruct or remove indigenous forest. The destruction or removal of indigenous forest is only permitted either if the activity is subject to an approved sustainable forest management plan or permit under Part IIIA of the Forest Act 1949. Therefore, the conversion of indigenous forest to plantation is not likely to happen.

The GRPA was established in order to avoid reduction of annual runoff by establishing plantation forests. Replanting is permitted in this area if it does not exceed the area of existing forest. However, new planting is only permitted if no more than 50 % of the area of any certificate of title may be in plantation forestry at any time. Fifty-six hector in Rural 2 zone was included in this area (Table 5-9 and Fig. 5-14). The LSPA are designating landscapes and natural features with significant character, quality, and visibility, which is outside of the National Parks. Nineteen hector of the predicted area within the Rural 2 Zone was included in this area (Table 5-9 and Fig. 5-14). Plantation forestry is not permitted in here and therefore needs a resource consent. No predicted area was under the SSHA, which established for avoiding soil erosion and slope instability. More than half of the predicted area in Rural 2 Zone was distributed in the NHA (Table 5-9 and Fig. 5-14). The NHA is identified for protecting significant indigenous vegetation and significant habitats of indigenous fauna. Modification in the area is not permitted unless it is approved by the Queen Elizabeth the Second National Trust Act 1977 or is limited to the removal of dead standing timbers for the owner's use.

Although the zone rules were strongly limited the conversion, the rules of the Special Areas can restrict even the activities that satisfy the zone rules. This suggests lesser possibilities of indigenous removals within the Tasman District.

2) Indigenous forest convertible to pasture

The majority of the area changeable to pasture distributed in the Conservation Zone followed by Rural 2 Zone, and Rural Residential (Table 5-10 and Fig. 5-15). As explained before, the removal of indigenous forest is restricted in all zones and therefore, conversion to pasture is unlikely to happen.

Some areas within Rural 2 zone and Rural Residential zone were found under the NHA: occupied 16,735 ha and 222 ha, respectively. Nineteen hector within the Rural 2 zone was also found under the LSPA. There were no areas distributed in GRPA and

SSHA(Table 5-10 and Fig. 5-16). Consequently, 56% of the area in the Rural 2 zone and 78% of the Rural Residential zone were under restriction due to the area rules. This fact indicates that the majority of the indigenous forests changeable to pasture are conserved very strictly by adopting both the zone and the area rules even if it is out of Conservation zone.

3) Shrub convertible to plantation

About 65% of the predicted area was found in the Conservation zone. The majority of the remaining 35% consisted of the Rural 2 zone (34%) and the area in Rural Residential zone was a little (less than 1%)(Table 5-11 and Fig. 5-17). In Rural 2 zone, removal of indigenous vegetation is only limited when the site is naturally occurring wetland greater than 500 square meters and the site includes indigenous dune vegetation, salt herb fields, and coastal shrub lands in the Coastal Environment Area. Establishment of plantation forests within the Rural 2 zone is a permitted activity if it complies with the regulated distance of setbacks for plantation forest (Appendix). Removing indigenous vegetation and establishing plantation forests in Rural Residential zone is a permitted activity under the same conditions with the Rural 2 zone. For this reason, it could be said that shrubs may be converted to plantations except in the Conservation zone.

However, approximately 3,000 ha of the areas outside of the Conservation Zones, were distributed in the Special Areas (Table 5-11 and Fig. 5-18). In detail, 2,614 ha were under the NHA, 87 ha under the SSHA, 58 ha under the GRPA, and 27 ha under the LSPA. As explained above, plantation forestry is not a permitted activity in those areas and therefore, the remaining 10,000 ha was considered to be convertible without resource consents.

4) Shrub convertible to pasture

The Rural 2 zone occupied half of the predicted area (52%) and the Conservation zone occupied most of the other half (44%). Other miner zones were Rural Residential (3%)and Rural 1 zone (1%) (Table 5-12 and Fig. 5-19). As well as Rural 2 zone and Rural Residential zone, removing indigenous vegetation in Rural 1 zone is only restricted if it is a wetland or coastal environmental area. Farming in the Rural 1 and 2 zones are also permitted. However, if the land-use is intensive pig farming, it is not permitted unless the distance of setbacks is satisfied. On the other hand, farming is designated as a discretionary activity in the Rural Residential Zone. Based on all of the zone rules, conversion of shrub to pasture can be carried out within Rural 1 and 2 zones (totally, 22 055 ha).

Among the areas within the two zones, approximately 3,000 ha belongs to the NHA and 93 ha to the SSHA, which indicates only 19,030 ha of the total area (41 349 ha) is available for establishing new pastures (Table 5-12 and Fig. 5-20).

5) Pasture convertible to plantation

Almost all of the predicted area was found convertible to plantation under the zone rules since the area was distributed in Rural 1 and 2, and Rural Residential zones (Table 5-13 and Fig. 5-21). Only 1% was in the Residential and Rural Industrial Zone. Plantation forestry is difficult to take place in those minor zones because the former restricts even establishment of new horticulture unit to avoid the adverse effect of trees to the neighbors such as shading, and because the latter is the area for rural industry but not for agriculture or forestry.

Plantation establishment will not be approved in the predicted area observed under the GRPA (2,498 ha) and the NHA (837 ha) according to their rules. However, areas found in the SSHA (152 ha) have some possibility if the planting is for soil conservation since the purpose of the area is to stabilize the slope (Table 5-13 and Fig. 5-22).

6) Pasture convertible to shrub

Pastures with high abandonment possibility were detected in Rural 1, Rural 2, Rural Residential, and Residential zones (Table 5-14 and Fig. 5-23). No particular statements were found in the zone rules that expressing the adverse effect of pasture abandonment and the following succession process. Hence, the abandonment is only restricted by the area rules. It is clear that pastures under the LSPA (419 ha) and the NHA (2,785 ha) need to maintain its condition to preserve its significant character or visibility (Table 5-14 and Fig. 5-24). On the other hand, rules of the SSHA restrict tree removal but not regeneration and thus, regeneration to shrub from pasture is possible to occur.

7) Pastures convertible to horticulture

Combining the predicted areas belonged to Rural 1, Rural 2 and Rural Residential zone where horticulture are permitted activity if the setbacks meet the rules (Appendix), the area occupied 98% of the total (Table 5-15 and Fig. 5-25). Conversion in the remaining 2% will rarely happen because of the rules for Residential, Rural Industrial and Recreation zones. Establishing new horticultural units within the Residential zone is limited to mitigate the adverse effects associated with the use of agricultural sprays which contravene the rule for air emission and dust. Rural Industrial zone is opened only for rural industries such as wood or food processing, and the land-use in Recreation Zone is limited to recreational use.

Nearly 300 ha of the area belonging to zones with no limitation for alteration, were found in the NHA, 411 ha in the GRPA, and 80 ha in the SSHA (Table 5-15 and Fig. 5-26). As explained before, areas in the NHA expected to remain its state as pasture and areas in SSHA might be able to change. While the rules of the GRPA restrict establishing plantation forests, no particular statement on horticultural use was found. It could be said that establishing new horticultural unit within the area is legally permitted, but concerns still remain whether it does not have any adverse effect on water flow.

5.6 Discussion

Areas where possible to experience land-use change to plantation, pasture and horticulture in the whole Nelson region was 216,984 ha (Table 5-16), 423,835 ha (Table 5-17), and 32,994 ha (Table 5-18) respectively (calculated based on Table 5-1, 5-2, and 5-3). However, each area decreases when the zone or area rules of the Nelson and Tasman RMPs were considered. Assuming that the land-use change only occurs within the area where it is a permitted activity, each of the convertible area decreases to 52,255 ha for plantation (Table 5-16), 19,027 ha for pasture (Table 5-17), and 31,406 ha for horticulture (Table 5-18). The reason for the remarkable reduction of the area for plantation and pasture were because large proportion of the area was predicted to convert from indigenous forest in the Conservation zone and other zones or areas that restrict the removal of indigenous forest. Shrub, which was the target to develop during the last 20 years, also contributed to the reduction by becoming a target of conservation under the RMPs. The area of horticulture showed only a little reduction because it was predicted to convert from pasture, which was less important in terms of its conservation value and was weakly restricted by the zone or area rules.

The conservation state of the current indigenous forest and shrub could be confirmed by figure 5-27. Almost all of the indigenous forest or shrub on the hill country surrounding the Nelson region is protected by the RMPs, which suggests the effectiveness of the RMPs on nature conservation. Although it is important to protect large patches of indigenous vegetation as the NRMP and the TRMP ensure, protection of fragmented indigenous forest and shrub on the lowland is another important issue in New Zealand (Taylor et al., 1997; Dickinson et al., 1998; Nelson City Council, 1999b; New Zealand Department of Conservation and Ministry for the Environment, 2000). The importance of lowland forest is also mentioned in the TRMP and the NHA was placed for protecting those fragmented indigenous vegetation. Nonetheless, a large blank of conservation area is observed on the lower lands in the middle of the Tasman District (Fig. 5-27). Most of the lands in this area were predicted to convert to plantations (Fig. 5-28). Lowland forests contain many of the New Zealand's unusual plants and animals (Ogedn, 1997; New Zealand Department of Conservation and Ministry for the Environment, 2000). Partial removal or fragmentation of ecosystems into "islands" lead their animal or plant populations in danger of extinction: from chance events like fire and flood; from lack of replenishment by immigration; and from increased competition – as the small "islands" can support only a few species comparing with the non-fragmented ecosystems (Bull, 1981; Taylor et al., 1997; Malanson and Cramer, 1999). It is said that patches of about 5 ha with 1 ha in a core (Young and Mitchell, 1994) are necessary at 5 km centers, with connecting corridors to maintain viable population for most of the New Zealand's wildlife (Meurk and Swaffield, 2000). This is recommended as a tangible goal for sustainable ecology together with the 20% area cover standard (Meurk, 1999). According to those studies, it could be said that the TRMP is insufficient to conserve lowland vegetation. Conserving the fragmented lowland forest or shrub and connecting those patches to the adjacent matrix of indigenous forest is necessary.

Currently, plantations surround the fragmented indigenous vegetation on lowlands (see Fig. 2-18) and further expansion is predicted (Fig. 5-28). This implies the possibility of plantation to take role as a corridor to connect those indigenous habitats. Although it is generally considered that the biodiversity in plantations is poor, various studies indicated that it is richer in biodiversity than previously considered (Allen et al., 1995b; Spellerberg and Sawyer, 1995; Dyck, 1997). Many studies reported that plantations have quite high plant species richness in their understories (e.g. Allen et al., 1995a; Ogden et al., 1997) and have an ability to maintain native birds (e.g. Gibb, 1961; Clout, 1980; Clout and Gaze, 1984). Hence, a plantation might function as a corridor to some extent.

However, covering most of the lowlands by plantation may contribute little to habitat or nature conservation. It is recognized that "Oases" of the native forest adjacent to or scattered in the plantations are important for the existence of native birds in plantations (Clout, 1980). It is also known that numbers of frugivorous and nectar-feeding birds and those requiring tree holes for nesting decrease in a matrix of plantation (Clout, 1984). Covering most of the lowlands with plantations as it was predicted (Fig. 5-28), will also lead the landscape homogeneous, which means that conservation or enhancement of biodiversity could be more difficult and threatened species could be more vulnerable (Naveh, 1994). Hence, in order to improve biodiversity and achieve sustainable ecosystem on lowlands in the Nelson region, planning at a landscape level that makes lowland landscape more diverse while paying attention on the patch size, location and connectivity of the indigenous vegetation is essential. For instance, this may be achieved by 1) retaining some old or dead trees as nest site and planting plants that can attract birds as food sources; 2) maintaining or establishing pastures or grassland (to avoid the plantation occupying the lowlands); and 3) conserving the current fragmented indigenous forest or shrub and setting up wide continuous corridors or stepping stones of indigenous vegetation by promoting regeneration.

It is notable to consider how to increase biodiversity while establishing plantations since the lowlands were predicted as an area with high plantation expansion possibility. Planting native species that attract frugivorous and nectar-feeding birds is effective not only for increasing the bird diversity but also for enhancing the plant species diversity within plantations. Old conifer stands can function as sanctuaries for birds (Clout, 1984) and also make the plantations more diverse. Retaining dead trees enables the birds need tree wholes to nest.

Maintaining or establishing pastures among forested area provides higher landscape diversity, and thus, contributes to enhance biodiversity. Some studies reported that pasture had larger number of invertebrate species than plantation especially on the boundary of forest and pasture (New Zealand Department of Conservation and Ministry for the Environment, 2000). Nevertheless, the prediction suggested that pastures on lowlands would decrease significantly due to the conversion to plantation and horticultural land.

The land-use competition between pasture and horticulture or plantation has been one of the biggest issues in New Zealand for a long time, especially on the lowlands where various kinds of land-uses are available (e.g. Chapman, 1962; Ward, 1963; McIntosh and Durbin, 1981; Fletcher, 1984; Ward and Cooper, 1997). In the Nelson region, it seems that the competition between pasture and plantation had been a greater issue than between pasture and horticulture based on the questionnaire conducted in 1984 (Smith and Wilson, 1984). The lands for horticulture needed to be fertile and was considered to be limited on LUC class 1 and 2, whereas pasture can be establish on lands with lower fertility and the LUC class 6 or 7 (Fletcher, 1984). Because of this land condition difference, the competition between pasture and horticulture was not regarded that serious. However, the land condition for plantation was exactly the same with pastoral farming and therefore, large argument between those two had occur. Nevertheless, in this study, the total area of pasture convertible to plantation and to horticulture showed only a little difference (Table 5-19), which suggests the competition between horticulture and pasture is also a big problem for maintaining pasture on lowlands. Higher competition of horticulture than the result of the questionnaire was pointed out because some of the lands with LUC class 3 were considered as an available land for horticulture in this study.

As horticulture and forestry is more profitable than pastoral farming (Fletcher, 1984; Masui, 1996), and land-use will change as a consequence of the profitability (Le Heron and Roche, 1985), pasture will difficultly compete with the former two land-use. In fact, the residents in the Nelson region now consider forestry and horticulture as a growth industry and are welcome their expansion (Parker, 1992) . However, still there is one solution that can achieve both the landowner's desire of profitable land-use and the improvement of landscape diversity by maintaining pasture. Farm forestry is it. As it is a set of forest and pasture which is more complex than the blanket-planted radiata pine, and the planted species is not always radiata pine but also the second-tier species such as cypresses, eucalypts, blackwoods, it is said that farm forestry has the ability to retain much higher level of biodiversity than the large scale corporate forestry (Treeby, 1997). It also can contribute to protect the traditional rural values and to avoid soil erosion by planting trees (Maclaren, 1996). In addition, a report indicated that returns from grazing do provide the expected short-run revenue to cover interest on invested capital while rate of tree growth portends a saw-log yield in line with prediction (Stover, 1979). The area of farm forestry is expanding recently (Hawke and Wedderburn, 1994; Kininmonth, 1997) and it is a promising land-use in both aspects of economic and environment.

As mentioned above, protecting the fragmented indigenous forest and shrub on lowlands is essential for maintain the environment on lowland for various kinds of indigenous flora and fauna species. In addition, promoting the connectivity of those fragmented forest by restoration is also important. However, productive systems occupying the land severely limit the opportunity to retire land for purely conservation purpose. Hence, regeneration must occur within the production matrix. Transforming plant species of shelterbelts, hedgerows, and riparian corridors to indigenous species could be one of the solutions (Meurk and Swaffield, 2000).

Pastures with high abandonment possibility might contribute to restore indigenous species, too. Once the pasture had been abandoned, it is known that introduce species such as gorse will invade and occupy the area (McQueen, 1993; Ledgard, 1994). Fortunately, most of the woody plants naturalized in New Zealand are light demanding and there are few cases of invasion of indigenous forest. Indeed, there are some studies report that introduced species can provide both nursery for indigenous plants (MacMillan, 1973; Norton, 1989) and habitat for indigenous fauna (Colbourne and Kleinpaste, 1983). For instance, gorse, one of the most widespread shrubs, is relatively short-lived and usually is replaced by indigenous shrubs within about 40 years, which suggests its ability to function as a nursery (McQueen, 1993). In order to establish a diverse landscape and to improve the region's biodiversity, the most efficient placements and techniques of restoration must be decided carefully. The restoration area must be placed on the most effective area to connect the fragmented forests. Leaving the area as it successes could be one technique but planting indigenous shrub or tree species could be another. The last target of the restoration could be the indigenous forest in some areas but shrub lands in another.

If this kind of landscape planning were conducted, the expandable area of plantation and horticulture would decrease a little. Nevertheless, it is clear that plantation or horticulture can still increase its area further more and would contribute to the region's economy as main industries. On the other hand, pasture might be able to increase its area by promoting farm forestry than it was predicted in this study. However, the prospect of pastoral farming is still not bright and its importance for the regional economy might diminish.

Table 5-1 Areas predicted to change from indigenous forest (ha)

	To Plantation	To Pasture	Not Predictable	Total
Nelson City	10,117	-	1,974	12,091
Tasman District	118,899	382,543	11,510	512,952
Total	129,016	382,543	13,484	525,043

Table 5-2 Areas predicted to change from shrub (ha)

	To Plantation	To Pasture	Not Predictable	Total
Nelson City	7,113	16	12	7,141
Tasman District	38,483	41,693	2,446	82,622
Total	45,596	41,709	2,458	89,763

Table 5-3 Areas predicted to change from pasture (ha)

	To Plantation	To Shrub	To Horticulture	Not Predictable	Total
Nelson City	4,272	0	1,532	141	5,945
Tasman District	38,100	67,621	31,756	5,518	142,995
Total Nelson Region	42,372	67,621	33,288	5,659	148,940

Table 5-4 Nelson Resource Management Plan and indigenous forest changeable to plantation

Zone Name	Area (ha)	%	Areas belonging to Overlays (ha)	
			Co	Lo
Conservation	8,508	84.3	-	-
Rural	1,581	15.7	209	-
Total	10,089	100.0	209	-

Note: Co: Conservation Overlay; Lo: Landscape Overlay.

The Total area (10,089 ha)shown in this table is less than that shown in table 5-1 because pathces less than 10 ha were excluded from the calculation due to their high possibility of errors.

Table 5-5 Nelson Resource Management Plan and shrub convertible to plantation

Zone Name	Area (ha)	%	Areas belonging to Overlays (ha)	
			Co	Lo
Conservation	1,488	21.2	-	-
Open Space and Recreation	136	1.9	-	123
Residential	264	3.8	-	103
Rural	5,143	73.1	113	642
Total	7,031	100.0	113	868

Note: Co: Conservation Overlay; Lo: Landscape Overlay.

The Total area (7,031 ha) shown in this table is less than that shown in table 5-1 because pathces less than 10 ha were excluded from the calculation due to their high possibility of errors.

Table 5-6 Nelson Resource Management Plan and shrub convertible to pasture.

Zone Name	Area (ha)	Areas belonging to Overlays (ha)	
		Co	Lo
Rural	16	-	-

Note: Co: Conservation Overlay; Lo: Landscape Overlay.

Table 5-7 Nelson Resource Management Plan and pasture convertible to plantation.

Zone Name	Area (ha)	%	Areas belonging to Overlays (ha)	
			Co	Lo
Conservation	35	0.8	-	-
Open Space and Recreation	37	0.9	-	18
Residenital	210	5.0	-	76
Rural	3,930	93.3	18	728
Total	4,212	100.0	18	822

Note: Co: Conservation Overlay; Lo: Landscape Overlay.

The Total area (4,272 ha) shown in this table is less than that shown in table 5-1 because pathces less than 10 ha were excluded from the calculation due to their high possibility of errors.

Table 5-8 Nelson Resource Management Plan and pasture convertible to horticulture.

Zone Name	Area (ha)	%	Areas belonging to Overlays (ha)	
			Co	Lo
Industrial	62	4.4	-	-
Open Space and Recreation	39	2.8	-	-
Residential	180	12.7	-	-
Rural	1,134	80.1	-	15
Total	1,415	100.0	-	15

Note: Co: Conservation Overlay; Lo: Landscape Overlay.

The Total area (1,415ha) shown in this table is less than that shown in table 5-1 because pathces less than 10 ha were excluded from the calculation due to their high possibility of errors.

Table 5-9 Tasman Resource Management Plan and indigenous forest changeable to plantation

Zone name	Area (ha)	%	Areas belonging to special areas (ha)			
			GRPA	LSPA	NHA	SSHA
Conservation	103,962	87.4	56	214	-	-
Rural 1	100	0.1	-	-	-	-
Rural 2	14,756	12.4	56	19	8,372	-
Rural Residential	68	0.1	-	-	-	-
Total	118,886	100.0	112	233	8,372	-

* The Total area (118,886ha) shown in the table is less than that shown in table 5-1 because patches less than 10 ha were excluded from the calculation because high possibility of errors were observed as a result of Overlaying.

Table 5-10 Tasman Resource Management Plan and indigenous forest changeable to pasture

Zone name	Area (ha)	%	Areas belonging to Special Areas (ha)			
			GRPA	LSPA	NHA	SSHA
Conservation	350,440	91.6	-	153	159	-
Rural 2	31,746	8.3	-	19	16,735	-
Rural Residential	284	0.1	-	-	222	-
Total	382,470	100.0	-	172.00	17,116	-

Note: The Total area (382,470 ha) shown in the table is less than that shown in table 5-1 because patches less than 10 ha were excluded from the calculation because high possibility of errors were observed as a result of Overlaying.

Table 5-11 Tasman Resource Management Plan and shrub changeable to plantation

Zone name	Area (ha)	%	Areas belonging to Special Areas (ha)			
			GRPA	LSPA	NHA	SSHA
Conservation	25,027	65.3	58	162	-	156
Rural 2	13,104	34.2	58	27	2,506	87
Rural Residential	215	0.6	-	-	108	-
Total	38,346	100.0	116	189	2,614	243

Note: The Total area (38,346 ha) shown in the table is less than that shown in table 5-2 because patches less than 10 ha were excluded from the calculation because high possibility of errors were observed as a result of Overlaying.

Table 5-12 Tasman Resource Management Plan and shrub changeable to pasture

Zone name	Area (ha)	%	Areas belonging to Special Areas (ha)			
			GRPA	LSPA	NHA	SSHA
Conservation	18,200	44.0	-	-	31	200
Rural1	459	1.1	-	-	14	-
Rural 2	21,596	52.2	-	-	2,937	93
Rural Residential	1,094	2.6	-	-	69	63
Total	41,349	100.0	-	-	3,051	356

Note: The Total area (41,349 ha) shown in the table is less than that shown in table 5-2 because patches less than 10 ha were excluded from the calculation because high possibility of errors were observed as a result of Overlaying.

Table 5-13 Tasman Resource Management Plan and pastures changeable to plantation

Zone Name	Area (ha)	%	Areas belonging to Special Area (ha)			
			GRPA	LSPA	NHA	SSHA
Residential	98	0.3	-	-	-	-
Rural 1	4,184	11.1	59	-	31	-
Rural 2	32,320	85.7	2,439	-	806	108
Rural Industrial	123	0.3	-	-	-	-
Rural Residential	981	2.6	-	-	-	44
Total	37,706	100.0	2,498	-	837	152

Note: The Total area (37,706 ha) shown in the table is less than that shown in table 5-3 because patches less than 10 ha were excluded from the calculation because high possibility of errors were observed as a result of Overlaying.

Table 5-14 Tasman Resource Management Plan and pastures changeable to shrub

Zone Name	Area (ha)	%	Areas belonging to Special Area (ha)			
			GRPA	LSPA	NHA	SSHA
Residential	104	0.2	-	-	-	-
Rural 1	7,570	11.2	-	-	47	-
Rural 2	59,100	87.6	-	419	2,738	156
Rural Residential	705	1.0	-	-	-	24
Total	67,479	100.0	-	419	2,785	180

Note: The Total area (67,479ha) shown in the table is less than that shown in table 5-3 because patches less than 10 ha were excluded from the calculation because high possibility of errors were observed as a result of Overlaying.

Table 5-15 Tasman Resource Management Plan and pastures changeable to horticulture

Zone Name	Area (ha)	%	Areas belonging to Special Area (ha)			
			GRPA	LSPA	NHA	SSHA
Recreation	103	0.3	-	-	-	-
Residential	245	0.8	-	-	-	-
Rural 1	19,598	62.1	227	-	198	-
Rural 2	11,105	35.2	184	-	142	57
Rural Industrial	193	0.6	-	-	-	-
Rural Residential	335	1.1	-	-	-	22
Total	31,579	100.0	411	-	340	79

Note: The Total area (31,579 ha) shown in the table is less than that shown in table 5-3 because patches less than 10 ha were excluded from the calculation because high possibility of errors were observed as a result of Overlaying.

Table 5-16 Areas available for plantation unit: ha

	Available areas				Areas not	Total
	Indigenous forest	Shrub	Pasture	Total	available	Predicted area
Nelson City	-	4,388	3,184	7,572	13,760	21,332
Tasman District	-	10,533	34,150	44,683	150,255	194,938
Whole Nelson Region	-	14,921	37,334	52,255	164,015	216,270

Table 5-17 Areas available for pasture

unit: ha

	Available areas			Areas restricted or not available	Total Predicted area
	Indigenous forest	Shrub	Total		
Nelson City	-	16	16	-	16
Tasman District	-	19,011	19,011	404,808	423,819
Whole Nelson Region	-	19,027	19,027	404,808	423,835

Table 5-18 Areas available for horticulture unit: ha

	Available areas	Areas not	Total
	Pasture	available	Predicted area
Nelson City	1,119	296	1,415
Tasman District	30,287	1,292	31,579
Whole Nelson Region	31,406	1,588	32,994

Table 5-19 Expansion possibility of pasture

unit: ha

	Pastures convertible to other land-use				Available for	
	to plantation	to horticulture	to shrub	Total ※1	new pastures ※2	※2 -※1
Nelson City	3,184	1,119	-	4,303	16	-4,287
Tasman District	34,150	30,287	64,275	128,712	19,011	-109,701
Whole Nelson Region	37,334	31,406	64,275	133,015	19,027	-113,988

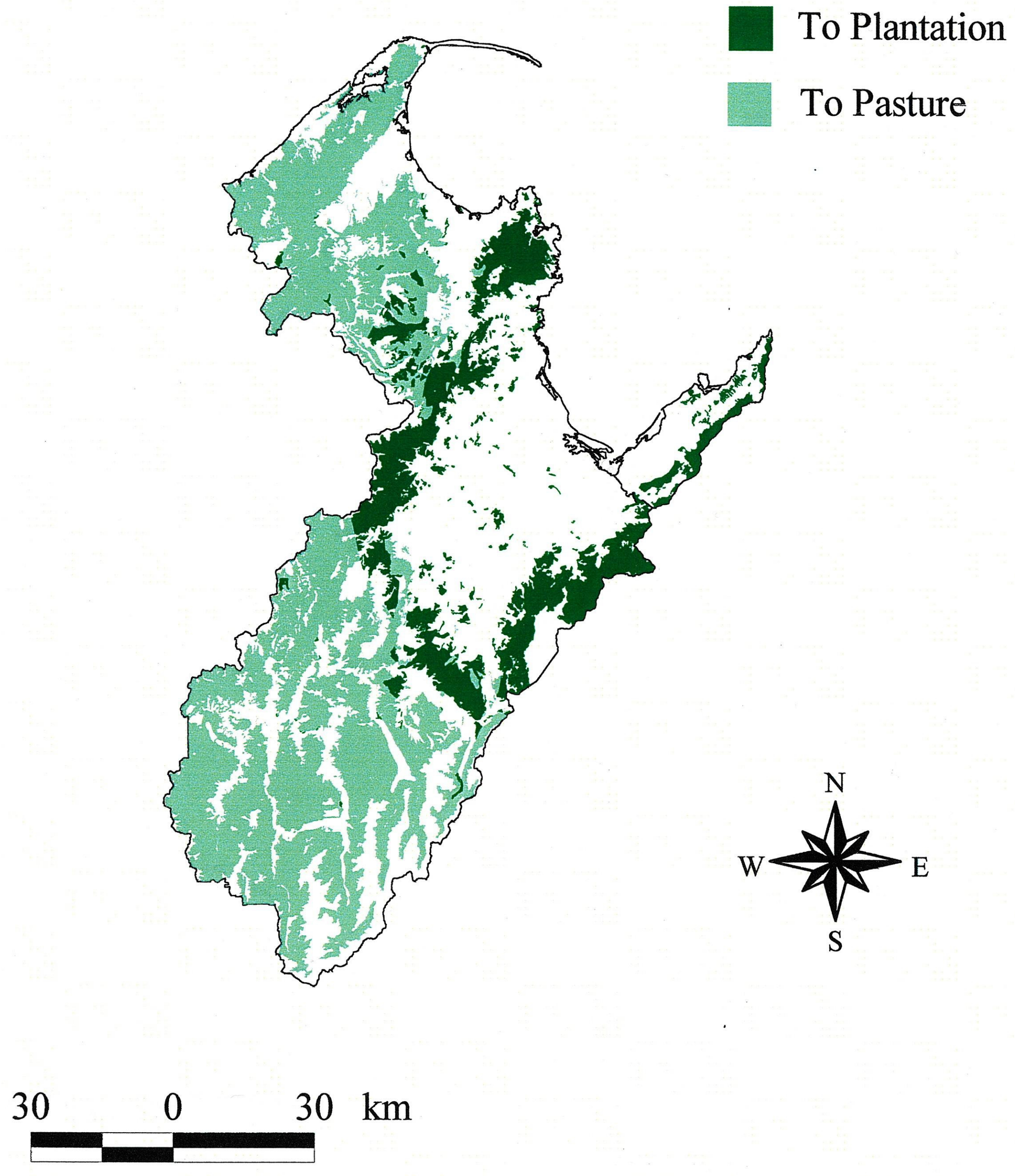


Fig. 5-1 Indigenous forest convertible to plantation and pasture.

