Sustainability of Agroforestry in New Zealand.

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Abstract.

The aim of this thesis is to assess the concept of sustainability and apply it in a practical sense to New Zealand agroforestry. Sustainable management of natural resources is fast becoming recognised as necessary for the long term survival of our species. The agricultural communities prominence as the major user and steward of New Zealand's natural resources requires change in the values placed on these resources by farmers, and the incorporation of the principle of sustainable management at the farm level.

The concept of sustainability is broken into three component parts; economic, environmental and social sustainability. Each of these components is broken again into specific measurable principles. Through literature research and a case study, the principles are applied to agroforestry, and a conclusion reached.

It is found that given good management practices and normal business risks, agroforestry had the potential to maintain the natural capital stock and remain relatively profitable. Agroforestry is also found to have the potential to maintain the life support systems and biodiversity of the environment. Finally agroforestry is found to positively impact on rural societies, and provide the necessities of life and is relatively robust to political change. This thesis concluded that agroforestry as practiced in New Zealand is a profitable enterprise which improves the environment and increases the viability of many rural communities.

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Table of Contents.

List of Figures.

List of Abbreviations.

A.E.M. =	Agroforestry Estate Model
CCA =	Copper-Chrome- Arsenic
DSIR =	Department of Scientific and Industrial Research
EEC =	European Economic Community
EPA =	Environmental Protection Agency
GATT =	General Agreement on Trade and Tariffs
GDP =	Gross Domestic Product
ICRAF =	International Council for Research in Agroforestry
LSU =	Live Stock Units.
MAF=	Ministry of Agriculture and Fisheries
MOWD =	Ministry of Works and Development
NPK =	Nitrogen Phosphate Potassium.
NZFS =	New Zealand Forest Service
PCP =	Pentachlororphenol
ppm =	Parts per Million
RMA =	Resource Management Act 1991.
SPH =	Stems Per Hectare

1
Introduction

1.1 Background.

Agriculture, Forestry and Agroforestry.

The commencement of European settlement in the 19th century heralded a marked change in New Zealand's landscape; the landscape of bush, grassland and tussock was cleared to extract timber and to develop suitable land for cropping and grazing. For the first few decades following land clearance, most farmers grew crops and farmed primarily for their own consumption (Jennings, 1992). In the South Island, merino sheep were raised for their wool and grazed among the high country tussock, while wheat was grown on the plains (Heinemann, 1987). In 1882, refrigerated shipping became established, and this signalled a major change in the types of farming practised in New Zealand, there being a move away from wool production to a mixture of wool, meat, and dairy products. These new farming endeavours required that more land be cleared and developed. Improvements in infrastructure, and demands for produce during World War I, accelerated the spread of pastoral farming throughout New Zealand. This spread of pastoral farming continued after World War II, with an influx of soldiers desiring to return to the land. The development of aerial topdressing also signalled a phase of major expansion, enabling fertiliser to be applied economically to hill country pastures for the first time, thereby opening up previously uneconomic land. Farmers took pride in clearing the land, and over time an ethos developed: of taming the bush and growing grass and produce for the "Home Country". New Zealand society applauded farmers in this endeavour, and during the 1940s and the 1950s pastoral farming came to dominate New Zealand's culture and economy (Heinemann, 1987, Jennings, 1992).

Preceding and concurrent with New Zealand's agricultural development was the development of the timber industry. In most areas, indigenous tree felling, and on-site sawmilling, was the first step in land clearance for pastoral and urban development (Roche, 1987a). As the indigenous timber supplies were exhausted, the sawmills progressively moved on to other untouched forests. The number of sawmills in New Zealand grew from 3 in 1842 to 534 in 1910, by which time the industry was the principal non-agricultural employer (Roche, 1987b). By the 1890s, concerns began to be raised that native forest logging could not be sustained, and in response, the government set up a Royal Commission on Forestry to suggest suitable exotic forest supplements. In 1913, the Commission on Forestry, after reviewing existing exotic and indigenous species in New Zealand, recommended that the state should plant extensive exotic forests (Hegan, 1993). However it was not until after the publication of the National Forest Inventory of 1921-1923, which predicted a national 'timber famine' by the year 1965, that large-scale planting programmes were put in place. During this planting boom predominantly *Pinus radiata* was planted at Kaingaroa, on the central plateau of the North Island. During the 1920s and 1930s, overproduction, imports, and export restrictions caused a decline in the timber industry, and many people lost their jobs. During this time a large number of private afforestation companies began to develop, and planted significant areas in pine. In the 1950s, another timber famine was predicted for the 1990s, thereby initiating the second planting boom (Roche, 1987b).

Until the 1960s, these two primary industries were almost mutually exclusive. Forestry was "banished to the poorest land by a national attitude that trees were for felling and land was for grass, sheep and cattle" (Hocking, 1993:16). Many young agriculturalists regarded grass as the only worthwhile usage for any lands but mountains. Their message was: "Do away with shelter trees, they are unnecessary and above all uneconomic, and grass enclosed by concrete posts and barbed wire is much more rewarding" (Strong, 1970:48). Farm forestry was thought to be much too long-term, and would give the farmer a poor return. Poor returns were particularly a problem during this time, as unco-ordinated attempts at marketing had left farmers at the mercy of sawmillers, who had lowered stumpage down to uneconomic levels (Strong, 1970). After the second planting boom in the 1950s, tension arose between the two primary industries regarding existing farmland being "lost to forestry". Many local authorities, in response to this tension, put restrictions on forestry, it being perceived that forestry was an inferior landuse and socially disruptive. (Bush-King, 1987).

Agroforestry was first considered in New Zealand in 1969, as a result of developments in 'direct sawlog' regimes for radiata pine. Grazing with sheep and cattle was considered an opportune way of utilising the undergrowth and receiving early returns (Knowles, 1991). Agroforestry was heralded as an important breakthrough for both forestry and agriculture, and was thought to offer a new landuse that would be more profitable than either individual use. It was also believed that this type of forestry expansion would defuse some of the tension that had accompanied the acquisition of rural land by forestry companies during the second planting boom (Roche, 1987b). Since 1969 agroforestry has spread and has become an accepted landuse in New Zealand (Stoddart, 1984).

Agroforestry and the timber industry are currently experiencing another economic boom (Hegan, 1993). In 1993 New Zealand sold nearly $2.3 billion worth of timber overseas, while in 1991, forestry and logging contributed more than $1,500 million to New Zealand's GDP (Statistics New Zealand, 1994). By the turn of the century the timber industry is predicted to earn more for New Zealanders than meat, dairy, tourism, wool or manufactured goods (Hegan, 1993). With the record returns for timber in recent years, and the rising acceptability of forestry as an alternative landuse, forestry and agroforestry have boomed in many farming regions. In 1993 it was estimated that 40,000 hectares of agricultural land would be converted to forestry, thus forestry and agroforestry are again causing the issue of "good pastoral land lost to trees" be raised (Hall, 1993).

In 1991, the New Zealand government passed the Resource Management Act, which was an innovative attempt to bring about significant changes to the management of New Zealand's environment. The Act requires sustainable management of natural resources in terms of economic, environmental and social needs for both current New Zealanders and future generations. The New Zealand agricultural industry needs to think more carefully about the impacts of its decisions on the use of natural resources, and what these decisions will mean in the long term (Ministry for the Environment, 1991a, Ministry for the Environment, 1991b, Mathieson, 1992).

The agricultural community's prominence as the major user and steward of New Zealand's land and water resources requires change in the values placed on these resources by farmers, and the incorporation of the principles of sustainable management into investment and production decisions at the farm management level (Mathieson, 1992). The decline in profitability, and the pressure of environmental and social changes, has already led the agricultural community to question the use of pastoral farming. Over the last few decades, the agricultural industry has responded to these pressures, in part by diversifying into other livestock systems, e.g. goats, and into other landuses. In the last 10 years, the sheep population has declined sharply (by more than 30%); conversely the numbers of dairy cattle, goats and deer have been increasing. This change is emphasised by the 8% increase in productivity last year, even though traditional sheep and beef livestock numbers have remained static or have declined (Statistics New Zealand, 1994). If agroforestry is to be sustainable, then it must fit within the agricultural industry's requirements, both now and into the future.

Change in the Agricultural Industry.

Since the second planting boom in the 1950s, New Zealand's agricultural industry has undergone significant economic, environmental, and social change. The issues concerning farming of that time, and the parts that agroforestry may have played, are very different to those of the present. If agroforestry is to be sustainable it must take into consideration the following:

Economics.

New Zealand exporters of agricultural produce are largely price takers, rather than price makers, on world markets. Generally declining terms of trade for farm products, as well as market uncertainty and rising expenditures, has led to steadily reduced farm profitability and unease concerning the future of farming. The result has been a reduction in capital inputs into many farming systems: farmers have been applying less fertiliser, stocking rates have dropped, pasture quality has fallen, and good management practices have been compromised especially on hill country. This reduction in capital inputs has further reduced farming output and profitability (Mathieson, 1992).

Environment.

New Zealand, in geological terms, is a young country. Much of the country is steep, and even with bush cover is prone to slump and slip (Jennings, 1992). In some regions, especially the hill country, the impacts following the removal of the indigenous vegetative cover have directly led to environmental damage, through soil slippage, fertility decline, flood damage, and increases in weed and pest problems (Williams, 1990, Maclaren, 1993). Traditionally, many of these problems were eliminated through artificial means, e.g. fertiliser and engineering works, but with the withdrawal of government assistance, the problems are becoming increasingly apparent (Mathieson, 1992). As farming returns have dropped in real terms, and incomes have shrunk, some fragile environments have been utilised by farmers seeking to use every corner of their property in order to maintain viability and avoid financial ruin (Jennings, 1992). It is now being realised that some traditional farming methods are ecologically unsuitable for the environment (Williams, 1990).

Social.

Government policies of privatisation and restructuring, together with natural depopulation of rural areas, have meant a decline in the level of facilities provided for many rural communities. The loss of banks, schools, public transportation, and population has left rural society weakened, concerned, uncertain, and often lacking in identity (Pomeroy, 1990, Mathieson, 1992). Compounding these losses is the changing place that farming holds within New Zealand society. Political changes, the decline in the importance of agriculture to New Zealand's economy, and a wave of environmentalism, have caused farming to come under scrutiny. The pressure to change has been driven partly by a global concern about environmental problems, which are now appearing within major physical systems of the biosphere as well as in the local ecosystems (Horsley, 1989). Societies worldwide are slowly coming to recognise that they are not only destroying their environment, but undermining their future (Starke, 1990). In many places social pressure is increasing to change New Zealand's predominant landuse.

1.2 Aims And Objectives.

The purpose of this study is to establish whether agroforestry, in the context of a case study, within the definition discussed in the next chapter, is an economically, environmentally and socially sustainable landuse.

1.3 Study Organisation.

Chapter 2: agroforestry will be discussed in a world and national context. The term "agroforestry", as used in this thesis, will be defined.

Chapter 3: will discuss the concept of sustainability.

Chapter 4: seeks measures of agroforestry sustainability.

Chapter 5: discusses the findings of other studies regarding the sustainability of agroforestry.

Chapter 6: will assess the sustainability of agroforestry, using a case study at Rangitoto Farm, Bulls.

Chapter 7: is the summary and conclusion drawn as to the sustainability of agroforestry in New Zealand.

2
Agroforestry

2.1 Agroforestry: The World Perspective.

In many developing countries, rapid population growth has increased pressure on the limited areas of arable land, thereby generating greater demands for fuel wood, building materials, and other products traditionally extracted from the environment. In many cases, the result has been deforestation, and increasing degradation of agricultural lands. Agroforestry systems have been developed with the aim of potentially reversing the degradation, thereby increasing the productivity of land through ecological competition, and providing optimal use of space both horizontally and vertically. Agroforestry is also being used as a tool in many specific sites and regions, as a method for solving problems of rural development. Wood and food crops are only two possible products produced by agroforestry systems, other products being nuts, livestock fodder, bark, leaf products, essential oils, and pharmaceutical's (Cook and Grut, 1991). In developed countries such as in Australia and New Zealand, agroforestry is becoming accepted as possibly the most profitable and desirable land management system.

Agroforestry Landuse Systems.

Within the world there are many agroforestry landuse sub-systems and practices. Combe (Gholz, 1987) suggested 24 classes based on assorted agricultural products, major functions of the tree component, spatial arrangement of trees, and duration of the combination. Generally, agroforestry systems, as they are practised throughout the world, may be separated into five structural groups (Nair 1985):

- **Silvoagriculture-** trees are the major landuse component, and less important agricultural crop are integrated with them. Examples are:

Tree Gardens - tree species are randomly mixed on the same unit of land, forming a tree garden. These tree gardens produce food, fodder, wood, and cash crops. This type of agroforestry sub-system is practised in the Pacific Islands, India, Paraguay, S.E.Asia, and many other countries (Nair, 1985).

Taungya - this is a sub-system whereby crops are planted between plantation forestry seedlings for the first few years of establishment. Originally the taungya plantation species was teak, and the crops were the subsistence crops of the plantation workers. This type of agroforestry is practised in S.E.Asia, Africa, and many other countries (Jordan *et al.*, 1992).

Orchard Grazing - fruit trees are interplanted with annual crops, for example wheat, or permanent pasture. In the Goulburn Valley, Australia, dairy cows are grazed between apricot trees (Reid and Wilson, 1986).

- **Agrosilviculture-** agricultural crops are the major landuse component, and trees are secondary to the crop. Examples are:

Hedgerow Intercropping - woody species are grown in hedges and agricultural species are grown between. In China extremely wide spaced trees are intercropped with wheat, soya beans, cotton, while the tree component provides both wood and fodder. Hedgerow intercropping is practised in S. E. Asia, Nigeria, New Zealand, and in many other countries (Nair, 1985).

Multipurpose Trees - trees and shrubs are randomly scattered on farmland to produce food, fuel wood, and other wood products. In Australia, 'wild' eucalypts produce shade, shelter, bee forage and firewood. In Ghana 'wild' trees are maintained for cash crops, and the land underneath is cultivated. This form of agroforestry system is found in most countries (Nair, 1985, Reid and Wilson, 1986).

Crop Combinations - plantation cash crops are combined with food crops, for example, coconuts and cacao are grown together. This system has been used in Brazil, Costa Rica, S. E. Asia, Western Samoa, West Indies, Kenya, and many other countries (Nair, 1985).

- **Silviopastoral and Pastoralsilviculture** - trees and grazing land are combined. Examples are:

Protein Bank - multipurpose fodder trees are grown for the production of fodder and food crops. In North Africa's arid zone, pastoral fodder for sheep is supplemented by *Acacia albida* trees. This system is found in India, Nepal, Sri Lanka, and many other countries (Nair, 1985, Reid and Wilson, 1986).

Living Fences - in this sub-system, fodder and food producing trees are grown expressly to provide fencing and other tree products, e.g. hazelnuts. This system is found in Cost Rica, Ethiopia, East Africa, and many other countries (Nair, 1985).

Forest Grazing - in this sub-system, plantation forest's and shrub's understorey is grazed by livestock. From this system, pasture, livestock, and wood are produced. This type of agroforestry is found in Europe, New Zealand, Middle East, Mediterranean, Indian sub-continent, and many other countries (Hammond, 1988).

Shelterbelts - in this sub-system pasture is grown in between shelter trees that are managed for shelter and high quality timber (Reid and Wilson, 1986).

▪ **Agrosilvopastoral** - trees, forage crops, and livestock have equal emphasis. Examples are:

Woody Hedgerows - trees are grown for browsing, mulch, green manure, food, and fuel wood. This type of system is found in the Indian subcontinent, S. E. Asia, and other countries (Nair, 1985).

Tree-Crop-Livestock Mix (or Home Gardens) - a mixture of food, fodder, fuel wood and other products for home consumption, and sometimes surplus produce for cash sales. This form of agroforestry is found in most regions, but specially in Asia, Africa, and Latin American countries (Nair, 1985).

▪ **Other Systems** - there are other less common and specialised forms of agroforestry, for example, apiculture and aquaculture, which combine trees with aquaculture in mangrove areas (Nair, 1985).

2.2 Agroforestry: New Zealand Perspective.

Trees have always been grown on New Zealand farms. In the 1950s, support for farm forestry was sufficient to produce regional newsletters, while in November 1958 the first national magazine *Farm Forestry* appeared (Strong, 1970). However it was not until the late 1960s that agroforestry as a concept began to develop. Plantation forestry research at the time created a forestry regime that required the forest to be kept open, and thinned to lower densities than previously. The aim of this new regime was to produce "fat" high quality logs. From these relatively low-density forests developed the idea of using sheep and cattle to remove the increased undergrowth, while at the same time providing a method to recoup early income.

Between 1969 and 1974, several research trials, notably at Tikitere near Rotorua, were established, involving the integration of existing pasture with pine (Knowles, 1991). In 1973 an independent working group on agroforestry was formed. This group comprised 15 members from four government departments: the Ministry of Agriculture and Fisheries (MAF), and the now defunct organisations: New Zealand Forest Service (NZFS), The Department of Scientific and Industrial Research (DSIR), and the Ministry of Works and Development (MOWD). This working group reviewed the concept of agroforestry, and recommended, and undertook, further research (Reid and Wilson, 1986). Through research and agroforestry demonstrations at the farm level in the 1980s and 1990s, the concept of agroforestry has been developed and disseminated as a viable and productive landuse system.

There are currently several agroforestry sub-systems and practices used in New Zealand:

Pine and Pasture Integration - the most common form of agroforestry in New Zealand, and the subject of the subsequent study into sustainability of agroforestry. Under this system *Pinus radiata* is planted out in wide spaced rows at a density of more than 100 stems/ha but less than a density of 300 stems /ha, and stock grazed underneath (Ministry of Agriculture and Fisheries, 1984a).

Forest Grazing - many plantation forests and woodlots in New Zealand are grazed by cattle and sheep. Forest grazing was first initiated by neighbouring farms as a method of obtaining additional winter feed for stock. It was found that forest grazing improved access for silvicultural workers, thereby decreasing labour costs and providing early income for forest owners through grazing licenses (Knowles, 1991). In a 1986 survey it was noted that 60,000 hectares of forest was then being grazed by cattle, and that there was potential for another 168,000 hectares to be grazed (Hammond, 1988).

Shelterbelts - have been a feature on New Zealand's lowland pastoral farms for more than 100 years. Many species are used but the most common is radiata pine (*New Zealand Tree Grower*, 1990,1:9). Most shelterbelts are simply planted and left unmanaged. In spite of this, many undermanaged shelterbelts have produced considerable quantities of sawn logs. Research into a wide range of shelterbelt designs, in a number of regions, has shown that on favourable sites good quality timber can be produced (Reid and Wilson, 1986, Knowles, 1991).

Less Common Sub-Systems.

Coppicing - is the very old practice of cutting a broadleaf tree back to a stump and then cropping the multiple regrowth shoots as poles or firewood. The poles are cut every seven to twenty years, depending on the site and species involved. Stock are grazed in between coppiced trees (New, 1985).

Firewood- fast growing trees, especially eucalypts, are used to grow large quantities of biomass for the explicit purpose of producing fuel wood. (Thomsen, 1990).

Multipurpose Trees - trees are grown with the view of receiving income not only from wood production, but also from other tree products. This includes the production of cash crops of edible nuts, the production of fodder for stock during droughts (ie. willows and poplars), and flower production for bee forage, etc (Phipps, 1989).

2.3 Definitions.

Agroforestry is a generic word for the practice of growing woody plants with agricultural crops, and/or livestock, together on the same unit of land.

Some other names for agroforestry are intensive pine-pasture management, farm forestry, multi-tier farming, three dimensional farming, forest farming, taungya system, intercropping and multi purpose plantation forestry.

Agroforestry is an interdisciplinary science, based on forestry, agriculture, animal husbandry, aquaculture, land resource management, and other landuse disciplines. It is difficult to find a clear, comprehensive, exact, and undisputed definition for agroforestry. This difficulty is because of the diversity of disciplines involved, and the vast array of cultural interpretations. Given the infinite combinations possible in mixing agricultural pursuits with the growing of trees, it is not surprising that many different definitions have evolved (Anon, 1982). A generic definition has been produced by the International Council for Research in Agroforestry (ICRAF), which defines agroforestry as the following:

"A collective name for land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos etc) are deliberately used on the same land management unit as agricultural crops and/or animals either in some form of spatial arrangement or temporal sequence" (Reid and Wilson, 1986:8).

Most definitions are similar to the above ICRAF definition, but where variations do occur it is usually because of the specific focus or field within which the author is involved. Some authors focus specifically on the ecology of agroforestry.

Oldeman suggested that *"Agroforestry is not one system, but a principle common to many potential and existing systems which display ecological and economic durability by virtue of their biological architecture including short-cycle plants, long-cycle plants and animals "... and which "aim at complete use of all inorganic resources in all available niches for useful plants and animals, as long as recycling of these resources is maximised"* (Anon, 1982: 8).

Other definitions expand on the social and productive potential of agroforestry.

Nair defined agroforestry as a *"... landuse system that involves socially and ecologically acceptable integration of trees with agricultural crops and/or animals ... so as to get increased total productivity of plant and animals in a sustainable manner from a unit of farmland, especially under conditions of low levels of technological inputs and marginal lands"* (Anon, 1982:8).

Mafura defined agroforestry as *"a form of landuse that successfully satisfies the needs of the crop farmer, forester and/or stock farmer."* (Anon, 1982:8)

Oldeman, went on to define agroforestry as a system which *"warrants social acceptability by breaking up long-term ecological cycles in a* *sequence of easy-to-understand daily and seasonal activities, moulded upon local tradition but conceived so as to increase efficiency"* and which should *"diminish the risk for the individual farmer by means of a wide variety of useful plant and animal species enlarging the range of products, providing a self-protecting system and enhancing the quality of the daily environment"* (Anon, 1982: 8-9).

Finally among the various definitions, there is a conflict over the extent of land involved in agroforestry.

Huxley (1985) saw agroforestry as *any* land system that provides produce from the woody perennials, and involves multiple mixed or zonal cropping. Conversely, Lewis and Henry stated that if all lands supporting woody plants, which were also grazed or cropped, were defined as agroforestry, then the only land excluded would be prairies, tundras and similar treeless areas. They defined agroforestry as *"the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals"* (Gholz, 1987:195).

Within New Zealand definitions of agroforestry have also varied.

The definition of agroforestry in New Zealand has progressively narrowed, as agroforestry has become established. In 1976, farm forestry was defined as "all uses to which a farmer or private forester can put to a tree (exception is fruit trees)" (Farnsworth, 1976:5). By 1985, agroforestry was defined as a landuse system "which combines wide spaced trees with livestock or cropping enterprises" (Reid and Wilson, 1986:9). Similarly the MAF defined farm forestry as either a woodlot or *Pinus radiata* trees integrated with pasture at a final density of 100-200 stems/ha (Ministry of Agriculture and Fisheries, 1984a). In more recent years, definitions of agroforestry have tended to widen to include a mix of species, at several densities, grown for a variety of purposes.

For the purpose of this study, agroforestry will be defined as:

a system where trees are planted out in wide spaced rows with a density of greater than 100 stems/ha, but less than 300 stems/ha, and the farmer has control over both the trees and the grazing animals on the same unit of land.

The tree species *Pinus radiata* was selected for this study for the following reasons:

. *Pinus radiata* is the most commonly grown agroforestry species in New Zealand: in a 1990 survey by the Farm Forestry Association it was found that 79.2% of woodlots comprised *Pinus radiata* (*New Zealand Tree Grower*, 1990, 1: 9). In addition *Pinus radiata* has established marketing and processing industries (Taranaki Regional Council, 1992).

.There is more information available on *Pinus radiata's* ecological, economic, and social impact than for other timber species (Taranaki Regional Council, 1992).

The lower tree density was selected as the minimum density required to achieve a high quality timber yield. This figure was generally advocated by MAF as the minimum worthwhile density required to make agroforestry profitable. A lower figure would be more likely to be interpreted as wide spaced shelter trees, than as an agroforestry enterprise (Ministry of Agriculture and Fisheries, 1984a).

The upper tree density of 300 stems/ha was selected as the upper limit whereby a farmer could continue to run stock on the pasture for a significant length of the silvicultural regime (Ministry of Agriculture and Fisheries, 1984b). In recent years there has been a progressive move towards higher density plantings, e.g. 200+ stems/ha, because farmers believe these to be more profitable than lower density plantings. Many farmers now see grazing more as a bonus to their agroforestry regime, than as an integral part.