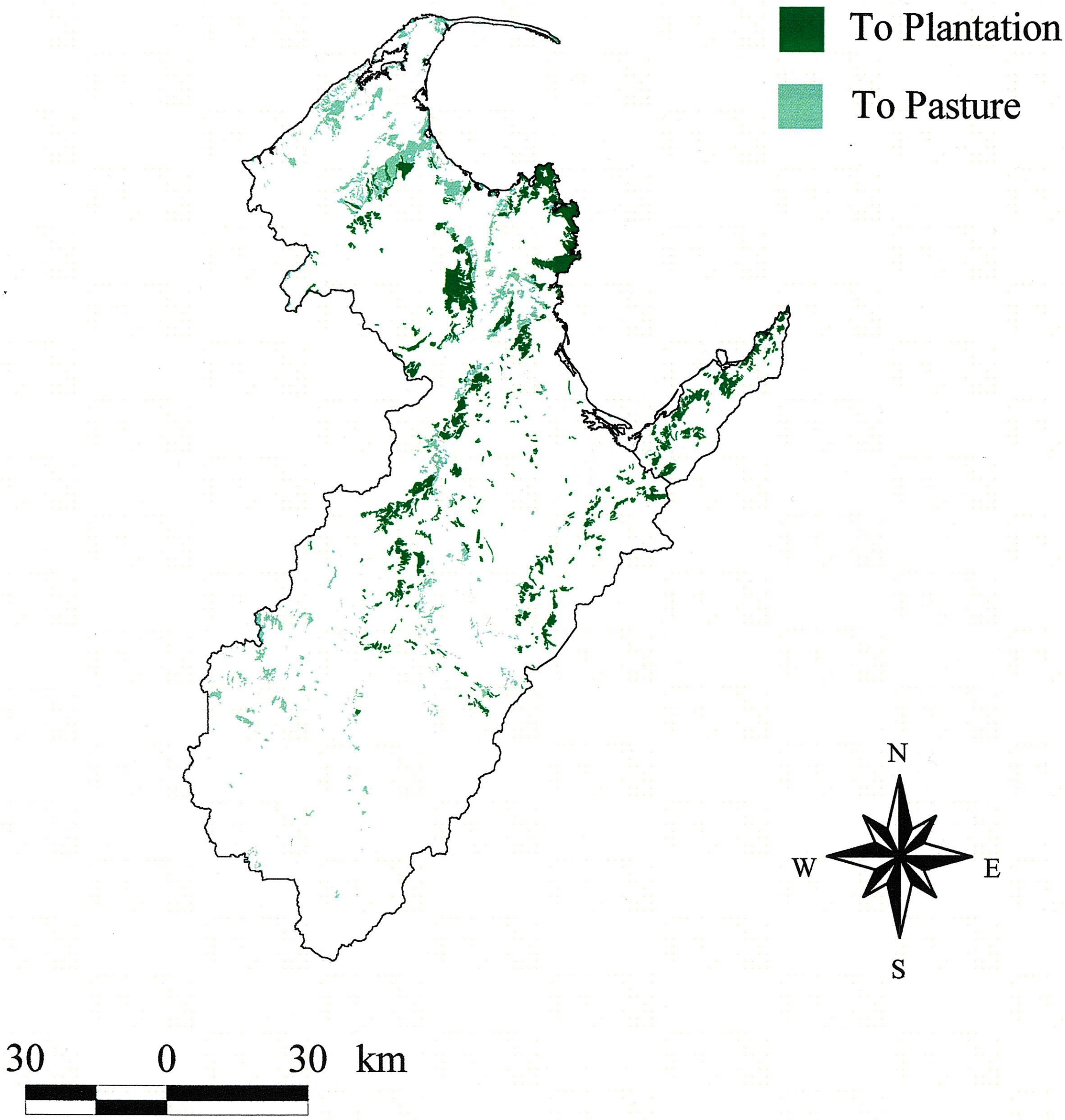


Fig. 5-2 Shrub convertible to plantation and pasture.

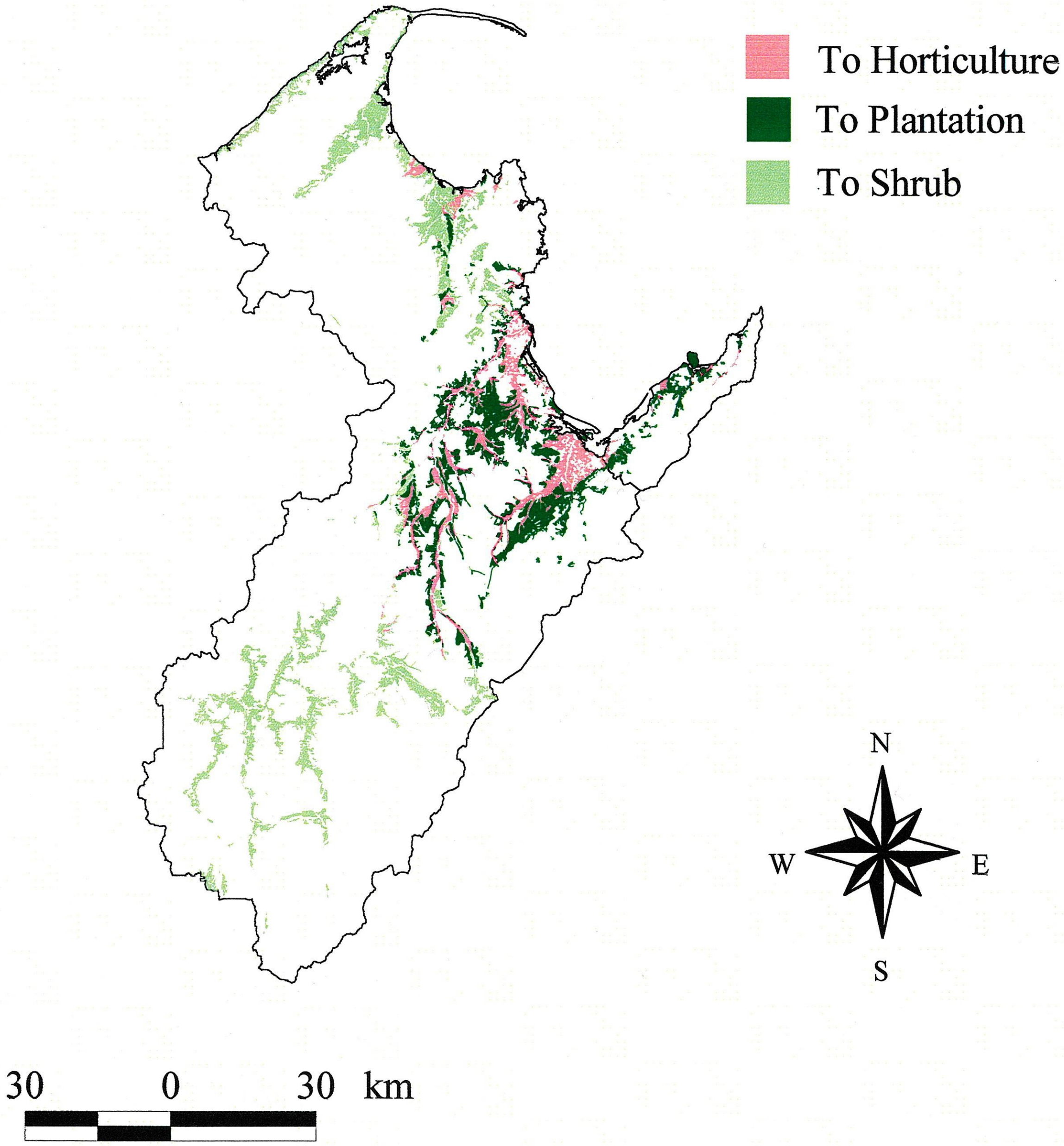


Fig. 5-3 Pasture convertible to horticulture, plantation and shrub.

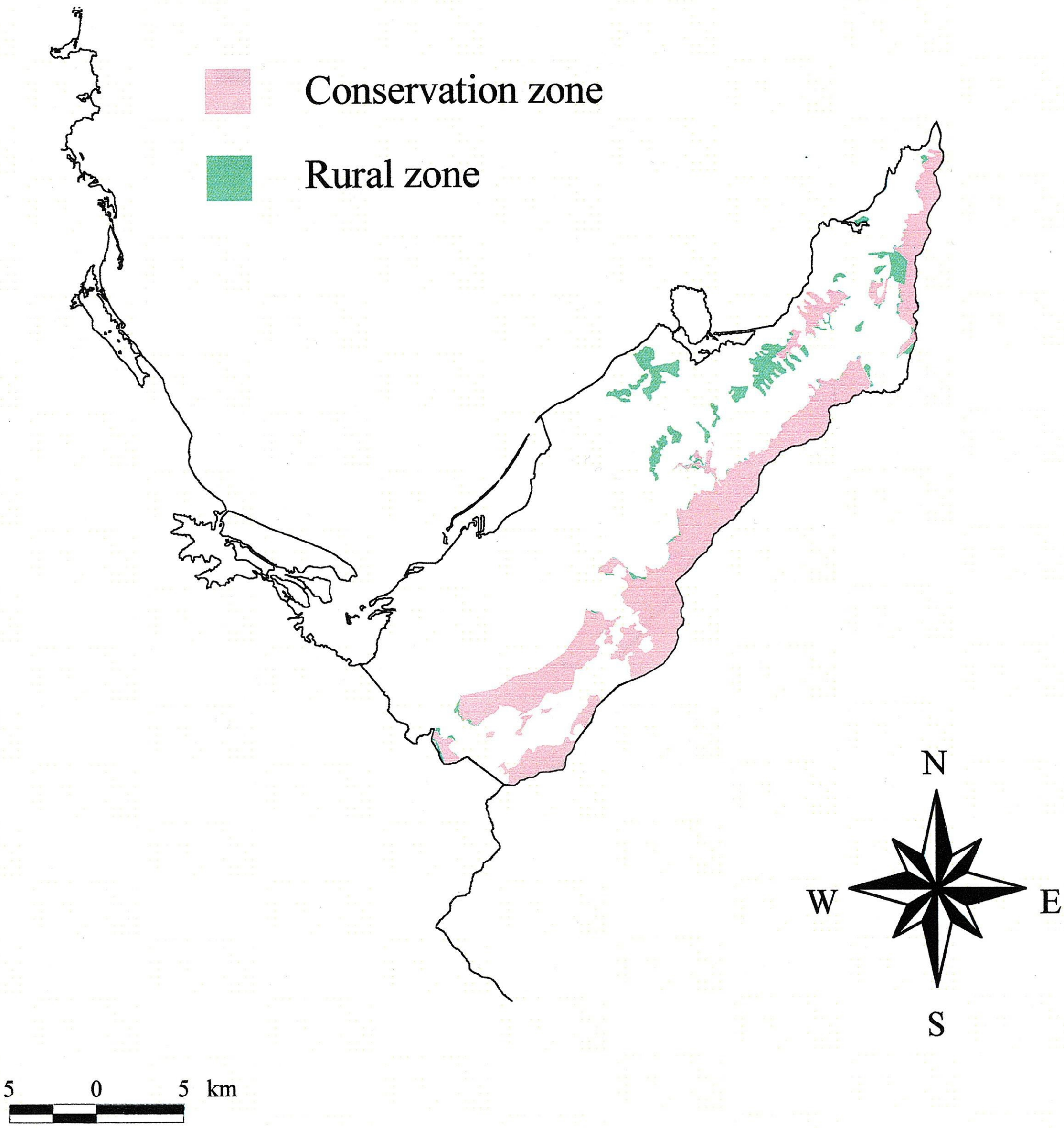


Fig. 5-4 Zones of indigenous forest convertible to plantation under the Nelson Resource Management Plan (NRMP).

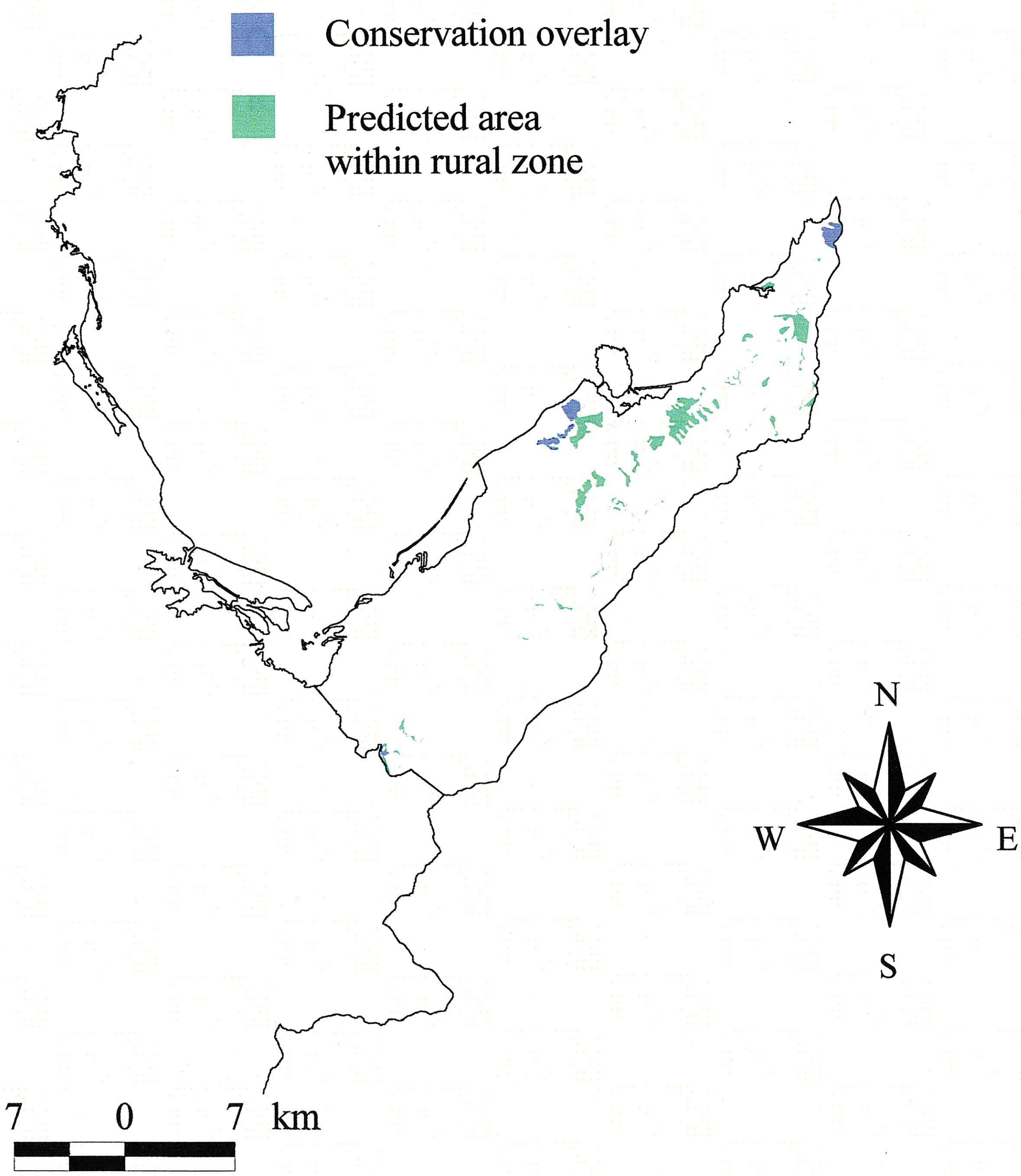


Fig. 5-5 Overlays within Rural zone: Indigenous forest to plantation.

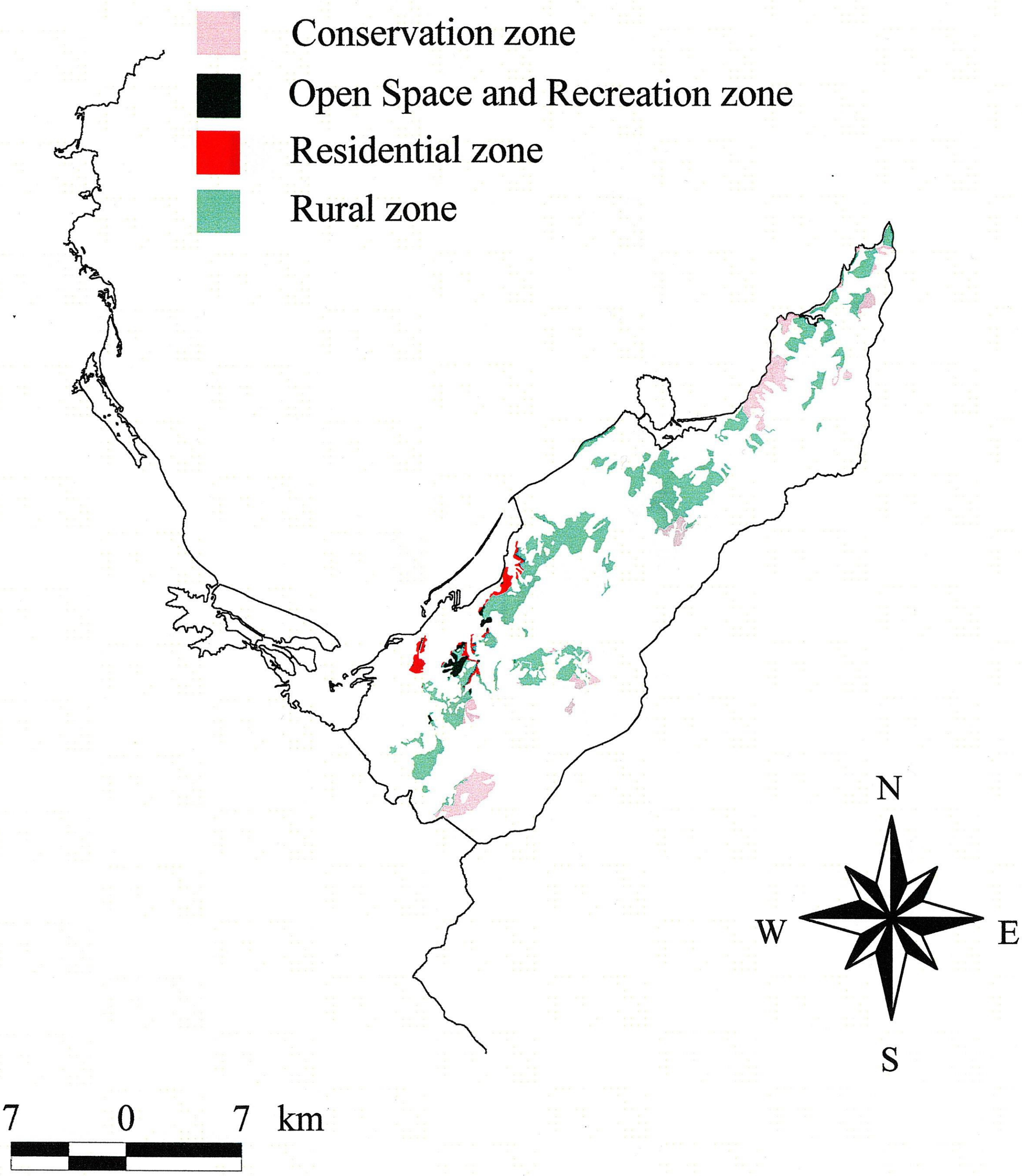


Fig. 5-6 Zones of shrub convertible to plantation under the NRMP.

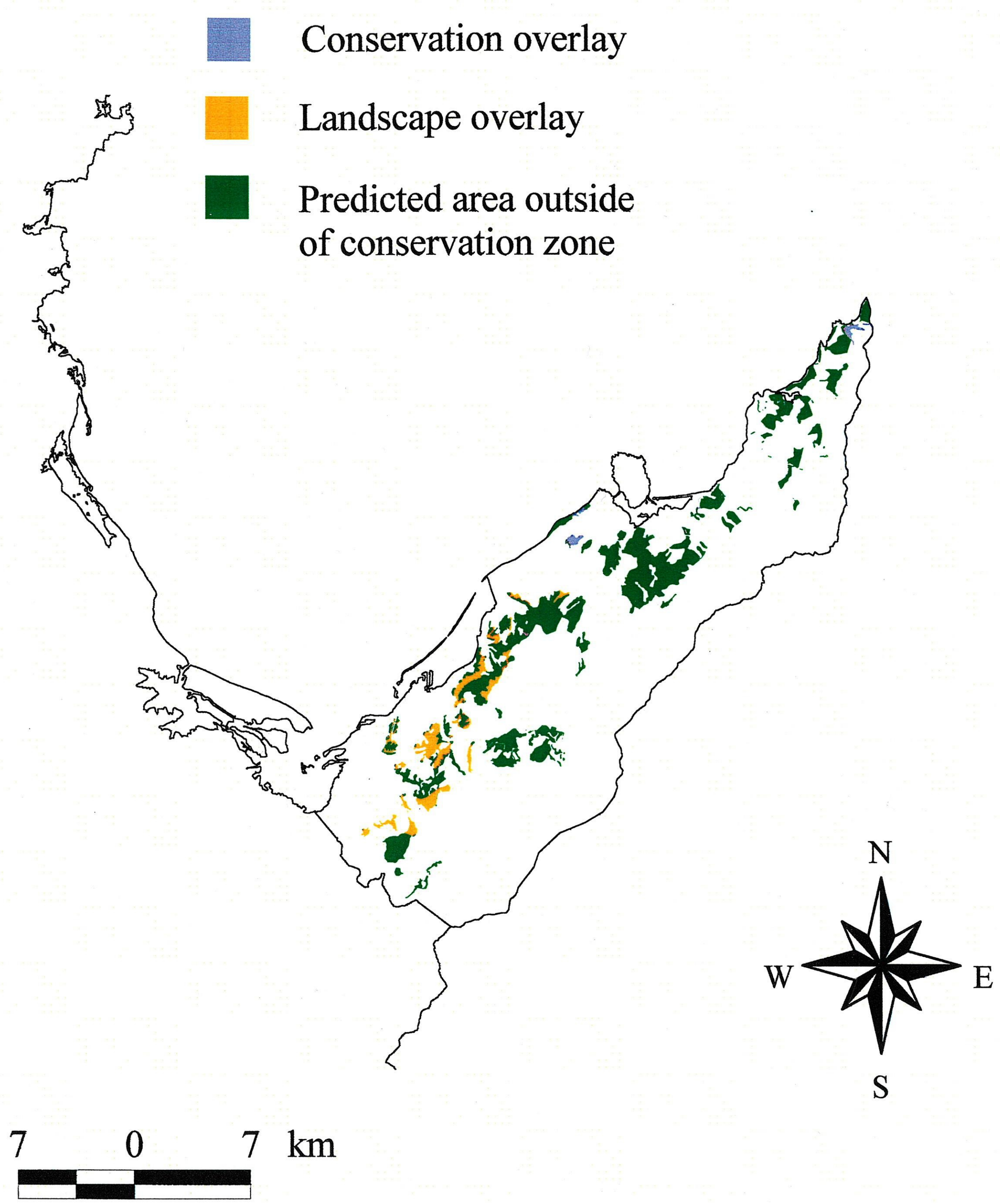


Fig. 5-7 Overlays outside of Conservation zone: Shrub to plantation .

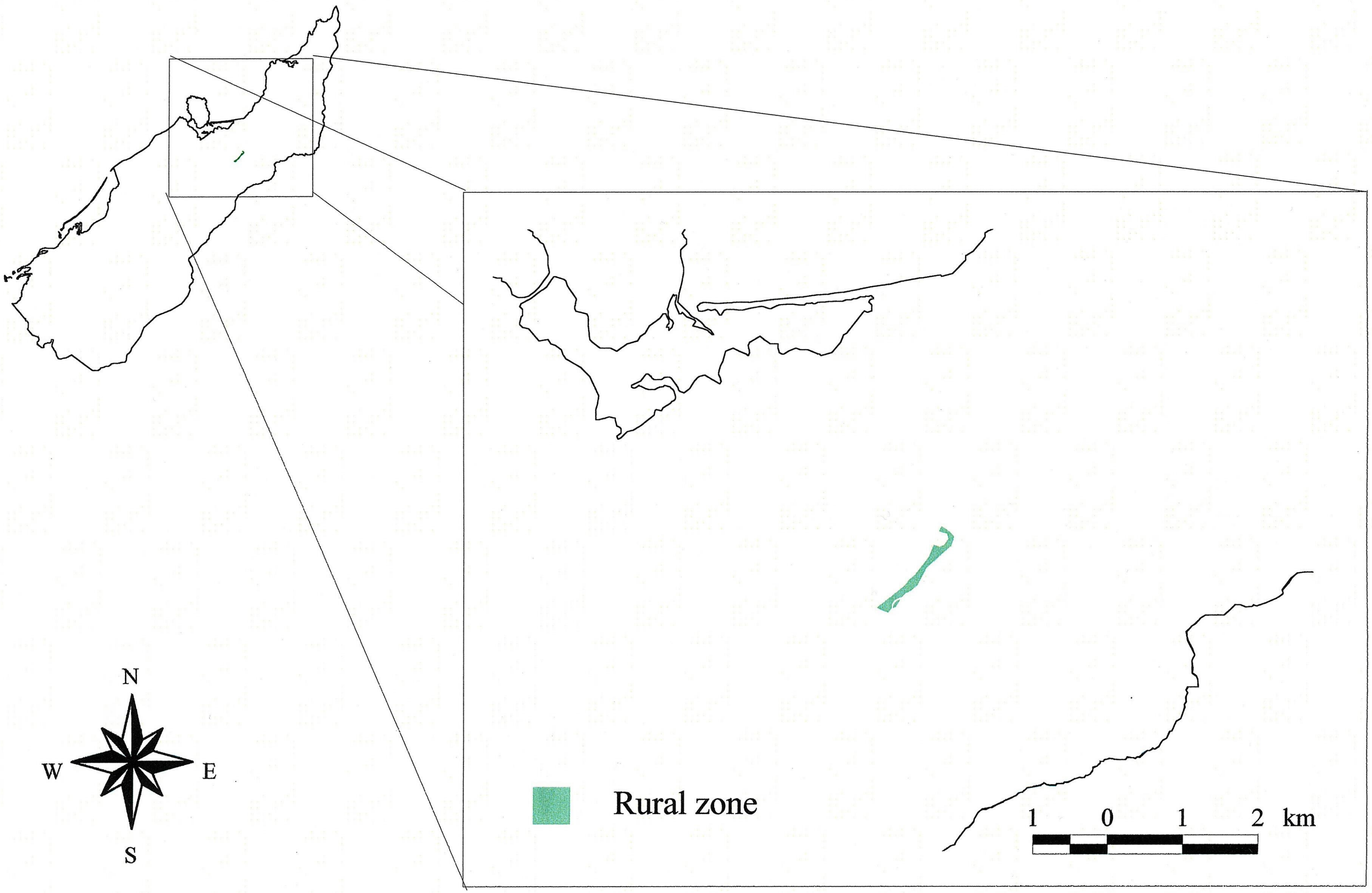


Fig. 5-8 Zones of shrub convertible to pasture under the NRMP.

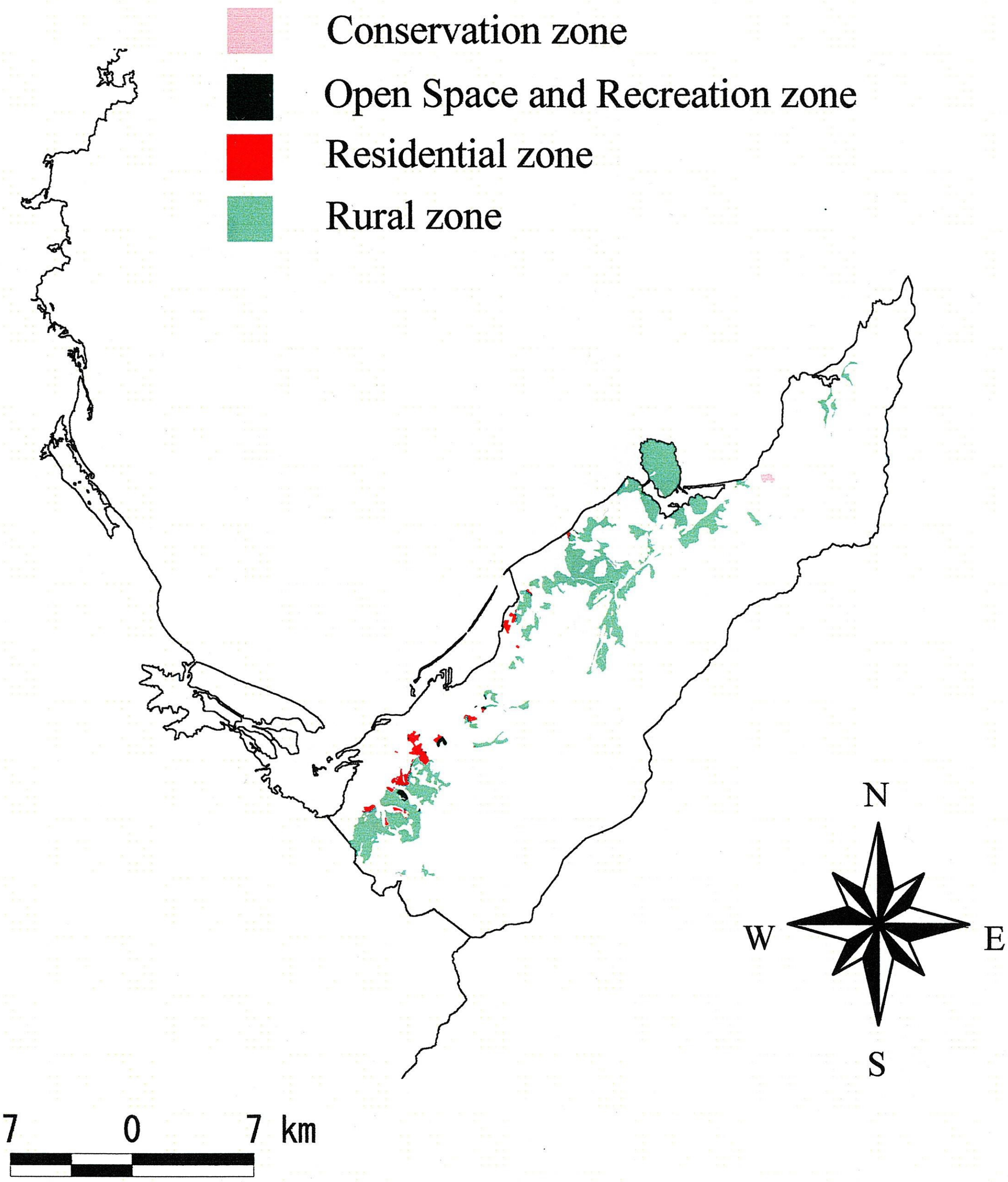


Fig. 5-9 Zones of pasture convertible to plantation under the NRMP.