3
Sustainability

The *Oxford Dictionary* broadly defines sustainability as the quality, of being able to maintain, at a certain rate or level, over a long time (Brown, 1993:3163). Sustainability therefore is a concept of "continuity over time". Many ambiguities have arisen in the application of the term "sustainability" over the last decade, and a diversity of meanings has arisen as different interest groups have applied sustainability for their own purposes (Hayward, 1990). The ambiguities have increased, as "sustainability" has become a sociopolitically correct word to associate with everyday processes. In literature, sustainable growth, sustainable development, sustainable society, sustainable economics, sustainable resource use, and many other "sustainable" terms may be found. Blowers (1993) saw a tendency to use sustainability as a device for mobilising opinion rather than as an analytical concept for developing specific policies. Because of this many people have dismissed the concept of "sustainability" altogether, as too vague to be useful.

However when sustainability is applied to agroforestry, clearly if agroforestry is to be sustainable, it must for all practical purposes continue for ever. The problem then arises when specific measures of sustainable agroforestry are sought (The World Conservation Union, *et al.*, 1991b).

Grundy suggested that one method of obtaining a useable definition of sustainability should involve empirical observations and normative concepts of justice, equality and liberty. These concepts in turn are based on the social values of judgement and moral belief. Moreover, he believed that sustainability "should not be considered a static concept", but a process that must evolve over time: as circumstances change so must the responses (Grundy, 1993).

There seems to be a consensus that a sustainable landuse comprises of the following three parts:

. Economic Sustainability.

The survival of the farm business over several generations is paramount at both the local, regional, and national levels, as a means of providing wealth and quality of life for many New Zealanders. Natural resource economists view the environment as natural capital. This natural capital stock is used to produce a range of services and physical natural resource flows, e.g. timber. Landuse systems that fail to conserve their resource base eventually loss the ability to produce, and therefore lose their utility to society (Costanza, 1991, El Serafy, 1991, Meister, 1992). To implement sustainability, all landuses should meet the following minimum criteria. The rates of resource harvest should not exceed the rate of resource regeneration. The rate of waste generation from the landuse should not exceed the assimilative capacity of the environment. Finally, the use of non renewable resources should be replaced with renewable resources where possible (The World Conservation Union *et al.,* 1991a, Blowers 1993). These are the minimum standards required to ensure the maintenance of natural capital stock in the landuse system (Costanza, 1991).

Once the minimum standards are met, landuses should be selected on other more traditional economic criteria. Farming is a business, and farm businesses are only sustainable if ongoing profitability is adequate to meet the needs of the two stake holders: namely the farmer and farm financiers. Economic sustainability can only be achieved where there is sufficient income from farming operations to cover reinvestment in the farming operation; debt servicing, including seasonal finance r requirements; the farm families' needs; normally acceptable financial and business risks; and finally a reasonable return on capital employed (Walker, 1990, Campbell 1992).

While there may be debate as to the level of profit desired by the farmer, there can be no doubt that achievement of some minimum level of profit is required before the landuse can be considered sustainable (Walker, 1990).

▪ Environmental Sustainability.

Environmental sustainability provides the overarching framework within which all activity must take place. It stresses the interdependencies and inseparableness of the natural world, and determines the ecological "bottom line" for the maintenance of essential ecological processes and life support systems (Grundy, 1993:27). Environmental sustainability is concerned with how natural systems operate and evolve in the long term (Mathieson, 1992). For a landuse to be environmentally sustainable it must use the components of the environment in a way that allows for the perpetuation of the character and natural processes of that ecosystem (New Zealand Ecological Society, n.d.). The environment can change and adapt to management impacts within certain limits, but any activity that exceeds threshold ecological processes and balances, and detrimentally affects the environment, is regarded as not sustainable (Williams, 1990).

Campbell (1992) proposed that sustainable systems are generally, stable; do not disrupt ecological systems, or over-exploit natural resources; and conserve genetic resources in plant and animal species. Campbell furthermore proposed that sustainable systems must be regenerative and resilient, so they can absorb changes and retain characteristics in the face of disturbances such as climatic extremes, or attacks by pests and diseases. Campbell finally suggested that environmental limits such as water quality, soil loss, soil biological activity, nutrient leaching, energy inputs, solar energy interceptions, and diversity of species and forms, are important when assessing the ecological sustainability of a landuse (Campbell, 1992).

▪Social Sustainability.

Social sustainability is concerned with human communities in perpetuity. Social sustainability concerns the interdependences of people and their environment, and the values that promote well-being, self sufficiency, and communities living in harmony with nature (Mathieson, 1992). Social sustainability is the maintenance of social well-being. Social well-being is a hard concept to define because well-being, in its social context, is socially defined, and is subject to definition and redefinition by different groups, at different times, and in different cultural settings. Social sustainability is concerned with inter-generation equality, and gender and ethnic equality, and is involved with the democratic processes of representation, participation, and consultation (Ponter, 1991, Grundy, 1993).

Campbell (1992) proposed that a sustainable landuse system should be socially appropriate, reflecting and adapting to the needs, skills, training and finances of landusers. And furthermore, the landuse should be non-disruptive, so that it does not destroy the socio-cultural environment. For example, it should not force people to adopt practices against their normal behaviours and traditions, or result in migrations from rural areas to the cities.

The above three components of economic, environmental and social sustainability define sustainability in different ways, but with a central theme (Mathieson, 1992).

For agroforestry to be considered sustainable, it must be able to maintain itself economically, environmentally, and socially at a certain rate or level over a long time.

4
Measures of Sustainability

In the previous chapter, sustainability was loosely defined as the quality, of being able to maintain, at a certain rate or level, over a long time. It was also found that sustainability comprised of three integrated components of economic, environmental and social sustainability. This chapter takes those three components and seeks methods of measuring sustainability as applied to agroforestry.

4.1 Economic Sustainability.

The following four principles have been identified from the literature as essential in achieving economic sustainability. The minimum necessary condition for economic sustainability is the maintenance of the total natural capital stock at or above the current level. This minimum is achieved through sustainable yield harvesting; sustainable waste disposal; and the minimisation of the depletion of non-renewable resources. Once this minimum standard is met, a landuse may be evaluated under more traditional economic criteria (Costanza, 1991).

4.1.1 Sustainable Yield Harvesting.

The minimum necessary condition for achieving the sustainability of agroforestry is the maintenance of the total natural capital stock, which consists of land, trees, pasture, animals, air and water. This is achieved through use of sustainable yield harvesting, or the periodic harvesting of a resource, in perpetuity (Meadows *et al.*, 1972, Costanza, 1991, Meade, 1994). The volume of the resource harvested is determined by the renewal, and the productive capacity, of the natural resource system. This volume may vary over time (El Serafy, 1991).

▪Renewal Capacity.

Populations of plants and animals may be harvested by taking a managed number, or proportion, in perpetuity, provided the rate of harvesting does not exceed the natural replacement and recruitment rate (New Zealand Ecological Society, n.d.). If more is harvested than is replaced, then the total natural capital stock declines, as does its utility to society. A decline in natural capital stock may be halted and restored if subsequent harvesting is less than the renewal capacity, thereby allowing the population to recover. Many natural resources have a threshold, where if harvesting depletes the population below this level, then the remaining population is too small to recover. Thus in effect the utility of the natural resource is lost for society. The renewal capacity of the agroforestry system, following harvesting or other forms of disturbance, is dependent on the nature and intensity of the disturbances, on the mode of species reproduction, and on management policies (Maini, 1992).

▪Productive Capacity.

Productive capacity is the combined capacity of the ecological support systems, e.g. nutrients, soil, and water, to sustain or produce natural resources. If the ecological support systems of agroforestry degrade, then the harvestable yield will also decline, and the total natural capital stock will be affected (Maini, 1992).

For agroforestry to be economically sustainable, then a continuation of material benefit and utility must be received from the natural resource, without liquidating the natural capital stock.

4.1.2. Sustainable Waste Disposal.

Sustainable waste disposal is the retention and maintenance of the capacity of the environment to assimilate waste streams from human activity, in perpetuity. All activities produce waste, in the form of gases, solids, liquids, microorganisms, or energy; most of this waste is assimilated into the environment, e.g. bacterial breakdown of sewage. Eventually all waste is broken down, eliminated, or stored in another form. But if production of waste exceeds the natural rate of assimilation into the environment, then the accumulation of waste will occur, which in turn will be detrimental to economic activity. Environmental pollution causes a shortage of clean air, water, and other natural resources required for most economic activity. At the accumulation stage, waste can still be eliminated, but only if the production of waste decreases, or is artificially treated, thereby allowing the "back log" of waste to be processed. If the production of pollution continues to rise above the capacity of the environment, then at a certain point the atmosphere, for example, will become so polluted that the action of the natural cleansing forces will be impeded. At this point there will be an explosive rise in environmental pollution as the natural assimilative capacity of the environment decreases, which will in turn choke economic and other natural resource-based activity (Meade, 1994). Waste does not necessarily have to constrain human productivity for it to be an economic concern. Some wastes are effectively irreversible and cumulative in their impact, e.g. DDT, and have the potential to threaten the consumers and the labour force on a global scale, and over a very long time (Baines *et al.*, 1988, Williams, 1990, Blowers, 1993).

The major waste streams from agricultural industries are:

. Sedimentation.

This is caused by soil being exposed to surface erosion, by wind and water. Sedimentation of water causes reduced clarity, reduction of spawning habitats, bed scouring, changes in aquatic food supplies, and most importantly can cause flooding through the raising of the river bed (Ministry of Agriculture and Fisheries, 1992). Much of New Zealand's economic activity is based on primary landuses that are extremely vulnerable to flooding.

. Nutrient Wastes.

Agricultural wastes such as nitrogen and phosphorus frequently find their way into streams, rivers and lakes, though leaching and runoff. Nutrient loading causes the growth of nuisance organisms downstream (Ministry of Agriculture and Fisheries, 1992). In several lakes bordering agricultural areas in New Zealand, excessive nutrient loading has caused eutrophication and subsequently the death of the waterway. Nitrate contamination of ground water is another problem (Williams, 1990), and. surveys have revealed levels of nitrates in groundwater much greater than the World Health Organisation's recommendation of 1 ppm (Mathieson, 1992). The two main sources of nitrate contamination are from artificial fertiliser application, and from faeces and urine (Ministry of Agriculture and Fisheries, 1992).

. Chemical Wastes.

The establishment of weed species, as a result of the absence of their normal pests and diseases, has led to a high level of herbicide use in New Zealand. The lack of diversity within the agroecosytem has also led to heavy reliance on pesticide use (Williams, 1990). There is only scattered information on agricultural chemical contamination in New Zealand and the few studies that have been done, indicated evidence of chemical pollution (Mathieson, 1992).

. Biological Wastes.

Faecal contamination can be a vector for disease, potentially causing illness if water is used for swimming, recreation, drinking by humans or livestock, or food processing (Ministry of Agriculture and Fisheries, 1992).

For agroforestry to be considered economically sustainable, it cannot constrict human activity by producing more waste than can be assimilated into the environment.

4.1.3 Depletion Of Non-Renewable Resources.

Natural resources exist in two forms; either non-renewable, where the maximum stock of the resource that can be used is fixed: this characteristic is shared by resources such as land area, metal ores, fossil fuels, scenic amenity, and other geophysical resources; or, the resource can be renewable, where the available stocks change at a 'natural' biological or biochemical rate: this characteristic is found in forests, fish stocks, natural fauna and flora, fresh air and water supplies, and the other biological resources (McInerney, 1994). The distinction between renewable and non-renewable resources in the real world is not clear cut. Land of a given quality may be reused if properly farmed; but it can also be mined if it is overworked or allowed to erode. Thus, the land's power to satisfy wants, like that of a stock of coal, are used up conclusively (Meade, 1994).

Resources should be used in a renewable way, and the use of crucial non-renewable resources must be minimised to achieve maximum continued benefit. Minimisation of resource use can be achieved through three means: by substitution; by recycling; and through efficiency of use (The World Conservation Union *et al.*, 1991b, Blowers, 1993).

.Substitution.

Non-renewable resources that are destroyed in the process of gaining their services should be substituted by renewable resources where possible. Baines *et al.* (1988) and McInerney (1994) suggested that unless the transition from non-renewable resources to renewable resources was made, then industries and society would be affected by rapid price rises for non-renewable resources. The importation of fuel and fertiliser make New Zealand vulnerable to the economic impacts of supply disruptions and large price discontinuities especially as alternative energy systems (e.g. natural gas) are currently incapable of adequate substitution. Baines *et al.* (1988) claimed that another steep rise in petrol prices, as in 1973/74, would be most damaging to rural users who live away from affluent city suburbs.

▪Recycling.

Many non-renewable resources, while they may be non-increasing stocks, are not necessary destroyed in the process of consumption. Their services are temporarily 'locked up' in a particular use, for a certain length of time, and can be used again once they undergo the process of recycling. These resources should be recycled to get the maximum continued benefit (McInerney, 1994).

▪Efficiency.

Non-renewable resources that cannot be substituted or recycled now or in the future, for technical and or economic reasons, should be used in a way that maximises the output per unit of resource (Baines *et al.*, 1988). Energy cannot be recycled, therefore improved efficiency of use is the only means for extending the utility derived from energy resources (Baines *et al.*, 1988).

For agroforestry to be considered economically sustainable, resources should be used in a renewable way, and the use of crucial non-renewable resources must be minimised to achieve maximum continued benefit.

4.1.4 Economic Return.

The above three principles are the minimum standard required to be met by a sustainable economic activity. Once these principles have been adhered to, then the activity chosen should be judged on more traditional economic criteria (Costanza, 1991). Profit may be defined as the difference between farm income and farm expenditure, and therefore is influenced by all endogenous and exogenous factors which effect either farm income or farm expenditure. The key factors influencing profit are, debt servicing, farming terms of trade, and levels of management (Williams, 1990). Economic sustainability can only be achieved when some minimum level of profit provides both the farmer and/or financier with a reasonable return on the capital employed.

For agroforestry to be considered economically sustainable, then it must Provide a minimum level of profit which provides both the farmer and/or financier with a reasonable return on the capital employed.

4.2 Environmental Sustainability.

The following two principles have been identified as essential in achieving ecological sustainability. The first principle is the conservation of the life support systems of the environment; and the second principle concerns the conservation of ecosystem diversity.

4.2.1. Conserving Life Support Systems.

Environmental sustainability is primarily based on maintaining and enhancing the life support systems. A life support system is that part of the earth that provides the physiological necessities of life, namely energy, nutrients, and the media which support life, air (the atmosphere), water (the hydrosphere), and the soil (the pedosphere) (Cronin, 1988, Odum, 1989).

4.2.1.1 Energy.

A well-developed natural ecosystem is relatively stable, self sustaining and able to maintain productivity from solar radiation. Energy flows through the system via a complex set of trophic interactions, and various amounts of energy are dissipated at stages along the food chain. Most energy moves along the detritus pathway (Gliessman, 1990, Williams, 1990). Energy obtained by decomposers from the detritus pathway, supports the activity of a number of other trophic levels in the soil. In turn this activity plays a primary function in nutrient cycling, and support of the plant life (Dick, 1992).

Energy flows in agroecosystems are very different to those in natural ecosystems, as a result of human intervention. In comparison with natural systems, the energy flow is much simplified, with the upper trophic levels missing and the function of decomposers in dissipating energy much reduced. In addition, much of the total energy is directed out of the agroforestry system through short cycles of stock or crop production (Williams, 1990). To overcome energy shortage, agroecosystems require energy imports, usually in the stored form of fossil fuels. The production of agricultural produce could not be maintained at its present levels without the consumption of these fuels (Williams, 1990, Mathieson, 1992).

For agroforestry to be considered environmentally sustainable then, it must be stable, self sustaining and able to maintain productivity from solar radiation, with the minimum reliance on external energy sources.

4.2.1.2 Nutrients.

Through complex interconnecting cycles, nutrients circulate within the ecosystem, where they are most often bound in organic matter. The animal and plant components of the system have a major bearing on how efficiently nutrients move through cycles with minimum loss. The productivity depends on the rate at which nutrients are recycled (Williams, 1990).

Sixteen elements have been recognised as being essential to plant growth. Three of these, carbon, hydrogen, and oxygen are supplied by water and air. The remaining 13 elements are considered to be plant nutrients and may be grouped into micro and macro-nutrients. The six macronutrients are, calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), sulphur (S), nitrogen (N) and are needed in large amounts. The seven micronutrients, boron (B), chlorine (Cl), copper(Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn) are only needed in trace amounts by plants (Thompson and Troeh, 1978).

▪ Nitrogen.

Nitrogen fixation is accomplished in nature by certain micro organisms, and by lightning, but the amount of nitrogen fixed is usually small and seldom as much as plants could use. Nitrogen deficiency limits the production of protein and other materials essential for the production of new cells (Thompson and Troeh, 1978).

.Phosphorus.

Phosphorus is a component of every living cell, and tends to be concentrated in seeds and in the growing points of plants. The phosphorus supply can be even more critical than the nitrogen supply in some natural environments (Thompson and Troeh, 1978). Phosphorus deficiency may lead to growth reduction (Maclaren, 1993).

.Potassium.

Plants absorb large amounts of potassium, that helps maintain electrical neutrality in both soil and plants by balancing the negative changes of nitrate, phosphate, and other anions. Plants require relatively large amounts of potassium, and often need more than soil can supply. Potassium is the third most likely nutrient element to limit plant growth (Thompson and Troeh, 1978).

.Calcium.

Calcium is a structural component of cell walls, and therefore vital in the formation of new cells. Plants deficient in calcium are stunted because they produce fewer and smaller cells. A calcium shortage restricts the growth of roots as well as stems, leaves, etc. The inability of calcium-deficient roots to elongate rapidly handicaps the plant from exploiting new portions of the soil volume, in order to obtain water and other nutrients (Thompson and Troeh, 1978).

.Magnesium.

Magnesium is vital to the production of chlorophyll, because every molecule of chlorophyll contains a magnesium ion at the core of its complex structure. Magnesium supply may be adequate to prevent deficiency symptoms from showing in the plants, and yet be inadequate for the nutrition of animals that eat the plants (Thompson and Troeh, 1978).

.Sulphur.

Plants absorb sulphur from the soil in the form of sulphate, and from the air as sulphur dioxide. The plant then reduces the sulphur to forms that can be built into organic molecules. Sulphur is a vital part of all plant proteins and some plant hormones. Sulphur deficiencies slow down protein synthesis, and slow the formation of all amino acids (Thompson and Troeh, 1978).

Only a small portion of each nutrient in the soil is available to plants at any given time. Most is locked up firmly in mineral and organic matter that is unavailable until decomposition takes place. Such decomposition occurs slowly over a long period, and nutrients are only gradually released. Therefore the productivity of an ecosystem depends on the rate at which nutrients are recycled. In turn the rate and efficiency of the nutrient cycling are dependent on the animal and plant components of the system (Williams, 1990).

In an agroecosystem nutrient cycling is minimal, with many of nutrients removed with the crop and stock at time of harvest. In addition large quantities of nutrients are lost through leaching and erosion, because the small permanent biomass in the agricultural system is unable to store nutrients, or hold the soil. These deficits are usually made up by using nutrients stored outside the biotic system, e.g. oil or minerals. As long as the inputs can be maintained, the system is sustainable; but as agroecosystems are dependent on finite resources, agroecosystems are unsustainable in the long run (Williams, 1990).

Nutrient supply is an important component of maintaining agroforestry life support systems, therefore agroforestry as a landuse must use nutrients in a non-resource depleting way

4.2.1.3 Air Medium.

The medium of air transports crucial gases, nutrients, and provides a home for many species. The modification of this transport system, or its degradation, may produce a significant impact on the agroecosystem. Agroecosystems and forestry have three major impacts on air. The first impact is the introduction of pollutants into the air, such as dust and chemical sprays. The second impact that agriculture can have is in the changing of the chemical composition of the atmosphere. While agricultural burnoffs and stock farming can increase the Co_2 in the atmosphere, a fast growing pine forest reduces the amount of Co_2 in the air. One hectare of New Zealand exotic forest has been shown to absorb an average of seven tonnes of atmospheric carbon per year, and turn it into timber (Hegan, 1993). The final effect that agriculture has relates to the disturbance in wind patterns, through changes in the ecosystem's vertical profile. Shelterbelts have been found to dramatically reduce the speed of wind over agricultural sites. The implications of this, apart from reducing dust and air pollution, may cause climatic change, which then alters ecological processes.

For agroforestry to be considered sustainable it should not detrimentally affect the medium of air by increasing the number of pollutants, or adversely affect the balance of gases and ecological process through climate change.

4.2.1.4 Water Medium.

Water is the universal internal medium of all living things: living organisms are made up of 90% or more water. Water is also the external medium of all aquatic life forms. Humans affect the hydrological cycle in several ways, through runoff, flooding, dams, pollution, and over use (Kupchella and Hyland 1993:45,48).

In measuring sustainability, agroforestry should not adversely affect the quality, or quantity, of water.

4.2.1.5 Soil Medium.

Soil is a fundamental component of the environment, which is composed of mineral particles, organic matter, water and air. Soil is also composed of numerous small animals, fungi, bacteria, and other microorganisms. The soil medium is home to a complex and natural community, as well as being a key substrate for the vegetation in and above it (Forman and Godron, 1986). Soil is extremely vulnerable to human degradation; and on a human time scale, soil is often non-renewable, with a millennium of soil formation being easily lost within hours, though erosion (Jenny, 1980).

Conceptually the degradation of the soil medium may be divided into three categories: physical, chemical, and biological. Commonly all three forms are interrelated (Basher *et al.*, 1992).

.Physical Degradation.

Physical degradation refers to the deterioration of the physical properties of the soil, and includes the impact of erosion, sedimentation, structural decline, compaction, and hardsetting (Basher *et al.*, 1992). Soil physical properties form a complex single interactive system; aggregation and pore space determine structure, consistency, bulk density and porosity, which in turn are linked to available water capacity, permeability, soil drainage and resistance to erosion. A well-developed soil structure provides favourable conditions for the development of fine feeder roots and mycorrhizae, thereby increasing efficiency of nutrient uptake (Young, 1989:145). Soil erosion has been a serious problem for agricultural lands almost as long as there has been agriculture. Prevention or reduction of soil erosion enables the landowner to retain the most fertile top layer, thereby avoiding losses of crucial plant nutrients and organic matter (Peterson and Swan, 1979). In addition, soil erosion produces sediment which in some areas is one of the major pollutants of streams, lakes, estuaries and coastal waters (Beasley, 1972).

.Chemical degradation.

Chemical degradation is the accumulated negative impact of chemicals, and chemical processes, on those properties that regulate life processes in soils. This includes nutrient depletion, with or without soil loss, decline in soil organic matter, elemental imbalance, and chemical toxicity such as salinization or pollution (Basher *et al.*, 1992).

.Biological degradation.

Biological degradation is the impairment or elimination of one or more significant populations of organisms in the soil, particularly microorganisms (Basher *et al.*, 1992). Agriculture usually involves the growing of monocultural crops, which upsets the balance of organisms, and often as a result, pests are created. In turn, the use of pesticides in an attempt to control a pest species may lead to the indiscriminate killing of other organisms, thereby impairing the soil ecosystem.

For agroforestry to be considered sustainable, it should not degrade the soil physically, chemically, or biologically, in such a way as to detrimentally effect the soil.

4.2.2. Biodiversity.

Biodiversity is important to ecological sustainability because diversity tends to enhance the complexity and resilience of systems to major disruptions, thereby allowing for flexible responses in the face of change. Diversity provides "functional redundancy", the term used when a particular life support process is performed by more than one class (e.g. species) of organism. Implicit in the concept is the idea that having several species perform the same function buffers that process. In other words, even though there may be a drastic reduction in the population of one of the species, other species in the group can still get the job done (Rice, 1992). In addition, genetic diversity is essential to evolutionary processes, not to mention its potential utilitarian and aesthetic value (Grundy, 1993). The long term viability of ecosystems will depend in large part upon their ability to respond to change. Some changes are on going major climatic modifications, and can be anticipated, even though the details of timing, and magnitude of effects, is uncertain. Other changes will come as complete a surprise, for example, Cyclone Bola (Gall and Orians, 1992).

Agroecosystems, in contrast to a natural ecosystem, have little biodiversity, and consequently little resilience. In agroecosystems, humans regulate population numbers to ensure the desired plants and domestic animal dominates. Biological diversity is deliberately reduced to channel maximum nutrients and energy through the desired species. Many potential species niches are unoccupied, thereby allowing invasion by unwanted plants (weeds) and animals (pests). The biological simplicity of agroecosystems leaves them vulnerable to pests, weeds and disease attacks (Williams, 1990, Altieri, 1991).

▪ Biodiversity Within The Species.

The amount of genetic diversity within an individual organism may be considered the lowest level of organisation within the biodiversity hierarchy (Rice, 1992:14). The diversity of a species in a mature (stable) ecosystem makes it resilient to all but the most extreme climatic or geological event. This dynamic nature allows ecosystems to change should the total environment change. When the environment changes rapidly, ecosystems with little diversity cannot adjust to the new conditions, thereby leading to species collapse (Williams, 1990).