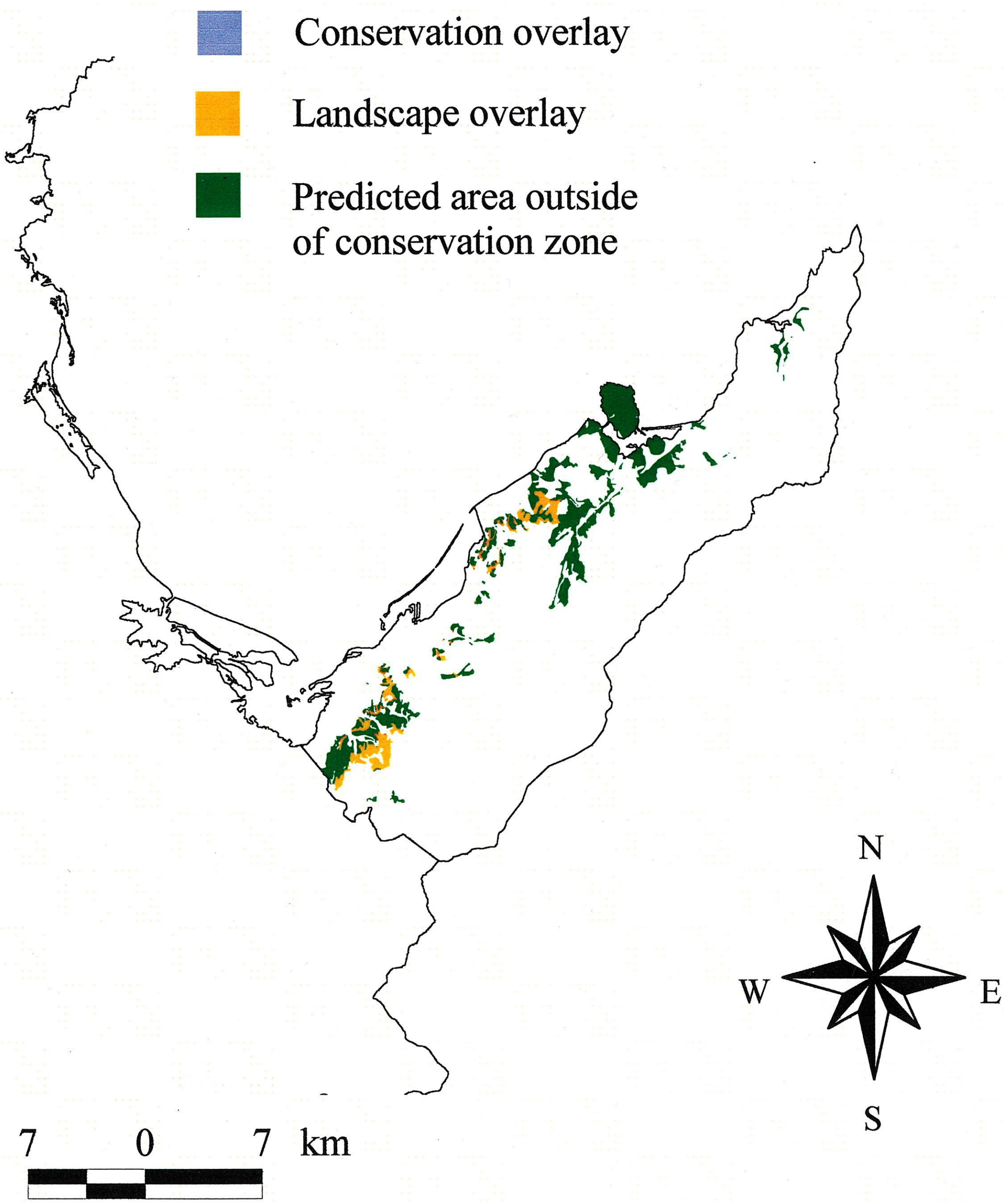


Fig. 5-10 Overlays outside of Conservation zone: Pasture to plantation.

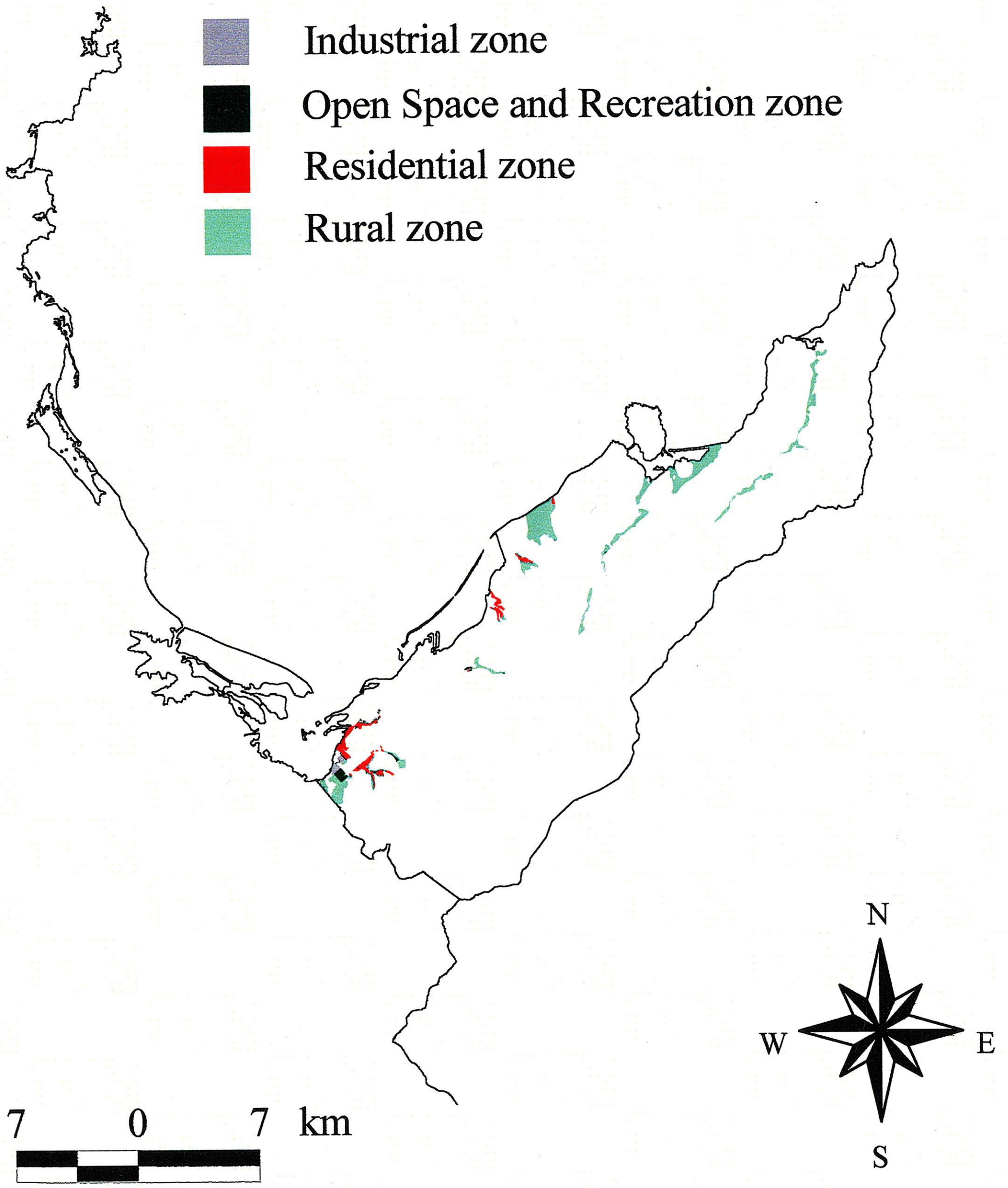


Fig. 5-11 Zones of pasture convertible to horticulture under the NRMP.

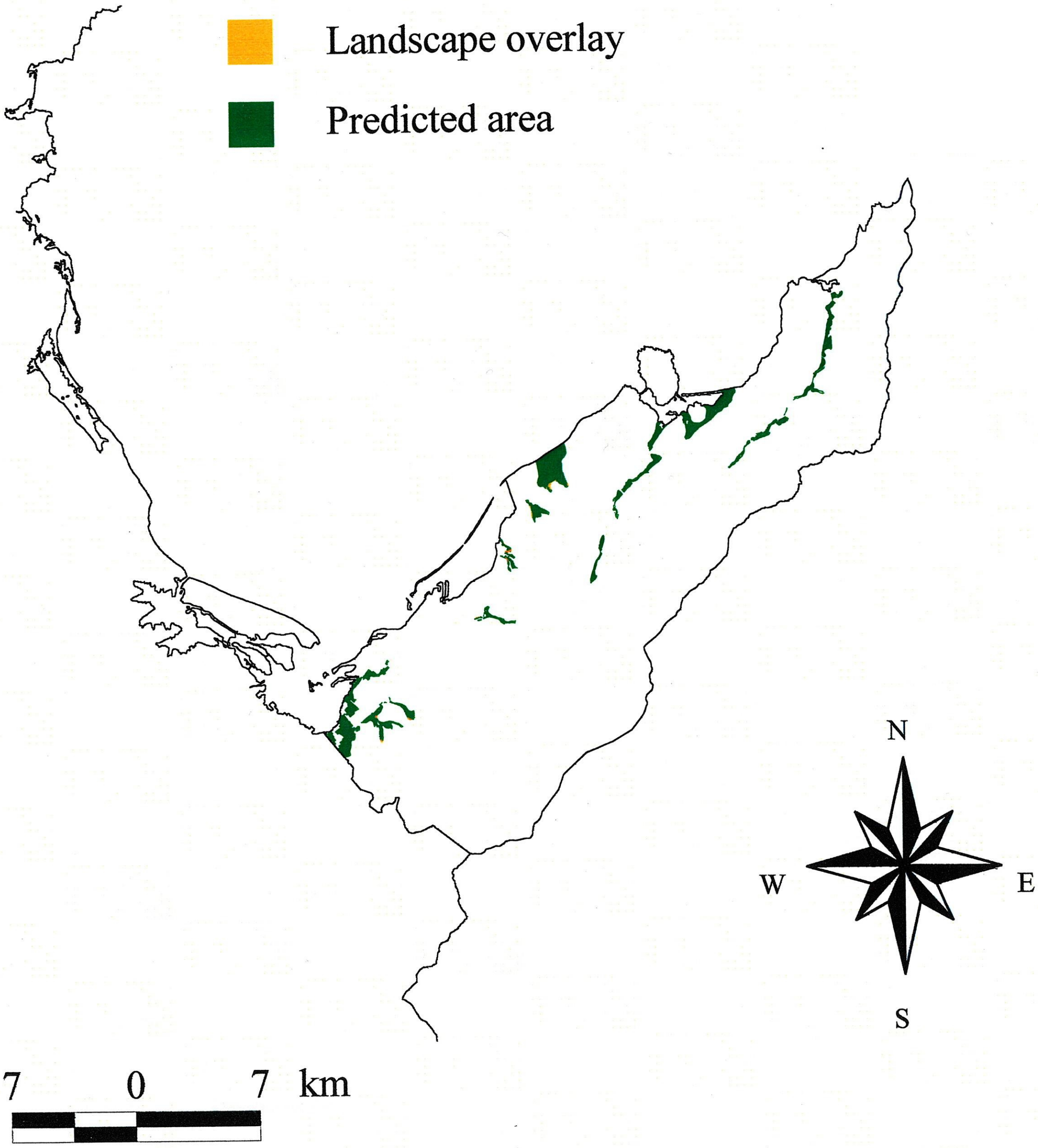


Fig. 5-12 Overlays of pasture convertible to horticulture.

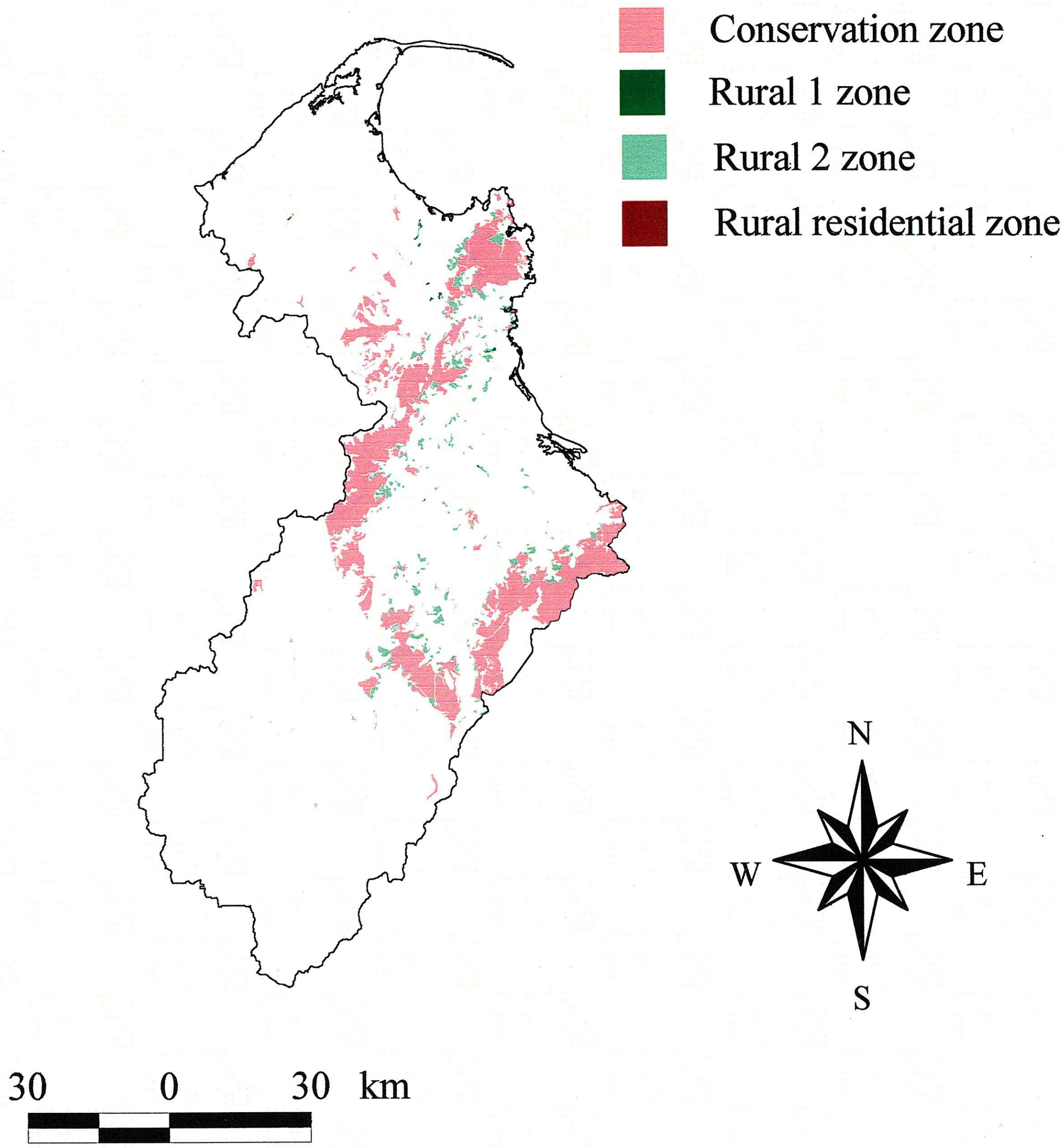


Fig. 5-13 Zones of indigenous forest convertible to plantation under the Tasman Resource Management Plan (TRMP).

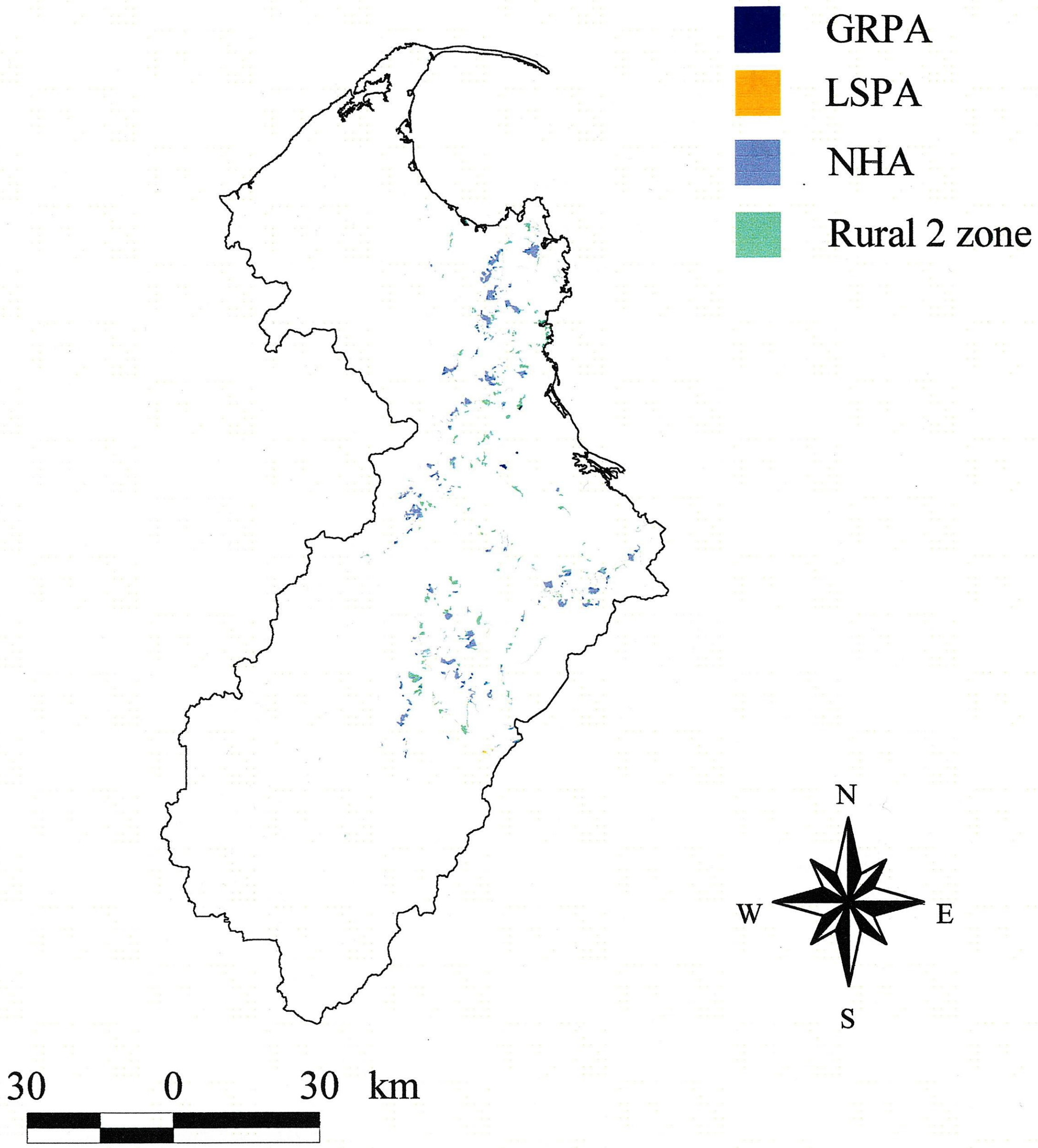


Fig. 5-14 Special areas in Rural 2 zone: Indigenous forest to plantation.

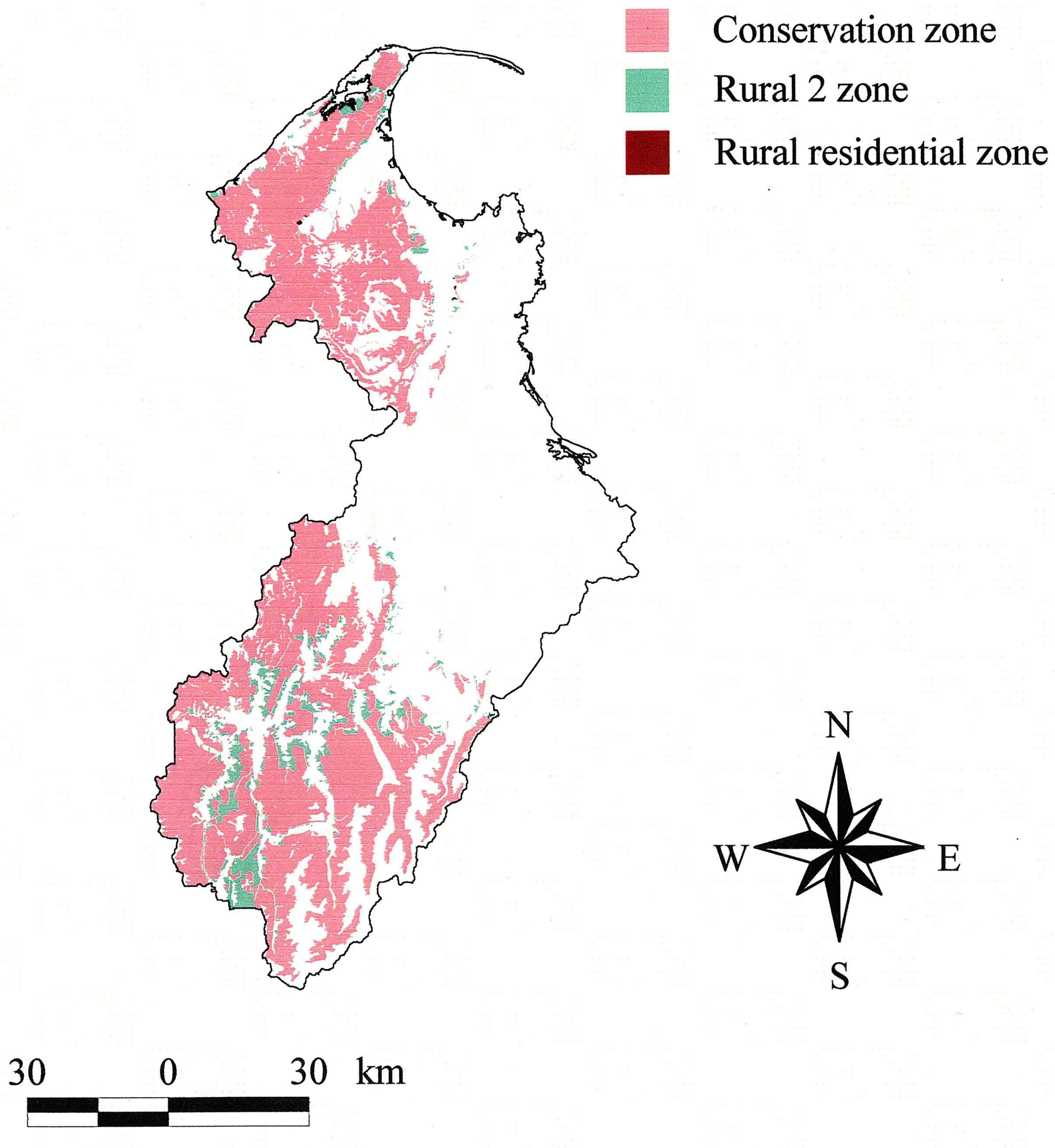


Fig. 5-15 Zones of indigenous forest convertible to pasture under the TRMP.

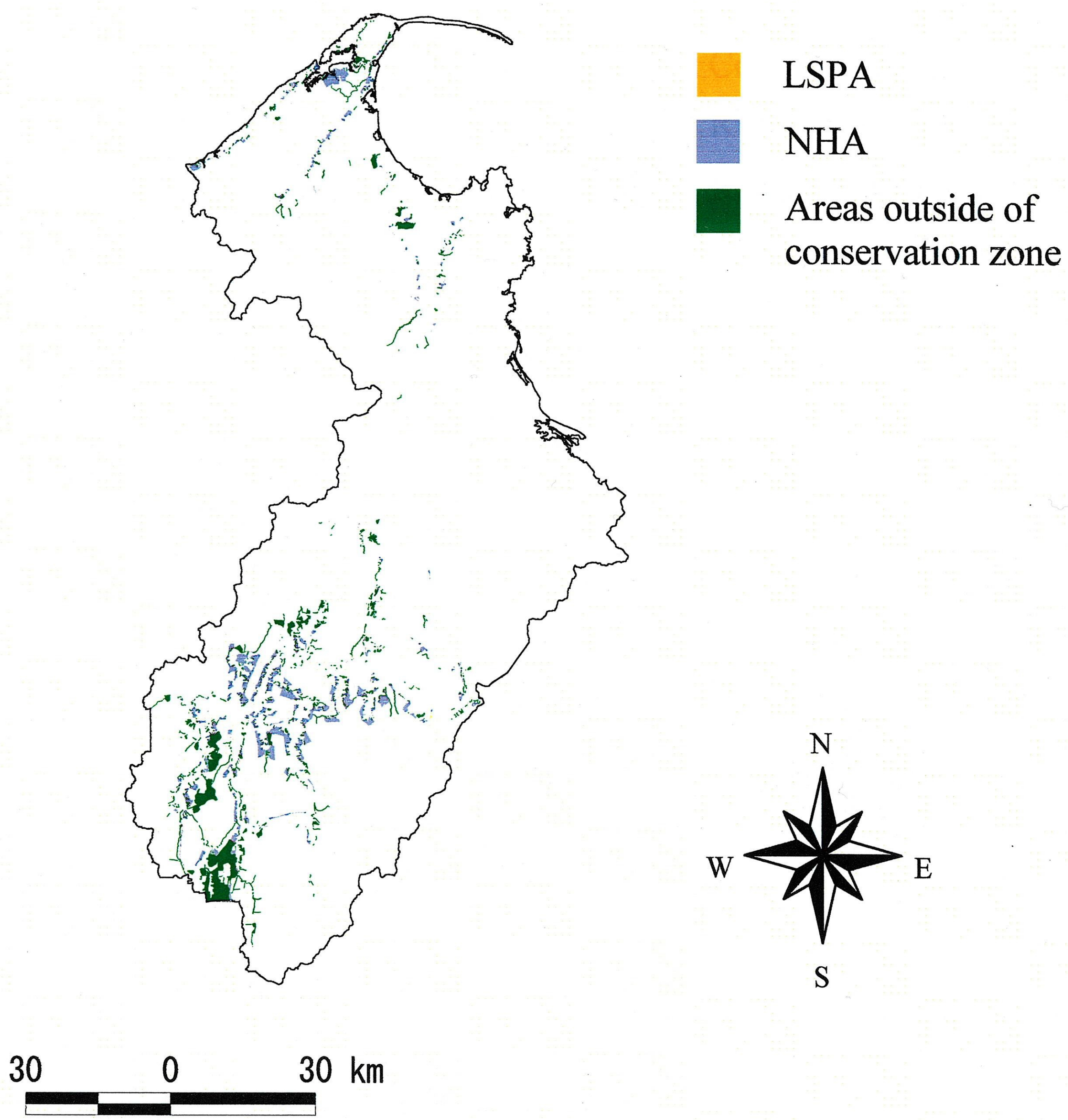


Fig. 5-16 Special areas outside of conservation zone: Indigenous forest to pasture.

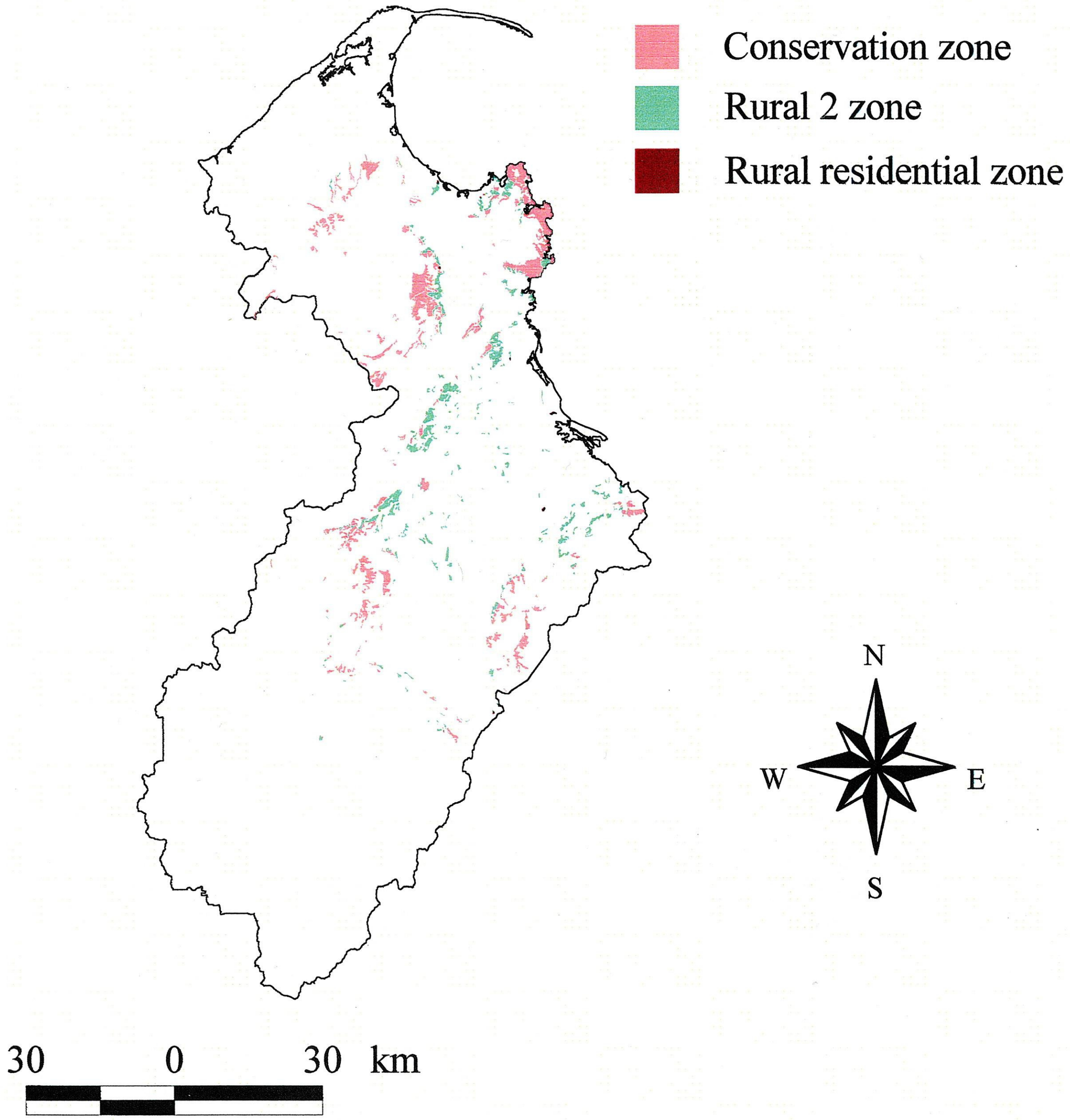


Fig. 5-17 Zones of shrub convertible to plantation under TRMP.

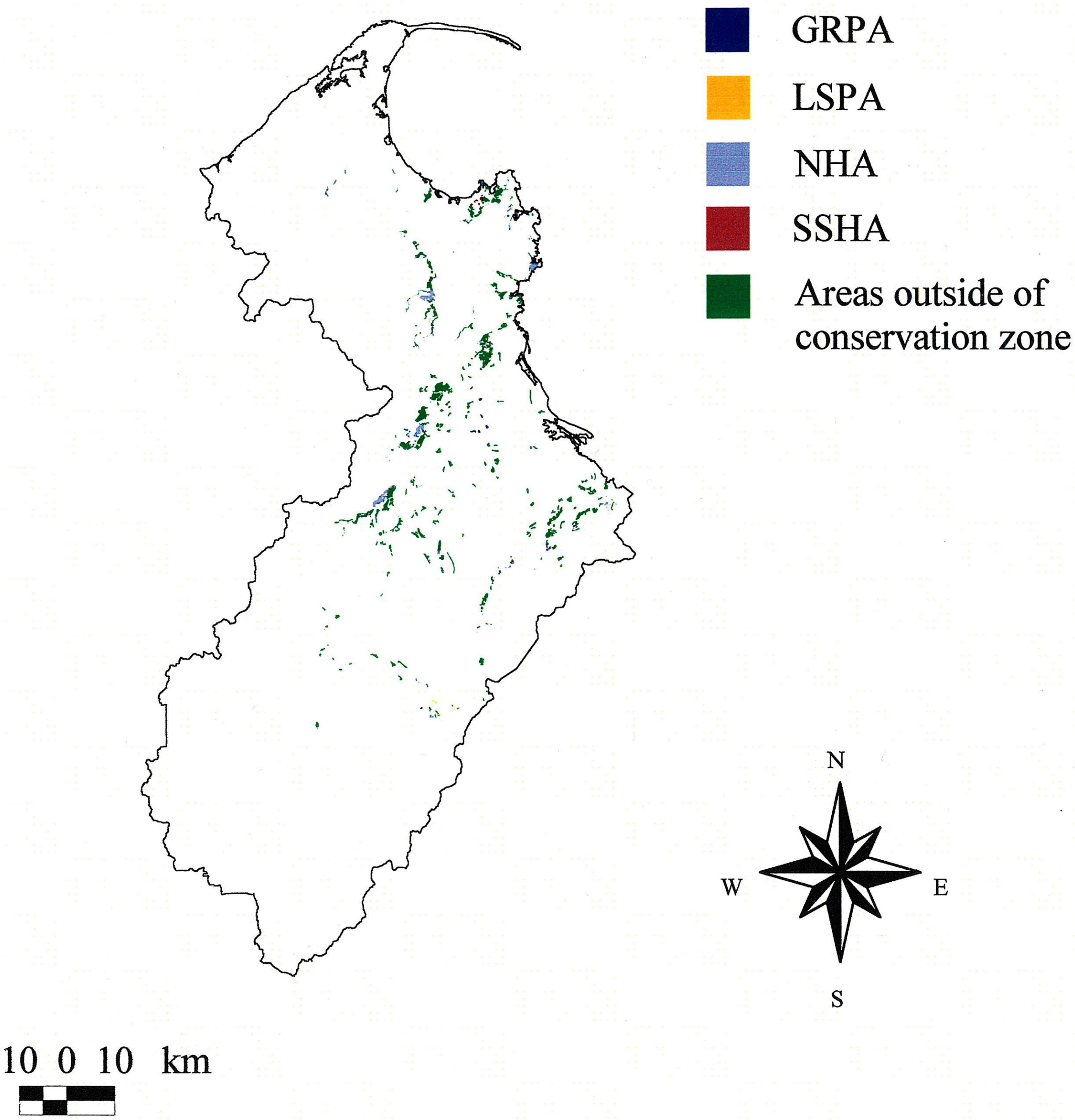


Fig. 5-18 Special areas outside of conservation zone: Shrub to plantation.

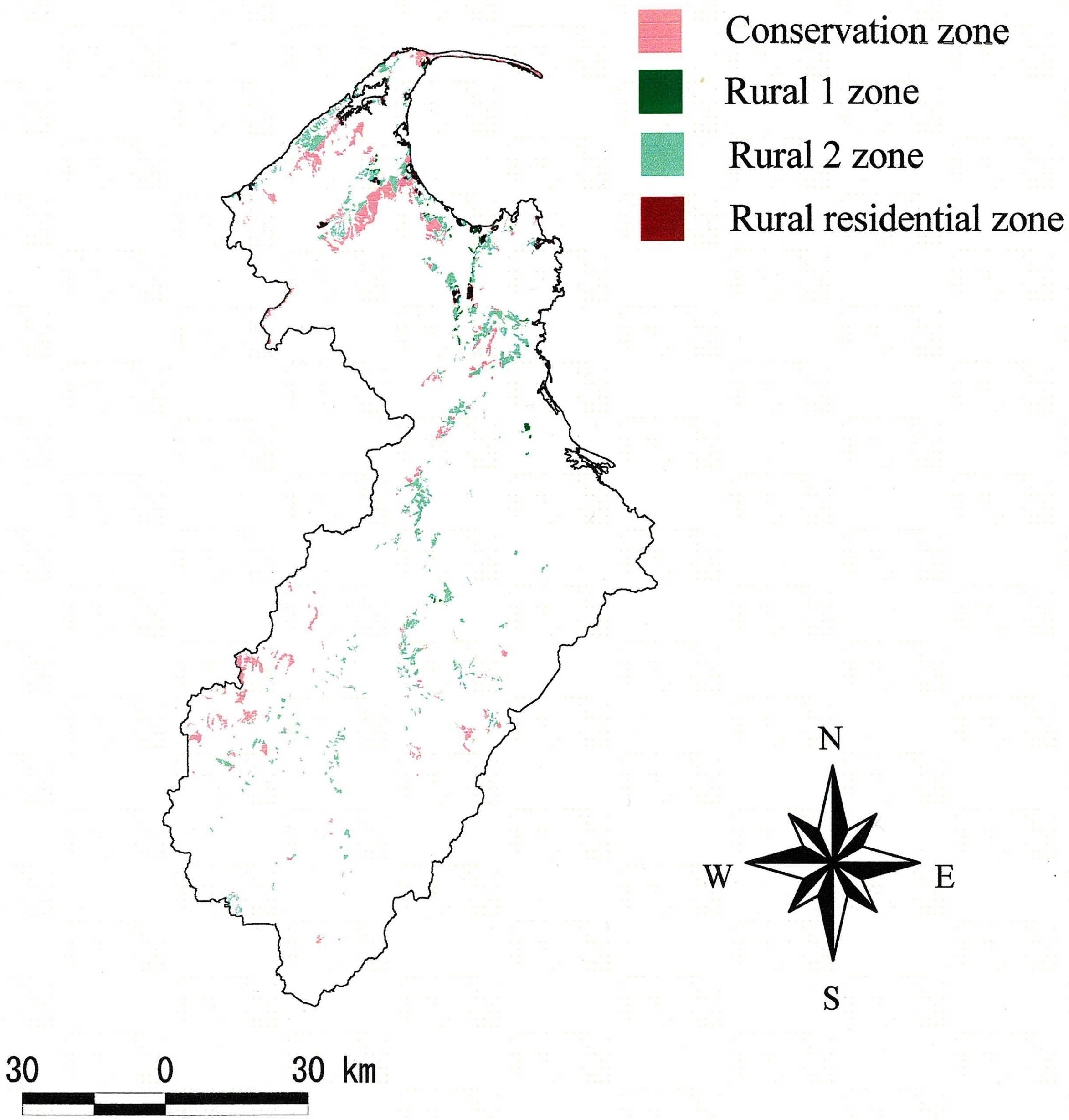


Fig. 5-19 Zones of shrub convertible to pasture under the TRMP.

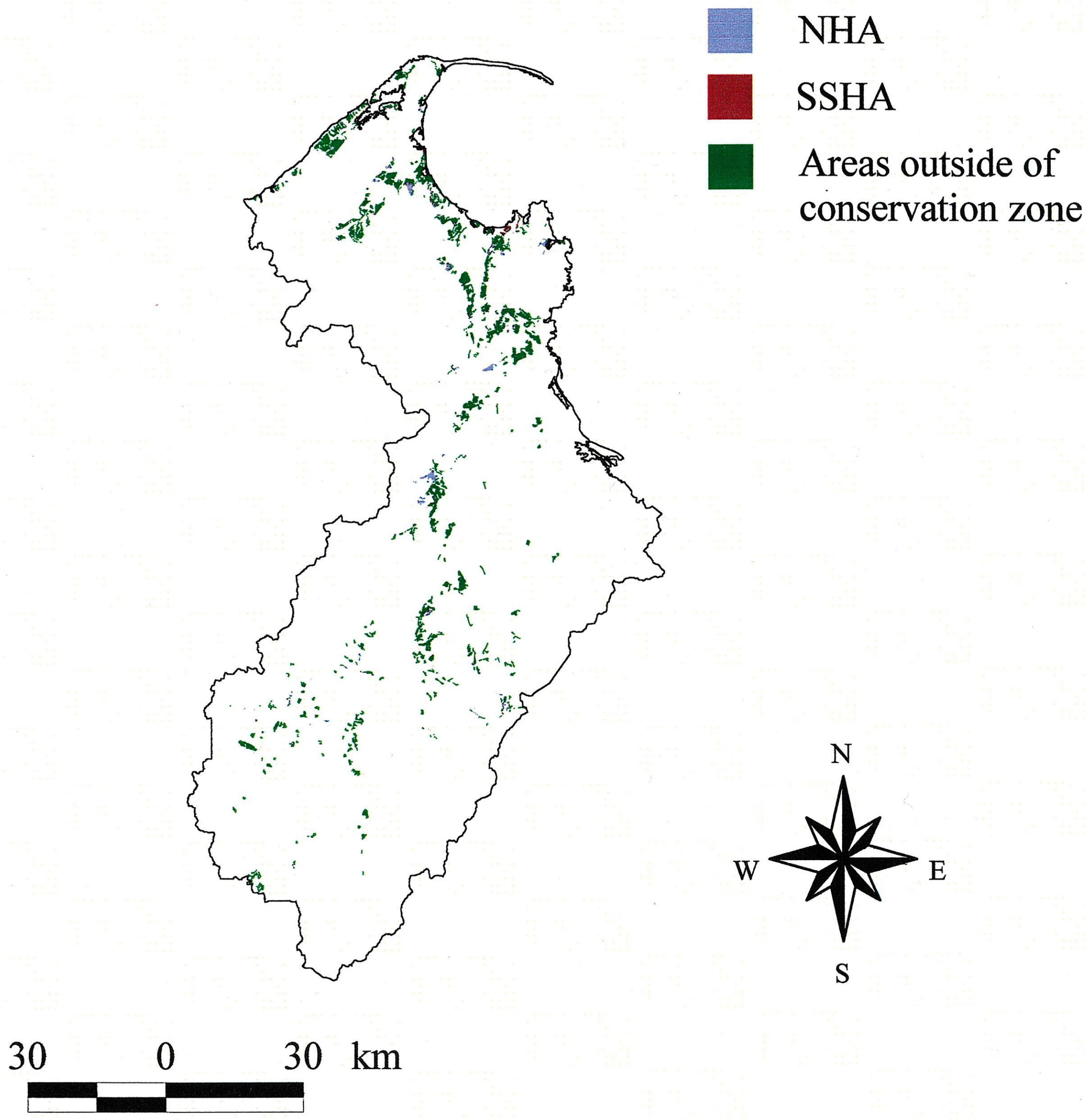


Fig. 5-20 Special areas outside of conservation zone: Shrub to pasture.

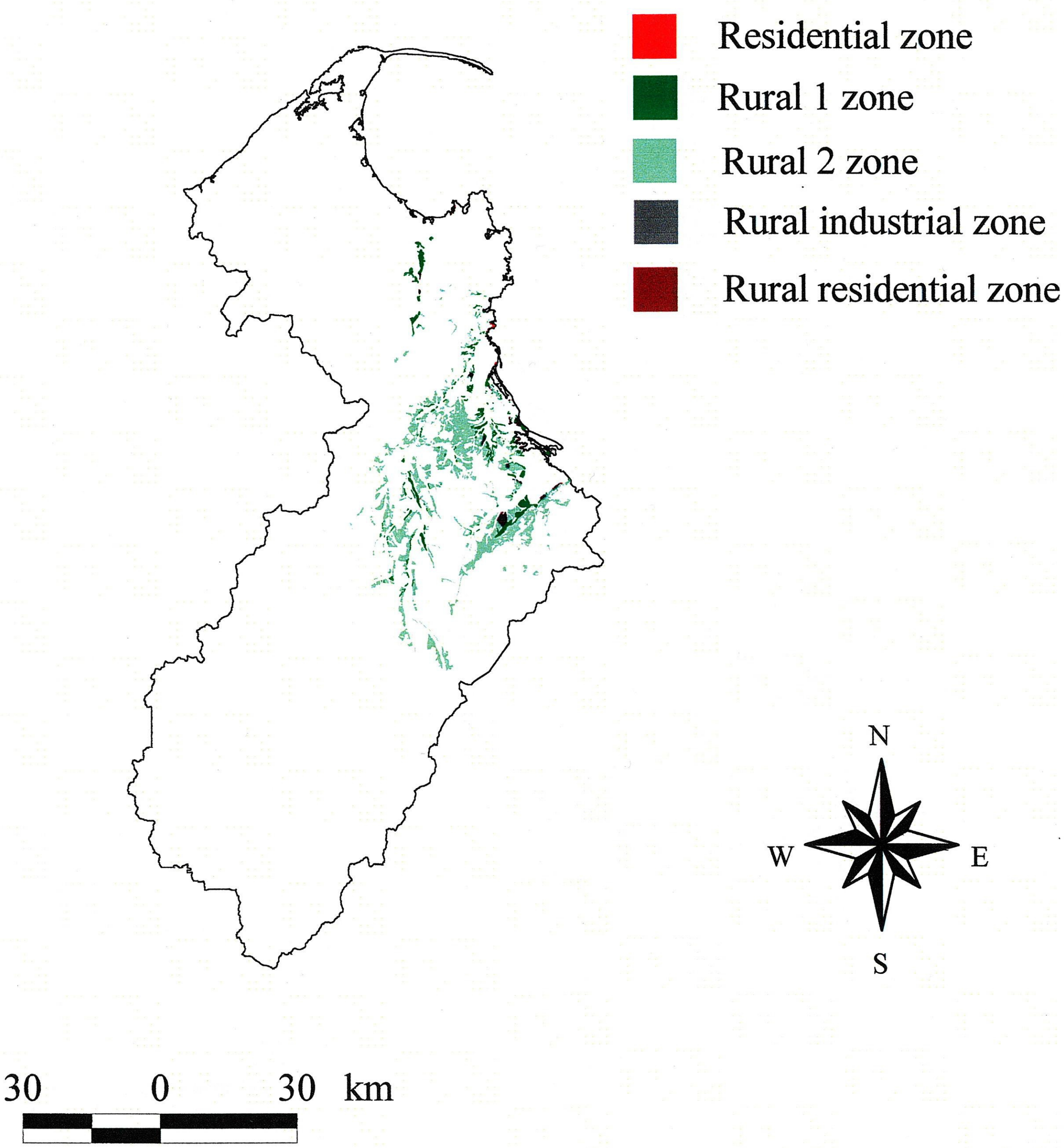


Fig 5-21 Zones of pasture convertible to plantation under TRMP.

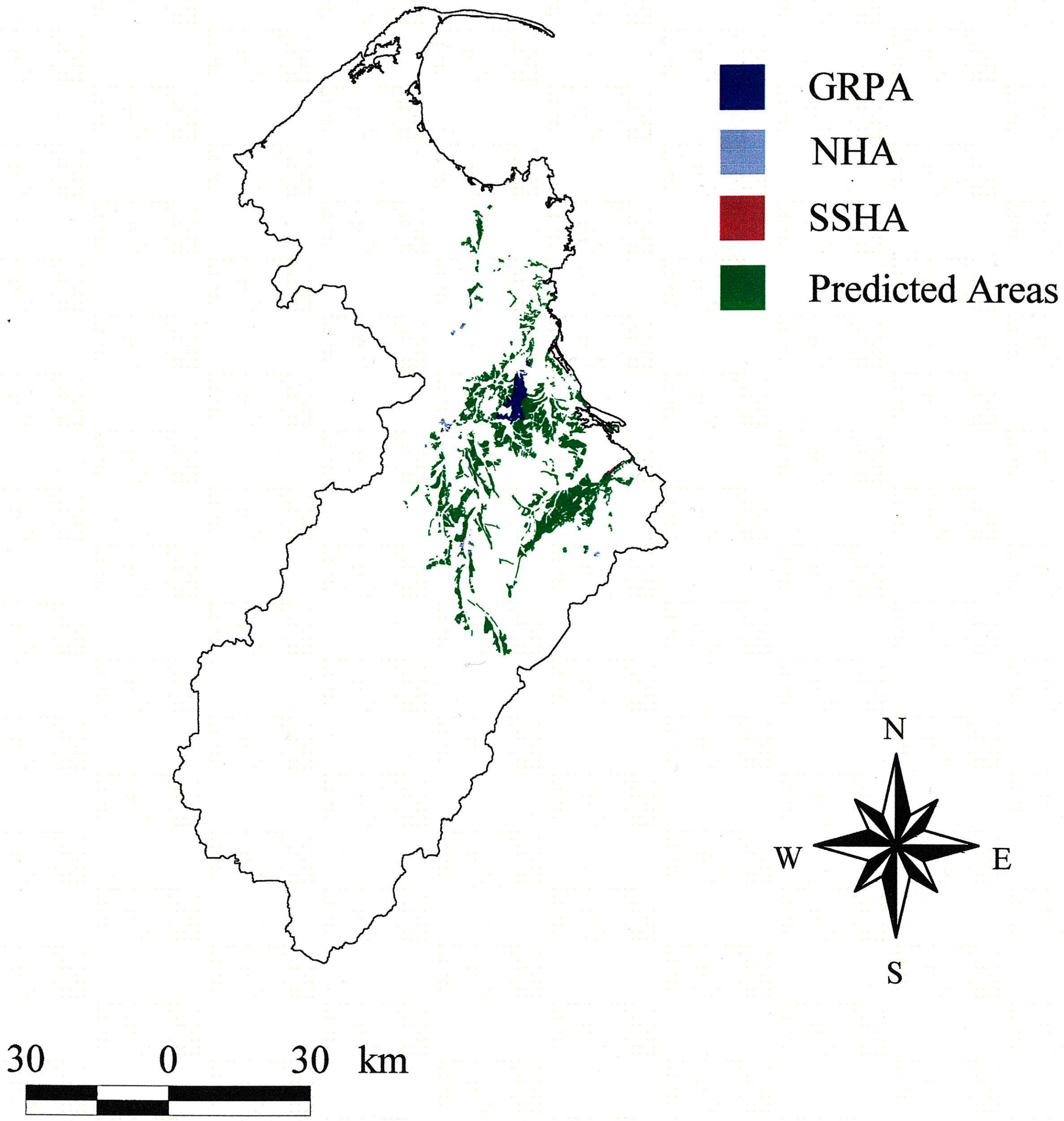


Fig. 5-22 Special areas of pasture convertible to plantation.

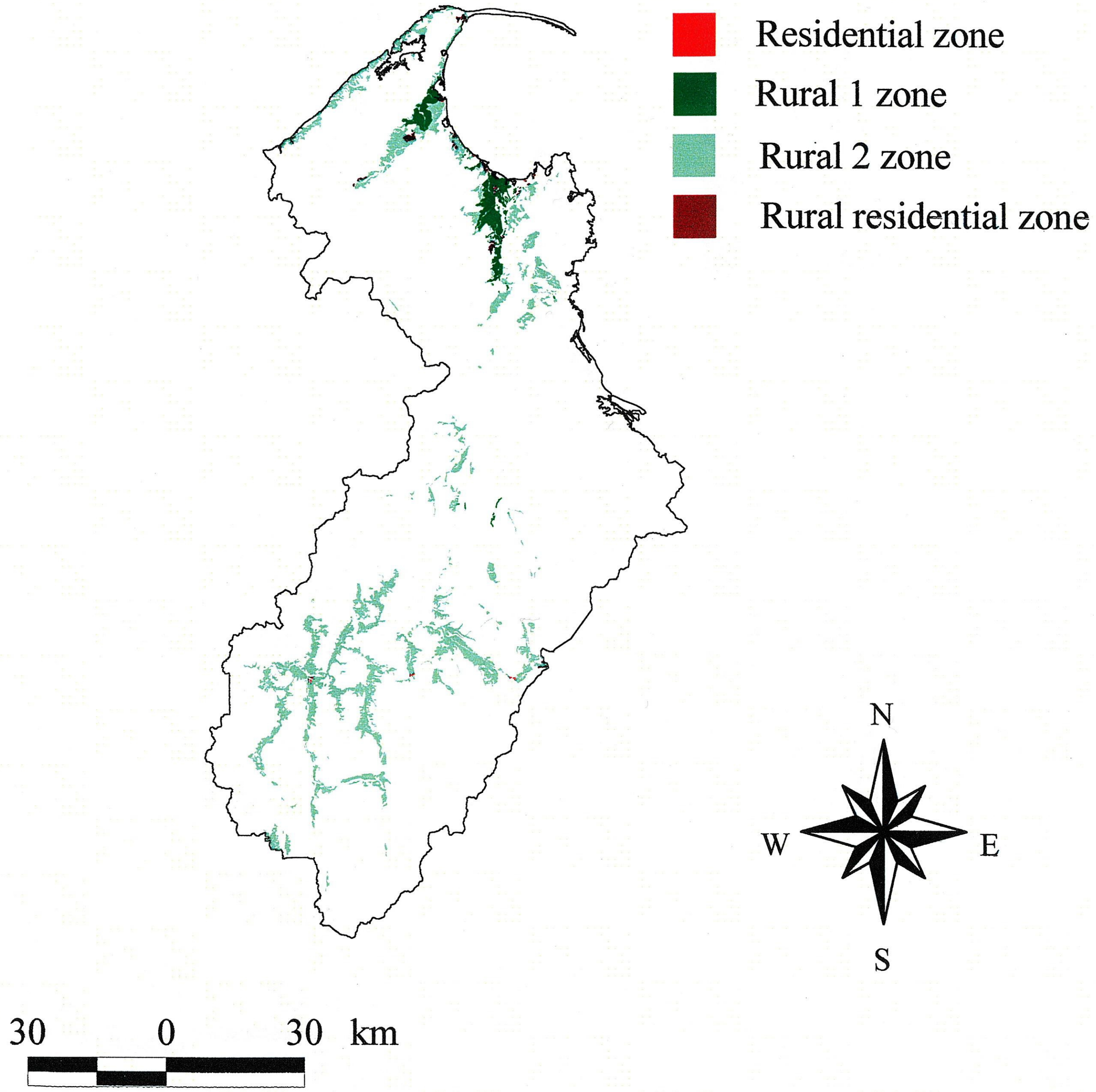


Fig. 5-23 Zones of pasture convertible to shrub under TRMP.

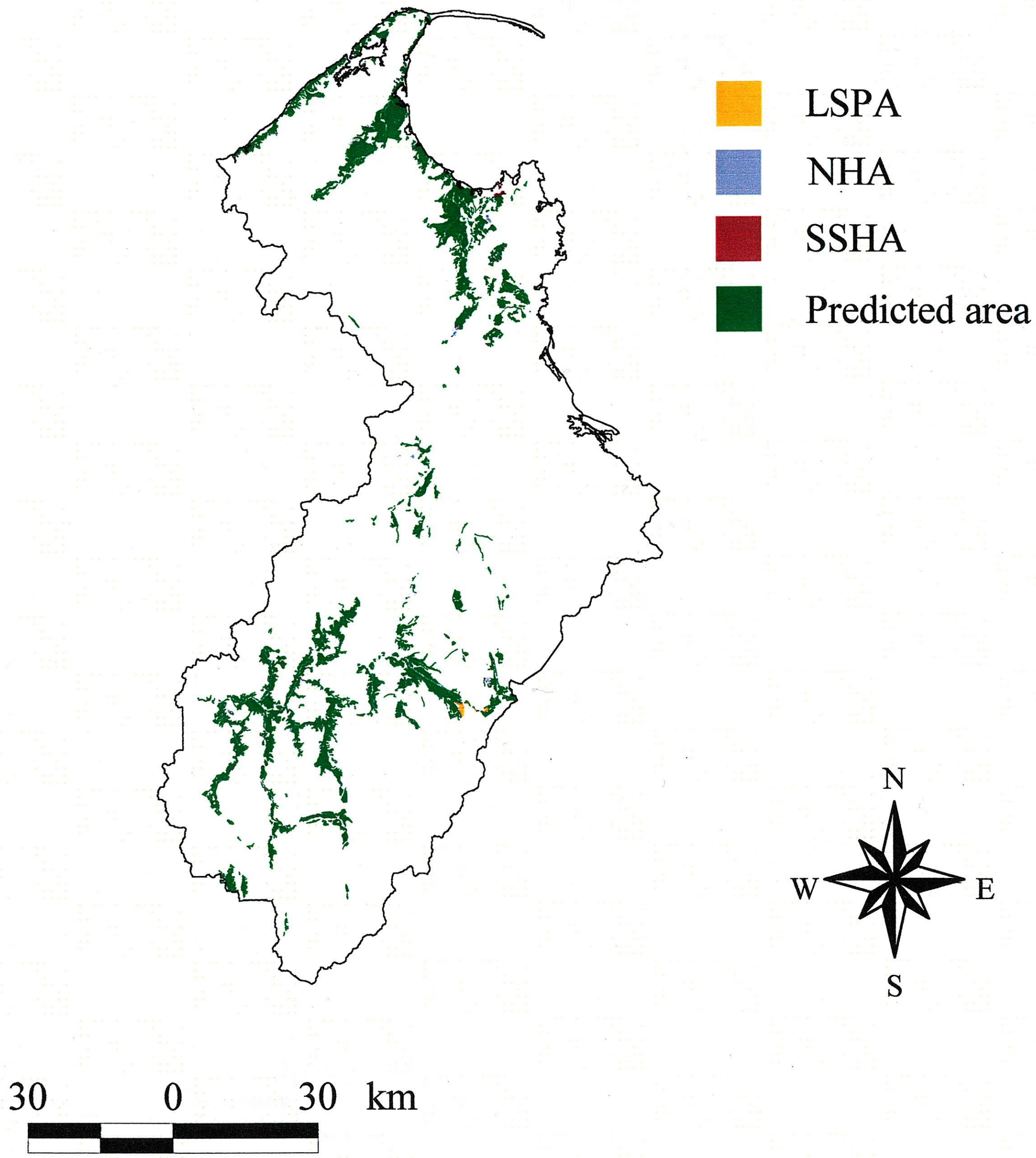


FIg. 5-24 Special areas of pasture convertible to shrub.

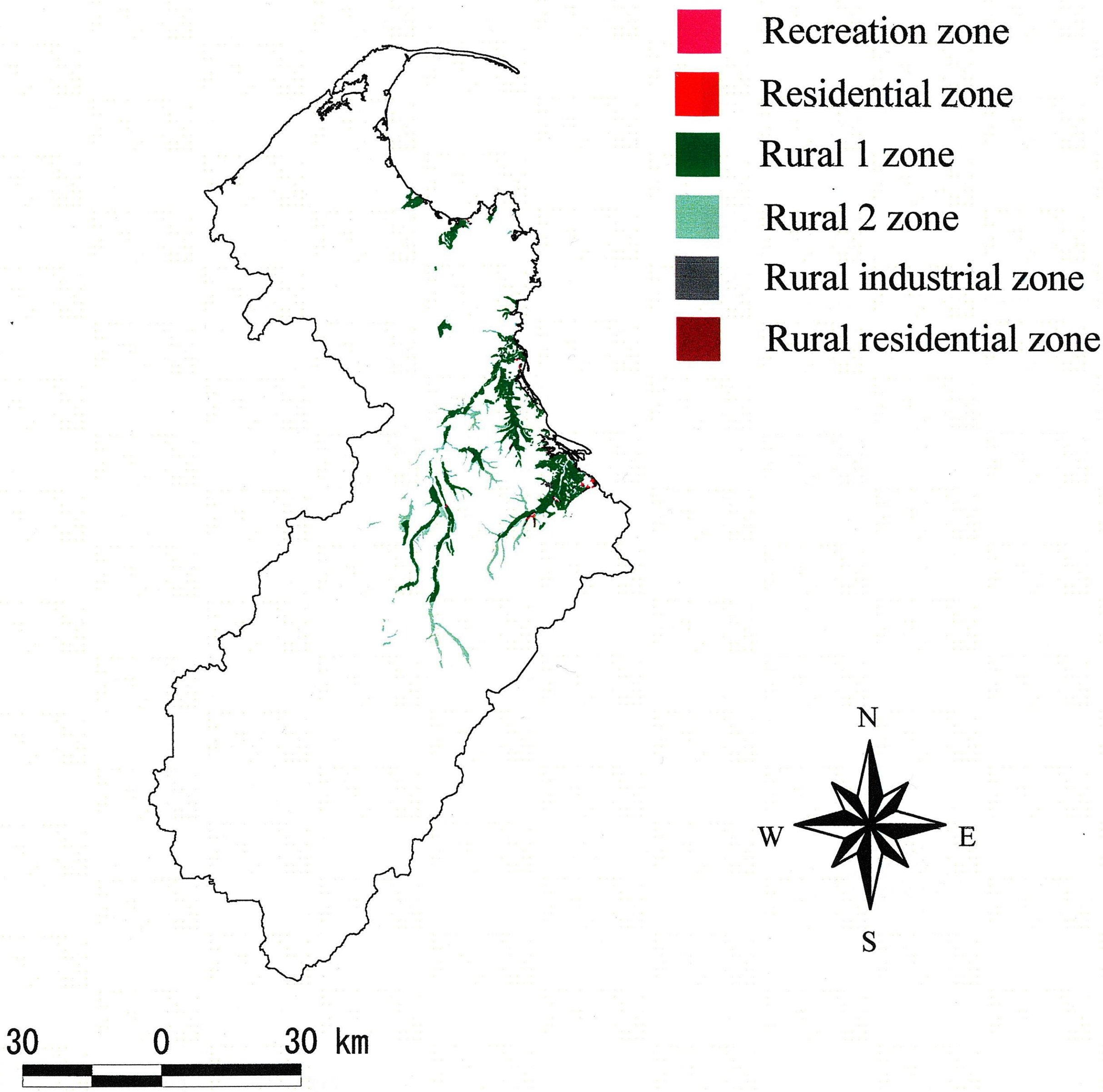


Fig. 5-25 Zones of pasture convertible to horticulture under TRMP.