▪Biodiversity Within Habitat.

In natural biological communities, the component species tend to play distinct ecological roles, although certain sets of species in a community may be functionally similar. These different component species are dependent upon each other for their ecological existence; for example, among microbial communities in the soil, sets of functionally distinct species form "consortia" in which each species carries out a particular biochemical step in the breakdown and recycling of nutrients (Rice, 1992).

Landscape Diversity.

The variability contained within a region, is made up of both within habitat and between habitat diversity. For example, imagine that the buffer zones between agricultural fields in a region contain several different plant species. However, because the plants disperse quite readily, the same plant species occurs in every buffer zone in the region. In this case, high diversity at the farm level does not result in high diversity at the landscape or regional level. Homogenisation of both flora and fauna at regional, continental and global levels is a serious concern (Rice, 1992).

For agroforestry to be considered sustainable it should maintain, or enhance, the biodiversity that it holds.

4.3 Social Sustainability.

The following principles have been identified as essential in achieving social sustainability. The first principle regards respect, care and equality within the community; the second is concerned with quality of life; the third seeks cultural sustainability; and the final principle involves political sustainability.

4.3.1 Respect, Care, and Equality within the Community.

4.3.1.1 Sharing of Benefits and Costs.

Respect, care, and equality within the community, means that agroforestry, as a landuse, should not be at the expense of the other groups. The benefits and costs of agroforestry must be shared among people of different communities, interest groups, wealth groups, genders, and ethnic groups. A sustainable society must allow an equitable distribution of societal goods to all members of that society (The World Conservation Union *et al.*, 1991b).

4.3.1.2 Adequate Participation.

Respect, care and equality within the community also means that community members should have equal access and adequate representation, participation and consultation. Adequate representation, participation and consultation are required, if resource decisions are to contribute to a sense of belonging and a sense of purpose. Without this, alienation, frustration, and anti-social behaviour is often the result (Grundy, 1993). If decisions that affect an individual's life are controlled by others, it creates inequality, and a separation of the powerless from the powerful. The practice of participation is particularly vital in situations close to an individual, such as work, home, and the community (Stephenson, 1981).

Respect, care and equality within the community are an important indicator of social sustainability. If agroforestry as a landuse is to be considered socially sustainable, then it must provide these aspects.

4.3.2 Quality Of Life.

The aim of development is to improve the quality of life. Agroforestry must provide the basic needs for a healthy and potentially fulfilling life for the landowner and family. Included here are the provision of food, shelter, health care, education, employment, and social care. Work is central to human life: it provides goods and services, it enables co-operation between people, and the growth of a sense of interdependence within the community. Work occupies most people's energies in their lifetime. It is a formative influence in behaviours, thinking, interactions, and ultimately, happiness. Therefore it is important to consider the type of work opportunities that are being created by a particular landuse (Stephenson, 1981). In addition, agroforestry must also provide a means that enables human beings to realise their potential, build self confidence, and lead lives of dignity and fulfilment (The World Conservation Union *et al.*, 1991b).

Quality of life is an important indicator of social sustainability. If agroforestry provides a reasonable quality of life, both at time of work and into retirement, then agroforestry is socially sustainable.

4.3.3. Cultural Sustainability.

This means that agroforestry as a landuse should take into account cultural differences that exist within the community and nationally. It should provide scope for local people to adapt agroforestry to their values, needs, and perception (Ponter, 1991).

Cultural sustainability is an important indicator of social sustainability, therefore if agroforestry provides cultural sustainability, then agroforestry can be considered socially sustainable.

4.3.4. Political Sustainability.

The political economy of the country, especially agriculture, has been radically transformed by the economic policies of the Labour Government that came into power in 1984. Heavy commodity production supports, land clearing subsidies, fixed exchange rates, and a wide range of tariffs and quotas were rapidly removed. Throughout the economy, the "user pays" principle was used by Treasury officials to "rationalise" both private and public enterprises. These, and other measures, have shifted New Zealand agriculture from one of the most protected and subsidised to one of the most open and unprotected agricultural sectors in the industrial world. At the same time, cutbacks have seriously weakened the rural sector and its quality of life by reducing rural services and supports (Dahlberg, 1990). Subsequent governments have affected agricultural industries through taxation changes, and changes in resource management laws.

For agroforestry to be socially sustainable then it must be relatively robust to political change.

5
Results From Other Studies.

In the previous chapter, methods for measuring the sustainability of agroforestry were found. This chapter takes the findings from various agroforestry, forestry and agricultural studies and analysis them according to these measures.

5.1 Economic Sustainability.

When the four principles of economic sustainability were applied to the studies the following was found:

5.1.1 Sustainable Yield Harvesting.

Sustainable yield harvesting, or the periodic harvesting of an agroforestry resource, in perpetuity, appears to be a common agroforestry practice.

Renewal Capacity.

The renewal capacity of the agroforestry system is dominated by humans, who control both replacement and recruitment rates.

Replacement for harvested trees and stock are either procured from the same landuse unit, or are purchased from areas of surplus. The predicted harvested yield is often predetermined at the time of recruitment, especially in the harvesting of wood, where trees are planted out and thinned to a predetermined density. The annual yield from stock and trees varies over the rotation period. At the early stages of agroforestry establishment, livestock yields are high and so is pasture productivity. During the later stages stock yields progressively decline as the trees establish and timber harvesting begins.

Productive Capacity.

The productive capacity of the agroforestry system, is vulnerable to human impacts. Orwin (1991) found that site preparation and the effect of heavy machinery was a significant factor in the long term productive capacity of forestry sites. Maini (1992:5) found that the removal of forest biomass through harvesting caused a net loss of nutrients from the site following the rotation period. At nutrient-poor sites, it was thought that this could represent a significant reduction in biomass yield in subsequent crops. It was also found that losses in productive capacity could be reduced or eliminated through site selection and good management practices, e.g. immediate replanting to reduce erosion.

Summary.

The ability to achieve sustainable yield harvesting in agroforestry is dependent on both the site and farm management policies. The productive capacity of the agroforestry system is vulnerable to logging, site preparation and heavy machinery, which can degrade the productive capacity of the agroforestry site. Some sites may be particularly vulnerable to human impacts. Given suitable sites and good management practices, agroforestry appears to be able to maintain its total natural capital stock indefinitely, and therefore sustains the material benefit and utility received from these natural resources.

5.1.2 Sustainable Waste Disposal.

No studies were found concerning the assimilative capacity of the agroforestry environment. However, as research had been undertaken in the related industries of agriculture and forestry, these findings have been applied to agroforestry in the absence of specific studies.

Sedimentation.

Forestry studies on unstable and steep hill country discovered that increased root cohesion under forestry decreased the rate of soil erosion and sedimentation. Supporting studies into the effects of planting riparian strips by waterways also found that trees reduced sedimentation. However, other studies have found that soil erosion can increase under forestry during and after harvesting. It was found that until the seedlings developed sufficient roots to restabilise the slope and the earthworks had firmed, that soil erosion and sedimentation occurred (Orwin, 1991, Blaschke *et al.*, 1992). Subsequent forest management studies have shown that logging methods, harvest planning and reduced site preparation can all contribute to reduce the impact of harvesting on sedimentation (Orwin, 1991: 35). From the above studies it may be reasonably assumed that agroforestry is likely to decrease sedimentation of waterways for the length of the rotation, except at time of harvest where sedimentation may increase, thereby adversely affecting the environment. Whether agroforestry will exceed the assimilative capacity of the environment is not known.

Nutrient Waste.

Fertiliser use in agroforestry systems is very limited. The Ministry of Agriculture and Fisheries (1984b) recommended that fertiliser should only be applied where agricultural returns were sufficiently high to justify its cost. Olsen (1987) also condoned the use of fertiliser only in the specific cases of phosphate-deficient clay soils, and where a specific deficiency of some trace element had been identified. Unlike most agricultural landuses, Olsen (1987) found that trees did not require nitrogen-phosphate-potassium (NPK) fertilisers, especially if the sites had been previously farmed.

Chemical Wastes.

Pesticides - Pesticides were not generally found to be associated with timber production (Ministry of Agriculture and Fisheries 1984b). However pesticides were associated with the stock component of agroforestry, e.g. drench. The ineffective disposal of sheep dip may be a further source of chemical pollution in the agroforestry system (Ministry of Agriculture and Fisheries, 1992:13).

Herbicides - Herbicides were generally used only once during the rotation, and that was before planting. The Ministry of Agriculture and Fisheries (1984b) recommended that because most agroforests were in extensive farming situations, that the control of the annual weeds was generally not warranted. Recent research has found that several of the herbicides recommended by the New Zealand Forest Research Institute for planting out, e.g. Simazine and Atrizine have been found in agricultural drains in Canterbury at 50 and 370, respectively, times the US EPA, and EEC threshold levels (Mathieson, 1992, Maclaren, 1993: 35-36). While it is not suggested that agroforestry was the reason for such high levels of Simazine and Atrizine in Canterbury, Mathieson (1992) raised concerns regarding their use, particularly of Atrizine, because it is a long-lasting herbicide in both soil and water, and its ecotoxicological effects were not fully known.

Fungicides - Most of the timber in New Zealand is treated with fungicides to help preserve the wood. The most common fungicide used until recently was pentachlorophenol (PCP). PCP has been estimated to have contaminated more than 800 land sites, and many of these are thought to be on farms through home timber preservation. No commercial clean-up strategies or disposal processes for PCP-contaminated soil exist (Stevenson, 1992). The wood preservative currently being used in New Zealand, is copper-chrome-arsenic, commonly known as "Tanalizing" or CCA. CCA has lower risks than PCP, and results have indicated that leaching rates were very low, but the chemical has been found to be hazardous if ingested, burnt and the smoke inhaled, or the ash buried (Hegan, 1993).

Biological Waste.

Faecal Waste - Agroforestry was not considered to be a major source of faecal waste in New Zealand (Ministry of Agriculture and Fisheries, 1992:12).

Slash Waste - Slash, or the branches, bark, tree tops and other tree waste left behind after successive silvicultural operations has been found to be a major constraint to farming. Slash has been found to cause reduced stock carrying capacity, create fire hazards, restrict access, increase shepherding problems, and to become a haven for rabbits and weed germination. But as slash has been found to break down and be assimilated into the soil within in three to four years, it does not appear to causing long term biological waste accumulation (Ministry of Agriculture and Fisheries, 1984b:1-2).

Wildings - Wildings, or the regeneration and spreading of *Pinus radiata* seedlings in many areas of New Zealand, have become a limitation on productivity. Wildings are a problem for two reasons: firstly the seedlings are genetically inferior, and secondly wildings can become an invasive weed that decreases the productivity of pastoral land, and can place an expensive burden of eradication on the landowner. In some areas (i.e. Central Otago and the Mackenzie Country), the spread of wildings from existing exotic forestry plantations is thought to be nearly out of control (Belton, 1988). If wilding numbers are high enough then they may become a problem on agroforestry sites.

Summary.

Given good management practices it appears that agroforestry is unlikely to produce more waste than can be assimilated into the environment, and thereby constrict human activity.

5.1.3 Depletion Of Non-Renewable Resources.

Substitution.

No studies were found concerning agroforestry and the potential for non-renewable resource substitution.

Recycling.

In agroforestry there appeared to be limited scope for recycling, as few of the resources used lent themselves towards recycling. The exception would be the use of metals, in the form of machinery, fencing, roofing, etc (McInerney, 1994).

Efficiency.

Studies found that the interactions between the biological and economic components of agroforestry result in competitive, complementary as well as supplementary conditions, created by the mixing of agroforestry system components in time and space. In economic terms, agroforestry as a landuse, when compared with non-agroforestry landuse systems, has been found to have a higher output value at the same resource cost, and/or to have the same output at a lower resource cost (Hoekstra, 1987).

Summary.

There was little information available regarding the substitution and recycling in agroforestry, so no conclusions could be drawn on these. However agroforestry studies have found that agroforestry was a reasonably efficient landuse, especially in comparison with agriculture.

5.1.4 Economic Return.

It appears that agroforestry meets the above three minimum standards required by a sustainable economic activity, therefore agroforestry will now be evaluated in terms of more traditional economic criteria. Section 5.1.4.1 will look at the factors affecting the profitability of agroforestry while Section 5.1.4.2 will use four agroforestry case studies to assess the profitability of agroforestry.

5.1.4.1 Factors Affecting Profitability.

"Will Morris has found the perfect answer to making use of unproductive land while eventually almost doubling the returns of his North Canterbury farm at the same time - plant trees" (Stephens, 10/8/94: 29).

Agroforestry as a landuse incorporates the benefits and costs of both agricultural and forestry landuse systems. The benefits are that livestock provides cashflow while the forest grows, and the trees provide a significant return at harvest. The costs are that the farmer loses an immediate income from the stock, and receives less money than if forestry was implemented. Studies into economic return from agroforestry systems have found that profitability for the individual property is dependent on the following endogenous and exogenous factors, which effect either farm income or farm expenditure.

Costs.

The first factor that affected profitability of agroforestry was costs.

Development Costs - The period between outlay and realisation of gains makes agroforestry difficult for farmers to adopt who had little finance available. Stewart (1985) found that in many cases having sufficient funds to continue farming until clearfelling of the trees, was a major problem.

Spall and Meister (1988) recommended that the burden of income loss and capital requirements could be eased by outside financial assistance, i.e. bank loans or joint ventures (Jvs), but only if the level of debt servicing was not crucial to the continuing viability of the farm. Debt servicing was found to markedly affect the profitability of the agroforestry investment (Spall and Meister, 1988, Knowles, *et al.*, n.d.).

An alternative to an increase in debt servicing was suggested by Aitken, who found that planting out a fraction of the farm per year, or only planting out in years of farm cash surplus, allowed the landowner to retain sufficient income to cover farm and living costs, and still receive a reasonable profit at time of clearfelling (Aitken, n.d.).

Harvesting And Transport Costs.

The profitability of an agroforestry venture was found to be affected by the quantity (economies of scale) being harvested, the difficulty of the terrain involved in harvesting, the distance from the point of sale, and the roading requirements. These factors were found to play a major part in the price received at harvest, and thus the profitability of the agroforestry investment (Stewart, 1985, Olsen, 1987).

Maclaren (1993) found that logging costs became a significant factor on difficult terrain. For example, in 1993 logging costs ranged from $5,000/ha to $20,000/ha or more. Thus, a difficult site equated to a revenue reduction of $15,000/ha, over the best site. In Spall and Meister's (1988) case study of a Wairarapa hill country farm, it was found that agroforestry was a relatively robust landuse, but profitability was very much influenced by site. The other major cost to the profitability of agroforestry was transport (Maclaren, 1993). In the Knowles *et al.* (n.d.) case study on a Bay of Plenty hill country farm, it was calculated that for each km increase (or decrease) in cartage distance, the cashflow was reduced (or increased) by $99/ha/km. Other studies indicated that one of the major costs at time of harvest for small woodlots, was not so much the actual cost of logging but the cost of installing roads (Maclaren, 1993). Overall, quantity, high logging, transport, and roading costs all affect the profitability of agroforestry.

Risks.

The second factor which affected profitability was the risks associated with agroforestry as an investment. Market and productivity risks were both found to effect the profitability of agroforestry.

Markets.

"encouraged by the rapid growth and success of the initial plantings, we planted out some of the unproductive faces using radiata pine, in the then fashionable spacings of 6 ft x 6 ft. These trees were pruned and it was hoped to sell the thinnings for post, but at age 6 it became obvious that there was to be no economic market for posts and we were forced to waste. The quantity of thinning slash turned the woodlots into a jungle, impenetrable to both man and beast" (Brann and Brann, 1988:40).

Agroforesters, like farmers, will have to remain price takers and not price makers. New Zealand currently accounts for merely 3.9% of the annual harvest of industrial round wood in the Pacific Rim, and this is projected to rise to only 8.5% by the year 2005 (Maclaren, 1993). It has been predicted that there is unlikely to be a major world shortage for forest products in the future. Demand estimates for most markets have been revised downwards in recent years, and a number of factors suggest that supply limitations are unlikely to be great. All indications therefore, point to strong competition for most timber markets (Maclaren, 1993).

In Spall and Meister's case study (1988) of a Wairarapa hill country farm, it was suggested that a ready market for the timber in 28 years' time could not be guaranteed. Spall and Meister thought potential growers should clearly identify appropriate regimes, and consider likely future market needs. It was suggested that potential growers, at the minimum, need to give thought to, and make some arrangements for, the disposal of their crop before planting.

Productivity Risks.

"The 1992 snowstorm caused havoc with his plantations, with trees up to 28 ha bent over 45 degrees. They are now only good for firewood, pulp or chip... We had quite a few stock losses on top of the trees we lost. But stock can breed back again, but trees don't" (Stephens, 10/8/94: 29).

Some regions and microsites are particularly prone to catastrophic damage from soil slipping, or from climatic factors such as drought, frost, snow, and most importantly, wind. Radiata pine was found to withstand droughts, but drought affects the growth and profitability of later timber harvest. Radiata pine has also been found to be susceptible to stem breakages, and toppling from wind and snow. Other risks include fire (Maclaren, 1993). Agroforestry productivity risks change with site location, and at high risk sites profitability may be vastly effected if a catastrophic event occurs causing product loss.

Skills.

The last factor which profitability is dependent on is the skills that the individual farmer possesses. Management, marketing, the agroforestry regime, and labour availability all affect the ultimate profitability of agroforestry.

Management - Knowles *et al.* (n.d.) found that because of the long-term nature of agroforestry, it was important that any significantly sized project be carefully planned. The scale and timing of the conversion from open pasture to agroforestry had to be done in such a way that both successful plantation establishment, and it was during this phase that labour and organisational demands were likely to be greatest (Gisz and Sar, 1980). Poor management could led to unnecessary expenditure on contract labour.

Marketing - Maclaren (1993) saw trees as an unusual commodity. The small New Zealand grower was not obliged to sell trees at any particular time or age like the farm's agricultural products. Unless there was a cashflow crisis, a grower could reject ludicrous offers, and wait for peaks in the spot market for genuine offers. In the meantime the trees would continue to grow, and in doing so, would increase in value. The tree grower was in a very strong position to dictate the terms of sale, as the cutting rights to stands of trees could be sold at any time during a rotation. However, Maclaren found that the prerequisite for effective marketing by the farmer was a sound knowledge of markets, their potential's and their requirements (Maclaren, 1993).

Agroforestry Regime - The agroforestry regime chosen and ultimately the wood produced, affect the profitability of agroforestry. Tight final stocking, or even just in the first half of the rotation, was found to reduce the diameter of individual trees. The would therefore have to be grown longer if they were to meet marketing constraints on minimum permissible diameter (SED). Pruning was also found to extend rotation length by slowing down the tree growth (Maclaren, 1993). Other factors such as final density and pruning, etc, were found to decide the volume and quality of wood, the livestock carried, length of rotation, and ultimately the income received from the timber at time of harvest.

Labour Requirements - The Taranaki Regional Council (1992) found that the introduction of forestry into the farming system would significantly increase the labour requirements and require new management skills and inputs when compared with livestock only enterprises. It found that agroforestry would reduce work requirements for some activities, such as shearing, drenching, etc; but the net effect on livestock labour requirements would not decrease directly proportionally to any reduction in stock numbers. Many of the maintenance operations within the plantation could be spread throughout the year, and to some extent over years, thereby enabling available farm labour to undertake most of the thinning and pruning work (Gisz and Sar, 1980:2). However, it was found that if contract labour was used to fill labour shortfalls, then agroforestry would be less profitable than if farm labour solely was used.

Summary.

The profitability of agroforestry is dependent on three important factors: cost; risks; skills. Costs were found to substantially increase if the farmer needed to borrow money for development, or if the agroforestry development was poorly sited. Agroforestry profitability was also found to be at risk from both market changes and productivity failures. The final factor effecting profitability was dependent on the skills that the individual farmer possessed. Marketing, management, etc, skills where found to affect the economic return of agroforestry. The combination of these three factors determined the farm income or farm expenditure on a given individual agroforestry investment, and ultimately the profitability.

5.1.4.2 Agroforestry Case Studies.

It should be noted that the following case studies make assumptions about the future, e.g. wood prices, stock prices and management standards, etc over 20 years or more. Therefore the findings of these studies are indicative only.

Case Study: Wairarapa Hill Country.

Introduction:

The following information was obtained from a 1988 discussion paper by Spall and Meister, on the potential for agroforestry as a diversification in the Wairarapa hill country. The research consisted of a realistic farm decision-making model based on a Wairarapa hill country farm, over twenty-one years.

Summary:

The study indicated that agroforestry was likely to be a profitable diversification for Wairarapa hill country farmers. It was demonstrated that when tested under a range of economic circumstances, the primary effect of changes in economic parameters was to alter the rate of development rather than the choice of agroforestry as an investment. Spall and Meister also found that agroforestry appeared to integrate well with existing hill country farming practices as the impact on farming was limited. In the case study, by year twenty, with more than one-third of the farm in trees, 80% of the original livestock was still being carried. A continuous planting programme, together with a high level of grazing underneath the trees, ensured that fluctuations in livestock numbers were minimised. It was also found that surplus winter labour was effectively utilised by the agroforestry programme.

Spall and Meister found that capital availability and timber values were major factors affecting the rate of development and profitability. Other variables, including labour availability, weights placed on final asset values, interest rates, and tax deductibility were also found to have affected the rate of development and profitability, but to a lesser extent. Regarding profitability, choice of planting site and ultimate timber value was cited as very important (Spall and Meister, 1988).

Case Study: Bay of Plenty Hill Country Farm.

Introduction:

The following information was obtained from a case study by Knowles *et al.* (n.d.) that evaluated agroforestry, based on Roydon Downs, a Bay of Plenty hill country farm. Roydon Downs consisted of 53 hectares of established radiata pine, 15 hectares of alternative species, and 30 hectares of pine to be planted. Most of the labour used in establishing and tending the pine plantations was provided from within the family. Experience from Roydon Downs was used as the basis to determine agroforestry costs for a "typical Bay of Plenty beef and sheep farm" (Knowles *et al.*, n.d.).

Cashflow:

The effect on the farm cash surplus was estimated for 135 stems/ha and for 225 stems/ha regimes on 83 hectares, using either family labour for silviculture, or contract labour. The 135 stems/ha regime had a maximum deficit of $14,700 in the 24th year (using contract labour), and $12,000 (using family labour). For the 225 stem/ha agroforestry regime, maximum deficits were $19,700 (using contract labour) and $15,100 (using family labour). Once felling started, the largest surplus was contributed by the 225 stems/ha regime using family labour (a net gain of $80,100 over farming), compared with a net gain of $68,500 using 135 stems/ha. Total farm (245 ha) cash surplus was predicted to increase from $56,000, without agroforestry, to $132,000, with agroforestry, using 225 stems/ha and contract labour.

Net Present Value (N.P.V):

The profitability of the various agroforestry options was compared with farming, for net present value. Using family labour, agroforestry for all three options was similar, with all being more profitable than farming at real pre-tax discount rates of less than 13%. An alternative option studied was the option to improve the carrying capacity of the hills under a more intensive agricultural system. Analysis of this found that the livestock carrying capacity would have to increase from the current 8 LSU/ha, to more than 16 LSU/ha, before agroforestry, at 225 stems/ha using family labour, was less profitable than farming. Knowles *et al.*, (n.d), concluded that while that was physically possible, to achieve such increases in productivity would require relatively expensive inputs of fertiliser, fencing, improved pasture species, and more labour. Furthermore, increased stock pressure could increase erosion.

Summary:

It was therefore concluded that agroforestry was highly profitable and appropriate for much Bay of Plenty hill country presently in pasture. The system was found to be a straightforward, low cost, environmentally sustainable way of using land. Planting the least productive third of the farm was predicted to more than double the farm surplus (Knowles *et al.*, n.d.).

Case study: Taranaki Hill Country.

Introduction:

This case study into sustainable landuse in the Taranaki hill country, was undertaken by the Taranaki Regional Council in 1992. For the case study, a 'representative' eastern Taranaki hill country property near the research area was chosen, and two computer models, 'STANDPAC' and 'Agroforestry Estate Model', were used for farm management evaluation. Based on information from existing production factors, and assumed price returns, these models were used to simulate selected livestock and forestry management scenarios. Three scenarios were used, of which two are detailed below. The first was for total farm agroforestry (581 hectares), which involved the eventual afforestation of the whole property, while maintaining sheep for grazing. The second scenario was for partial agroforestry (347 hectares) which took into account practical aspects, such as forestry location, fencing, etc.

Cashflow:

During the initial 28 years of forestry establishment, a steady decline in farm cashflow occurred, which led to a deficit of $ 22,404 (or $115,497 below the agricultural cashflow) in year 28. It was found that if the farmer's labour was substituted for contract labour, then a larger deficit of $48,577 (or $141,670 below the agricultural cashflow) would occur. In year 2020 it was predicted that the harvesting of the total farm forestry area, at an equal annual rate, would create a farm cashflow of approximately $450,000 per year. When substituting contract labour, the total farm cashflow was found to reduced to a constant sum of $425,000 per year. Under partial farm forestry, it was found that a total cashflow of $300,000 using own labour, and $285,000 using contract labour, would be achieved.

It was concluded that there was the potential for a significantly higher cash surplus to be generated from agroforestry enterprises, by 2.5 times those for livestock only enterprises on the farm, and a 3.2 fold increase in cashflow for partial farm forestry. It was also found that as agroforestry involved the growth (over 26 years) of a substantial asset on the property, when compared with a full sheep grazing enterprise, the farm was found to have an asset value of $120,233, which was less than 2% of the predicted forest value of partial farm forestry.

Net Present Value (N.P.V.):

Under total farm forestry it was found that at higher discount rates, agriculture showed a net present value superior to agroforestry, while at lower discount rates this was reversed. This was because of the relatively early and constant returns from agriculture compared with the returns from agroforestry, which took longer to evaluate. At a discount rate of 9.8 % (own labour) the net present value of agriculture equalled that of the agroforestry project. When using contract labour for the total farm forestry project this figure reduced to 7.1%. The discount rate below which partial farm forestry becomes more profitable than agriculture was 9.7% (using own labour) and 7.0% (using contract labour).

The study concluded that at low discount rates the agroforestry project was significantly preferred over livestock farming. However, at high discount rates the differences were much less significant between agroforestry and livestock, with livestock being marginally preferred. Therefore in a high interest rate market environment, there was found to be little difference between the livestock and agroforestry enterprises but in a low interest rate market agroforestry was significantly superior. In view of this, overall it was concluded that agroforestry was the better landuse.

Internal Rate of Return:

The internal rate of return for agriculture was found to be 9.9% compared with 9.6% for total farm forestry. For partial farm forestry these figures were found to be 7.6% and 8.9% respectively.

It was found that the internal rate of return between total farm forestry (9.9%) and agriculture (9.6%) was very close, and that the external investor would find very little difference between the two investment options. But the comparison of internal rate of returns for agriculture and partial farm forestry found a marked difference: for partial farm forestry these figures became 7.6% and 8.9% respectively.

Summary:

It was found that agroforestry had the potential to increase the income generation capacity on this type of hill country by 3-5 times that of livestock farming alone, and that at such an increased level, farm viability would not be a problem. The study found that no other farm enterprise was known to offer anything close to those benefits (Taranaki Regional Council, 1992).

Case study: King Country.

Introduction:

This case study into farm scale agroforestry in the King County, came from a paper on "agroforestry in practice". The 330 hectare farm consists of five agroforestry blocks and 4000 stock units of sheep, goats and cattle. The program STANDPAC was used to evaluate the economics of Cumberland Farm.

Net Present Value (N.P.V.):

It was found that the farmer would have been better to leave his land in grass if the discount rate was 7% or higher, if the discount rate was less than 7%, then agroforestry was the best option.

Internal Rate of Return (I.R.R.):

Under this criterion it was found that the farmer would have been better to leave his land in grass (Cumberland, 1990).

Summary:

From the four case studies it was found that agroforestry negatively affects the cashflow during time of agroforestry establishment; after that time it was found to strongly increase the farms' cashflow, above what could be expected from any other farm enterprise, e.g 3-5 times that of livestock farming alone. The studies also concluded that at low discount rates agroforestry was significantly preferred over livestock farming, but at high discount rates there was little to chose between the two, with livestock being marginally preferred. It was generally found that the Internal Rate of Return between farming and agroforestry was very close, or the farmer/financier would be better to have left the land in pasture.

5.2 Environmental Sustainability.

Information from the studies was applied to the two principles of environmental sustainability and the following was found.

5.2.1 Conserving Life Support Systems.

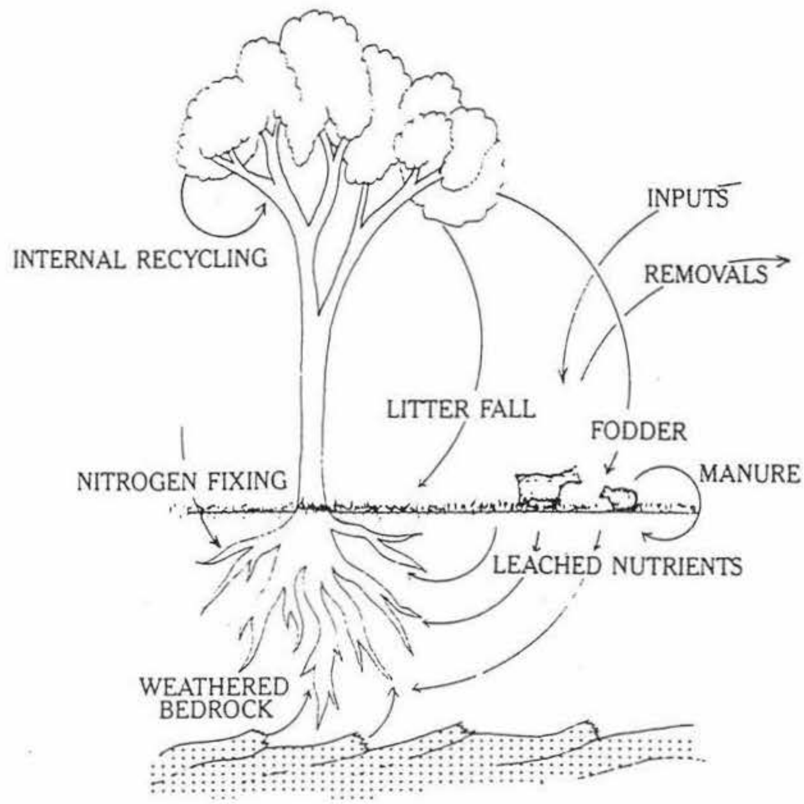
Energy.

No information was found on agroforestry energy consumption.

Nutrients.

Studies into nutrient cycling under agroforestry found that the tree component played an important role in the maintenance of nutrients within the agroforestry environment (see Figure 1).

Figure 1: Agroforestry Nutrient Cycle.



(Reid and Wilson, 1986:35)

Young (1992) found that the tree root system was able to trap nutrients in the soil solution that would otherwise be lost by leaching. It was also found that the tree root system was able to use newly-released minerals from the bedrock. Many of the nutrients used by the trees were found to be returned to the topsoil as dead leaves, twigs, and seeds, which slowly decomposed on the soil surface, or were eaten by animals. Within the system, nutrients were found to continually flow from the soil to the trees and pasture, to the animals as feed, and then back to the soil. Trees have been found to improve the nutrient cycle by continually bringing nutrients to the surface and eventually replenishing the topsoil, from where the agricultural crops draw their nutrient demands (Reid and Wilson, 1986:35).

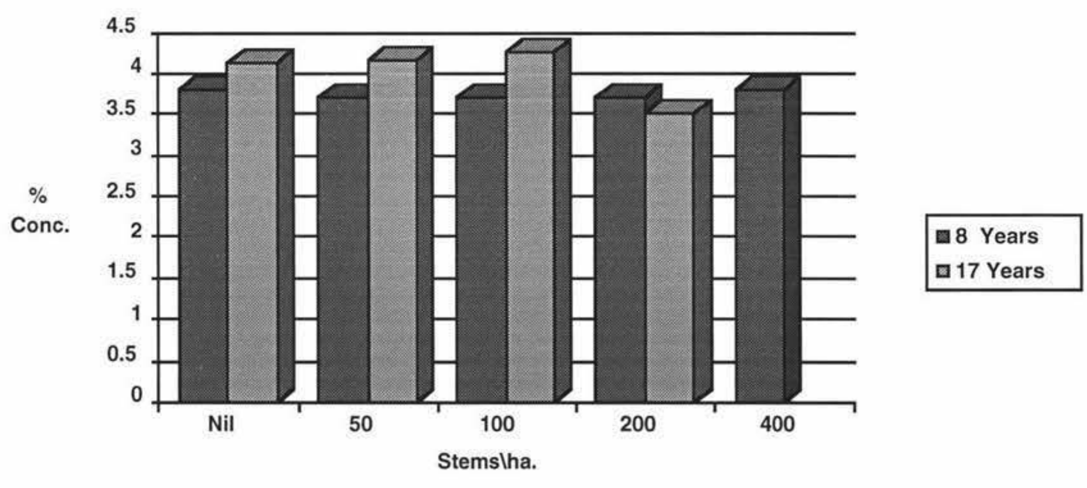
More specifically agroforestry studies have found the following:

Nitrogen Concentration (N):

Studies at Invermay and Akatore, showed no detrimental effect on the N concentration in the soil (Cossens, 1984:42). However, contradicting studies at Tikitere found there was a progressive reduction in mineralisable nitrogen (Figure 2)(Knowles *et al.*, 1993:17).

The N fixation studies at Tikitere indicate that the proportion of N from clover derived from the atmosphere was unaffected by the trees at either 200 or 400 stems per hectare. However, as the yield of white clover declined with increasing tree density, the reduction in the total N fixation was likely to be proportionally greater than the effects of the trees in reducing pasture yield. It was suggested that if white clover was the major source of nitrogen in an agroforestry system, then there may be a long term decline in N. Nitrogen fixation by legumes other than white clover could become an important alternative source of N (Percival *et al.*, 1984c:51).

<u>**Figure 2: Soil Nitrogen At Tikitere.**</u>

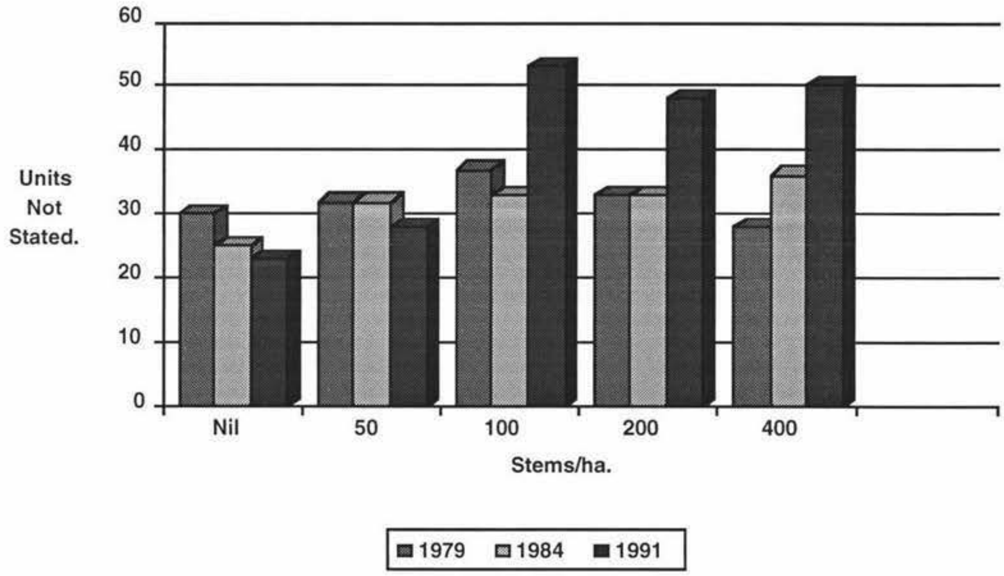


(Percival *et al.*, 1984c:51, Knowles *et al.*, 1993:17)

Phosphate (P):

Studies at Waratah and Tikitere, found that agroforestry had no effect on the soil P (Percival *et al.*, 1984c:51). However, continued studies at Tikitere (Figure 3) found that surface P levels increased with tree age and tree stocking even though it had received less fertiliser. Knowles (1991) linked the accumulation of P to pasture yield decline. A study at Invermay also noted a P increase when high stocking rotational grazing was introduced: soil P levels rose from a mean Olsen of 9 to 20 over three years (Cossens, 1984:42).

Figure 3: Soil Phosphorus At Tikitere.

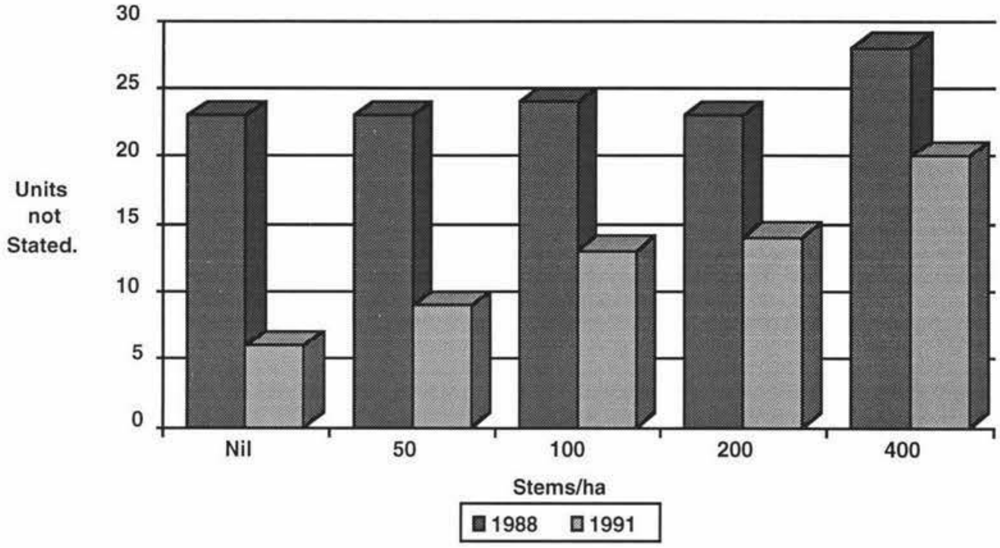


(Knowles *et al.*, 1993:18)

Sulphur (S):

At Tikitere (Figure 4), Invermay and Akatore, it was found that there was no detrimental effect on the concentrations of sulphur in the soil (Cossens, 1984, Percival *et al.*, 1984c:51, Knowles *et al.*, 1993:17).

Figure 4: Soil Sulphur At Tikitere.

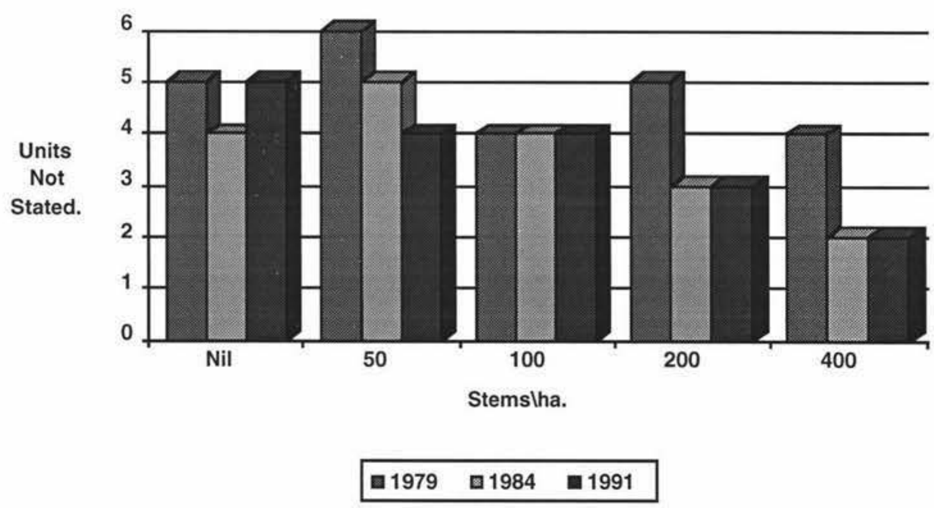


(Knowles *et al.*, 1993:18)

Calcium (Ca):

Studies at Invermay, Akatore, Waratah and Tikitere (Figure 5), found no detrimental effect on calcium concentrations in the soil (Cossens, 1984:42, Percival *et al.*, 1984c:51, Knowles *et al.*, 1993:17).

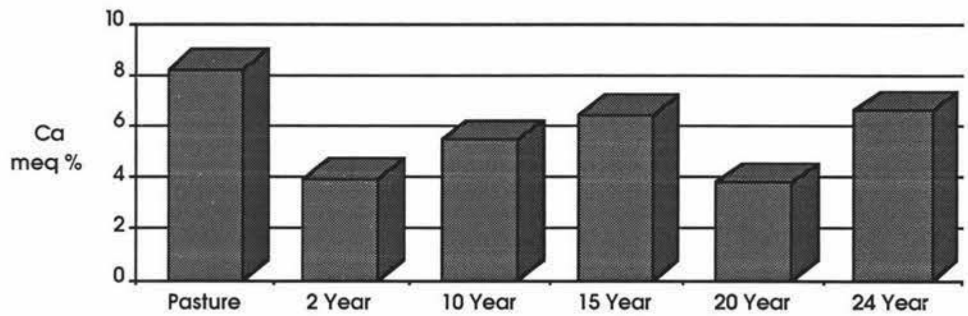
Figure 5: Soil Calcium At Tikitere.



Knowles *et al.*, 1993:18)

However contradicting these studies, Stoddart (1984) found a significant difference between calcium concentration of plantation soils, and that of pasture soils: the pasture soil was found to be higher in calcium (Figure 6). However the validity of this result was questioned by Stoddart, as superphosphate had been applied to the pasture in the past.

Figure 6: Calcium Concentration Changes.

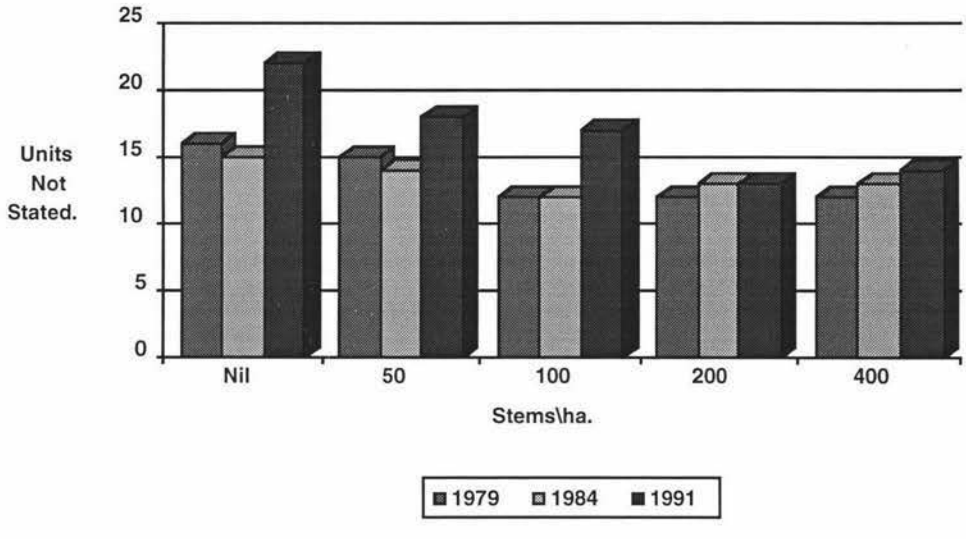


(Stoddart, 1984:34)

Magnesium Concentrations (Mg):

Studies at Invermay, Akatore, and Waratah, found that neither tree density nor age had any detrimental effect on magnesium concentration in the soil. At Tikitere (Figure 7), it was found that overall there was no effect on the magnesium level, but that there were significant differences between tree densities in some years. No constant pattern was observed (Cossens, 1984:42, Percival *et al.*, 1984c:51), although ten years later at Tikitere it was noted that magnesium levels had increased since year fifteen at the lower tree stocking rates (Knowles *et al.*, 1993).

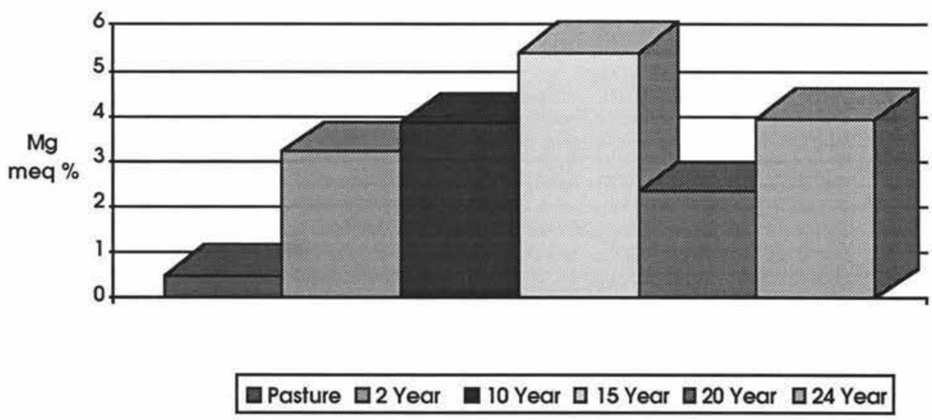
Figure 7: Soil Magnesium At Tikitere.



(Knowles *et al.*, 1993:18)

Stoddart (1984) also found significant variation in the sample means, and overall that the pasture soil contained a very low amount of magnesium, compared with those under plantation *Pinus radiata* (Figure 8).

Figure 8: Magnesium Concentration Changes.

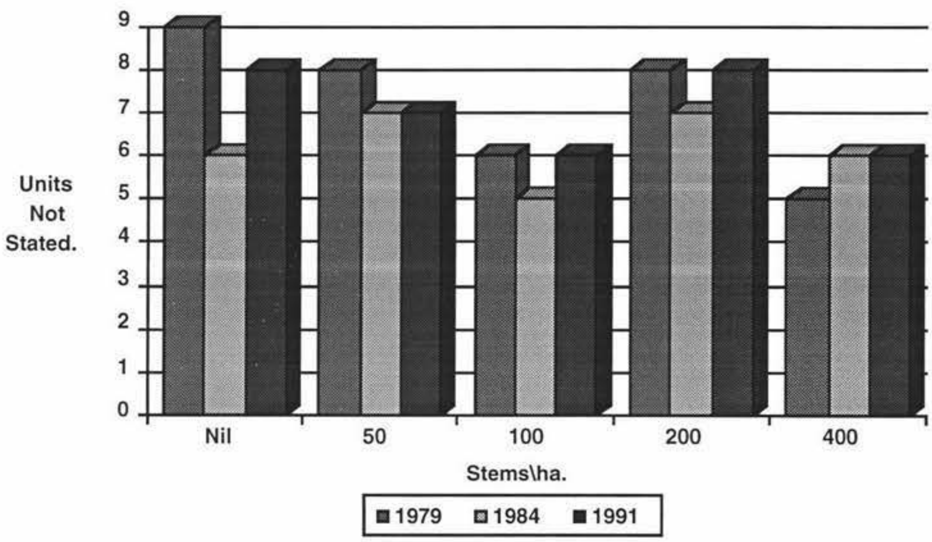


(Stoddart, 1984:34)

Potassium (K):

Studies at Invermay, Akatore, Waratah and Tikitere (Figure 9), found that neither tree density nor age had any detrimental effect on K concentrations in the soil. At Tikitere the K values were noted to have shown significant variation at the same tree densities between years, but there was no apparent pattern with time (Cossens, 1984: 42, Percival *et al.*, 1984c:51).

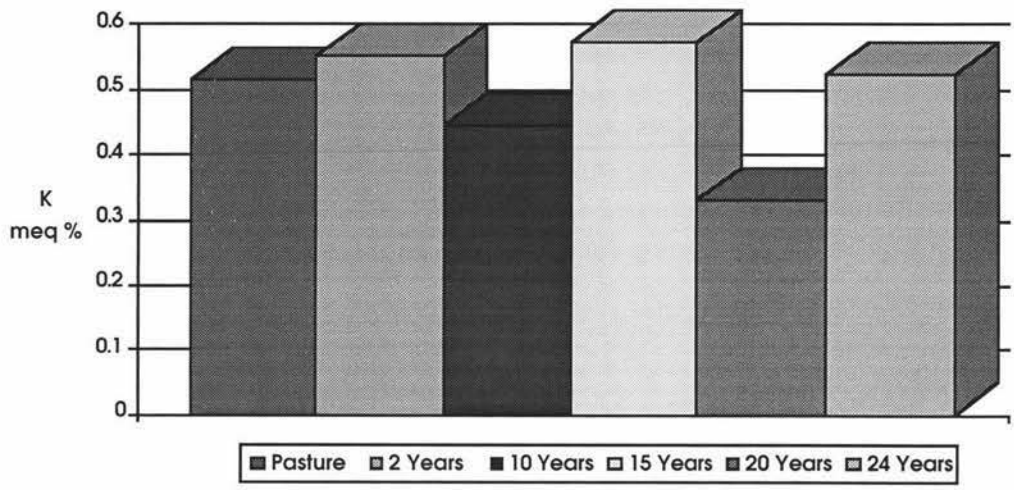
Figure 9: Soil Potassium At Tikitere.