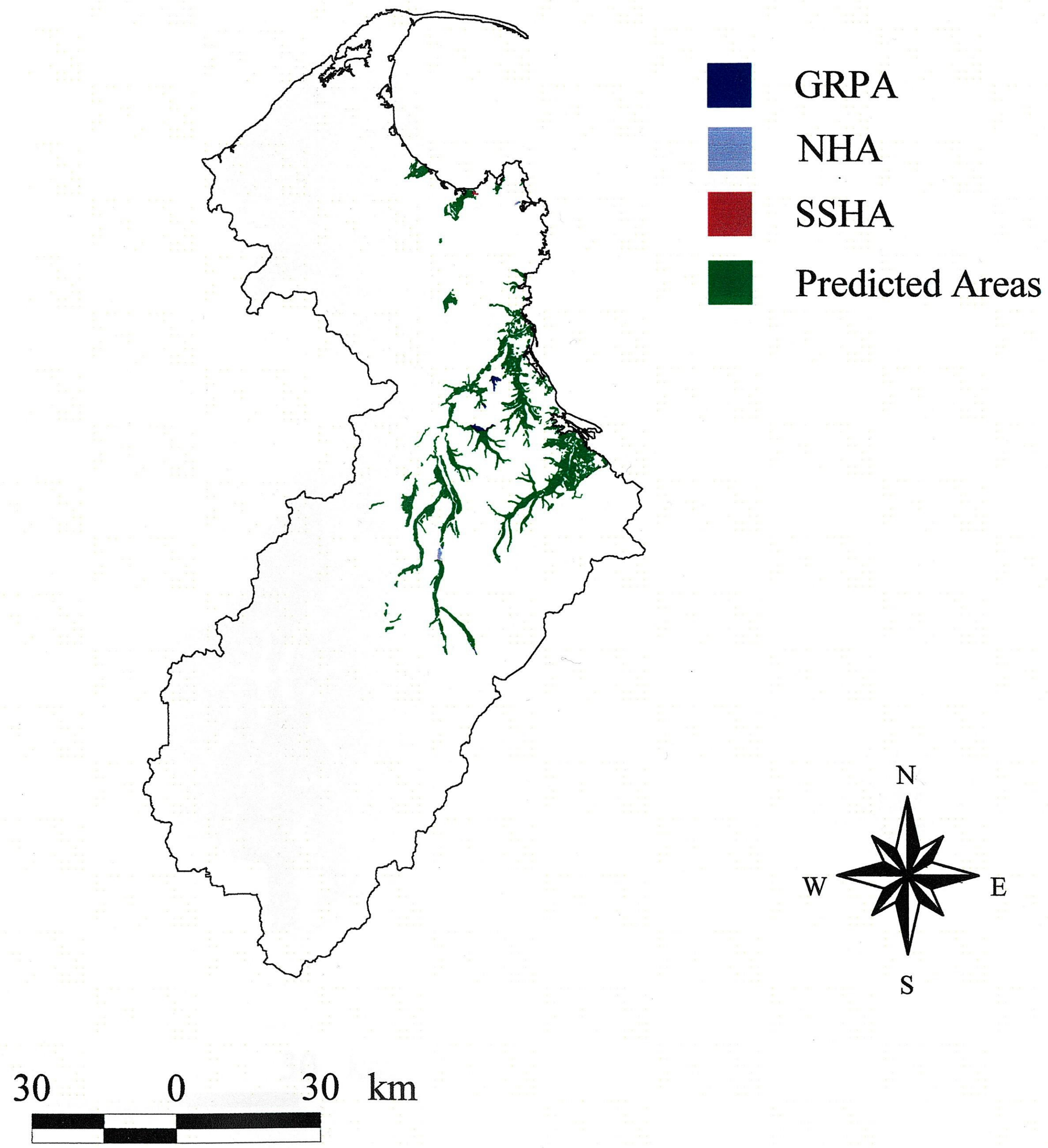


Fig. 5-26 Special areas of pasture convertible to horticulture.

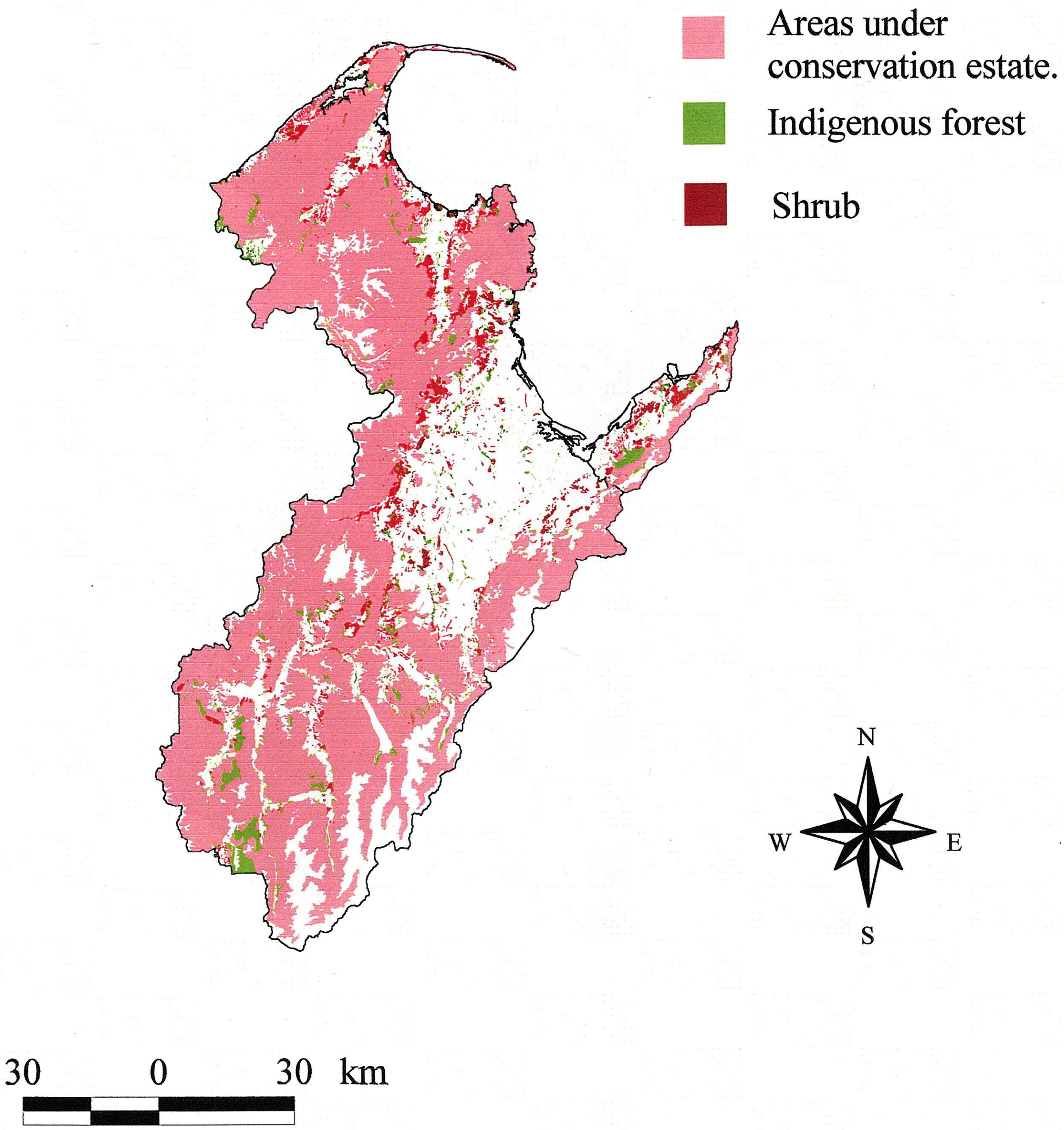


Fig. 5-27 Conservation estate of current indigenous forest and shrub lands.

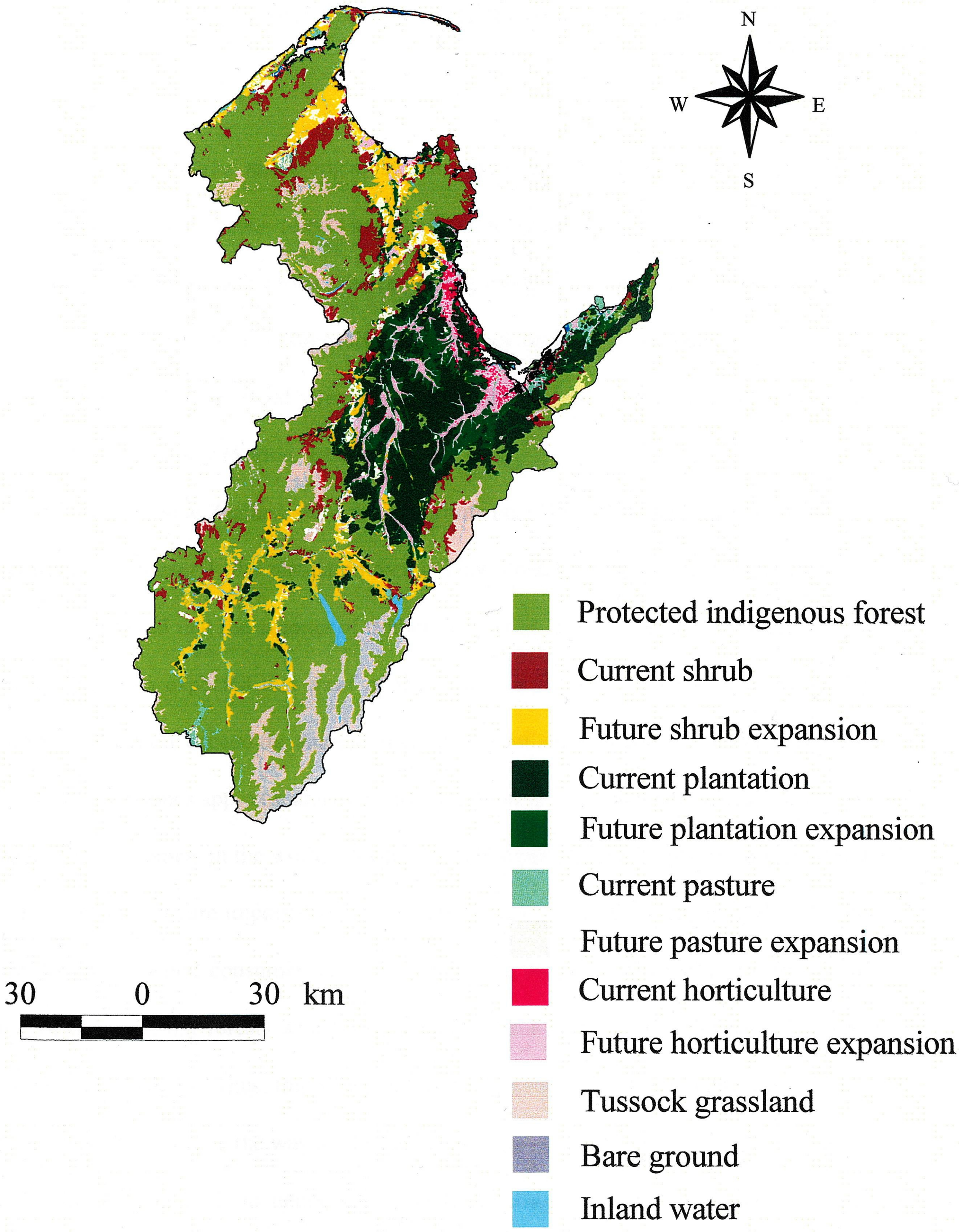


Fig. 5-28 Future land-use in the Nelson region.

Chapter 6

New Zealand Wood Utilization in Japan

6. 1 Introduction

Under the resource management system, especially by dividing the objective of natural forests and plantation forests management, it could be said that plantations in New Zealand are contributing to protect the remaining indigenous forests by allow them to be free from wood harvest. This suggests that advocacy of plantations reduces the need for wood harvests from the world's remaining indigenous forests and reduces threats to the world's forest diversity (Sutton, 1995).

In addition, New Zealand looks to be a promising country for stable wood supply. As mentioned in chapter 1, the plantation area in New Zealand shows a remarkable increase and it is predicted that the amount of timber production will increase dramatically in the future. It is also expected that most of the timber will be for exportation because the amount will largely exceed the amount of New Zealand's timber consumption needs.

Japan consumes approximately a hundred million m^3 of timber per year and is one of the largest consumers in the world. The timber self-support rate of Japan is only 20% and most of the timbers are imported from overseas (Forestry Agency of Japan, 2000). As the world's largest wood consumer and timber importer, Japan is responsible for importing logs or timbers from forests which have less influence on the remaining natural forests and on their diversity. Thus, importing and using logs harvested from plantations in New Zealand might be one of the ways to fulfill Japan's responsibility.

This chapter aims to understand how New Zealand wood (NZ wood) has been utilized in Japan and to examine the possibility of further expansion of NZ wood utilization, by reviewing the history of its utilization both in Japan and New Zealand.

6. 2 Change of importation and utilization of New Zealand wood in Japan

Importation of New Zealand wood was begun in 1958. Ninety-nine percent of the species were radiata pine until 1987 but recently changed to 90% of radiata pine and 10% of Douglas fir. Looking the change of importation from Fig. 6-1, it could be divided into five different periods as the following,

1. Increasing period from 1958 to 1972.
2. Decreasing period from 1973 to 1975.
3. Recovering period from 1976 to 1979.
4. Re-decreasing period from 1980 to 1986.
5. Sudden increasing period from 1987 to the present.

Most of the imported NZ woods were in the form of logs (Fig. 6-1) and these logs were used mainly for sawn timber until 1989 (Fig. 6-2).

1) Increasing period from 1958 to 1972

First of all, it should be informed that statistical data showing the use of NZ wood in Japan only existed from 1971 in the "Report of Timber Demand and Supply," which was edited by Statistics and Information Department of Ministry of Agriculture, Forestry and Fisheries. Therefore, data for only two years existed for understanding the utilization in this period.

Judging from the limited data, the increase of importation amount in this period was caused by increase in packaging and construction timber uses (Fig. 6-3). The reason why NZ logs were used for construction timber could be attributed to the restrictions of log exportation from the area west of hundred degrees west latitude in the United States from 1968. At that time, Japan was experiencing a remarkable increase in new housing developments with the strong economic growth (Fig. 6-4). North American wood was the main resource for construction and the restriction, therefore, caused concerns to obtain wood resource in Japan. As a result, NZ log was selected as a substitution for North American wood and was utilized for construction wherever possible. However, it seems that the utilization was only a temporary phenomenon according to the sudden increase and decrease of the amount as shown in figure 6-3. The increase of use in packaging materials in this period was the result of the gradual increase of packaging demand in Japan (Fig. 6-5).

2) Decreasing period from 1973 to 1975

The sudden decrease of importation amount in this period (Fig. 6-1) was accompanied by decreases both in construction timber and packaging utilization (Fig. 6-3). The reduction was occurred due to the declining of demand both for new housing development and packaging (Figs. 6-4 and 6-5), which was affected by the depression after the 1973 oil shock.

While in the previous period, the use of construction timber was larger than that for packages, the former became a little smaller than the latter (Fig. 6-3) because the demand for construction was more sensitive to the depression and reacted faster than that of packages (Figs. 6-4 and 6-5).

3) Recovering period from 1976 to 1979

As a result of the prosperity of the United States economy from 1975, the exportation of Japanese products to the United States increased, which led to the increase of package shipments (Fig. 6-5). Consequently, the packaging shipment of NZ wood also recovered and the amount of importation increased till 1979 (Figs. 6-1 and 6-3).

On the other hand, the use for construction timber decreased steadily (Fig. 6-3) while Japan's economic situation regained its strength and the number of new housing developments remained almost on the same level from 1976 (Fig. 6-4). The quality of NZ logs was the reason for the decline. NZ log imported at that time was the timber from the forests planted in the first boom of afforestation, known as "Old Crop." Old Crop had lots of knots and was too weak to use for construction timber (Miyajima, 1980). This low-quality product was caused by poor management, without enough thinning and pruning practices, seen in the first boom of afforestation. Additionally, the properties of radiata pine itself such as the wide growth ring and the excessive weakness of the corewood (Mishiro, 1984) were also considered as negative qualities in construction timber. Thus, NZ logs were avoided using as construction timber.

4) Re-decreasing period from 1980 to 1986

The total packaging shipment decreased until 1982 as a result of the tie-up of exportation from Japan caused by the depression of the United States of America. From 1983, it shifted to increase associated with the recover of the United States' economy. The little decrease in 1986 might be caused by the depression together with the high yen value (Fig. 6-5). Anyhow, entirely, packaging demands had not changed largely in this period. Nonetheless, the amount of NZ log importation decreased and this was later followed by a reduction in NZ wood packaging shipments (Figs. 6-1 and 6-3). Comparing NZ wood packaging shipments with other kinds of woods' packaging shipments (Table 6-1), strong negative correlation was found between NZ wood and North American wood, and also between NZ wood and domestic wood. This means that the decrease of NZ wood packaging shipment was made up by the increase of packaging shipments of North American wood and domestic wood.

This movement implies that the reduction of NZ log importation was not caused by the conditions in Japan, but in New Zealand. This can be also confirmed by a corresponding reduction in log exportation in New Zealand (Fig. 6-6). It is said that the conditions, which amounted to the restrictions of wood resources in New Zealand, occurred because this was the time of changing from Old Crop, planted in the first boom of afforestation, to New Crop, planted in the second boom (Minowa, 1988). However, looking at the amount of roundwood removal in New Zealand, it did not show any reduction over the period (Fig. 6-7). On the other hand, the timber demand in New Zealand was increasing (Fig. 6-8). This situation suggests that NZ log exportation decreased because the domestic log demand in New Zealand was increasing while the amount of roundwood removal was not.

5) Sudden increasing period from 1987 to the present

The amount of NZ log importation has been increasing since 1987, particularly it showed a remarkable increase in 1990 (Fig. 6-1). This rise occurred due to the increase in packaging shipment (Fig. 6-3) and by the additional use for plywood as seen in Fig. 6-2. Changes in the situation of tropical log supply and NZ log supply were the reason for this additional use. The importation of tropical log (the most common timber for plywood production,) had been decreasing affected by the restriction or prohibition of log exportation (Fig. 6-9). Hence, plywood producers in Japan needed to consider a new resource for producing plywood and conifer trees were singled out. NZ logs were notable because imported NZ logs had changed to the New Crop harvested from the well-managed forests, of better quality, knot-free wood.

6. 3 Utilization of Radiata Pine in New Zealand

From the 19th century till the early 20th century, kauri and rimu were widely used for many purposes in New Zealand, such as framework, and exterior and interior cladding. After the shortage of these resources became clear, radiata pine began to be used. Trials using radiata pine as construction timber started in 1949. However, it took 15 years before radiata pine was recognized as a real resource of construction timber (Sugiyama, 1983). For construction purposes, it was difficult to accept the lower quality wood with wider growth rings, lower density, and more knots because people had used high quality woods with narrower growth ring, higher density, and less knots for many years by then (Fenton, 1983). At first, radiata pine was used only for studs. As the research in several areas such as solid wood processing, timber engineering, wood preservation, timber drying, and adhesives progressed, and additional techniques were developed, the use of radiata pine has expanded.

Currently, radiata pine is widely used as the primary resource for construction timber under a strict structural grades, particularly in the so-called “2×4 system” which is the best-accepted system in New Zealand. Especially, in this field, products incorporating finger-joint timber such as laminated beams, wall studs and posts are playing an active part. Radiata pine is also used for exterior and interior cladding, furniture and floorings. In these products, plywood, laminated veneer lumber (LVL), particleboard, and medium density fiberboard (MDF) are used (New Zealand Pine

Remanufacturers' Association, 1996, New Zealand Forest Owners Association Inc., 1992).

Other external uses include silencers for bore holes in geothermal energy systems and uses in marine and fresh water piles. Glue-laminated beams are also used for bridges and arches.

It could be said that radiata pine is used for many different purposes at the present due to successful achievement both in the research and development of processing techniques.

6. 4 Possibility of further expansion of New Zealand wood utilization

New Zealand wood was utilized mostly for packaging over the time although it has started to use for plywood recently. However, the subject that consumes the largest amount of timbers is the use for construction (40%) followed by for plywood (15%). It is desirable to increase the use of NZ wood in those subjects so that Japan can support protecting indigenous vegetation in the world. In this section, the possibility of enhancing NZ wood utilization for those two subjects are examined by understanding the relationship with other imported woods.

1) Plywood

Restriction or prohibition of tropical timber exportation and the policy for protecting their own timber industries in tropical countries has changed the environment of wood resources obtainment for Japanese plywood industry. Although coniferous species were utilized to compensate for the reduction of tropical log supply (Fig. 6-10), plywood production in Japan decreased steadily. Instead, importation of plywood had increased and made up the shortage (Fig. 6-11).

The coniferous trees utilized as a substitution for tropical logs were NZ logs and Siberian logs, which showed a high negative correlation with the tropical logs: -0.97 and -0.80, respectively. Although NZ log reacted faster to the reduction of tropical logs than Siberian logs, Siberian log increased its amount dramatically from 1993 and it get far ahead in 1996 (Fig. 6-10). The reason why NZ logs are not used more positively in this subject would be:

I. Because NZ log has high moisture content, it can be easily warped and this make the processing cost higher (Japan Economical Newspaper Inc., 1997).

II. Siberian log, which is from natural forest and whose age is between 150 to 200 years old, has higher quality than NZ log, which is from plantation and whose age is about 28 years old. The former has white color, less and smaller knots, and fine grain while the latter has blueness stem, more knots, and weakness (New Zealand Forestry, 1998).

2) Construction timber

The shipment of North American wood, the most common resource for construction timber, has been decreasing since 1989 (Fig. 6-12) according to the reduction of its log exportation which was caused by the growing movement of environmental conservation and the limited amount of resources (Fig. 6-13). Any other resources, however, have not increased instead, which implies the gradual reduction of construction timber production in Japan. The number of new wooden housing development over the period indicated that the demand of construction was almost stable although a little fluctuation could be observed (Fig. 6-14). What compensate the lacking were the increase of produced construction timber from North America (Fig. 6-13).

It is clear that NZ woods are not recognized as a resource for construction timber as its amount kept little over the time. The main reason for this is again the weakness of radiata pine. The outlook for using NZ woods as a pure timber for construction would be bleak. Nevertheless, there is still a gleam of hope left for NZ logs to expand its use in this subject. Processing it to engineering wood is it.

In Japan, the supply of engineering wood such as particleboard (PB), fiberboard (FB), and laminated wood (LW) is increasing these days (Figs. 6-15, 6-16, and 6-17). This is because earthquake-resistant, high-insulation, and shortening of construction period are requested in house-construction.

Air-conditioned houses are very common now and therefore, room with air-tightness and high-insulation is demanded. To satisfy these qualities, PB, FB, and LW are considered as superior materials than non-dried pure timber because of less contraction and warp.

The earthquake-resistant started to be requested with more emphasis after the Hanshin-Awaji earthquake in 1995. Disbelief of post and beam construction houses appeared by the earthquake and this make the proportion of prefabricated houses and houses built by the 2×4 system increase (occupied 6 % in 1988, 8 % in 1993, and 13% in 1997)(Fig. 6-14). In addition, new technique to make the house stronger, for example using wood panels for box frame, is developed in post and beam construction.

In this increase of opportunity to use engineering wood, the utilization of structural laminated wood is increasing in particular. Consequently, it is used in 20% of the wooden houses as post (Nakauchi, 1997). Its purpose for utilization has expanded in many different parts such as post, beam, and sill.

Although radiata pine is difficult to use as a pure timber because of its weakness, it has a high possibility to utilize the processed timber for construction. In fact, as mentioned before, New Zealand had solved its fault and use radiata pine for many purposes including construction by developing the technique to process radiata pine into engineering wood. Moreover, its exportation amount shows a favorable increase (see Fig.1-5), and is expected to become one of the competitive subjects in the global market.

In Japan, New Zealand's position as a supplier of engineering wood is up to the product. Importation amount of PB from New Zealand tends to increase but its proportion to the total is decreasing since the peak in 1993 when it occupied 21% (Fig. 6-18). On the contrary, PB from Malaysia, Canada, and Indonesia is increasing.

Medium density fiberboard (MDF) is the main FB that New Zealand provides. The supply of MDF is increasing in Japan and half of them are imported (Fig. 6-19). New Zealand is a primary supplier of MDF for Japan during the last ten years (Fig. 6-20). Its proportion had increased till 1992 when it occupied 66 % of the total. However, as observed in PB, its proportion had decreased to 36% in 1997. Malaysia again increased her competitive power and increased its proportion from 9 % in 1992 to 30 % in 1997.

Laminated wood is increasing its supply as well as the previous two engineering wood, and 30 % of the total are imported (Fig. 6-17). Although the United States is the primary foreign supplier of structural laminated wood and its amount is increasing steadily, its occupation to the total is decreasing from 90% in 1991 to 51% in 1996 (Fig. 6-21). Alternatively, the proportion of Canada and Sweden increased. On the other hand, New Zealand's proportion is on the level of 5% since 1993 and there is no tendency to increase (Fig. 6-21). This might be because the negative image of radiata pine such as its weakness is too strong to use it for structure whatever its quality has highly improved by processing. Additionally, because there are more interests in structural laminated wood made by North American wood which is well-known as a resource for construction timber in Japan. European countries supplying "White wood" are now also occupying the attention of the domestic timber industry (Nakauchi, 1997).

6. 5 Discussion

NZ logs are used mainly for packaging in Japan and because of the additional use for plywood production its importation amount increased dramatically these days. Although the utilization for plywood is apt to increase, remarkable increase of Siberian log utilization indicates the keen competition in this subject.

Utilization of NZ logs for construction was little because of its low quality; wide growth rings, low density, and lots of knots. As the use for construction occupies 40 % of the total timber consumption, effective utilization of NZ logs in this subject is recommended, which may support to protect the world's remaining indigenous forests. Fortunately or unfortunately, the utilization of engineering wood is increasing in Japan due to the Hanshin-Awaji earthquake. Developing the technique to process radiata pine into engineering wood together with improving its quality, New Zealand increases its exportation amount to Japan. In particular, it is sharing relatively large proportion in the field of PB and MDF. Although this implies a great possibility to expand NZ log utilization in Japan, the future of NZ logs in those subjects is not bright at all. Other countries such as Malaysia became conspicuous in those subjects and more keen competition among the suppliers is expected. It is a significant issue for New Zealand to figure out how to compete with those countries where labor cost is cheaper. In addition, wiping away the negative image of radiata pine might be another issue to overcome the difficult situation for New Zealand.

Table 6-1 Packaging shipments depending on woods from different sources and its correlation coefficient

Shipments of packaging (1000m^3)

year	NZ wood	North American wood	Siberian wood	Domestic wood	Tropical wood
1979	677	418	207	922	518
1980	696	523	195	996	410
1981	604	539	196	988	354
1982	506	504	201	1,022	317
1983	500	557	213	1,056	444
1984	492	596	257	1,076	477
1985	486	618	187	1,122	462
1986	462	677	146	1,013	424

Correlation coefficient (calculated from the data of the above table)

	NZ wood	North American wood	Siberian wood	Domestic wood
North American wood	**-0.7453**			
Siberian wood	0.0765	-0.3454		
Domestic wood	**-0.7311**	0.6747	0.1734	
Tropical wood	0.1008	-0.0342	0.2619	0.0234

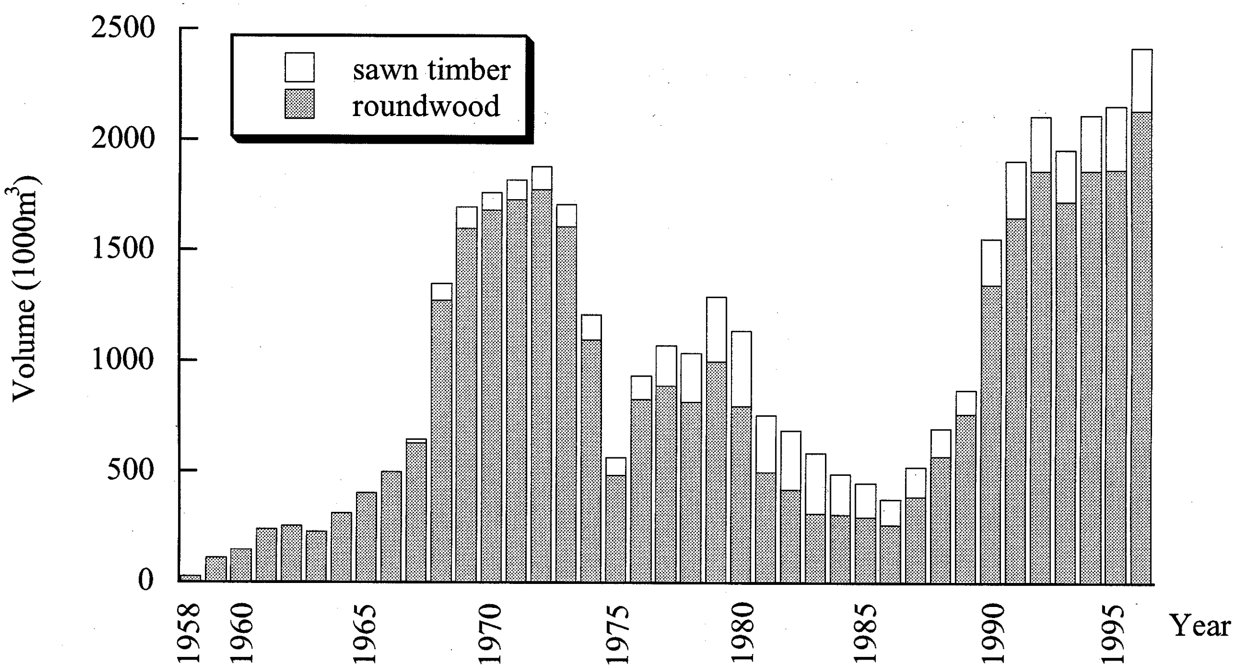


Fig. 6-1 Importation amount of NZ wood.
Source: Japan Forest Products Journal, 1989 and 1997.