(Knowles *et al.*, 1993:18)

Stoddart's study supported the above findings with no significant difference being found in potassium concentration. However pasture soil was found to have a higher potassium concentration than the older plantation soils This was taken to suggest that *P. radiata* might decrease the potassium concentration in the soil, if introduced onto pasture (Figure 10). However, the validity of this result was again questioned through the application of superphosphate in the past (Stoddart, 1984).

Figure 10: Potassium Concentration Changes.

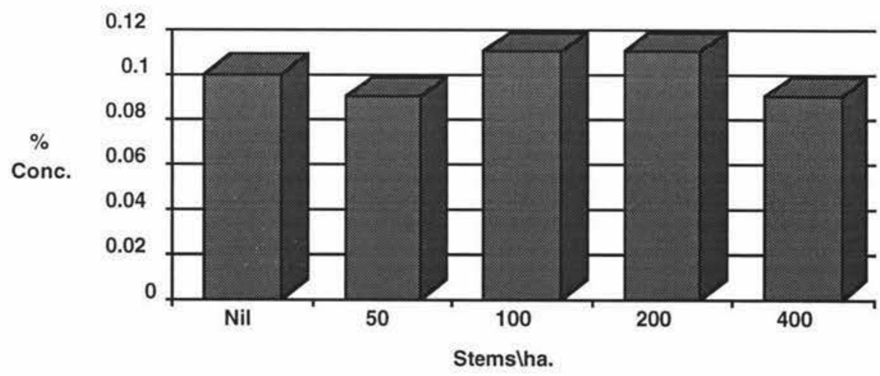


(Stoddart, 1984:34)

Sodium (Na):

Studies at Invermay, Akatore, and Tikitere (Figure 11), found that trees had no detrimental effect on the concentration of sodium in the soil (Cossens, 1984:42, Percival *et al.*, 1984c:51).

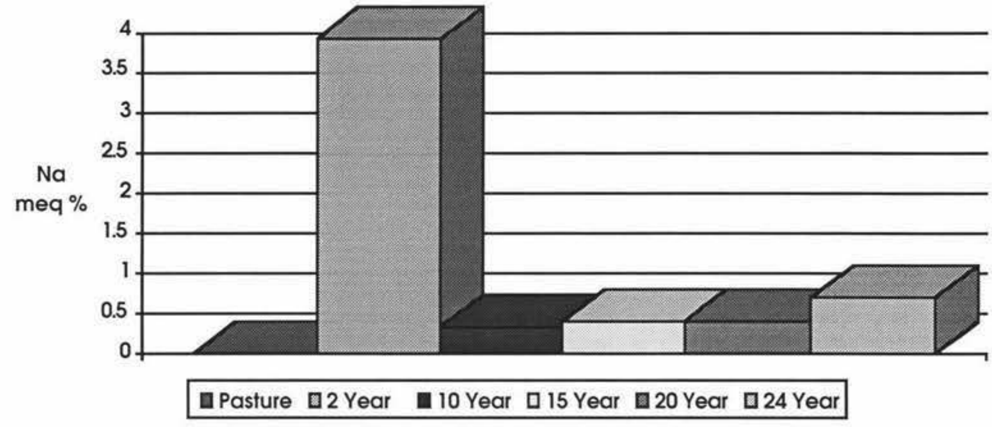
Figure 11: Soil Sodium At Tikitere.



(Percival *et al.*, 1984c:51)

However, Stoddart found significant sodium decreases in plantation soils from age two to twenty years old (Figure 12). Pasture soils was found to be much lower in sodium than the plantation soils (Stoddart, 1984).

Figure 12: Sodium Concentration Changes.

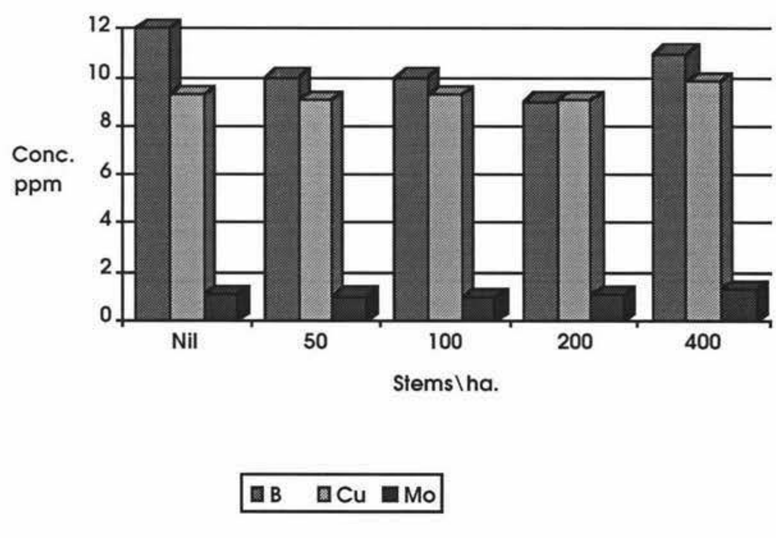


(Stoddart, 1984:34)

Minor Nutrients (Mo, B, Cu):

At Tikitere, except for Mo which was higher under 400 stems\ha, there were no effects found on the minor elements and no apparent pattern was found with time (Figure 13) (Percival *et al.*, 1984c:51).

Figure 13: Soil Minor Elements At Tikitere.



(Percival *et al.*, 1984c:51)

Summary of Nutrient Studies

The study at Tikitere concluded that under agroforestry most elements were at an adequate to high level. The exception was mineralisable nitrogen that was noted to progressively reduce when trees were planted on to farmland. Both surface phosphorus levels and some magnesium levels were found to increase over the rotation of the agroforestry site (Knowles *et al.*, 1993).

Stoddart found that there were no obvious trends, owing to other factors operating on the system that were not accounted for. The findings of her study indicated that the impact of *P. radiata* on the soil nutrient system was a dynamic and open one, in which a large number of factors and processes were operating. The consequences of an agroforestry system on the soil and vegetation were therefore uncertain. Stoddart concluded that the effects of agroforestry on the nutrient system appeared to be positive, as under agroforestry, the density of trees would be lower than that of the plantations sampled, thereby leading to less extreme effects on the environment (Stoddart, 1984).

Air Media.

Studies found that agroforestry affected the air in two ways. The first effect related to the chemical composition of air. Fast growing pine trees were found to affect the ability to store atmospheric C in stem wood. It was found that some C was stored in the stem wood that decayed after harvest, C was also released into the atmosphere. The balance of these two effects was critical to the impact that agroforestry has on the atmosphere (Maclaren and Wakelin 1991).

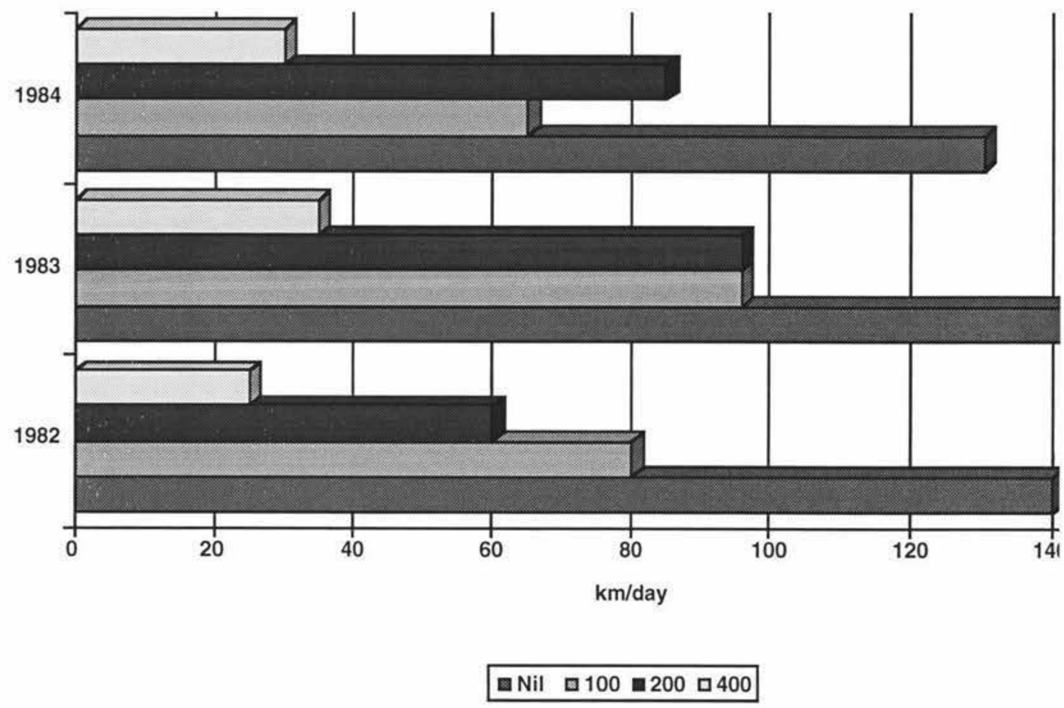
The second impact that was found on the air, was that on wind patterns. It was found at Tikitere that agroforestry regimes modified the understorey climate, and had the following effects:

.at the sheep grazing height, there were substantial reductions in wind run (Figure 14).

.a reduction in the wind run under trees was found to reduce thermal strain on livestock. In extreme situations of temperatures of 24 oC and above, it was thought that the presence of shading would also reduce stress on livestock.

.the reduction in windrun was also thought to cause a rise in grass minimum temperature. (Percival, *et al.*, 1984e, Hawke and Wedderburn, 1993).

Figure 14: Daily Wind Run At Tikitere.

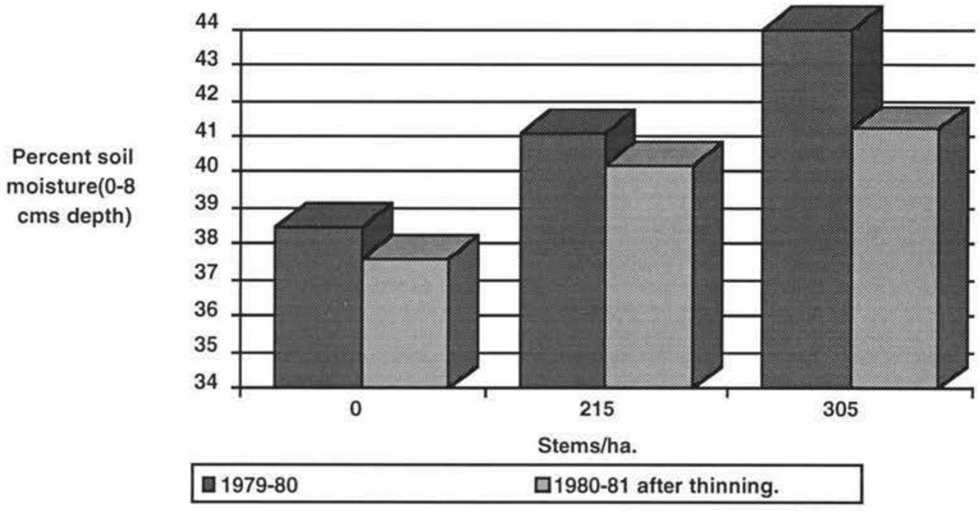


(Knowles *et al.*, 1993:23)

Water Media.

No studies into the effect of agroforestry on the aquatic environment were found. There was anecdotal evidence from agroforesters who claimed that water quality had improved, while others suggested that water yield had declined. However, there was a study into the effect of agroforestry on soil moisture. Soil moisture monitoring at Invermay showed a seasonal and an annual trend, for moisture levels to increase with increasing tree density (Figure 15). Cossens concluded that this was because the denser planting and canopy were acting as a mist screen, collecting additional rainfall, precipitating it on to the ground and raising soil moisture levels. Reduced windspeed within the trees was also thought to have raised soil moisture by reducing evapotranspiration (Cossens, 1984:43).

Figure 15: Mean Annual Soil Moisture At Invermay.



(Cossens, 1984:41)

Soil Media.

Physical Degradation.

.Erosion.

Young (1992) found that agroforestry systems maintained a more favourable soil physical structure than did agriculture, through the combination of erosion control, and increased organic matter. Erosion control was achieved by the trees acting as a barrier, checking water runoff and suspended sediment. Erosion control was also achieved by the trees reducing the soil water levels, and by physically binding the soil together. Trees were found to prevent some rainfall from reaching the ground through the process of interception and evaporation. In addition, trees were found to suck up water through their roots and "transpire" it out through the leaves (Young, 1992).

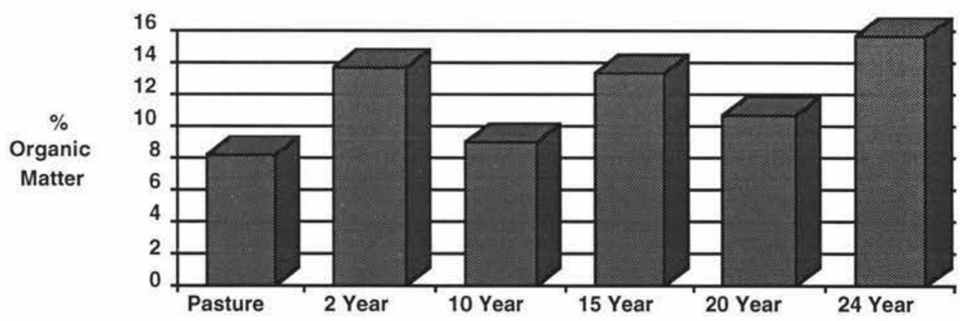
Radiata pine was found to control some deep seated mass movement, and it was found that a 10 fold reduction in erosion rate could be achieved in 15 years or so after planting. Shallow transitional landsliding was also found to be successfully ameliorated by radiata pine, if the trees were older than 8 years (Marden *et al.*, 1992, Maclaren, 1993). However other studies found that logging and roading operations were often the cause of forestry-related environmental damage. In most instances of such damage, more than 90% of the sediment in waterways was produced from the roads, tracks, and landings. Poor practices were found to result in nutrient losses, and to reduce soil water-holding capacity (Maclaren, 1993).

.Organic Matter

Young(1992) found that agroforestry systems could maintain soil organic matter at levels satisfactory for soil fertility. Young found that the strongest indirect evidence for this was the high organic matter content of most soil under natural forest, coupled with observations of the decline in soil organic matter when land was cleared for agriculture (Young, 1992). More specifically at Tikitere, it was found that at 200 stems per hectare, needle fall contributed 1.5 t of dry matter, to the 7.0 t annual dry matter yield (Hawke *et al.*, 1984).

Stoddart found that organic matter content increased from year ten to year twenty four in plantation soils, as was expected. It was found that pasture soil contained significantly less organic matter than the older plantation soils (Figure 16) (Stoddart, 1984).

<u>**Figure 16: Soil Organic Matter.**</u>

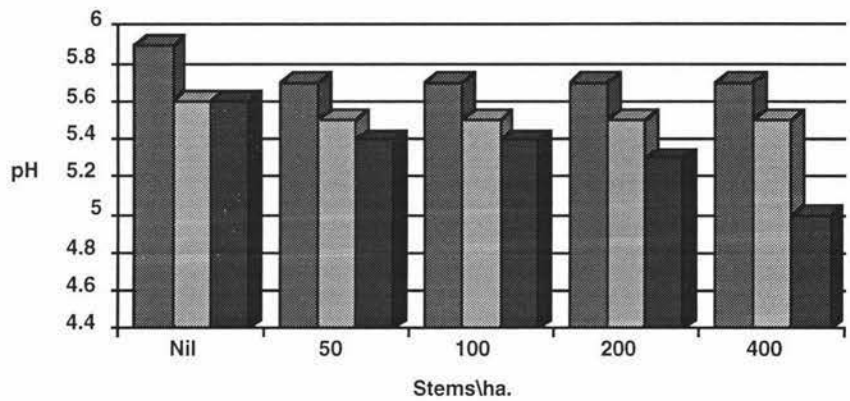


(Stoddart, 1984:34)

Chemical Degradation.

Studies at Invermay and Akatore showed no change in soil pH (Percival *et al.*, 1984c:51). Studies at Waratah and Tikitere also found no changes in soil pH in the early 1980's when the trees were relatively young (Percival *et al.*, 1984c:51). However continuation of the research at Tikitere found that increasing tree age and tree stocking appeared to increase soil acidity (Figure 17), particularly near the surface (top 150 mm). Knowles *et al.*, (1993) attributed this to the organic anions from decomposing pine needles, and possibly with a decline in earthworm population.

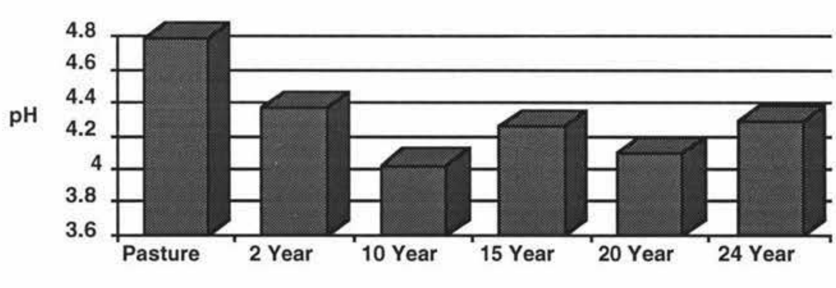
Figure 17: Trends In pH At Tikitere.



(Knowles *et al.*, 1993:18)

Stoddart (1984) also found that the soil increased in acidity, from tree age year two to year twenty (Figure 18).

Figure 18: Changes In Soil pH.



(Stoddart, 1984:34)

Biological Degradation.

At Tikitere and Waratah, agroforestry was found to have had an effect on the soil fauna. On the agroforestry sites the species of mycorrhizal fungus commonly found on forestry sites, *Rhizopogon rubescens*, was replaced by two less common types. In addition, earthworm, nematode and grassgrub populations all declined with development of the trees (Percival, *et al.*, 1984d:53, Knowles, 1991, Knowles *et al.*, 1993).

At Waratah, it was found that agroforestry caused a change in grass minimum temperature; this coupled with changes in soil moisture may affect soil microbial population (Hawke and Wedderburn, 1993).

Summary.

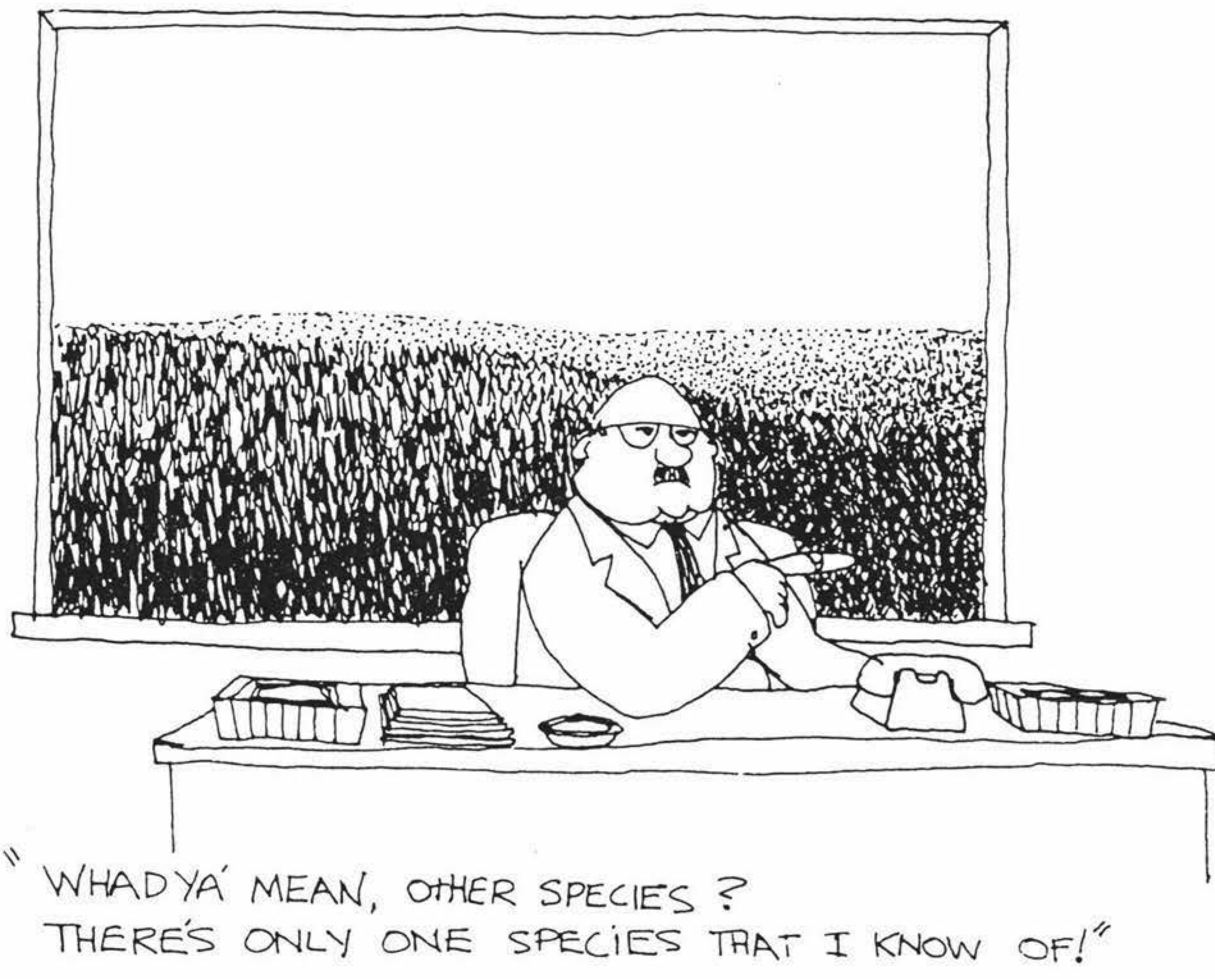
No studies were found involving energy consumption by agroforestry systems. The nutrient studies noted individual elemental changes, Stoddart concluded that there was no obvious trends in nutrient changes under *Pinus radiata*, and the Tikitere *et al.* studies concluded that under agroforestry most elements were at an adequate to high level. Agroforestry was found to have two impacts on air. The first concerned the C balance and the second effect concerned the reduction in wind speed and a change in the understorey climate. This change was thought to improve the environment for stock. No studies into the effect that agroforestry had on the aquatic environment were found. Anecdotal evidence suggested that agroforestry increased the quality, but decreased the quantity. Specific studies into soil moisture found that soil moisture increased under trees; therefore no conclusion could be reached on the effect agroforestry had on water. Soil studies showed that agroforestry maintained a more favourable sol structure and increased organic matter, but poor management practices at the time of logging affected the physical structure. Agroforestry appeared to increase pH in the soil, under increasing tree age and tree density. Finally agroforestry decreased the numbers of some biological soil species. Overall, while agroforestry impacts on the air, water, and soil environment, however the effects of these changes are unknown.

5.2.2. Biodiversity.

Biodiversity Within The Species

Trees - Agroforestry uses a single species of pine tree, that has been genetically improved and is far superior in forestry terms than any predecessor. In addition the trees are usually planted at four to five times the planned final density, which allows for further selection of the "best trees". (Ministry of Agriculture and Fisheries, 1984b).

Figure 19: Biodiversity.



(Stephenson, 1981:17)

Critics of the *Pinus radiata* industry argue that tying up nearly eighty per cent of New Zealand's agroforestry in a single species poses an unacceptable risk. The critic's concerns are supported already by two events. In 1946, a population of the wood boring wasp *Sirex noctilio* exploded on the volcanic plateau; within three years, up to two thirds of the trees were dead. *Sirex* was subsequently controlled by introduced parasites and has ceased to be a problem. In 1962, the pine needle blight, *Dothistroma pini* arrived in New Zealand, and became established in areas of high rainfall and humidity. Blight resistant strains of radiata have since been developed. In the past few years there has been mounting concern over the potential introduction of the Asian Gypsy moth, which has already attacked Chile's radiata stands (Hegan, 1993).

In response, all of the major planters of pine belong to the national breeding co-operative. The breeders believed that if a disease did strike, then a new species of pine could be rapidly developed, and the disease struck wood would still be harvestable and return some income (Hegan, 1993).

Stock - Ministry of Agriculture and Fisheries (1984b) have found no experimental evidence to suggest that any one breed of sheep performs better under agroforestry. However, they do suggest that clear legged breeds such as perendales should be used on scrubby land, while for cattle, beef breeds are recommended over dairy breeds. No preference is given for goat breeds. Livestock biodiversity would be therefore individual to the farm and its breeding policy.