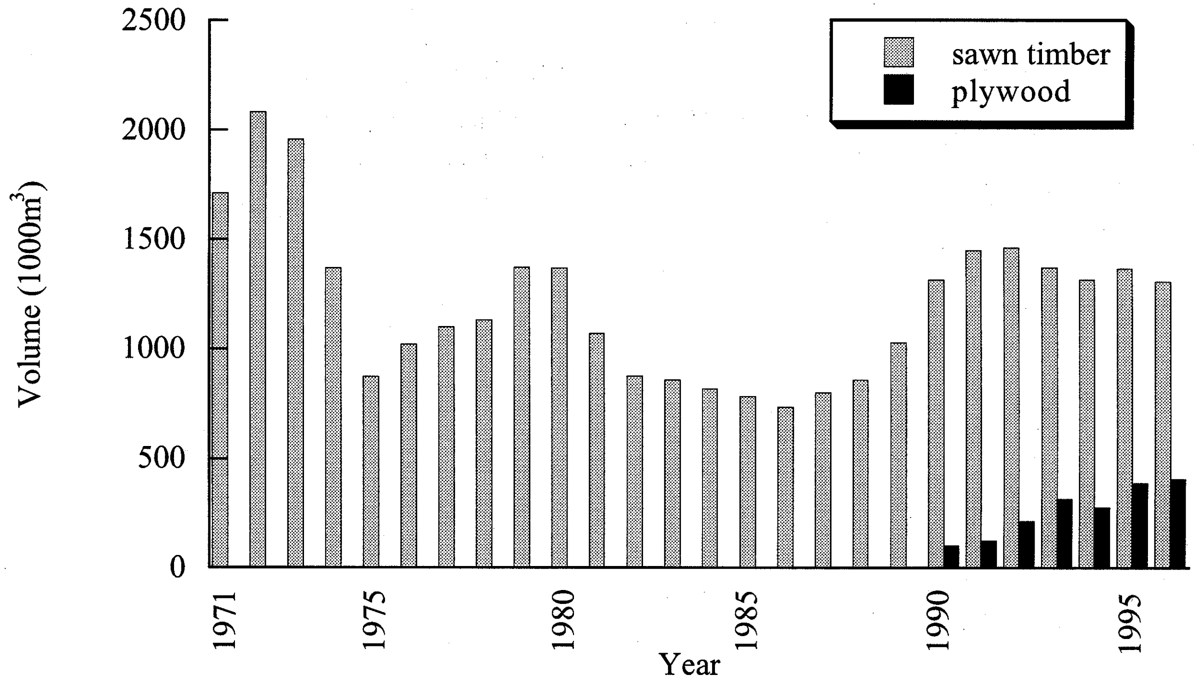


Fig. 6-2 The use of NZ logs.

Source: Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries, 1973-1998.

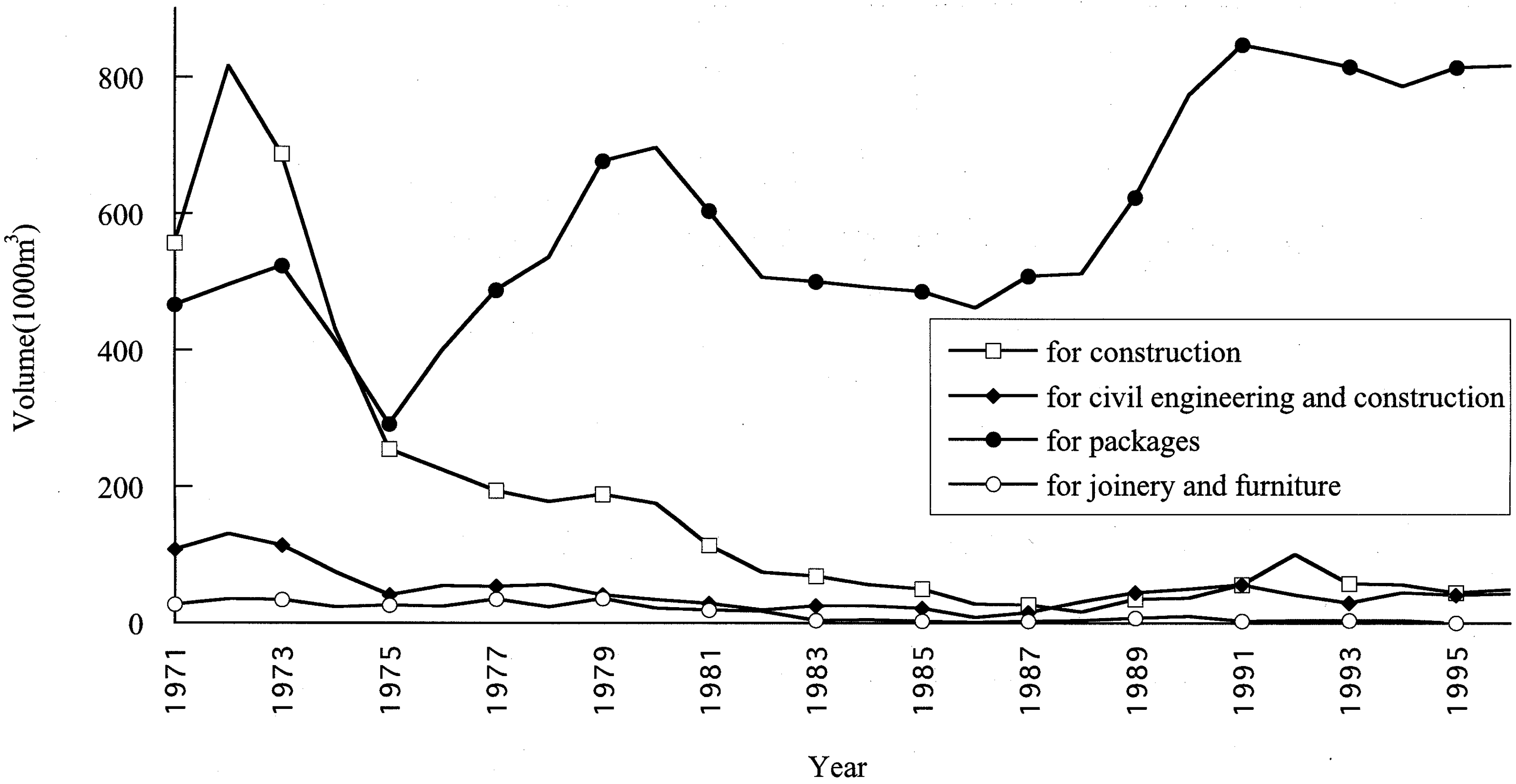


Fig. 6-3 The use of sawn timber.
Source: Statistics and Information Department of Ministry of Agriculture, Forestry, and Fisheries, 1973-1998.

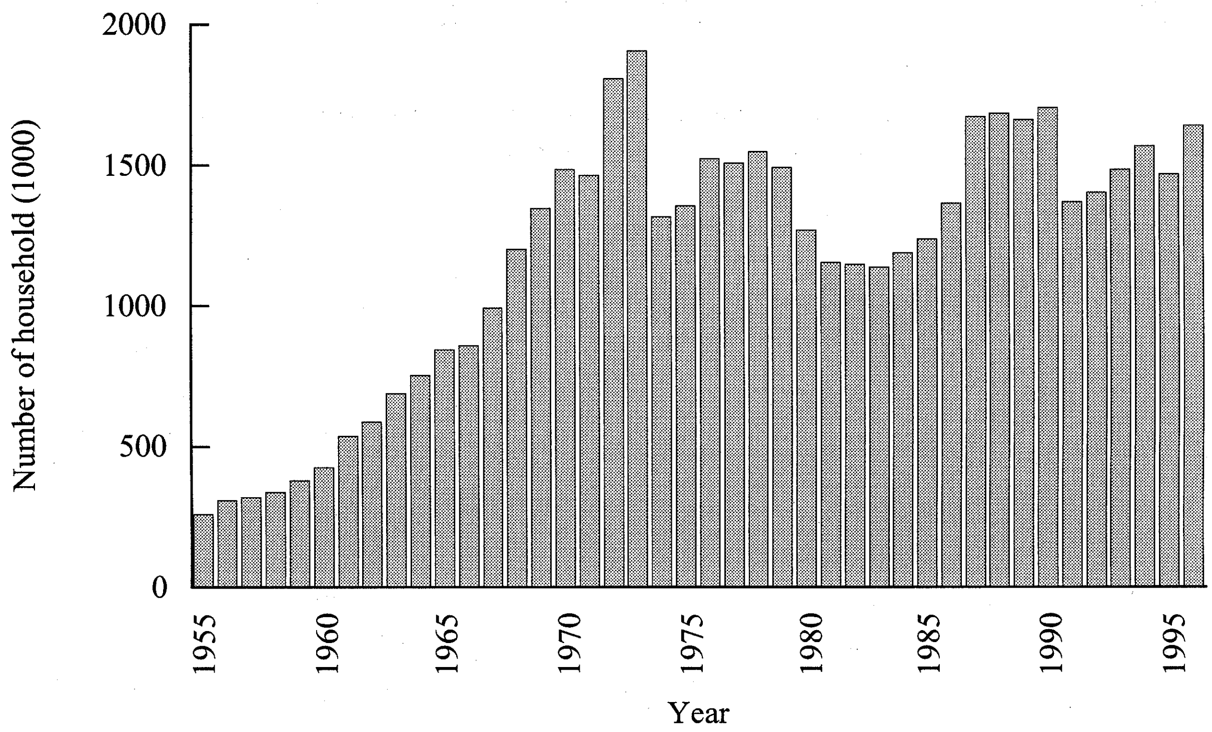


Fig. 6-4 Number of new housing developments.
Source: Japan Forest Products Journal, 1989 and 1997.

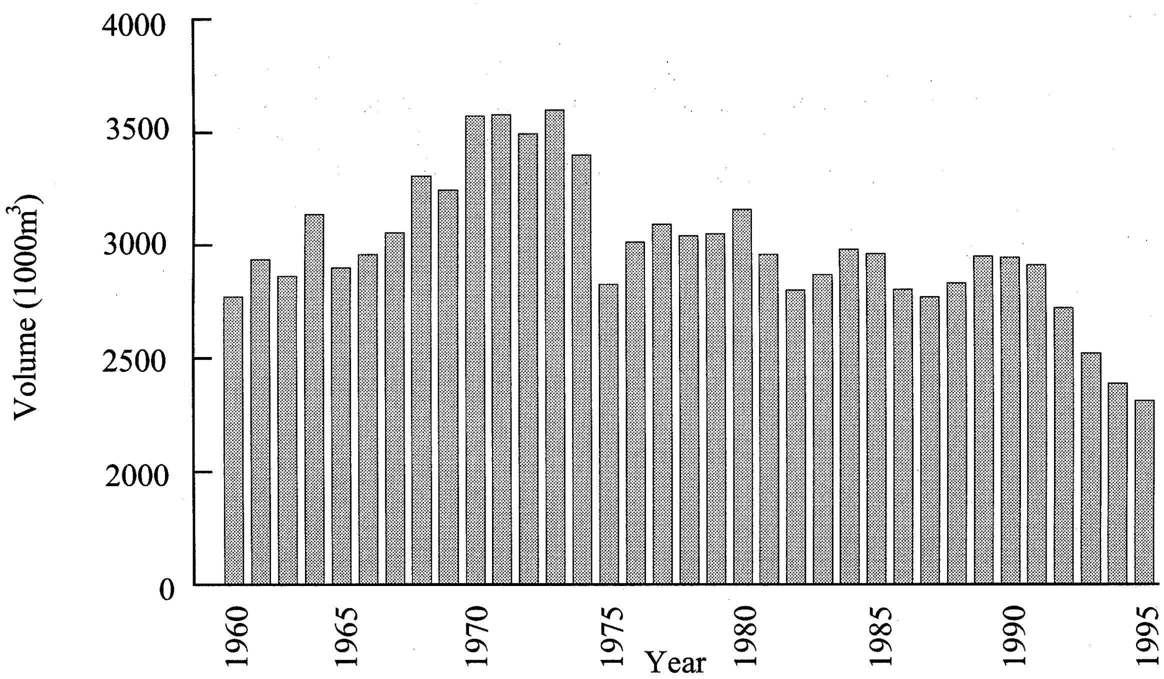


Fig. 6-5 Total shipment of packages.
Source: Statistics and Information Department, Ministry of Agriculture, Forestry, and Fisheries, 1970-1998.
Note: There was no available deta of the year 1962.

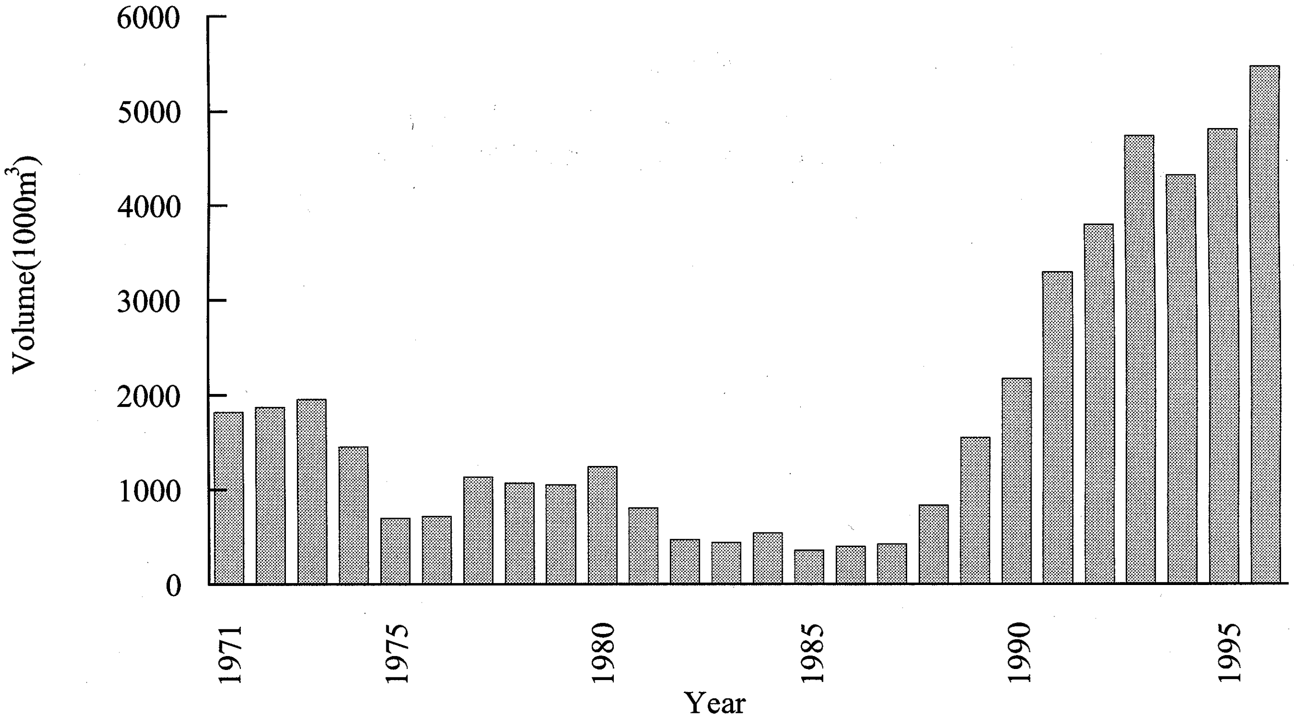


Fig. 6-6 Log exportation from NZ.
Source: NZ Ministry of Agriculture and Forestry, 1998.

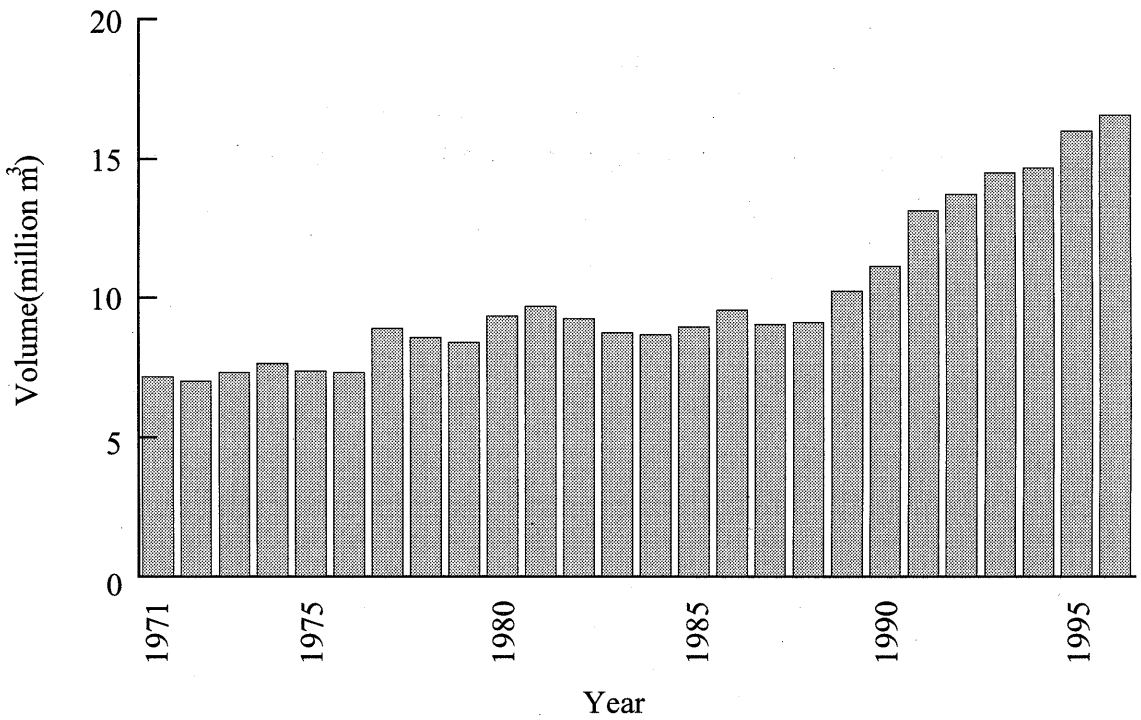


Fig. 6-7 Planted production forest removals.
Source: NZ Ministry of Agriculture and Forestry, 1998.

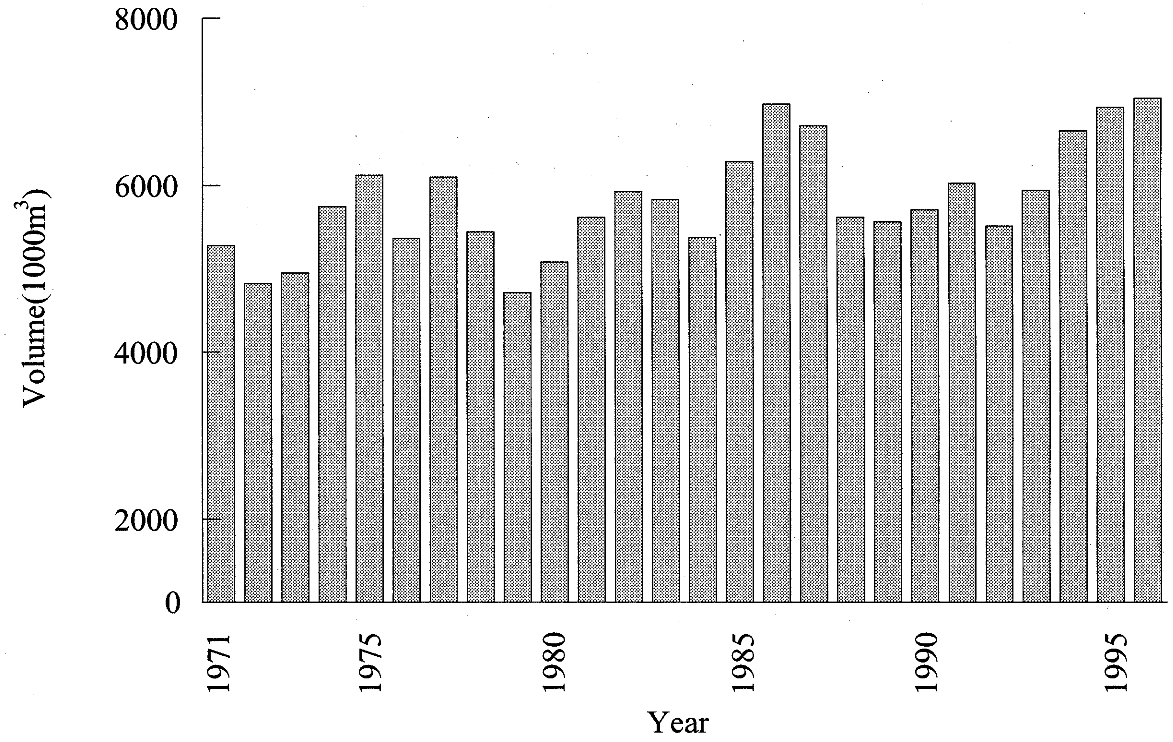


Fig. 6-8 Estimated NZ timber consumption.
Source: NZ Ministry of Agriculture and Forestry, 1998.

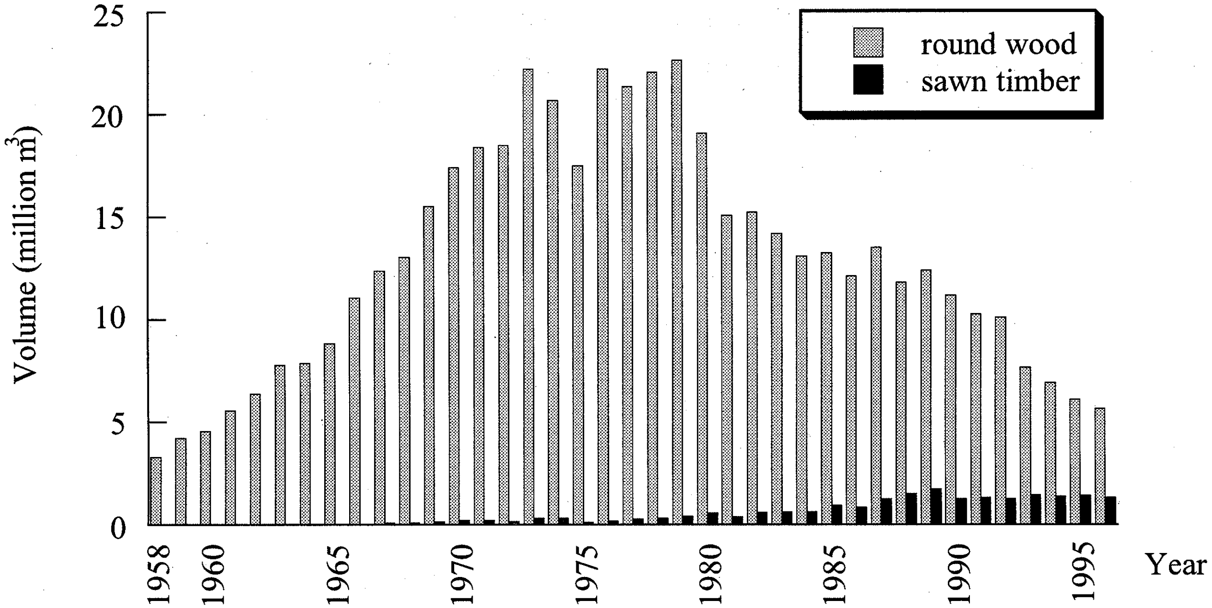


Fig. 6-9 Importation of Tropical Wood in Japan.
Source: Japan Forest Products Journal, 1989 and 1997.

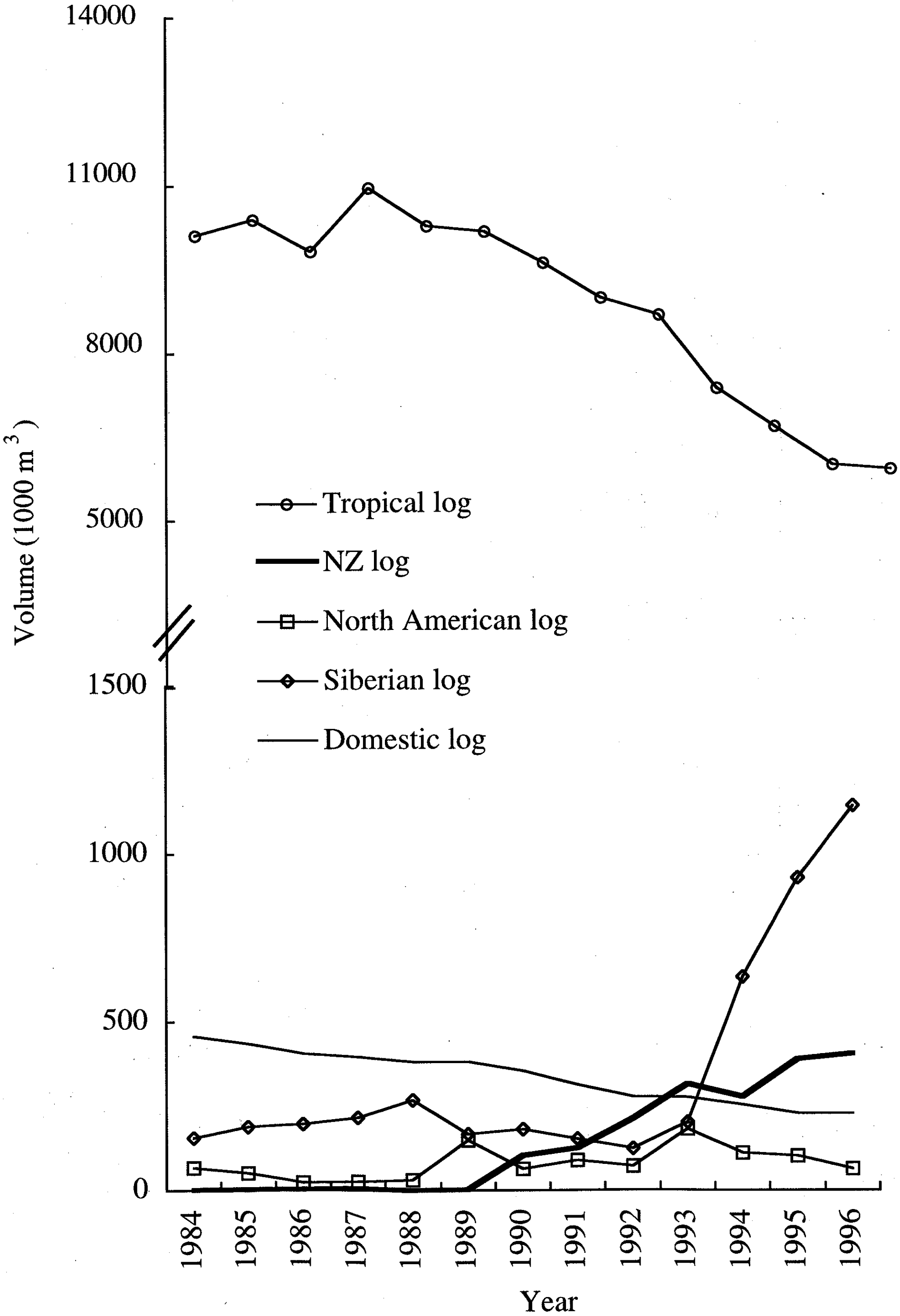


Fig. 6-10 Log supply for plywood production depending on sources.
Source: Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries,1986-1998.

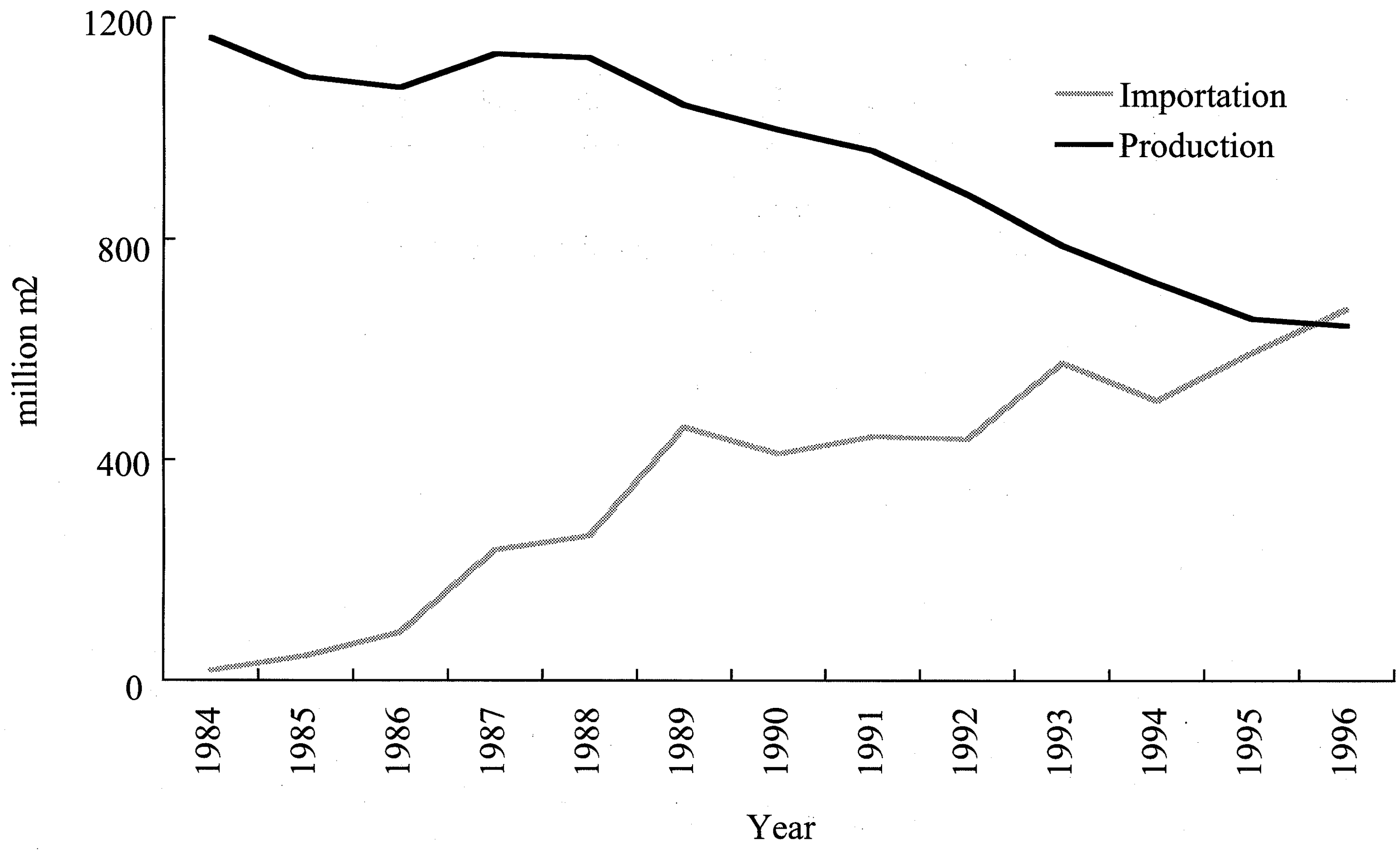


Fig. 6-11 Production and importation of plywood in Japan.
Source: Forestry Agency of Japan, 1997 and 1998.