Grass - Predominantly improved grasses are used on developed land and therefore tend to have a narrower genetic diversity. On extensive unimproved land and on some developed land, wild grasses and plants are more prevalent and correspondingly there is greater diversity within the species. At Tikitere it was found that the wild type of Yorkshire fog was better suited and grew better than the improved strains of Yorkshire fog under agroforestry (Percival *et al.*, 1984a).

Biodiversity Within Habitat.

Pasture - Studies at Tikitere found that pasture composition changed with increasing tree stocking or age. Clover and ryegrass decreased in proportion, and inferior grasses increased (Knowles *et al.*, 1993). At Tikitere it was found that there was little effect of the trees on browntop cover, but Yorkshire fog content was greater with increasing tree density. Poa spp., sweet vernal, Yorkshire fog and goose grass were found to have partly filed the niche left by the decline of ryegrass and white clover (Percival *et al.*, 1984a:18). At Tikitere, prairie grass, tall fescue, and cocksfoot were found to have greater persistence and production than ryegrass (Percival *et al.*, 1984a:21).

Akatore conversely showed a slow increase in the proportion of ryegrass in the pasture between 1977 and 1984. Under that grazing regime, ryegrass was found to continue to replace "other grasses (mainly browntop, sweet vernal, dogstail) in the pasture. At Akatore cocksfoot showed a slow increase but the other grasses declined from 80.3% to 62.7% between 1977 and 1984 (Cossens, 1984:46-47).

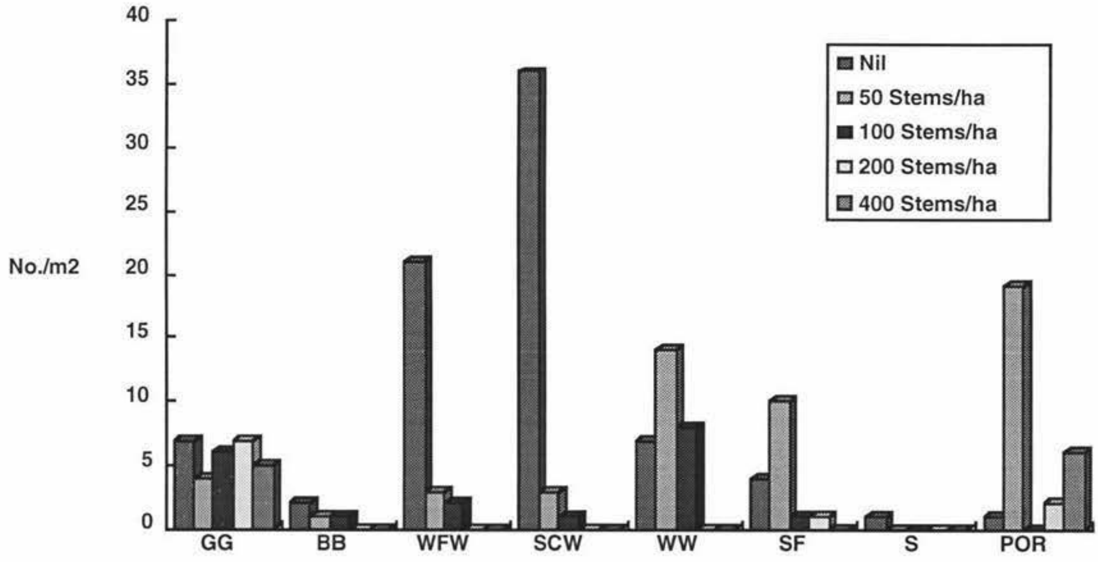
At Invermay cocksfoot and "other grasses" also declined from 30% and 50% respectively to 8% and 26% respectively between 1978-1982/83. However between 1974 and 1978 when haymaking was carried out, the "other grasses" increased their percentage of the total yield but decreased once haymaking was stopped. Under the grazing regime it was noted that "other grasses" were being progressively replaced with ryegrass and clover. The proportion of cocksfoot appeared to have stabilised.

At Tikitere and Waratah it was found that the number of unwanted plants (weeds) tended to have higher populations under agroforestry than in with open pasture. Most were associated with the slash that accumulated following successive prunings and thinning. Annual weeds were found to increase in the short term, but as the tree canopy developed, these were unable to compete and ultimately declined. Perennial weeds, such as blackberry or gorse which were longer term species, were thought unlikely to be affected in the same way as the annual plants (Percival *et al.*, 1984a).

Vertebrates - Exotic forest plantation studies found that native insect eating birds used pine forests as an extension of their natural habitat feeding on invertebrates and travelling from one native stand to another along the exotic corridors. Surveys of the Kaingaroa forest in 1948-49 found an abundance of grey warbler, pied tit, robin, fantail, whitehead, silvereye, the two native cuckoos, moreporks, and the New Zealand falcon. In addition many introduced bird species were found to be using the forest as well (Hegan, 1993).

Invertebrates - Earthworms, nematodes, and grassgrubs were all found to have declined under agroforestry at Tikitere (Figure 19) and Waratah (Percival *et al.*, 1984c:53, Knowles, 1991, Knowles *et al.*, 1993).

<u>**Figure 20: Soil Fauna at Tikitere, 1991.**</u>



Notes:

GG Grass grub beetle *(Costelytra zelandica)*

BB Black beetle larvae *(Heteronychus arator)*

WFW White fringed weevil larvae *(Listroderes delangnei)*

SCW Sub clover Weevil larvae *(Listroderes delangnei)*

WW Wire worm larvae *(Conoderus excel)*

SF Soldier fly larvae *(Inopus rubriceps)*

S Devil's Couchman *(Staphilinidae spp.)*

P Porina larvae *(Wiseana cervinata).*

(Knowles *et al.*, 1993:19)

Summary.

Biodiversity within agroforestry species is low, and could be of concern especially for the trees if Asian Gypsy moth or pathogen became established, as stock biodiversity is dependent on the individual farmer. Biodiversity within the habitat appears to be increasing, in some studies and in other studies to be decreasing. Vertebrate biodiversity under forestry appears to increase, while soil invertebrate biodiversity under agroforestry appears to decline. Pasture biodiversity appears to be increasing at some sites, and declining at others.

5.3 Social Sustainability.

When the studies were applied to the four principles of social sustainability, the following was found.

5.3.1 Respect, Care And Equality Within The Community.

5.3.1.1 Sharing of Benefits and Costs of Agroforestry.

Benefits.

In Spall and Meister's (1988) case study of a Wairarapa hill country farm, it was suggested that agroforestry development would bring the following benefits to the Wairarapa District:

.Agroforestry would lessen the dependence of the district on sheep and beef production by augmenting the already established timber industry.

.Agroforestry would expand production without the marked loss in agricultural production and rural depopulation implied by conventional forestry.

.Agroforestry would provide additional employment, both directly for workers in the timber industry and indirectly through multiplier effects.

Spall and Meister concluded that agroforestry could potentially improve the viability of much of the Wairarapa, especially if there was a concentration on high value timber products, which could lessen the problems of isolation and transportation (Spall and Meister, 1988).

Aldwell (Wilson, 1986) however, believed that it was unlikely that farm scale forestry would make an important contribution to rural development. He found that the great majority (92%) of growers had woodlots smaller than twenty hectares, and about 64% of woodlots were smaller than four hectares. Owners of small woodlots, up to 2-3 ha, tended to use their own labour to look after their trees, and where a contractor was employed, the contractors were mostly located in rural towns. It was therefore unlikely that the population in the farming hinterland would rise simply by increasing the number of small woodlots. Aldwell did suggest however that if woodlots of 100-150 ha were formed - a size that would make it profitable to employ a resident forest worker then rural development could occur (Wilson, 1986). It was found that where farmers could form co-operatives or joint ventures and grow larger stands, new employment opportunities would be created in both the townships and district centres, and in the farming hinterland.

"The trees will come regardless, because forestry is so much more profitable than meat and wool farming and, on unstable land, more environmentally desirable. We in farm forestry have the desire to see existing landowners planting the trees and gaining the benefits." (Flett, 1994)

With the current plantation forestry boom in New Zealand, conflict has risen again between large scale forestry companies and rural communities. Foresters have come to realise that future expansion of forestry in New Zealand lies in plantations on fertile sites presently occupied by pastoral agriculture. Most forestry development is occurring in rural areas that are presently seen as "underdeveloped": agriculture has not been highly successful, unemployment is relatively high, or the local economy is stagnant through lack of diversity. For local people, forestry is often hailed as a long looked for form of regional development that must benefit them in the long run. Contrary to this belief, studies into the impact of forestry in rural areas have found that large forestry companies used outside gangs of workers, and build large mechanised plants which import outside skilled workers. It was also found that the impacts of large scale forestry on the number of indirectly created jobs was also minimal, because in areas where forest industries were to set up, services were at that time under-utilised, so that the increase in population did not create more jobs, but simply used the present services better (Stephenson, 1981).

In comparison, the study found that small local industries (i.e. sawmills) based on local resources (agroforestry) and local talents would be likely to:

.create proportionally more jobs per dollar invested;

.be able to use local labour more effectively, as jobs were less likely to be highly skilled and more likely to be long term;

.be able to provide goods required locally, as well as directing some to wider markets, either within New Zealand or abroad;

.be able to use local services and servicing industries, thereby creating greater down-stream employment;

.be based in rural localities or townships where jobs are required, and where social disruptions are likely to be minimal; and

.be owned and operated locally and/or co-operatively (Stephenson, 1981).

As a result, another benefit of agroforestry would be raising the profitability of farming communities to such a level that massive encroachment of extensive forestry into communities would be less likely to occur.

Maclaren identified the following additional community benefits from trees: provided shelter, muffled noise, filtered the air of dust and other contaminants, provided provide better quality water, reduced some types of erosion, and could lessen the impact of flooding. Maclaren also found that plantation grown wood was a sustainable renewable resource that can be substituted for non-sustainably grown wood, fossil fuels, and other polluting materials (Maclaren, 1993).

Costs.

In Spall and Meister's (1988) case study of a Wairarapa hill country farm, it was suggested that the development of agroforestry would bring heavier demands on Wairarapa rural roads by logging trucks. Other studies into traffic generation supported this, and found that forestry generated more trips per unit area of land than any other landuse, apart from dairying. It was also found that logging traffic flows were concentrated during the years of harvesting, which compounds the roading problem. On rural roading, forestry logging demands were found to accelerate the requirement for maintenance and in some cases, required improvement or upgrading of rural roads (Clough, 1987, Spall and Meister, 1988).

In regard to agroforestry, it was suggested by Clough (1987) that agroforestry may increase the roading problem because large scale forestry often develops and maintains its own internal transport system, whereas smaller dispersed plantings of agroforestry could cause logging trucks to be channelled on to public road networks.

However on the issue of equity, it should be noted that logging companies pay user charges on all the roads which they use. One study concluded that logging trucks, through user charges, paid more than the equivalent damage they created. Community inequity exists under current transport legislation, because it allows the users' charges collected from the logging trucks, not to be specifically returned to the area of damage (Clough, 1987). Maclaren (1993) believed that agroforesters should be expected to compensate the wider community for road damage and other inconveniences, but not to a greater extent than agricultural or other non-forestry producers, i.e. dairy farmers.

Another potential cost to the community was visual impact. Landscape is of importance to a large section of the community, and some people consider that a hillside of pine is unsightly when compared with pasture, particularly if the block has straight edges or, affects the skyline (Maclaren, 1993). Much of this visual cost can be lessened by landscaping (Lucas, 1984, McKelvey, 1984, McFaddon, 1988).

The final potential cost to the communities is lost revenue. Studies have found that in areas where forestry had significantly replaced farming as a landuse, the regional community lost part of its economic base, through reduced farm income and agricultural processing, for the length of the rotation (Stephenson, 1981). When these findings were applied to agroforestry the income loss from agroforestry was likely to be less, and the economic benefit from agroforestry was more likely to be retained within the community. However stock reduction and reduced farm cashflow would affect the region's economy, especially if many of the farms were to undertake agroforestry.

Other nuisances created by agroforestry may be in, wilding eradication, and noise and dust generation at time of logging (Maclaren, 1993).

5.3.1.2. Equitable Distribution of Resources.

Between Different Generations.

Intergenerational equality in the distribution of resources has been practised by the farming community for a long time. There still is, even in times of economic hardship, a compelling desire to hand on the farm to a family member, preferably in an improved condition financially and environmentally (Jennings, 1992). Unfortunately intergenerational inequality still arises because farms are a significant family asset that is, proportionally, capital rich and chattel poor; this causes difficulties in distribution between more than one beneficiary. At the time of death, or retirement, the farm may be subdivided. However many farms are too small to support multiple families, and increasingly restrictions have been placed on farm fragmentation. Therefore most often only one beneficiary can remain to work the family farm, which leads to significant assets being tied up in a farm for the other beneficiaries, to which they have little access to (Keating and Little, 1994).

Agroforestry has been found to allow for a more equitable solution to rural intergenerational inequalities. When the farm is passed from one generation to another, the principal beneficiary of the farming unit can continue to farm, while other beneficiaries receive cutting rights to the timber. Cutting rights provide a sizeable asset and may maintain close links between non-resident beneficiaries and the land. Extended family members, or friends, may wish to become involved in agroforestry in order to develop stronger links with the property and have the opportunity to either participate in aspects of the agroforestry work in their spare time, or to enjoy the 'country life' (Maclaren, 1993).

Between Genders.

Another form of inequality on the farm is between genders. Keating and Little (1991,1994) found that farming daughters had limited access to the family farm and were not usually considered as potential successors. They also found that many would continue in farming through marriage, but their hopes of greater influence in their new farms were often thwarted. Females were often relative newcomers to farm and family, and they were least likely to be involved in discussions about the future of the business. They also found that generally, women of all ages were less involved in the farm work, management, decision-making, and ownership of the farm. Little (1982) found that although women were seeking a wider involvement in farm decisions, they faced entrenched family expectations based on role models of previous generations. Bearing in mind that agroforestry is primarily an agricultural society diversifying its production, it could be expected that agroforestry would not significantly change these two inequalities. Agroforestry, does however, provide the potential for women to increase their involvement on the farm. Agroforestry allowed greater labour flexibility than agriculture, ie pruning and logging could be put of for months/ years, it was found to be a landuse that blended it self to rural woman's lifestyles, while giving a sense of achievement and contribution to the farm (Hocking, pers com.).

Water.

The final issue is that of the equitable distribution of water resources under agroforestry. New Zealand has dry areas, e.g. Nelson, where there is a restricted water supply that is crucial for irrigation purposes, and industrial development. Even though the farmer may have entitlement to the first use of rain water that falls on the property, large scale afforestation could have significant repercussions to other users by reducing the water yield through increased interception (Maclaren, 1993).

5.3.1.3 Equal Access to Participate in Agroforestry.

Three barriers to participation in agroforestry were found.

.Finance could to be a barrier for farmers who wished to implement agroforestry. It was found that a farm may be too marginal to consider implementing an agroforestry development programme (Section 5.1.4.1).
.Location of the farm might be a barrier to participation. Ensor (1988) a high country farmer found that when he milled a small block of trees, at the end of the logging he received barely enough money to clean up the mess left by the logging process (Ensor, 1988). There are many places in New Zealand where remoteness and transportation problems make agroforestry a less viable option (Section 5.1.4.1).
.The third barrier to participation in agroforestry was knowledge. The Taranaki Regional Council (1992) found that most farmers did not possess the required skills for agroforestry work and management, and that undertaking agroforestry even at the smallest scale required the acquisition of many new and unique skills for the farmer (Section 5.1.4.1). (McKelvey, 1984). However it was found that knowledge could easily be acquired from governmental, educational and private organisations (Harper, 1974, Hocking, 22.8.94).

5.3.1.4. Adequate Participation.

New Zealand's resource use is controlled primarily by the Resource Management Act (RMA) 1991. Under the RMA, there are provisions for all community members to be represented, to participate, and to be consulted in the areas concerning resource use. However, the RMA only focuses on the impacts of proposed landuses on the environment. Social and economic factors are not often taken into account, exceptions being Section 6 (e), 7(a), 7(e), and (8) of the RMA (New Zealand Government, 1991). The inability of New Zealand planning law to take into account social issues may lead to social disharmony, as seen below. In the Wairoa District concern had been raised at the extensive purchase of hill country farms by forestry interests. It was felt that a change in landuse from farming to afforestation would adversely affect the local freezing works and the local community. There was been a call for the Wairoa District Council to stop or control "the green tide of pines that threatens to engulf our hill country". The Wairoa District Council found that they could not stop the change in landuse, and rejected an intervention role, seeing its role as looking for opportunities for the betterment of the community as a result of that change (Owen, 10.8.94).

Summary.

Costs and Benefits. From the studies, agroforestry appears to have the following benefits:
. agroforestry may provide rural diversification;
. agroforestry may expand productivity;
. agroforestry may provide additional employment;
. agroforestry may increase the rural economy; and
. agroforestry may muffle noise, provide shelter, and allow better water quality, etc.
From the studies agroforestry appears to have the following costs:
. agroforestry may place a roading burden on the community;
. agroforestry may have a visual impact;
. agroforestry may reduce the rural economy until time of harvest; and
. other nuisances may be attempts at wilding eradication, noise and dust generation at the time of logging.

It was found that sensitive locating and good management practices could eliminate most of the costs to the community, and agroforestry had the potential to improve the viability of many rural areas. From the studies it was found that agroforestry had the potential to provide a equitable solution to the distribution of resources between generations and between the sexes. Agroforestry was however found to potentially effect the equitable distribution of water resources. Three barriers where found to the participation in agroforestry by members of the community, these where lack of finance, distance from market, and lack of knowledge. Finally it was found that communities had strong provisions to be represented, participate, and be consulted in areas concerning resource use.

5.3.2 Quality Of Life.

No studies into the quality of life resulting from agroforestry were found. It is assumed that the provision of basic needs, i.e. food, shelter, and healthcare, would not differ greatly from that of agriculture. Economic studies found a reduction in farm cashflow for the first rotation, which would lead to a reduction in income for a period of time (Knowles *et al.*, n.d.). This loss of income could affect the quality of life for farmers, if the income reduction was significant. However quality of life would only be affected during the first rotation because subsequent years of harvesting would produce a higher income, therefore a better quality of life than received from agriculture alone (Section 5.1.4.2).

Agroforestry appears to provide a means for humans to realise their potential, build self confidence, and lead lives of dignity and fulfilment, especially if a diversity of trees is used.

"The place looks so much better with trees" (Stephens, 1994)

"The semi retired couple have worked hard to beautify their farm..." (Bland, 1994)

Finally agroforestry investment is often initiated by farmers to provide social care, in the form of a retirement investment (Hegan, 1993).

Summary.

Agroforestry appears to provide an adequate quality of life. However, if the farmer has a high debt servicing level, then an undertaking such as agroforestry may decrease the quality of life.

5.3.3. Cultural Sustainability.

Cultural sustainability means that agroforestry should take into account cultural differences which exist within the community and nationally.

Farming Community.

The level of agroforestry planting in New Zealand is low, considering the percentage of suitable land. Knowles *et al.*, (n.d.) found that lack of funds was not the reason for the reluctance of the New Zealand farmer to implement agroforestry. Spall and Meister (1988) thought that such reluctance was because of the long production period of agroforestry, that tended to reduce the perceived economic advantage and made trialability and observability more difficult. Hawke and Maclaren (1990) thought that the difficulty lay with agricultural organisations who needed to accept that agroforestry was not an 'alternative landuse' but an opportunity for most farmers. In Morey's 1985-86 study into farm practices, it was found that only 7% of the respondents had established agroforestry, and 76% of farmers did not intend to establish agroforestry in the future. The study found that farmers had yet to accept agroforestry as a profitable landuse, and that profit was not a significant motive for farmers to plant trees (Morey, 1988). The reasons given for not planting trees included (in order): displacement of agriculture, inadequate finance, a low rate of return, a distant return, and sufficiency of planted land. The proportions of farmers planting forest trees varied both regionally and by farm type: agroforestry was most popular on "hard hill country", followed by "hill country", and "high country", (Morey, 1988).

Morey (1988) also found that there was an association between past and intending planters; those who had established agroforestry previously were more likely to plant in the future than non-agroforesters. It was found that among those intended to plant trees within 2 years, 63 % had been planters previously, compared with 8% overall (Morey, 1988). Knowles (1991) concluded that those investing in profitable agroforestry in the future would encompass a much wider group than the current landowners, and that joint ventures in agroforestry between urban financiers and investors would increase.

For whatever reason, it appears that there is a reluctance by the New Zealand farmer to implement agroforestry, indicating that perhaps for some farmers agroforestry is not culturally compatible for them.

Tangata Whenua.

No information was found that indicated agroforestry was a culturally significant issue for the Tangata Whenua. Parore (1987) claimed that Maori aspirations were to acquire skills of the modern world, while retaining their identity as Maori people. Maori aspirations for their land included retaining its ownership and developing it in order to provide a basis for Maori social and cultural achievement. Parore (1987) found that there was already a large area of Maori land under trees, and that significant areas of unutilised land could be further developed. He saw forestry as one of the areas of potential economic development that could enhance the future of Maoridom. Malloy (1981), also saw the potential for investment in Maori land based forestry.

However Mete Kingi (1994) identified the following financial and cultural barriers to the Ngati Apa, becoming agroforesters:

.Ngati Apa had very little land, and their residual tribal estate were composed of small blocks that were leased to local farmers.

.several attempts had been made to organise plantings but the problem was one of getting sufficient owners to meetings, and then endeavouring to get a consensus on such issues as collecting annual rent, and forgoing annual rent, for long term gain.

.many Maori were unable to comprehend long term strategies because their predominant needs were immediate and short term. Day to day cashflow was a fact of life for them, so landuse was less important than the more practical issue of "how much rent will I get".

.any progressive thinking came largely from the younger educated Maori, who must influence their parents and elders who were the owners of the land. They were often be met by the refrain "after I'm gone", meaning that they would have to wait until they become owners (Mete Kingi, 1994).

In Mete Kingi's view, agroforestry had the potential to reflect Maori development needs. In Maori cultural history there is a traditional reverence for the forest, because of the many benefits it brought to the people. Today, wellbeing and employment opportunities are the major needs of Maori. Forests are capable of healing and providing opportunities for sustainable and gainful employment. Mete Kingi believed that what was needed was a model for Maori landowners to follow (Mete Kingi, 1994).

Environmental Groups

Except for Greenpeace, most environmental organisations support exotic forestry. The New Zealand Forest Accord was signed by environmental groups, which endorse the marketing of pine and other plantation timber as a clean, renewable resource. In return for this endorsement the forestry industry has ended native forest clearance which allows the retention of existing biodiversity in native forests (Hegan, 1993). Greenpeace did not support plantation forestry however, claiming concentration of monoculture forestry was a breach of the International Biological Diversity Convention, signed at the Rio Earth Summit in 1992 (Drent, 1994). The final area of concern for some environmental groups was the issue of priorities in the use of farm forestry and forestry to reverse land degradation in outstanding landscape areas like the New Zealand High Country (Ministry of Forestry, 1993).

Summary.

There appears to be a reluctance for New Zealand farmers to undertake agroforestry, which may be through some cultural incompatibility. The Tangata Whenua appear to have no cultural problems with agroforestry, and environmental groups also seem to accept agroforestry.

5.3.4. Political Sustainability.

5.3.4.1 Central Government.

"However will this type (agroforestry) *of long term investment ever get a fair chance while the average New Zealand attitude threatens, or desires, to tax the hell out of any person who is prepared to create long term growing or increasing assets, such as this would be."* (Ensor, 1988)

There have been at least seven major forestry taxation changes in the last 25 years. Agroforestry projects typically span 30 years, with most of the expenditure incurred near the beginning, and most of the revenue earned near the end. The planning of projects spanning such a long time requires assumptions about tax legislation and therefore it is preferable that the legislation is stable (Ministry of Forestry, 1993).

During the period of 1962 to 1987 the government offered positive fiscal and taxation policies that rewarded financial expenditure on the basis of employment and regional development, and provided financial incentives to encourage landuse diversification. These policies and their effects are summarised as follows (*Farm Forestry*, 1962, McKenzie, 1987).

1962 Forestry Encouragement Loans. The government decided, on the advice of the New Zealand Forest Service, that New Zealand should aim at an extra 1,000,000 acres of trees by the year 2000. Locality was the primary deciding factor on applications, with "timber hungry" areas given priority. A 3%-5% interest rate was placed on the loan, and farmers were given 20 years to repay (*Farm Forestry*, 1962). Within a very short time of the scheme being implemented, it was realised that interest rates on the loan were immediately repayable, and many suitable areas were withdrawn from the scheme by farmers when it was found that the banks would not give them loans to cover the interest repayments (Barr, 1963).

1965 Amended Farm Forestry Loan Scheme. The previous scheme was amended so that the agroforester could borrow the full amount of the loan and not repay for twenty years. The eligibility of a site was decided by predicted economic returns from the wood (Smith, 1965). By 1968, five years after the original loan scheme had been put in place, 10,000 acres had been established (Poole, 1968).