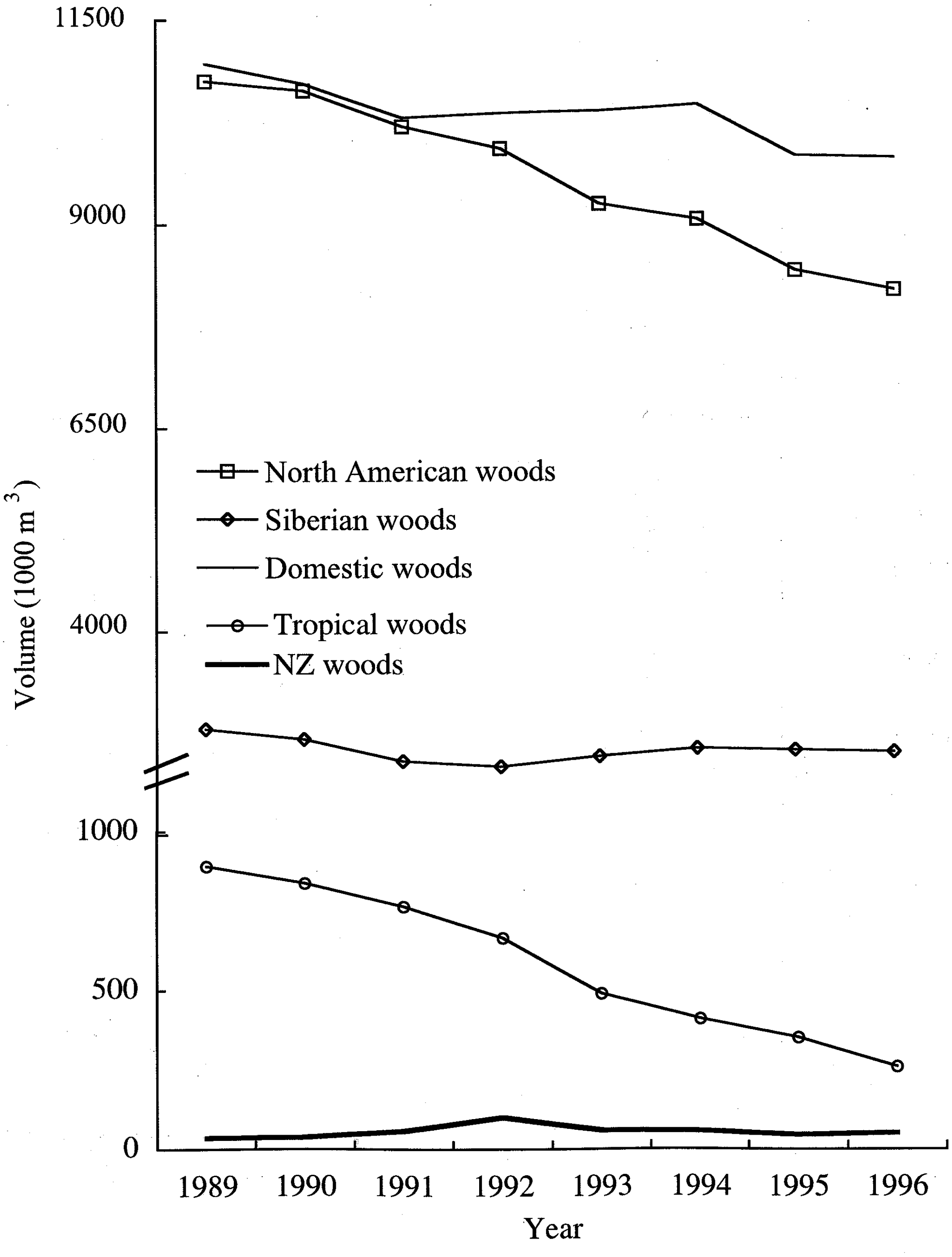


Fig. 6-12 Shipment of construction timber depending on sources.
Source: Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries,1991-1998.

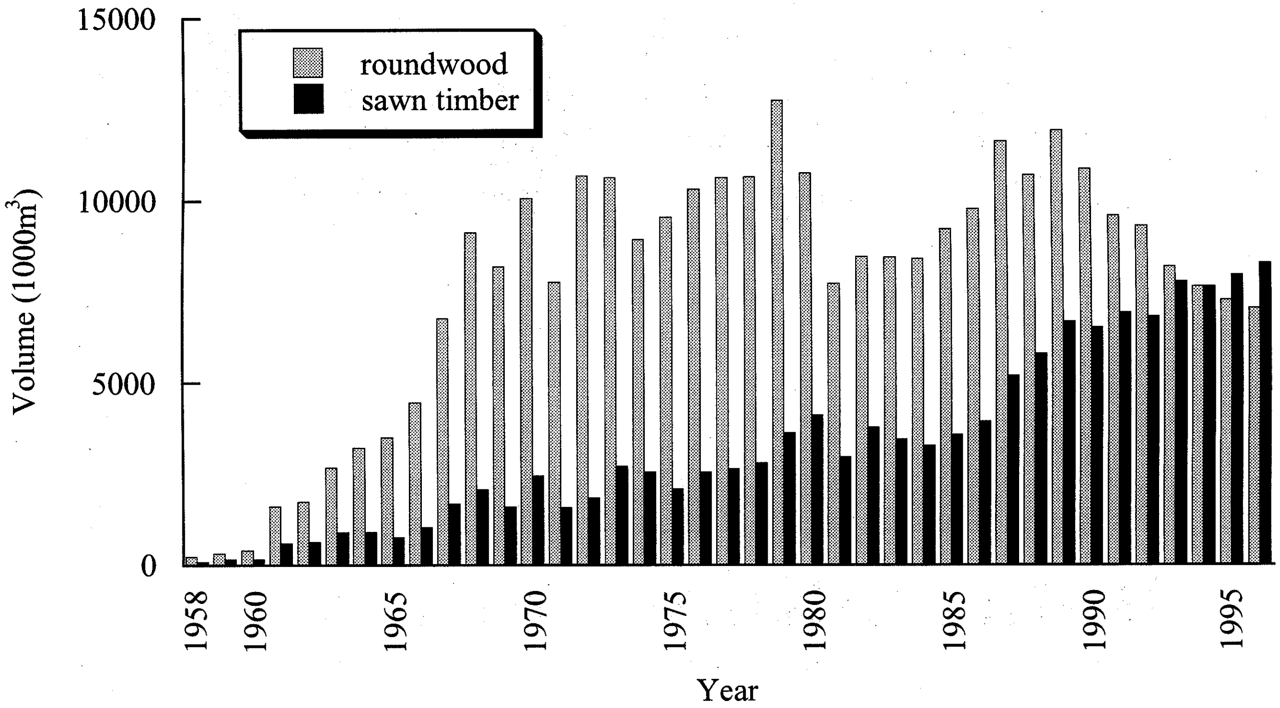


Fig. 6-13 Importation of North American Wood.
Source: Japan Forest Products Journal, 1989 and 1997.

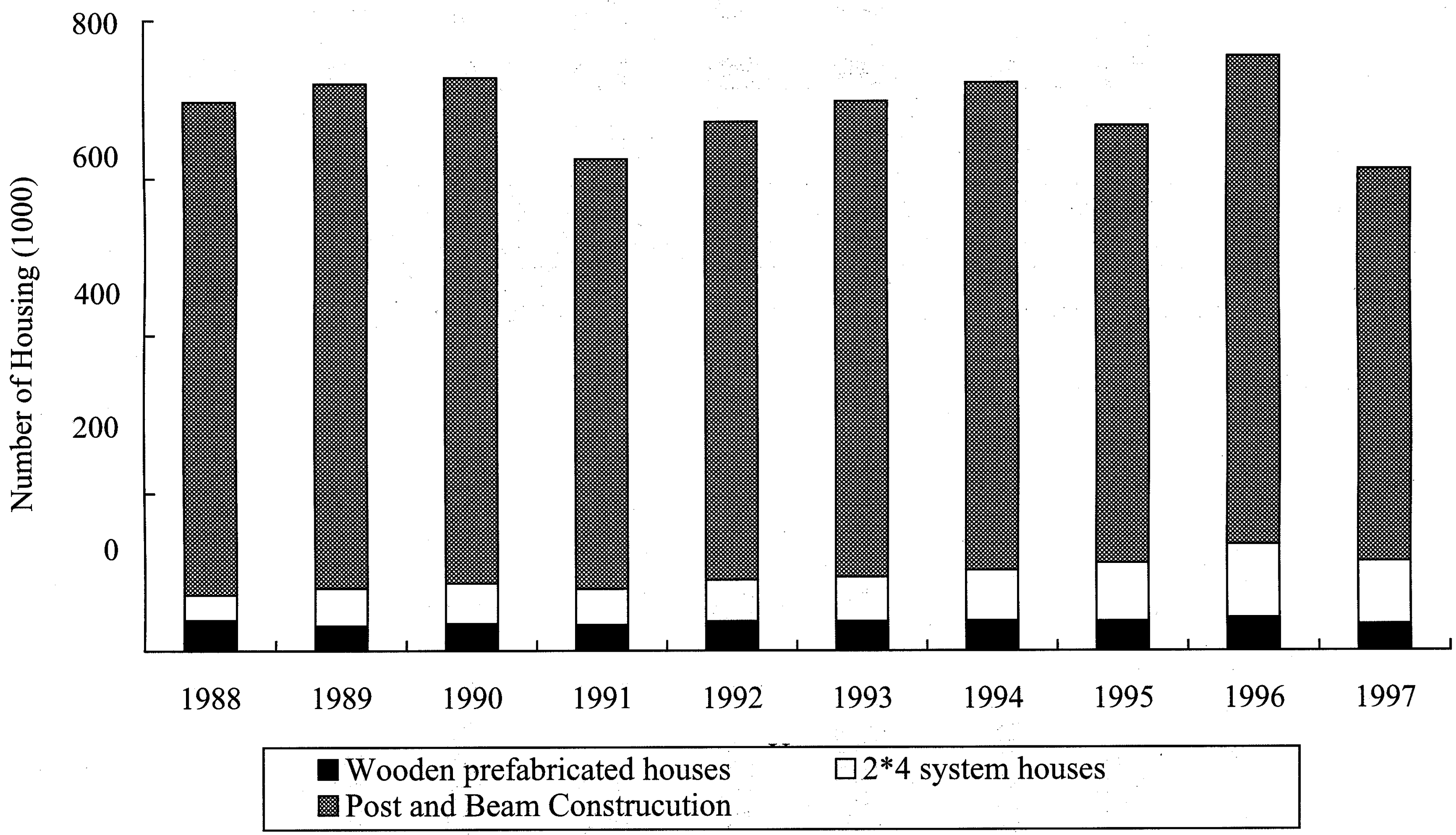


Fig. 6-14 Number of New wooden housings depending on different construction styles.

Source: Japan Forest Products Journal, 1998.

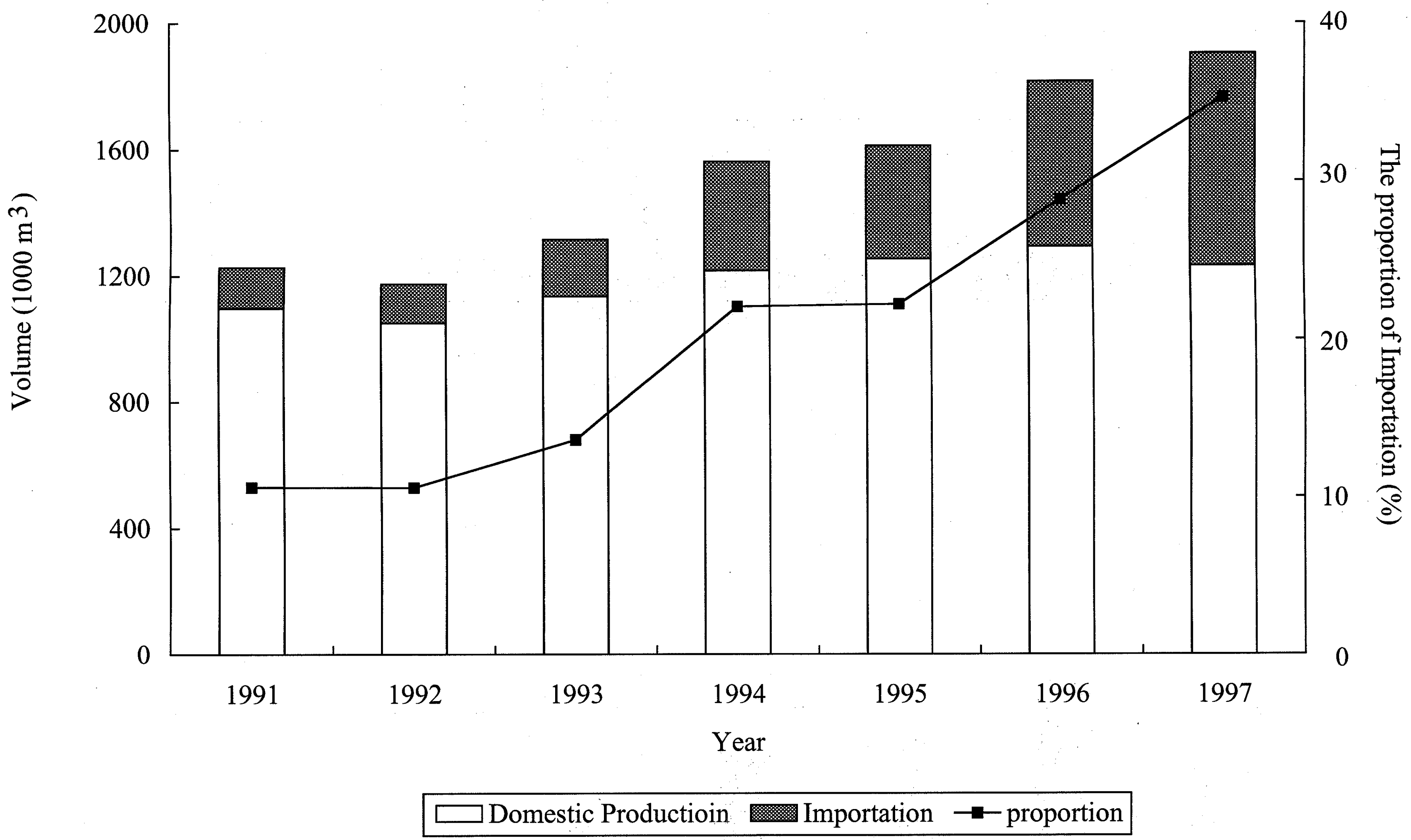


Fig. 6-15 Supply of PB.
Source: Japan Forest Products Journal, 1997 and 1998.

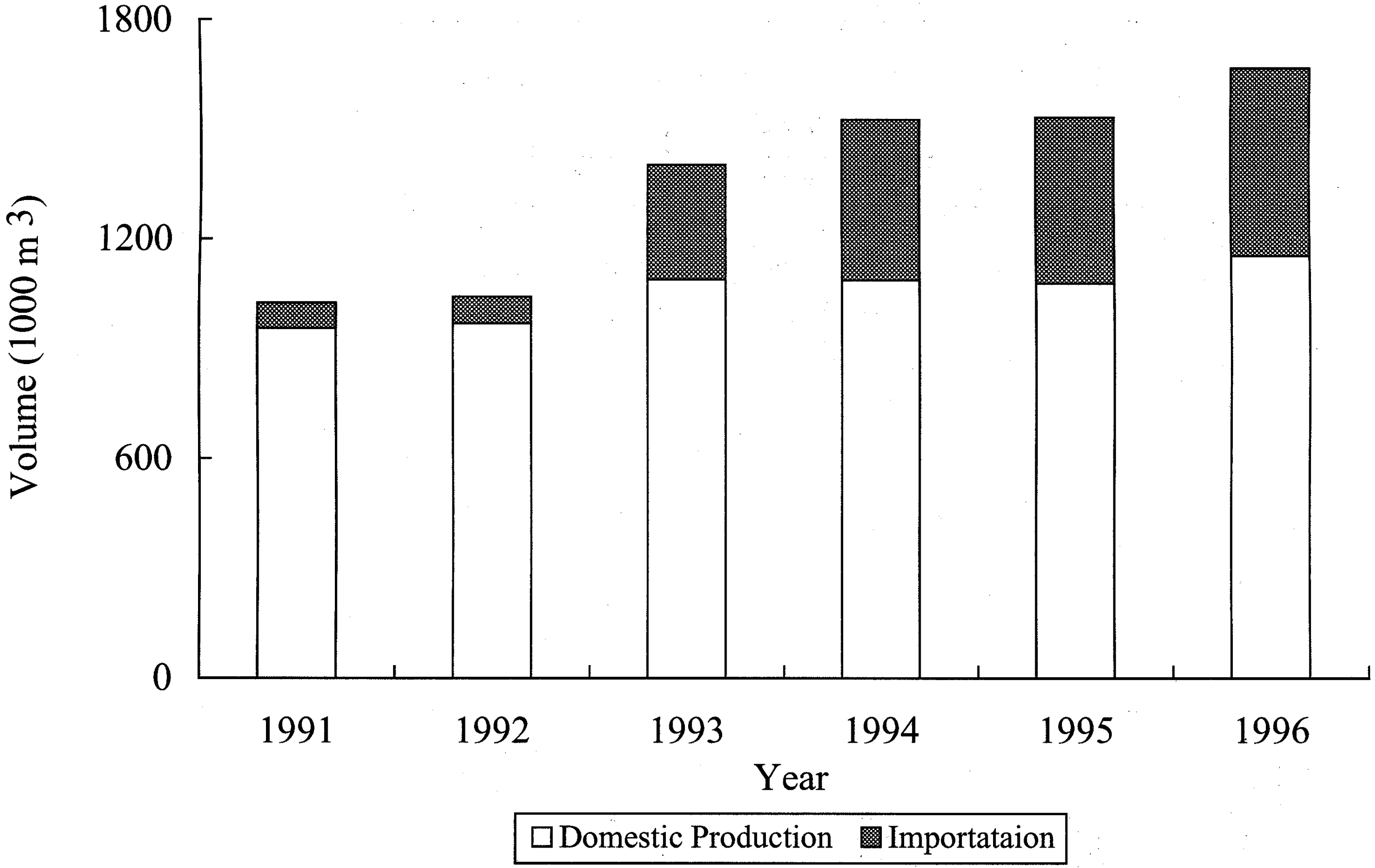


Fig. 6-16 Supply of FB.
Source: Japan Forest Products Journal, 1997.

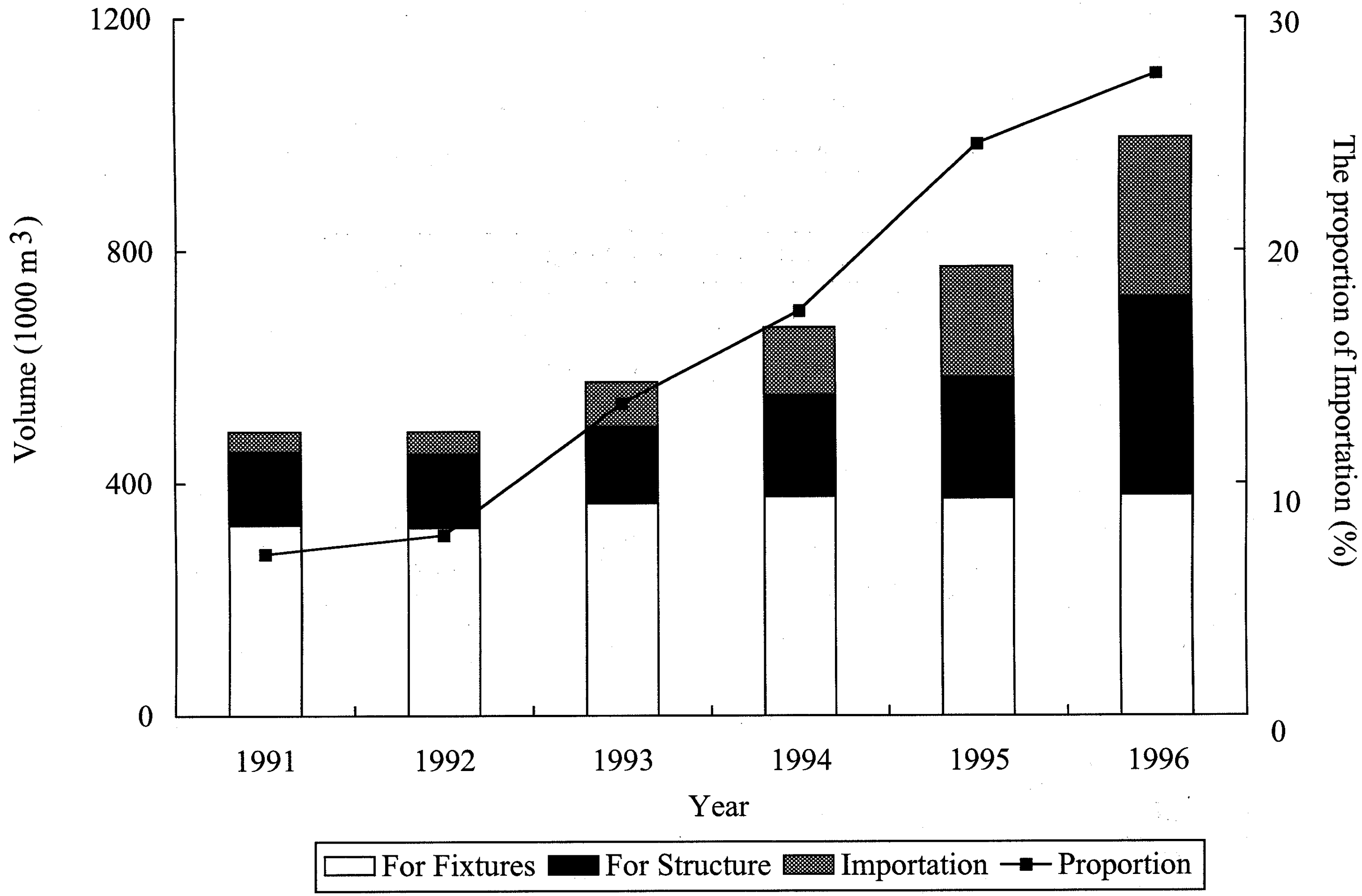


Fig. 6-17 Supply of LW.
Forest Agency of Japan, 1998.

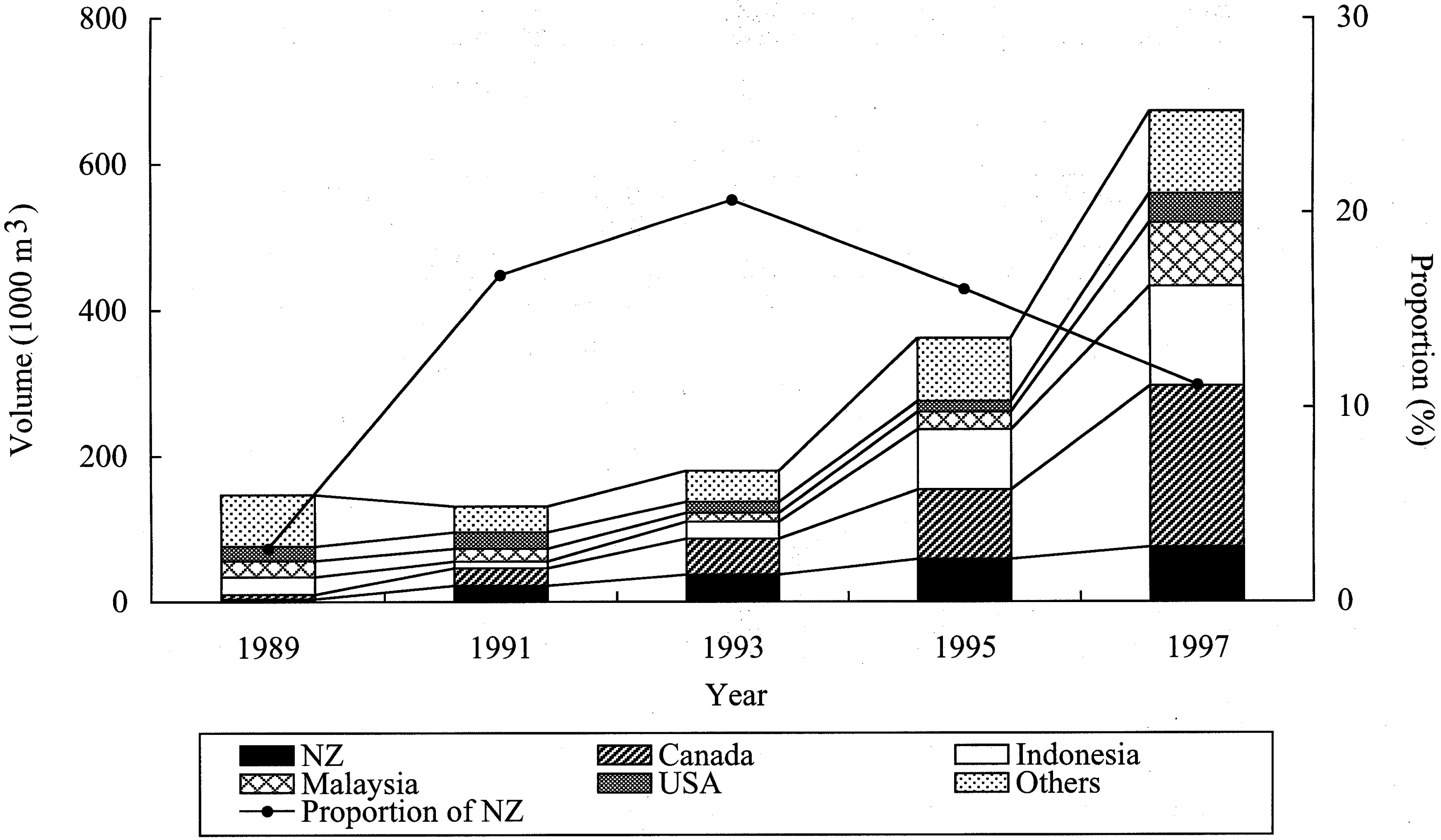


Fig. 6-18 Foreign Supplier of PB.
Source: Statistical data was supplied from the Forestry Agency, where arranged the data from "Ministry of Finance, Trade Statistics."

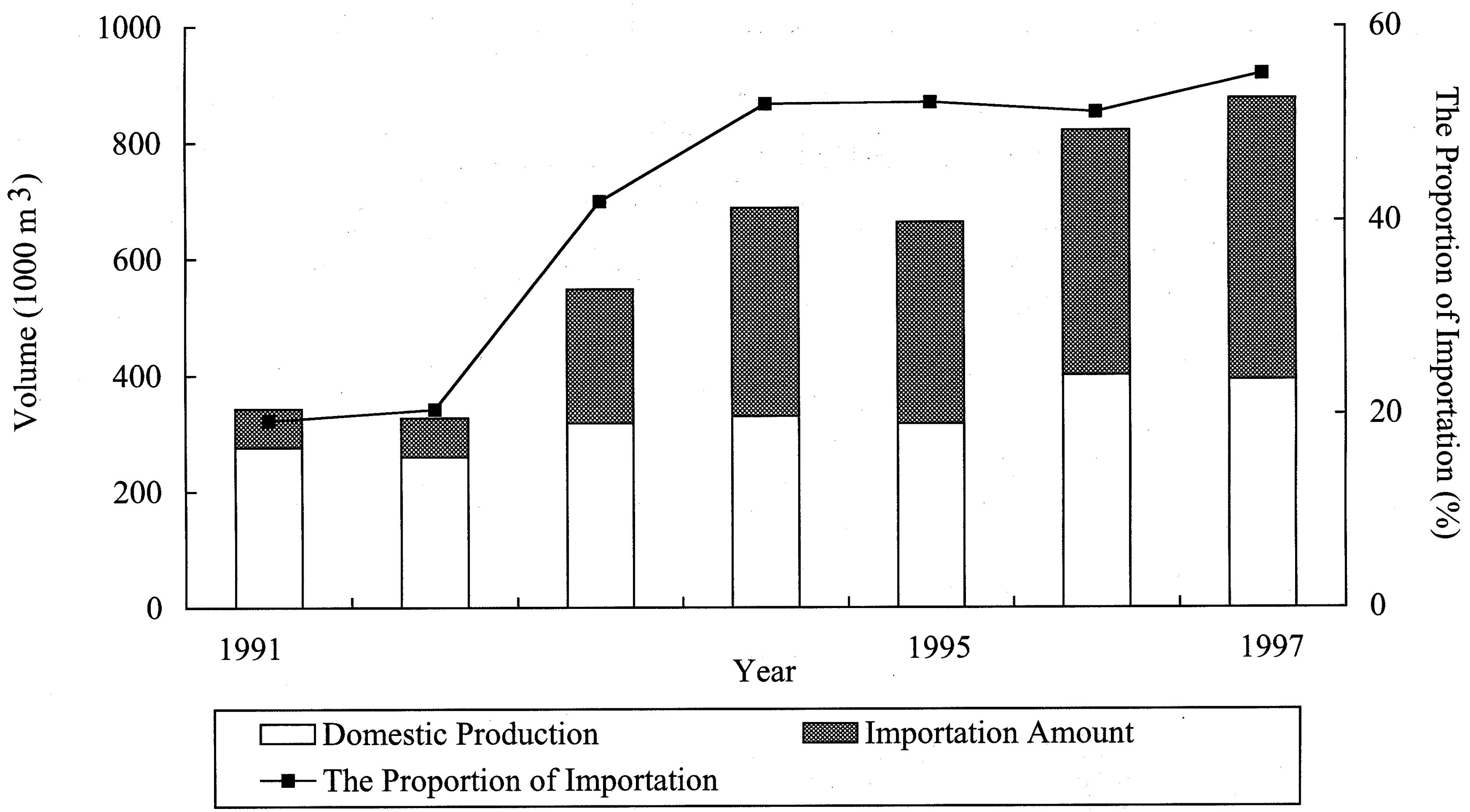


Fig. 6-19 Supply of MDF.
Source: Japan Forest Products Journal, 1997.