1970 Forestry Encouragement Grants. This scheme was in addition to the other scheme, and allowed payments of 50% of forest costs to be deducted from small private forest growers income, under a state approval system (*New Zealand Tree Grower*, 1970). This scheme encouraged a minor boom, with new woodlots being planted during the buoyant economic period of the early 1970s.

"At that time, you could pay yourself to plant your own trees, and end up with cash in your pocket, even if you burnt down native forest to clear the land." (Hegan, 1993)

As the economy turned sour and the rate of inflation soared in the late 1970s, the anomalies and weaknesses began to show up. Despite repeated efforts by interested groups, the Government steadily stonewalled on any improvements, other than somewhat tardy increases in the grant's upper limit to compensate for inflation costs (Frost, 1983).

In 1980, farm forestry became ineligible for Forestry Encouragement Grants, following the 1980 budget. Agroforesters where caught unaware by the sudden change, and feelings ran high at the time. Farm foresters were advised to lobby their local member of parliament. The president of the New Zealand Farm Forestry Association wrote at the time.

"For the past decade, the National party pre-election manifesto has invariably supported the concept of a vigorous private grower sector in the national wood industry. This must surely bring into question Government credibility. On the one hand promising support and even expansion, and on the other hand reducing farm forestry support by letting the value of the incentives dwindle rapidly away, while giving increased incentives for forestry companies, that in addition, have no quality controls, no regional controls, no upper limit, no economic criteria all of which apply to the forest farmer....Under the present situation, the larger companies can, with tax advantages, afford to pay more for existing farmland. We will thus see county planners reacting, and district schemes will worsen the already unsatisfactory position of forestry as a landuse, ownership will be polarised towards big companies" (Treeby, 1980:1).

Later in 1980, the maximum amount for forestry encouragement loans and for loans for small private forestry was raised, allowing most farm foresters access to money again. The raise was promoted by the expectation that landowners who were noted to be deterred from pruning and thinning because of a lack of finance would undertake these crucial operations. It also was noted that the decreasing value of the grant had caused a steady drop in the rate of new plantings by farmers and other private landowners. The increase in grant was also hoped to change this (*New Zealand Tree Grower*, 1980, McKenzie, 1981, McKenzie, 1987).

1983 Forestry Encouragement Grants. The scheme was expanded to include all private growers at 45 % payment level, and replace the previous tax concessions and funding through the loans and grant schemes (McKenzie, 1983, McKenzie, 1987).

In 1984 the Forestry Encouragement Grant was abolished in the 1984 Budget, and replaced with a tax deductibility system similar to that for agriculture. The abolition of the system again caused some growers difficulties (Treeby, 1984). Immediately preceding the change, a "Transitional Hardship for Forestry Encouragement Grant" was lobbied for by the New Zealand Farm Forestry Association and other organisations. The Government's response was to provide Rural Bank loans for growers facing financial hardship as a result of the Forestry Encouragement Grant abolition (*New Zealand Tree Grower*, 1985).

In the late 1980s, the Labour government altered forestry tax laws in such a way that expenses incurred in establishing and tending a forest could not be claimed until the forest was harvested- some 25 to 30 years later. Forestry planting rates again collapsed (Hegan, 1993).

However, in the early 1990s, the National Government amended the law, and planting rates skyrocketed (Hegan, 1993).

Numerous changes have been made to forestry taxation regulations in the last 15 years, and it is predicted that this trend will continue (Maclaren, 1993). There has been considerable debate over the effects of taxation changes on farm forestry profitability. In Spall and Meister's case study (1988) of a Wairarapa hill country farm, it was found that changes in tax deductibility limits had relatively minor effects on economic returns from agroforestry which would indicate that agroforestry is a relatively robust landuse. However, despite this, the above findings have found that there was a dramatic decline in planting rates during periods of no tax deductibility, i.e. in the late 1980s when the planting rates collapsed.

Butcher (1988) believed that in the past, several Government policies have effectively operated against agroforestry. The sale of State wood at artificially low prices discouraged tree planting as an investment, particularly for the small private grower. Forestry encouragement loans and grant schemes were administered to require minimum tree stockings, and management regimes that were inappropriate to agroforestry.

5.3.4.2 Local Government.

From the mid 1970s to the early 1980s, almost without exception, each time a county district scheme was proposed, there arose a clash between farming and forestry interests. Gradually county councils endeavoured to control forestry (and other rural landuses) by means of special zonings and development control ordinances in their district schemes (Bush-King, 1987).

Justification for control was grouped into four main reasons:
.problems perceived with an increased demand for public services, especially roading, with the burden of cost falling on the ratepayer;
.the threat posed by forestry in competing for land with other uses like pastoral farming and recreation, and the consequential disruption to the delivery of rural services;
.a concern that forestry would adversely affect visual and other qualities in rural areas, or unreasonably disrupt established (traditional) agricultural practices; and
.resistance towards forestry because of the differences in land ownership, scale of enterprise, and access to resources and information (Bush-King, 1987).

The diversity of approaches used by councils in providing for forestry created two problems for the agroforester:
. different aspects of agroforestry activities were artificially separated and controlled individually, when often different agroforestry practices co-existed in space and in time. Some schemes also attempted to differentiate between opportunities, e.g. planting of trees may have been permitted, but the harvesting was subject to control.
. many schemes developed arbitrary planning conditions which failed to match perceived impacts with the scale of the forestry, so the minor farmer-initiated developments were treated the same as large scale forestry.

Bush-King suggested that imposing unnecessary restrictions on some forest operations, particularly though the use of controlled and discretionary resource consents, had the potential to seriously limit future investment in the establishment, management and harvesting of forests, and in the downstream processing of forest products; and could threaten the achievement of Government's economic goals, and opportunities to generate employment. It was also found that historically, imposing unnecessary controls on forestry development under the Town and Country Planning Act 1977, resulted in a major transfer of new planting from those regions to regions that had more liberal controls. The results has been the rapid expansion of forestry in Northland, the Central North Island, Hawkes Bay, Nelson, inland Marlborough, Otago, and Southland and limited development in areas such as Wairoa, the King Country and Clutha (Bush-King, 1987).

Since 1987, there has been a major legislative change regarding resource use. Many of the problems concerning local government have been resolved through the RMA, although the uncertainty regarding harvesting rights still remains. Under the RMA, there is no guarantee that the crop can be harvested in 30 years time. The Ministry for the Environment suggests that a measure of uncertainty would always exist, because it was not always possible to determine today what conditions will be appropriate in 30 years time (Wells, 1994).

Summary.

Agroforestry appears too be vulnerable to political change by people relying heavily on government support. If agroforestry is undertaken without governmental incentives, then agroforestry appears to be relatively robust to political change. Legislative changes effecting resource use at the local government level have reduced much of the conflict that previously existed, but there is still a level of uncertainty regarding the granting of logging consents, which makes agroforestry vulnerable to political change.

6
Case Study: Rangitoto Farm, Bulls.

The previous chapter took the findings from various studies, and applied them to the methods for measuring the sustainability of agroforestry which were generated in Chapter 4. On reading Chapter 5, it becomes apparent that although there is a vast array of information regarding the sustainability of agroforestry, it is piecemeal. The purpose of this chapter is to both provide an integrated approach to the sustainability of agroforestry, and to fill in any gaps left by the other studies. The first Section of this chapter, explains the methodology used. The second Section, introduces Bulls and Rangitoto Farm, which was used in the case study. The final Section, presents the results from the case study.

6.1 Methodology.

6.1.1 Economic Sustainability Methodology.

The first three principles: sustainable yield harvesting, sustainable waste disposal, and depletion of non-renewable resources, were investigated through a series of questions put to the landowner regarding practices and intentions. The final principle of economic return was examined through the following predictive computer models.

The Agroforestry Estate Model (A.E.M.), version 2.3, an excel based program, was used to show the effect of a sustained tree planting and felling programme on the farm's physical and financial flows. The model required data on the farm's planting and felling programme, log yield values, understorey carrying capacity, labour data, and other farm variables. These data were provided by Rangitoto Farm where possible, with additional data coming from PC-STANDPAC, and other sources (Knowles and Middlemiss, 1992, Taranaki Regional Council, 1992) (Appendix A).

PC-STANDPAC is a collection of integrated computer models that was used to simulate the growth of a stand of trees. This model was used to predict the height and diameter growth of a hypothetical stand, which was then used to determine the quantity and quality of logs, and log yield data. In addition, PC-STANDPAC was used to predict the changes in understorey livestock carrying capacity of the farm, as the canopy closed over (Knowles, n.d.) (Appendix B).

These two components were used in conjunction to simulate agroforestry economic returns from Rangitoto Farm.

6.1.2. Environmental Sustainability Methodology.

Four sand dunes were chosen from Rangitoto Farm to assess the environmental sustainability of agroforestry. The first three dunes were under agroforestry, for varying time lengths, and the fourth was under pasture. These four dunes were chosen because they were physically similar. The three agroforestry sites were chosen because they all carried *Pinus radiata* agroforestry, and the sites had been under agroforestry for a range of years, 104, 30 and 23 years. The agricultural dune was chosen for its top dressing record. Samples were taken from three transect lines that were zigzagged along the sand dune. The first ran from bottom to top on the eastern slope of the dune. The second, from right to left, along the top of the dune. Finally, the third was from top to bottom along the western slope of the dune. Transect lines were run across the dunes in such a manner as to avoid tree trunks and other obstacles. Inter-sampling point distance was determined by a combination of the following factors: number of samples required per transect line (i.e. 20 + /dune), the length of the transect (m), and the presence of obstacles at the sampling point. Consequently the inter-sampling point distance ranged between two metres on the small dunes to five metres on the large dunes. Sampling point initiation was usually several metres from the base of the dune, to avoid anomalous results caused by the mixing of dune soils with the sand plains soils. All the soil samples were stored individually in labelled bags, except the soil fertility samples that were stored in one bag per site.

6.1.2.1 Life Support Systems Methodology.

Energy, air, and water are global, and transient, life support systems that make them hard to quantify. Therefore this study focuses on the impacts of agroforestry on the more enduring and quantifiable life support systems of nutrients and soil.

Nutrient and Soil Life Support System.

.Fertility.

Core samples were taken from the top 10 cm of each of the four dunes. The soil fertility testing was carried out by the Fertiliser and Lime Research Centre, Massey University, for pH, Ca, Olsen P, K, SO_4, Mg, Na, and CEC (exchangeable cations). Additional data were provided by previous soil fertility results. The soil fertility results for each dune were then compared.

.Soil Erosion.

The four dunes were visually studied for the presence and extent of erosion, which was then used to evaluate the impact of agroforestry on soil erosion.

.Organic Matter.

Soil cores were collected from each of the four dunes, and dried in an oven overnight. Hydrogen peroxide was then added to a weighed soil sample (W1), and heated slowly in a beaker. When the oxidation had ceased, the mixture was dried and reweighed (W2). The difference between the two weights (W1-W2) represented carbon loss and was taken as an indicator of organic content. The organic matter content from each of the dunes was then compared.

The formula:

$$\text{Organic Content (\%)} = \frac{\text{(W1) Weight of Soil Before Oxidation (g).}}{\text{(W2) Weight of Soil After Oxidation (g).}}$$

(Bray, 1989:17)

The surface of the agroforestry dunes were covered in a layer of pine needles that was mostly undecomposed. This layer was removed to expose the soil before the soil organic samples were taken, and therefore this organic matter was not taken into account.

.Moisture Content.

Soil cores was collected from each of the four dunes, on the same day. The wet soil was weighed (W1) in the sample bag and then placed in the oven for four days. The soil and bag were then reweighed (W2) when the soil was dry. The difference between the two weights was calculated to give the percentage of moisture lost. The moisture content of each dune was then compared.

The formula:

$$\text{\% Moisture} = \frac{\text{(W1) Wet Soil (g) - (W2) Dry Soil (g)}}{\text{(W2) Mass of Oven Dry Soil. (g)}}$$

.Bulk Density.

Soil cores from each of the dunes, of a known volume (V1), were dried at 105 degrees centigrade for twenty-four hours. The dry cores were then immediately weighed (W1), to give the dry weight. The dry bulk density was then calculated from the dry weight, divided by the known volume. The bulk densities of each dune were then compared.

The formula:

$$\text{Dry Bulk Density(g/ml)} = \frac{\text{(W1) Dry Weight of Soil (g)}}{\text{(V1) Volume of Cylinder (ml)}}$$

(Ministry of Agriculture, Fisheries and Food, 1982).

.Structural Development.

Soil horizons were collected from each of the four dunes using a soil core sampler. The depth of the A and B horizons within a twenty five cm core was then measured and compared for each dune. The removed surface litter in the agroforestry samples was not included.

6.1.2.2 Biodiversity Methodology.

Two primary indicators were used to determine the effect of agroforestry on biodiversity at Rangitoto Farm: these were flora and soil macro-fauna. Note was also taken of the presence or absence of mosses, lichens, and mushrooms.

Botanical Composition.

A 30 cm quadrat was used on each of the four dunes. Within each square of the quadrat, the number of individual plant species was recorded. The number of each species within the quadrats was then totalled, and this total was taken to be representative of the whole dune. The botanical composition of each dune was then compared.

Soil Fauna.

Seven turfs were dug from a randomly chosen agroforestry dune, and from the pastoral dune. The turfs were placed on a tray, and crumbled until all of the macrofauna was collected. The macrofauna was then separated into species and counted. Once the turf had been sorted, the soil and macrofauna were returned to the place of removal. This process was repeated on all fourteen sample sites. The soil fauna from both dunes was then compared (Anderson and Ingram, 1993:44).

6.1.3 Social Sustainability Methodology.

Data were collected primarily by a question-answer session with the landowner. Additional data were taken from other members of the community, through articles, letters, and census publications.

6.2. Rangitoto Farm, Bulls.

6.2.1 Introduction.

The rural township of Bulls is located on the northwestern bank of the Rangitikei River, at the junction of highways one and three, in the lower North Island (Wises, 1987). Bulls sits among one of New Zealands largest coastal sand areas, which by its nature places severe limitations on farming. The most significant of these limitations are summer drought and the potential for wind erosion. Traditional uses of the sand county are pastoral, but large areas of erosion prone soils have been established in exotic tree plantations from an early age. Inland from the coast there is a mix of productive uses - forestry on the dune soils, pastoral farming on the drier sand plains and market gardening or other forms of horticulture on the better mineral and organic soils of the sand plains (Molloy, 1988).

In addition to being a service centre for the surrounding area, Bulls acts a dormitory town for the nearby RNZAF station at Ohakea, and for the nearby cities of Palmerston North and Wanganui, both which are less than 40 km away. Flock House, a farm training centre run by the Ministry of Agriculture and Fisheries, and situated 15 Km southwest of Bulls, is also served by this town. Despite these additional functions Bulls, like most rural communities, is declining, e.g. the population declined 10% between 1981 and 1991 (Rangitikei Information Centre, n.d., Department of Statistics 1982, Department of Statistics, 1987, Wises, 1987, Department of Statistics, 1992, Unknown, n.d.) (Appendix E: Figure E1).

6.2.2 Rangitoto Farm.

Rangitoto Farm is located 3 km from Bulls, on Parewanui Road. The farm consists of 247 hectares, of which 160 hectares were the original home block; an additional 87 hectares was purchased in 1989. The farm was purchased in 1955 by the current landowner's father, with forestry potential in mind. The land is of very low productivity, and the soils are excessively free draining and leach readily especially in nitrogen and potassium. The prevailing saline westerlies, and frosting on the flats are the main limitations for agricultural production. Combined with a sometimes erratic rainfall, the farmer describes Rangitoto Farm as a rather "infertile and drought-prone farm". The landowner believes that as a pastoral farming unit the farm would be sub-economic in today's economic climate. Typical stocking of Rangitoto Farm is 1,000 ewes, 300 hoggets, 110 breeding cows, and some goats (Hocking, n.d.).

Rangitoto Farm has a long history of *Pinus radiata* forestry, with the first trees planted in 1890 in an early attempt at erosion control. Between 1955 and 1978, significant numbers of *P. radiata,* and others species were planted in woodlots and shelterbelts. Between 1979 and 1989 the present farmer undertook experimentation into alternative species, on a variety of dunes. This included a mix of eucalypts, cypresses, and acacias, along with black walnut, catalpas, and chestnuts. After 1989, with the purchase of an additional 87 hectares of land, the farmer has returned to planting larger areas solely in *P. radiata.* Within the next few years the farmer intends to have planted all the sand dunes, approximately 100 hectares or 40% of the farm in agroforestry (Hocking, n.d.).

6.2.3. The Four Dunes.

Brandon Hall Dune.

The Brandon Hall dune is a high dune located south of Brandon Hall Road, Bulls. (Figure 23). This dune has been under clean pasture for the last 10 to 15 years, and has been regularly fertilised (Figure 21).

The sunny western slope of Brandon Hall dune was mostly covered with grass, gorse and weed species. The dunetop however, appeared to be wetter, soils deeper, and the grass denser, than either of the sides. Erosion was evident in isolated areas on the top where blowouts had occurred. The darker eastern slope of Brandon Hall dune was also predominantly covered with grass and gorse. There was little evidence of erosion on this slope, which may have been influenced by the greater presence of gorse. Visually the dune was weedy, eroding and appeared not to be highly productive as pastoral land.

Rangitikei Dune.

This low dune is located near Parewanui Road, on Rangitoto Farm (Figure 23). This agroforestry block was planted in *P. radiata* in 1971, and the trees are at 100 stems/ha and 23 years old. An internal farm road cuts across the lower western slope of the dune giving access to the south of the farm from the main road (Figure 22). Large tree stumps were found near the south end of the dune, indicating that trees had been planted on this dune, at some time in the past. The western slope was predominantly covered with grass and rushes (Juncus spp.). The dune top and darker eastern slope were covered with grass, blackberry, and gorse. Lichen, moss and several different species of mushrooms (i.e. *Amarita australis)* where found independent of, and in association with, decaying wood.

No.1 Dune.

This low dune is located west of the Rangitoto Farm stock yards, and south of the farmhouse (Figure 23). This block was first planted out in 1890, and first felled in 1963. The block was subsequently replanted, and was felled again a few years ago. This block is currently under its third rotation of *Pinus radiata* over a period of approximately 104 years. The dune was replanted in two stages, the northern end of the dune 2 years earlier than the southern end of the dune (Figure 24).

Large slash and stumps were still evident from past pruning and logging operations, making access to the dune difficult. The dune had been shut off to stock for a number of years, enabling *P. radiata* and other species to regenerate. Regeneration of the exotic species included, Gorse Blackberry, Broom, eucalypts species and *Pinus radiata.* Regeneration of native species included *Pteridium esculentum* (Bracken), *Juncus spp.* (Rushes) and *Solanum laciniatum* (Poroporo), and there were several other species that could not be identified. Mushrooms, lichens, and mosses were generally again associated with decaying wood.

Rangitoto Dune.

This high dune is located towards the rear of the Rangitoto Farm (Figure 23). The southern end of this dune was under agroforestry and the northern end under pasture. The block was originally planted out at 2000+ stems/ha in the 1960s, as an attempt to stabilise the shifting sand that the dune was composed of, but since then the trees have been thinned to 200 stems/ha. This dune has been under *Pinus radiata* for approximately 30 years, and felling began in July 1994 (Figure 25).

A trig station was located at the southern high point of the dune, and a service road to it was installed. The western slope was predominantly covered with pine needles, with few grass and weed species. The dunetop was comparatively narrow, and in parts was dissected by the recent logging. Finally the eastern slope of Rangitoto dune was predominantly covered with grass. Many different species of mushrooms where found on this dune, independent and associated with decomposing wood.

Figure 21: Brandon Hall Dune.

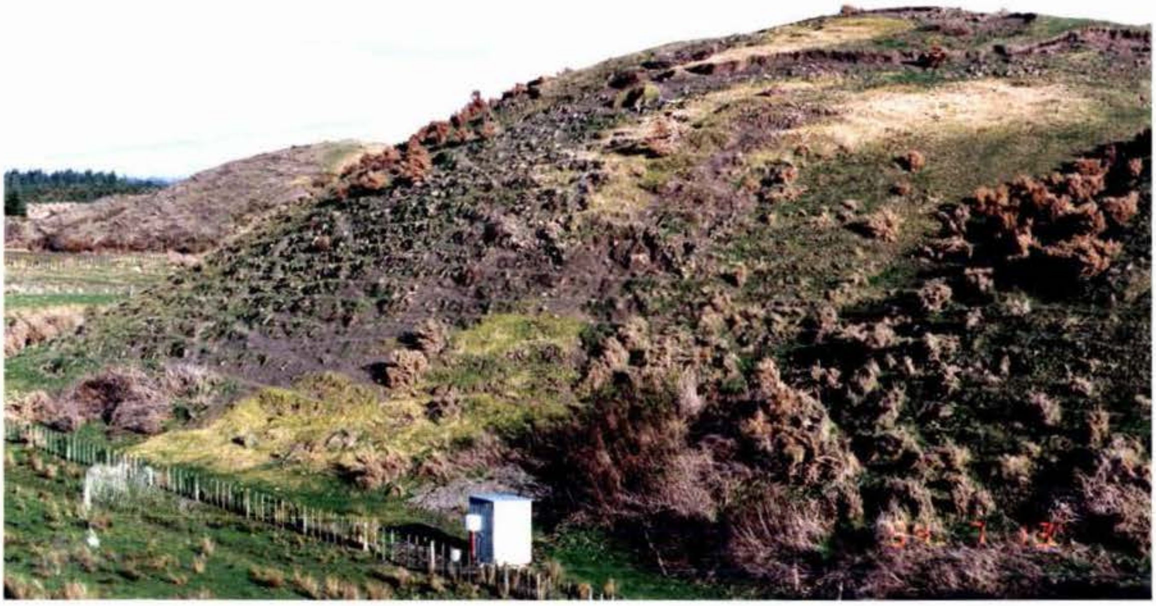


Figure 22: Rangitikei Dune.

Figure 23:

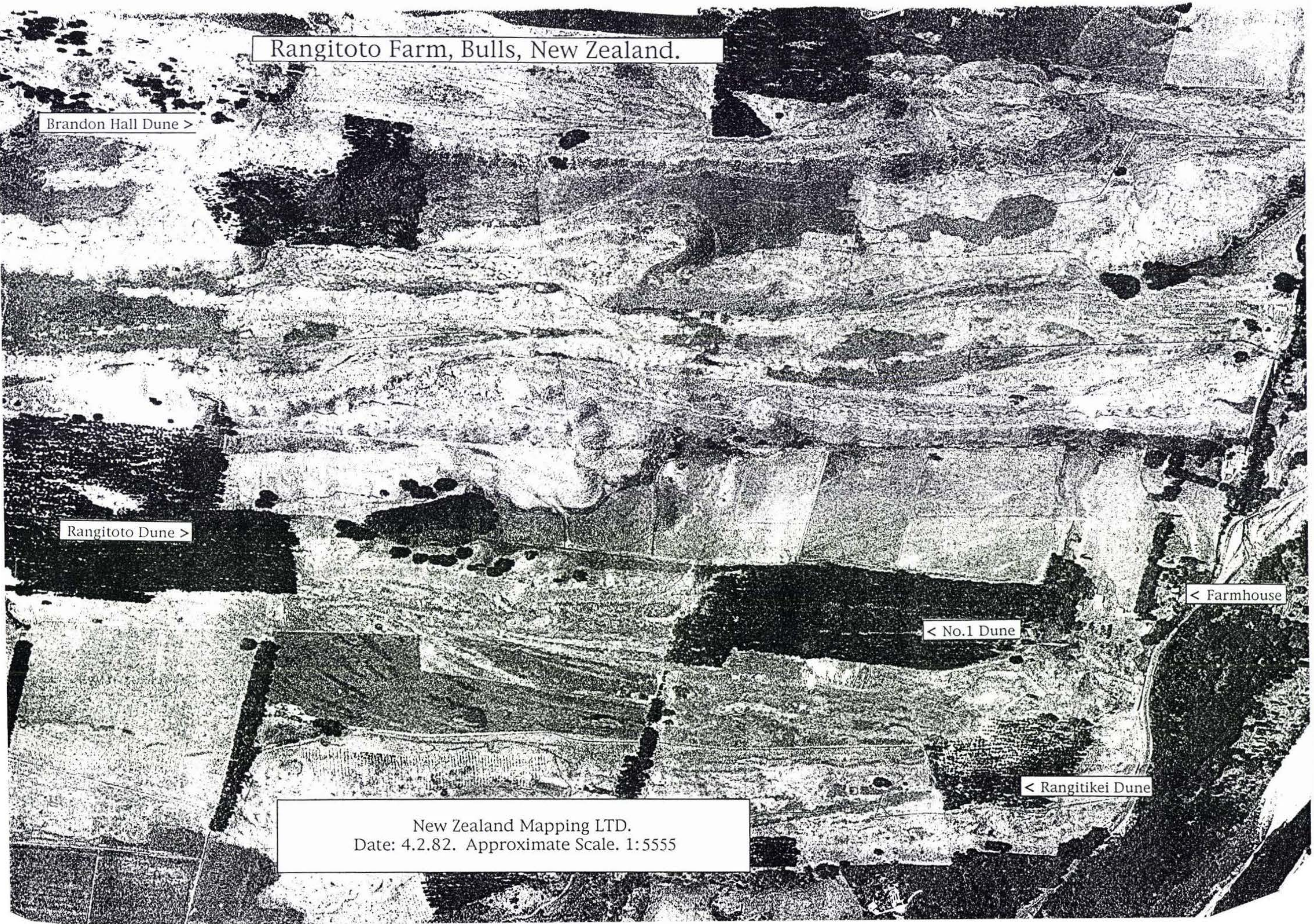

Rangitoto Farm, Bulls, New Zealand.
Brandon Hall Dune >
Rangitoto Dune >
< Farmhouse
< No.1 Dune
< Rangitikei Dune
New Zealand Mapping LTD.
Date: 4.2.82. Approximate Scale. 1:5555

Figure 24: No.1 Dune.