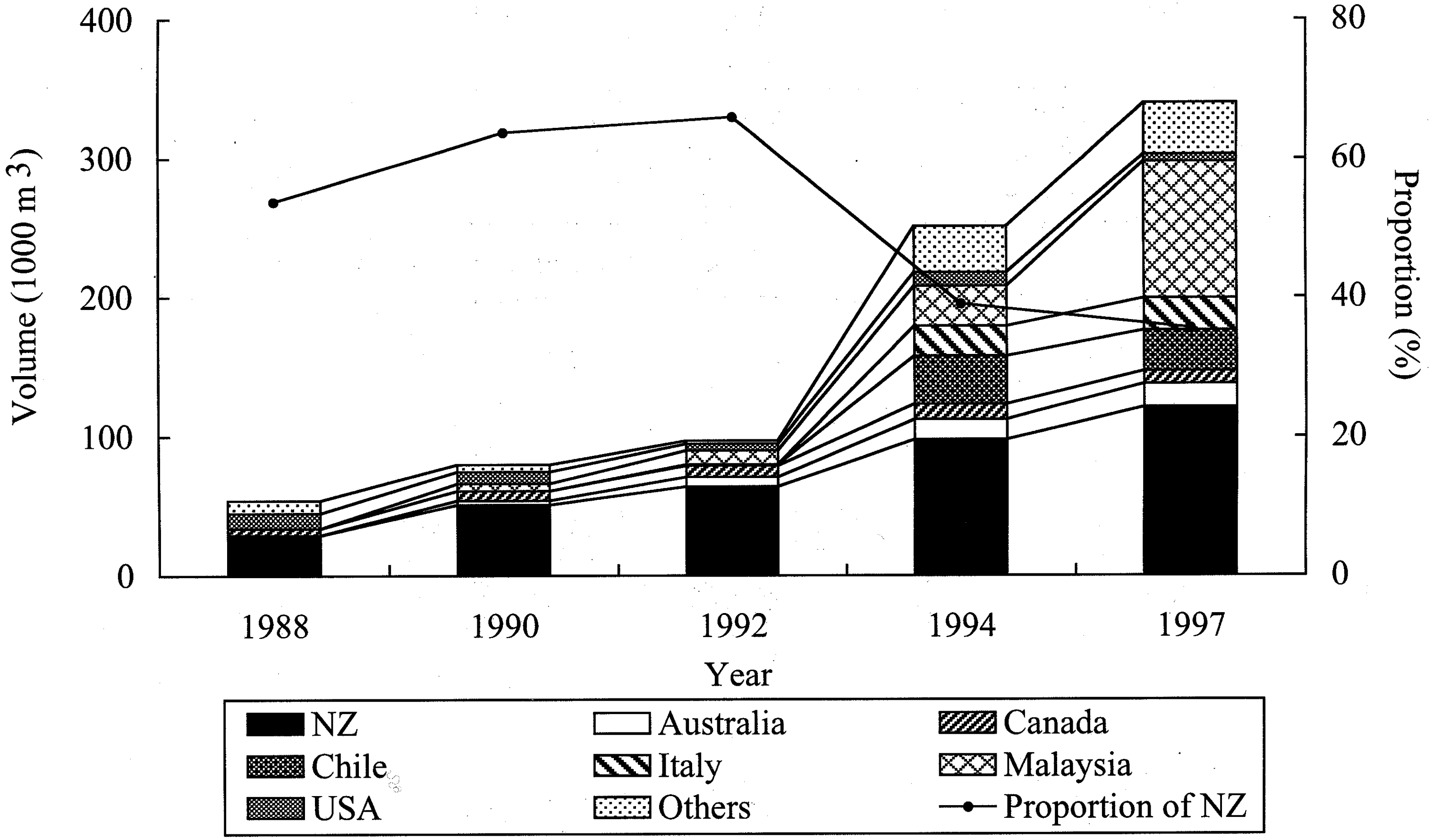


Fig. 6-20 Foreign Supplier of MDF.
Source: Statistical data was supplied from the Forestry Agency, where arranged the data from "Ministry of Finance, Trade Statistics."

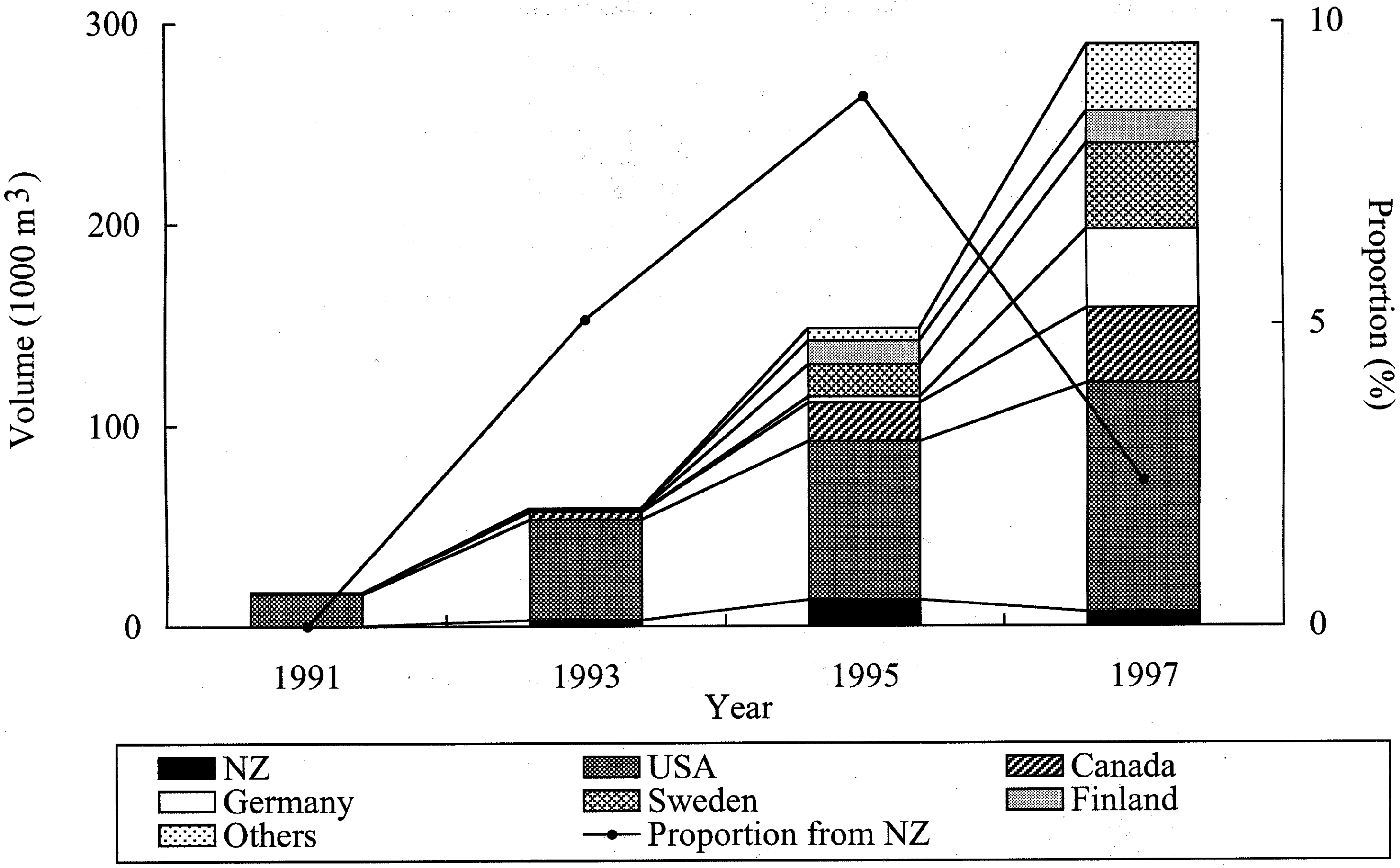


Fig. 6-21 Foreign Supplier of LW.
Source: Statistical data was supplied from the Forestry Agency, where arranged the data from "Ministry of Finance, Trade Statistics."

Chapter 7

General Discussion

7.1. Impact of forestry expansion

Forestry has altered the landscape largely. Shrub land was mainly converted to plantations over the last 20 years. The conversion was well suited to the LUC which suggests the success of previous land-use management system with its main objective on soil conservation. In fact, current plantation distribution consisted well with the LUC (Chapter 3). Nonetheless, remarkable conversion of shrub was not adequate from the aspect of natural environment conservation. As shrub land has high biodiversity, the conversion means the destruction of habitats for various kinds of fauna and flora. Although there are some reports that mention plantation forests are expanding by converting pasture (Fletcher, 1984; Maclaren, 1995 and 1996; Taylor et al., 1997; Alfredsson et al., 1998) and so that there are less influence on environment with high natural value, the fact observed in this study was different. Conversion of pasture to plantation was considered as a new tendency after the dichotomous forest management system was implemented.

Indigenous forest was less affected by the forestry expansion. Indigenous forest was tended to conserve since the environmental boom in 1970s and thus it was less affected regardless of the implementation of the new resource management system.

The land-use distribution pattern was considered to be change in the near future by the plantation expansion: push pasture away from the city center and put plantation closer to the city (Chapter 4). This alteration does not always produce bad results. Plantations might be able to take a role as a corridor to connect fragmented natural forests and shrubs on lowlands. However, it is necessary to take notice of maintaining or enhancing landscape heterogeneity in order to conserve or improve the lowland biodiversity. Planning at the landscape level is required to achieve this.

7.2 The Effectiveness of the new resource management system on environmental conservation.

The new resource management system showed its effectiveness on conserving the remaining large area of natural forest and shrub lands surrounding the Nelson region. It was clear that dichotomous forest management system allow the natural forests to be free from harvesting, and that the Resource Management Plan was contribute to manage the adverse effect on natural environments. Regulations to avoid or mitigate the negative effects of forestry on surrounding environment are well incorporated to the rules of the Resource Management Plans. Those negative effects include sedimentation and water yield.

Forestry has been identified as a major source of sediment (Johnston et al. 1981). Logging and roading operations are the cause of sediments reaching stream channels (Fahey and Coker, 1992; Maclaren, 1993). Needless to say, careful execution of forest operation based on the revised New Zealand Forest Code of Practice (Vaughan et al. 1993) is needed. However, careful management of riparian areas for protection of streams and lakes is considered effective to moderate the impacts of sedimentation by forest activities on middle and upper slopes. The Resource Management Act recognizes the benefits of riparian protection and provides a legal framework for the use of riparian buffers (O'Loughlin, 1994). Hence, both the resource management plan of Nelson city and Tasman District includes the rules for the use of riparian buffers.

The reduction in water yield due to plantation development has been reported by number of studies (Dons, 1987; Fahey and Watson, 1991; O'Loughlin, 1994). The reduction is critically important particularly in summer when demand of water for irrigation and domestic supplies is at a peak, and in areas where water supplies are heavily utilized and under stress. Tasman District is one of those areas. The Groundwater Recharge Protection area was, therefore, lay down under the TRMP and regulates establishing plantation forests.

Although the new resource management system seems to be well designed for accomplishing sustainable development, one thing seems to be lacking. It is the planning at the landscape level for conservation or restoration of fragmented forest and their biodiveristy on lowlands. Lack of landscape planning in the regional plan is the problem not only for Nelson but also for most of the regions in New Zealand. Majority of agencies responsible for biodiversity protection generally focus on the protection of significant patches only and the role of corridors (or greenways) has not been recognized (Viles and Rosier, 2001). In the case of Nelson region, most of the area surrounding the fragmented forests was predicted to convert to plantation and this might lead the area to a homogenous landscape. In order to conserve and enhance the lowland biodiversity, specific plan for arranging where to regenerate natural forests, where to maintain as shrub lands, and where to utilize as pasture or plantation are needed.

Even though there are some points that need to be improved, it is obvious that the resource management system had a great contribution on environment conservation. In other words, lots of efforts were put into avoiding, mitigating, remedying the adverse effect of plantation forestry on the environment. Japan, as the world largest wood consumer, is required to utilize woods harvested from forests that have less impact on the environment. Thus, enhancing New Zealand wood utilization in Japan can be one of the ways to perform its duty.

7.3 Future forestry expansion

In the Nelson region, 216,984 ha were possible to change to plantation. Although the Resource Management Plans restricted and reduced this amount, large area (52,255 ha) was still convertible. As each district council has its own district plan, the rules regulating forestry activities might be differ in levels. Some local authorities might treat plantation establishment as a permitted activity but others might treat it as a discretionary activity. Therefore, it is difficult to say in which amount that plantation can expand in the whole country without specific research examining the relationship with the land-use and the RMPs as conducted in this study. However, it is said there are 5 million ha of pasture that should be planted because it is under the risk of erosion and is unsustainable (Maclaren, 1993). When considering the conversion from other land-use, the possible area of forestry expansion in the whole country might get larger than 5 million.

The high possibility of further forestry expansion would provide a good opportunity for Japanese forestry industry to invest. As investors from many countries have played an important role in developing the forest industry in New Zealand by introducing capital, technology and market access, the New Zealand government put a lot of efforts on creating environment attractive to international capital. Liberal foreign exchange policies have been introduced to allow currency to be freely taken into and out of the country. A well developed, stable and cost-competitive business infrastructure, with low inflation, low energy costs and high labor productivity ensures internationally competitive returns (New Zealand Ministry of Forestry, 1995a). Several Japanese companies such as Juken-Nissho, and Pan Pacific Forest Industry (Oji Paper Co., Ltd.), took this advantage and branched in New Zealand. Both Juken-Nissho and Pan Pacific forest industry established plantation, about 60,000 ha and 32,000 ha respectively, and become one of the major forest owners in New Zealand.

Plantation establishment in New Zealand by Japan or Japanese companies has also a great possibility to contribute toward accomplishing the emission target of greenhouse gasses set by the Kyoto Protocol. The Kyoto Protocol was adopted at the Third Conference of the Parties to the UN Framework Convention on Climate Change (COP3) to reduce greenhouse gas emissions by harnessing the forces of the global market place to protect the environment. A central feature of the Kyoto Protocol is a set of binding emissions targets for developed nations (U.S. Bureau of Oceans and International Environmental and Scientific Affairs, 1998). Japan would be obligated under the Protocol to a cumulative reduction in its greenhouse gas emissions of 6% below 1990 levels averaged over commitment period 2008 to 2012 (Forestry Agency of Japan, 2001). The framework for those emissions targets includes the concept of "sinks: Activities that absorb carbon such as planting trees will treated as offsets against emissions targets" and of "emissions trading." Emissions trading had introduced in order to allow countries to seek out the cheapest emission reductions because the cost for reducing 1 ton of greenhouse gases would differ from country to country (Japan Ministry of Environment, 2001). Three types of emission trading are cited: international emission trading; joint implementation among developed countries; clean development mechanism. Under the international emission trading regime, countries or companies can purchase less expensive emissions permits from countries that have more permits than they need (because they have met their targets with room to spare). Under the joint implementation among developed countries, countries with emissions targets may get credit towards their targets through project-based emission reductions such as afforestation in other developed countries. The private sector may participate in these activities. With the clean development mechanism, developed countries will be able to use certified emissions reductions from project activities in developing countries to contribute to their compliance with greenhouse gas reduction targets (U.S. Bureau of Oceans and International Environmental and Scientific Affairs, 1998). Plantation establishment by Japanese companies in New Zealand could be classified as joint implementation if it is the part of the emission reduction project and therefore, has a significant contribution to achieve the emission target.

7.4 Application of the Resource Management system to Japan.

1) Integrated resource management

In order to implement the Agenda 21, a new single environmental policy that covers a wide range of environmental issues was required. The Basic Environment Law was, therefore, established in 1993. It provides the principle of environmental policy and covers the issues of nature conservation, pollution control and other environmental issues including the problems at the global level (Sasaki, 1998). In accordance with the provision of the Basic Environment Law, the Basic Environment Plan was formulated and adopted by the Cabinet in 1994. The government copes with every kind of environmental issues based on the plan. The plan prescribes four long-term objectives; namely, environmentally sound material cycle, harmonious coexistence, participation and international activities. The Plan also identifies outlines of the policies, the roles of each entity of the society, and the use of various policy instruments to achieve the objectives (UN, 1997). Since the Basic National Environment Plan was adopted, there is a mass movement among local authorities to establish a Local Basic Environment Plan together with a Basic Environment Ordinance.

Although the Basic Environment Plan is a plan for environmental conservation, it does not include any rules for integrated land-use control. The National Land Use Plan under the National Land Use Planning Law is the one that controls land-use and provides the basic framework for integrated land-use management. The National Land Use Planning Law also prescribes the prefectural governors to formulate a Land Use Master Plan that covers matters dealing with the designation of five areas (urban, agricultural, forest, natural park and nature conservation areas), and the coordination of competitive land-uses (UN, 1997). The plan is placed above the individual laws for the above five areas (City Planning Law, Agriculture promotion Area Management Law, Forest Law, Natural Parks Law and Nature Conservation Law), and functions as a means of comprehensive intra-administration coordination (Mizuguchi, 1997).

Japanese government is putting its effort to develop a sustainable society and establish an integrated resource management system. However, it seems the system is still remain fragmented and incomplete. Nakagushi (1998) pointed out that the Basic Environment Plan lacks the system to evaluate other plans like National Land Use Plan from an environmental aspect so that their relationship is obscure. This suggests that the Basic Environment Plan have little contribution on sustainable land-use management. As land-use management and environmental conservation cannot be considered separately to accomplish integrated resource management, this is a big theme for Japan to deal with.

Another problem is the difficulty of the local governments to establish an original land-use plan based on their local needs and local environmental issues. Although the National Land Use Planning Law provides the prefectural authorities to make a Land Use Master Plans, the master plan is restricted by the land-use classification (zoning system) of the individual laws, particularly for the City Planning Law (Mizuguchi, 1997). In addition, several studies suggest that the zoning system under the City Planning Law is insufficient for controlling the spread of development into the Urbanization Control Area (Kidani and Kawakami, 1998; Mikuni, 1999).

On the other hand, it seems that New Zealand had well incorporated those two points to their resource management system. New Zealand integrated the Resource Management Act with other legislation in order to establish a consistent resource management system. The enactment of the RMA amended 50 statutes and repealed a number of major pieces of legislation including the Town and Country Planning Act 1977, the Water and Soil Conservation Act 1967, the Clean Air Act 1972, and the Noise Control Act 1982 (Milne, 1992; Hiramatu, 1997a; Williams, 1997). It also approved the local land-use planning responsibility so as to cope with the local environmental issues.

Although the Act has a number of advantages, it also has a range of problems at an operational level as follows (Novis, 1997),

- The resources required to effectively participate in the process are considerable and often beyond the means of small agencies and individuals;
- Treatment of the effects of different land-uses is often inequitable;
- The number of planning documents that a resource manager may need to abide by can be considerable, creating complex planning environment;
- There are startling inconsistencies across some district boundaries with respect to objectives, policies and method of implementation;
- Plans are complex and often difficult to interpret with certainty;
- The costs of obtaining resource consents can be high;
- The time taken to negotiate consents through all legal processes does not seem to have been reduced.

The difficulty of "Effects-based approach" is also pointed out. The "effect" defined by the Act includes the cumulative effect (see Chapter 1), which suggest to put cumulative impact assessment as a part of decision-making process. However, council planners are facing a great question: how cumulative impact assessment can become part of the decision-making process even as we are learning about natural systems and at the same time about the appropriate methods to evaluate impacts on natural systems (Dixon and Montz, 1995). Because of this question, regional or district plans commonly focus on the control of activities, rather than the control of adverse effects of activities (Novis, 1997).

Several studies were conducted in Japan to interpret the system of the RMA and its effectiveness. Kakizawa and Nozaki (2001) mentioned that the effects-based approach is only useful under a specific condition: low population density; strict nature conservation system; limited area with high development possibility. As for New Zealand, remaining natural environment is well protected and most of the development is predicted to occur on pastures. On the contrary, Japan has high population density and its land development patterns are more complicated. Thus, it might be difficult to establish the same system as the Resource Management Act in Japan. However, considering the RMA's effectiveness on environmental conservation at a certain level, both the strong and weak points of the RMA are full of interesting suggestions to set up a more effective integrated resource management system in Japan. In particular, for solving the problems that Japan currently has such as fragmented resource management policy and difficulty of local-based land-use management.

2) National Forest Management

Japan is rich in forest. Approximately 70 % of the land (25 million ha) is covered by forest, of which 60 % is natural forest. Forty percent of the total forested area (7.6 million ha) is National Forest managed by the Forest Agency of Japan (Forest Agency of Japan, 2001).

As New Zealand used to do, the Forest Agency has been taking the multiple-use approach. More emphasis had been put on timber production than nature conservation for a long time, since the World War II. However, the situations of forestry in Japan have changed remarkably over the last three decades. The demand for domestic timber decreased because cheaper imported timber was preferred in the market. Reduction of domestic timber demand led to the declining of domestic timber price. On the other hand, the labor costs had increased during the high economic growth era. Consequently, forestry in Japan became unprofitable. As the Forestry Agency was taking the self-supporting accounting system, the situation brought a great loss. The financial condition hardly allowed the Agency to manage the forest appropriately and forest began to be degraded (Yamamura, 1994). Forest degradation can cause soil erosion, flood and many other kinds of hazards, and expose the people to danger. Thus, means for solving financial problem and promoting adequate management operation were strongly required.

There was also a great change in the functions that the people expected to forests. More interests arose in nature and land conservation than timber production. Forests also became an important place to provide recreation opportunities.

In order to cope with these changes, the National Forest management system reformed in 1998. Three significant points were changed: 1) The main objective was switched from timber production to nature and land conservation; 2) The accounting system was converted from self-supporting accounting system to special accounting system that premises transfer of the general account (Forestry Agency of Japan, 1999); 3) Forest management works such as afforestation, thinning, pruning, and deforestation will commit to the private sector in order to rationalize the forest management system. The government is going to concentrate on the policy and regulatory role together with nature and land conservation (Forestry Agency of Japan, 1999).

When the reform of national forest management system was protested, several proposals were discussed. One recommended managing the national forest by the prefectual authorities (Kasahara, 1996). One of the others suggested dividing the national forest into two groups: forest for cutting and forest for land conservation. As the latter was for public purposes, transferring the general account was recommended (Iida, 1992).

Privatization of the national forests was also considered referring to the New Zealand's case. Privatization was recognized as one of the way to get out of the red operation and to rationalize the forest management system. The proposal suggested dividing the forest for timber production and for public interests, and privatizing the former. However, it was doubted whether the privatized forest could be profitable like in New Zealand under the difficult situation of forestry in Japan (Iida, 1992). In addition, the cutting period in Japan was different from New Zealand. It is not so short as in New Zealand: 50 to 60 years in Japan and 30 years in New Zealand (Konohira, 1989). To be profitable, the quality of the privatized forest must be extremely high, which was far from the real estate (Iida, 1992). Moreover, there was a question whether it is possible or not to divide the objectives clearly into forests for production and for public benefits. Japan is more mountainous than New Zealand and it was obvious that even the production forests needed to manage from the aspect of land conservation. The boundary of natural forests and production forests, also, is not that clear as like in New Zealand (Minowa, 1997a).

Consequently, the privatization proposal was not accepted. However, it is clear that Japan had learned many things from the New Zealand's forest management system, particularly, for finding out the way to rationalize the system. It could be said that commitment of the forest management operations to the private sector was one of the result of referring to New Zealand's case.

In addition to the resource management system, New Zealand has a potential to provide many other suggestions to Japan such as to improve the profitability of forestry. Although the new national forest management system is expected to be useful for reducing the debt of the Forest Agency and enhancing adequate management operation, the problem of the low profitability of Japan's forestry (including both the national forest and the private forests) still remains. As New Zealand succeeded to establish a profitable forestry operation system by mechanization and improving breeding techniques based on strict researches, New Zealand might be able to provide interesting advices on those points.

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Summary

Chapter 1

The expansion of plantation forestry in New Zealand during the last century has altered the landscape. However, its influence on the landscape level has not been well investigated. The implementation of recent resource management system (division the roles of natural forests and plantation forest clearly and establishment of the Resource Management Act [RMA]), which took the lead of integrated resource management in the world, will also influence the impact of future plantation expansion on the landscape. The influence of new resource management system on further forest expansion is the main interest not only for New Zealand but also for Japan, especially for Japanese companies having interests in timber importation and in establishing plantation in New Zealand. Understanding the effectiveness of the RMA will also provide a hint to form a system of integrated resource management in Japan. Hence, this study aims 1) to interpret the effects of forestry expansion on land-use pattern, 2) to examine the effect of the RMA on land-use, and 3) to investigate the potential of further forestry expansion. In addition, the expansion possibility of New Zealand wood utilization in Japan was also interpreted.

Chapter 2

The Nelson region was selected as a study area to examine the land-use patterns. As the adopted data set was based on the definition or system that is specific to New Zealand, this chapter provides an explanation of the data set (e.g. LCDB map and NZLRI map) together with the outline of the study area.

Chapter 3

Interpretation of current land-use pattern is the first step to examine the influence

of forestry expansion on landscape level. Picking up Nelson region as an area for case study, this chapter aims to understand the land-use distribution patters and their relationship with the land characteristics. The factors determining the land-use distribution pattern were also examined by using conjoint analysis. Consequently, the land-use distribution pattern could summarized as the following from the city center: Urban; Agricultural, pastoral and forestry area; Transitional zone from plantation dominant area to indigenous forest area; Indigenous forest area. The distribution pattern resembled to the Barlowe's land-use model. In addition to the physical attributes of the land, the influence of land-use management policy was obvious.

Chapter 4

Interpreting the land-use change pattern and its factors may provide more detail and adequate information on understanding how the current land-use pattern was formed. Overlaying the LCDB and NZLRI map, forest expansion from 1970s to 1990s was observed mainly from shrub or pasture, and horticulture expansion from pasture. Both changes probably related to the higher returns from forestry and horticulture than from sheep grazing or dairy farming. Based on the discriminant analysis, the distance from the city was the main factor determining the land-use change. Conversion to plantation over the 20-year period was closer to the city than conversion to pasture. If this tendency continues, it will probably change the regions land-use distribution pattern in the future. Based on the discriminant analysis, the data set utilized in this study was useful for predicting the future land-use.

Chapter 5

Predicting the future land-use change and comparing it with the regional and district plans under the RMA are essential for interpreting the influence and effectiveness of the RMA. Using the Fisher's classification function derived from the discriminant analysis in chapter 4, the convertible area of indigenous forest, shrub, and pasture to other land-use on the LCDB map were predicted. The predicted areas were overlaid with the regional plan maps to examine whether or not the conversion will happen. Conversion from indigenous forest to other land-use is not likely to happen because of the rules of the regional plans. Plantation, however, still has a possibility to expand its area about 50,000 ha, especially by converting pasture. Although the resource management system in New Zealand seems well conserving the surrounding large area of indigenous vegetation, the fragmented forests on lowlands are less conserved. In order to conserve lowland forests effectively, landscape planning is essential.

Chapter 6

As one of the world's largest wood consumer, Japan is responsible for importing logs or timbers from forests, which have less influence on the remaining natural forests and on their biodiversity. Thus, importing and using logs harvested from plantations in New Zealand might be one of the paths to fulfill its responsibility. In Japan, New Zealand wood has been utilized for packaging and recently for plywood. It was not utilized for construction because of its weakness. However, there is a possibility to expand its use for construction if it processed to engineering wood.

Chapter 7

Forestry expansion had a significant effect on shrub lands. The new resource management system showed its effectiveness on conserving the remaining large area of natural forest but not on fragmented lowland forests. The concept of landscape planning should be added to the Resource Management Plans. Approximately 5 million ha of pastures might be available for further plantation establishment in the whole country.

The resource management system in Japan is still fragmented and insufficient. Although it might be difficult to establish the “effective base” system in Japan, it is full of interesting suggestions, especially for establishing local-base resource management system.

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Appendix

1. **Rules for plantation forests, and orchards in the Rural 1 and 2 zone**s.

Planting plantation forests and orchard is a permitted activity that may be undertaken without a resource consent, if it complies with the following the following conditions:

Plantation Forest Setbacks

Plantation forests are set back at least:

(i) 50 m from a Residential zone boundary;

(ii) 30 m from a dwelling;

(iii) 10 m from any boundary, except that

(a) trees are not planted or allowed to grow in a position which could result in any dwelling on an adjoining property becoming shaded between 10:00 am and 2:00 pm on the shortest day; and

(b) this setback need not apply where there is a written agreement between adjoining property owners that is lodged with Council;

(iv) 10 m from the intersection of any formed legal road.

Orchard Setbacks

Orchard are set back at least:

(i) 10 m from the intersection of any formed legal road;

(ii) 3 m from property boundaries;

In addition, Orchard are set back at least:

(i) 30 m from any dwelling, school or school grounds, or early childhood education facility or its grounds on an adjoining property; and

(ii) a spray belt is established along the boundary common to the crop and the buildings or grounds;

unless the orchard is registered or certified by the Biological Producers' and Consumers' Council or the Biodynamic Farming and Garden Association.

2. **Rules for plantation forests, and orchards in the Rural residential zone.**

Tree setbacks and Height

(a) Orchard, shelter belts, and spray belts are set back at least 10 m from the intersection of any formed legal road.

(b) Orchards are set back at least:

(i) 30 m from any dwelling, school or school grounds, or early childhood education facility or its grounds on an adjoining property; and

(iii) a spray belt is established along the boundary common to the crop and the buildings or grounds;

unless the orchard is registered or certified by the Biological Producers' and Consumers' Council or the Biodynamic Farming and Garden Association.

(c) Plantation forest is set back at least:

(i) 10 m from any boundary, except that

(a) trees are not planted or allowed to grow in a position which could result in any dwelling on an adjoining property becoming shaded between 10:00 am and 2:00 pm on the shortest day; and

(b) this setback need not apply where there is a written agreement between adjoining property owners that is lodged with Council;

(ii) 30 m from a dwelling;

(iii) 50 m from a Residential zone boundary.

(d) Orchards, spray belts and shelter belts have a maximum height of 6 m within 20 m of all internal boundaries.