Figure 25 Rangitoto Dune.

6.3 Case Study Results.

6.3.1 Economic Sustainability.

6.3.1.1 Sustainable Waste Disposal.

Nutrient Waste.

The landowner topdresses Rangitoto Farm annually with 250 kg/ha of potassic super, excluding the agroforestry blocks. He has occasionally put 150 kg/ha of NPK on the agroforestry blocks, and twice on the plantations, to overcome N limitations (Hocking, pers com, 1994).

Discussion.

The sand flat and sand dune system of the sand country are unique in that there is a very high water table under the flats. The implication of this are that fertiliser use, the leachability of the soil, the high water table, and the proximity of the farm to the Rangitikei river, would leave Rangitoto Farm vulnerable to nutrient wasting. If the irregular fertilisation of agroforestry is ignored, then the agricultural system used 7500 kg/ha more fertiliser than agroforestry over a 30 year rotation. In addition the landowner believes that the deeper root system of agroforestry would be more effective in using nutrients before they were leached away. Overall, it appears that agroforestry will not produce more waste than can be assimilated into the environment (Hocking, pers com., 1994).

Pesticide, Herbicide and Fungicide Waste.

.Agriculture.

Forty hectares of thistles were sprayed in 1994 (typically twenty to thirty hectares would be sprayed annually), in addition five hectares using Roundup, and seven hectares using Simazine and Paraquat were sprayed also for weed control. For pasture regeneration, the landowner used MCPB on two to five hectares, and used Gallant, direct drilled with legumes, on another five hectares. Roundup was used on a further twenty-five hectares, which was then direct drilled with green tip maize. Later that year, Roundup was sprayed on a further two to five hectares of crops. The landowner has sprayed Rangitoto Farm for both grassgrub and porina in the past. In the future he intends to move away from the current generalist pesticides to specific biological controls. The landowner uses normal long life drenches, and would on average drench his ewes once per year, and his calves up to four times per year. His stock is either dipped outside the farm, or a commercial pour-on mixture is used (Hocking, pers com, 1994).

.Agroforestry.

For release spraying, the landowner spot sprayed with Simazine, Gallant, and Gardoprim, or with a combination of these, depending on the weed species present. According to manufacture's instructions, 240-360 ml/ha of Gallant, 800 ml- 1.2l/ha of Gardoprim, and 6l/ha of Simazine, would generally be applied pre-planting. If required, Grazon was hand sprayed to clear gorse. No other chemicals were applied during the trees' rotation. The landowner had milled timber at Rangitoto Farm on a number of occasions, especially macrocarpa; this wood was subsequently used around the farm as yarding and fenceposts, and it is assumed that this wood was treated on-site. In more recent years timber has been sent away to be milled and treated, therefore any resultant pollution would occur off-site (Hocking, pers com, 1994).

.Discussion.

It was found that significantly more pesticides and herbicides were used on the agricultural component of the farm, than in the agroforestry component. The use of treated timber on the farm was of a level similar to that found on other agricultural landuses, therefore pollution created directly by treated timber would be of a similar scale to that found on most New Zealand farms. Thus if Rangitoto Farm was entirely an agricultural landuse, then the potential for chemical waste would be higher than the current landuse is producing. However there are three qualifiers to this statement. The first is that high use of pesticides and herbicide was economically unlikely on the sand dunes, even if the dunes were under pasture. Secondly, under agroforestry, internal parasites in stock have been found to be higher, as a result of poorer pasture quality (Percival *et al.*, 1984b:30), therefore there could conceivably be an increase in pesticide use. Finally many of the herbicides and pesticides used by agroforestry are long term, i.e. Gardoprim (Ciba, 1994) and Atrizine, and thought to be relatively toxic. It may be concluded that pesticides, herbicide, and fungicide waste from agroforestry were likely to be low, and therefore were most likely to be assimilated into the environment, thereby causing no waste accumulation.

Biological Contamination.

.Slash Waste.

At Rangitoto Farm, slash was left where it fell. The landowner found that slash quickly rots away, causing no waste accumulation. Unmerchantable timber from clearfelling is also left on the dune, and subsequently replanted through. The landowner did find however that slash became a problem when left close to exposed fence lines, where it tended to blow around. It may therefore be concluded that the production of slash waste was adequately assimilated into the environment, and caused no waste accumulation (Hocking, pers com., 1994).

.Wildings.

The only wildings noted on Rangitoto Farm were found on No.1 dune, where the regeneration of many species was occurring. The wildings on No.1 dune were notably smaller and thus easily identifiable for thinning. It was concluded that wildings as a waste product of agroforestry were not a significant problem.

6.3.1.2 Depletion Of Non-Renewable Resources.

Substitution.

The landowner had substituted the following non-renewable resources: fossil fuel use had been substituted by draft horses, for production pruning; and a bicycle was used as an alternative form of transport around the farm. In addition, the landowner was growing several alternative species of naturally durable timber, with the intent of replacing tanalized softwoods that required expensive, non-renewable, imported, chemicals (Hocking, pers com, 1994).

Recycling.

Little evidence of recycling was found on Rangitoto Farm in association with agroforestry (Hocking, pers com, 1994).

Efficiency.

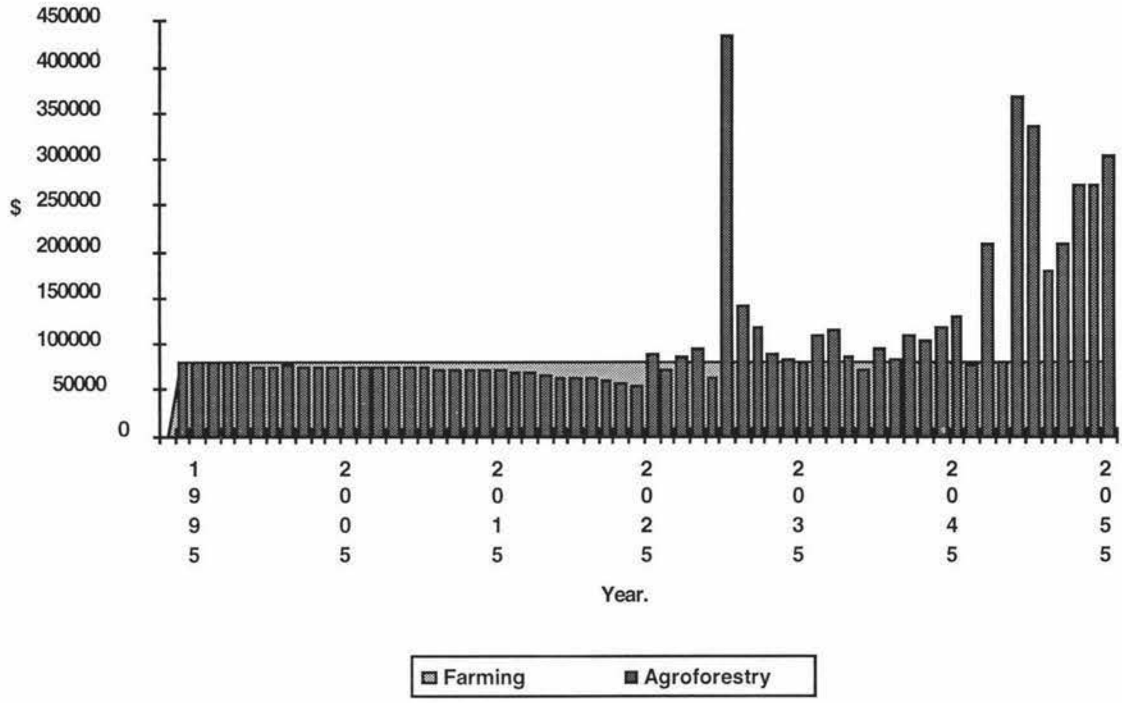
The two main non-renewable resources in agroforestry, fuel and fertiliser, were both found to be used reasonably efficiently. The landowner used little fuel on the farm, a 12 gallon drum of diesel lasting between one and six months. In comparison a cropping enterprise was found to use up to 3 times that amount, in one day. The landowner did however use significant amounts of fuel indirectly, through the use of agricultural contractors. This indirect fuel use was primarily related to maintenance of the agricultural component of the farm. The use of non-renewable fertiliser was also primarily related to the maintenance of the agricultural component of the farm. Overall, it may be concluded that Rangitoto Farm under agroforestry uses minimal non-renewable resources (Hocking, pers com., 1994).

6.3.1.3 Economic Return.

Cashflow.

During the thirty years of agroforestry establishment a steady decline in farm cashflow is expected, leading to a maximum decline of $53,831, or $26,249 below the agricultural cashflow in year 30 (Figure 26). If the landowner's labour was substituted for contract labour, then a larger decline of $48,591, or $32,489 below the agricultural cashflow would occur. After the year 2024, at the start of harvesting, the farm cashflow expected to be greater than that of the agricultural cashflow except on six possible occasions. The maximum increase in cashflow is expected in the 36th year to be $432,937, or $346,270 above the agricultural cashflow (for contract labour) (See Appendix C: Table C2).

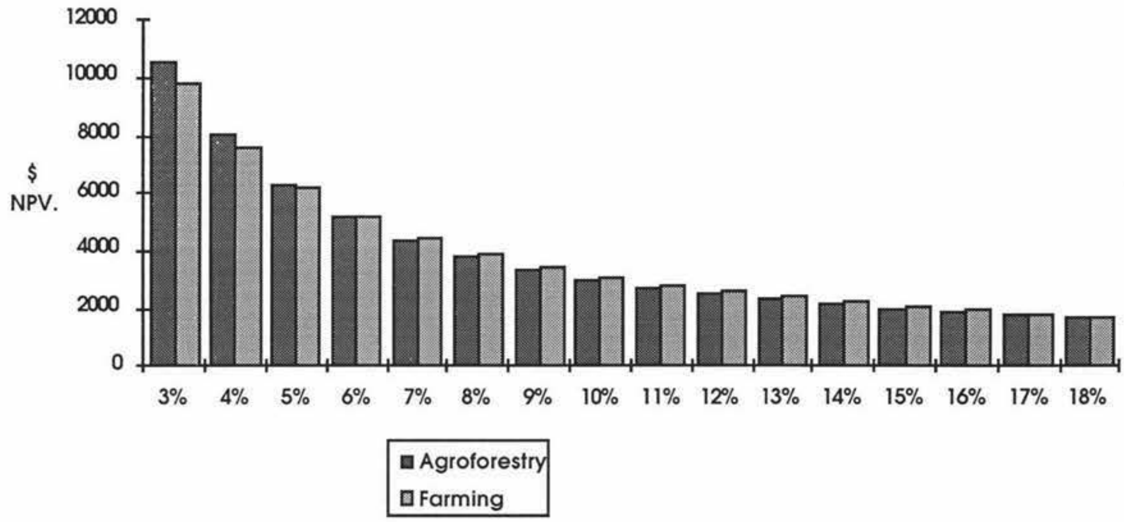
Figure 26: Farm Cashflow - Using Own Labour.



Net Present Value.

Under agroforestry at Rangitoto Farm, it was found that at higher discount rates, agriculture showed a net present value superior to that of agroforestry, while at lower discount rates this was reversed (Figure 27). At the highest discount rates, agriculture and agroforestry were about the same, this resulting from the relatively early and constant returns from agriculture compared with the later returns from agroforestry. At a discount rate of 6% (own labour), the net present value of agriculture equalled that of the agroforestry project (See Appendix C: Table C1).

Figure 27: Net Present Value - Using Own Labour.



Thus at low discount rates (below 6%) agroforestry is preferred over livestock farming; at the higher discount rate (7% or more), the differences were very small, with livestock being marginally preferred.

Internal Rate of Return.

The internal rate of return for agriculture was found to be 9.9% compared with 9.3% (contract labour) and 8.9% (own labour) for agroforestry. It was further found that the internal rate of return between agriculture 9.8% and agroforestry 9.3% (contract labour) were very close, and that the external investor would find very little between the two investment options. When comparison was made between the internal rate for return of agriculture (9.8%) and agroforestry (8.9% own labour), the differences become more pronounced, and the external investor would be better to invest in agriculture (See Appendix C: Table C3).

6.3.2 Environmental Sustainability.

6.3.2.1 Soil Erosion.

Evidence of erosion was found on three of the dunes to a varying extent. There was no evidence of active erosion on No.1 dune, although previous erosion could have been masked by long grass and slash.

Brandon Hall Dune.
Two forms of erosion were noted on this dune. Soil creep was noted on the western slope of the dune, especially on the northwest end (Figure **20)**. Minor blowouts occurred at the summit that appeared to have been initiated by rabbits and stock camps. There was little evidence of erosion on the eastern side of the dune.

Rangitikei Dune.
Erosion found on this dune consisted of slumping, which was associated with the undermining of the dune by the roading cut (Figure 28).

Rangitoto Dune.
There was extensive soil creep on the northwestern slope of Rangitoto dune; in parts there was no topsoil, just unconsolidated sand that moved when walked on. There appeared to be little soil development from the original raw sand, despite 30 years of agroforestry. Part of the southwestern slope of Rangitoto dune was under agroforestry and the remainder was under pasture, when comparing the two parts it was found that the pastured part had both blowouts and soil creep, while on the agroforestry part there was little evidence of erosion. Erosion on the eastern slope of Rangitoto dune was primary associated with the trig. station roading cut (Figure 29).

Figure 28: Slumping On Rangitikei Dune.

Figure 29: Eastern Slope Of Rangitoto Dune.

.Logging.

The part logging of Rangitoto dune occurred a few days before data collection in June 1994. The use of a skidder had cause deep grooves (30 cm) to be cut into the soil (Figure 30). But at no time was the vulnerable subsoil seen to be exposed by the logging process. The logging site itself was littered by debris, and scarred by drag marks. But again the erodible subsoil appeared not to have been breached. It can therefore be concluded that while logging on the dunes was not beneficial to the environment, the damage was not extensive enough to cause erosion.

Figure 30: Gouging Caused By Skidder.

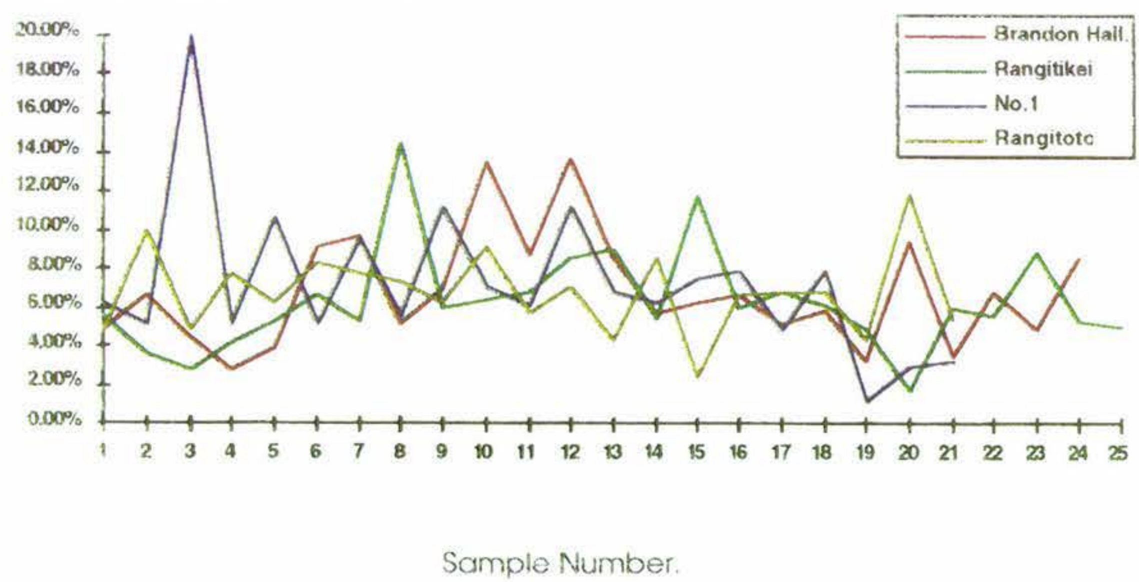
Discussion .

Most erosion found on the agroforestry dunes at Rangitoto Farm was caused by roading cuts. The roading cuts had exposed loose weak subsoil, thereby causing slumping. No evidence of blowouts was found on the agroforestry dunes, and soil creep was generally absent except on Rangitoto dune. The unconsolidated sand found on the northwestern slope of Rangitoto dune, while extensive, was more stable than the raw sand that existed before the trees were planted (Hocking, pers. com. 1994).

6.3.2.2 Organic Matter.

Investigation showed (Figure 31), that No.1 dune, which had been under *Pinus radiata* for the longest, had the highest organic content (7.22%), followed by Brandon Hall dune (6.85%), and Rangitoto dune (6.75%). The lowest organic content was found at Rangitikei dune (6.31%), (Appendix D: Tables D1 and D2).

Figure 31: Organic Content .



Discussion.

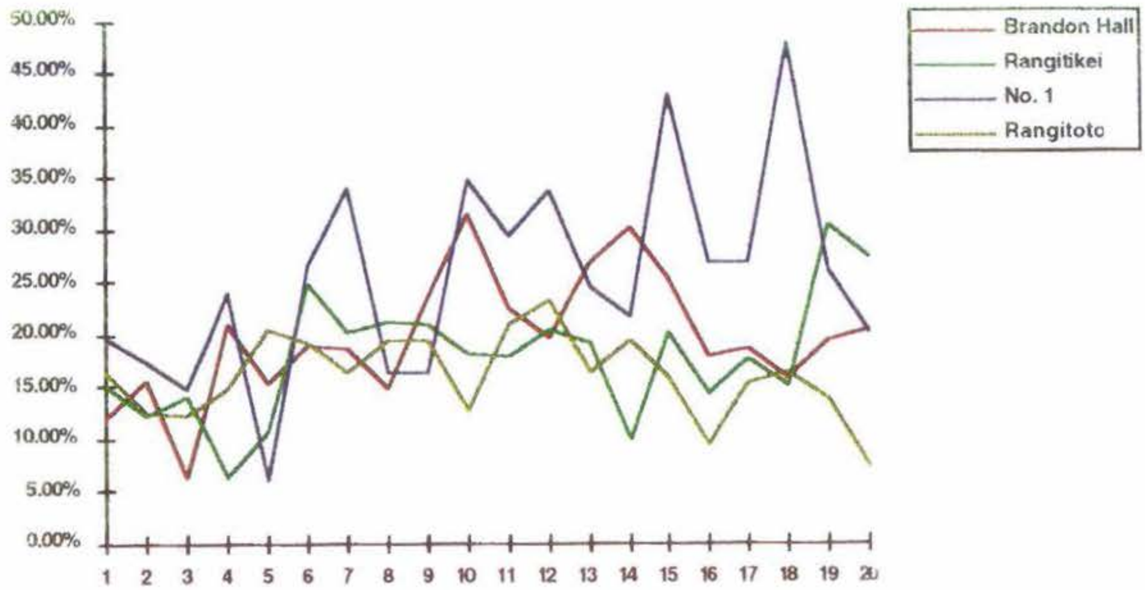
Overall, it appears that soil organic content was marginally lower under agroforestry than pastoral production; however, it appears that over several rotations this trend reverses. The absence of worms (Section 6.3.6), and the presence of a thick litter layer, indicate accumulation of undecomposed organic matter on the agroforestry sites. If the organic matter is returned to the soil at a slower rate than it is being assimilated, then this would lead to the observed results of decreasing organic content, as the trees age. On harvesting, increased soil fauna activity, moisture, and light penetration may allow the accumulated litter layer to decompose more rapidly than previously, and subsequently return significant organic matter to the soil. This would lead to the observed results of the highest organic matter being found at No.1 dune. The decline in organic content under agroforestry leads to the conclusion that agroforestry is adversely affecting the soil environment. However the decline in organic content was small, and it appears over several rotations, or at least post clearfelling, that the organic content improves significantly. Thus the effect that agroforestry has on the organic matter at Rangitoto Farm is unclear.

6.3.2.3 Physical Properties.

Moisture Content.

Measurements showed (Figure 32) that No.1 dune had the highest moisture content (25.54%), followed by Brandon Hall dune (19.75%), and Rangitikei dune (17.82 %). The lowest moisture content was found under Rangitoto dune (16.09%). The three lowest results all fall within the expected range of 16-20% for Foxton Black sand, with No.1 dune exceeding the range (Molloy, 1988),(Appendix D: Tables D3 and D4).

Figure 32: Moisture Differences.



Sampling Number

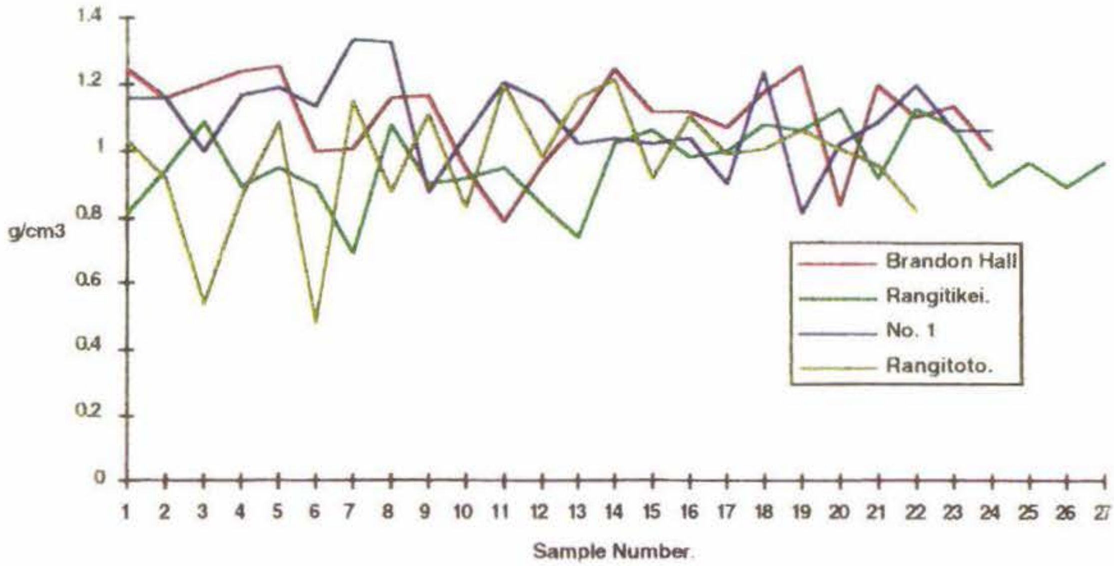
Discussion.

The soil moisture content, appears to have decreased with increasing tree age and crown density. This decrease in soil moisture is important, as moisture is an environmental-limiting factor at Rangitoto Farm. However the farmer believes that trees, with their longer root system, are able to reach down into the water table and use water not available to the pasture species, therefore moisture content may only be important to pastoral species, which decline with increasing tree age anyway.

Bulk Density.

Results show (Figure 33) that Brandon Hall dune had the highest bulk density (1.11). The second and third highest bulk density were at No.1 and Rangitoto dunes (1.0 and 0.97) respectively, and the lowest bulk density was at Rangitikei (0.96). The general trend was decreasing bulk density with decreasing age of trees. The bulk densities for Brandon Hall and No.1 fall between the expected range of (1.0-1.1 T/m3), but the bulk densities for Rangitikei and Rangitoto are below what was expected (Molloy, 1988). The greatest sample variation was found at Rangitoto dune, which was probably caused by the impact of recent logging on the soil. Overall it is concluded that there is not a sufficient difference between the results to be significant (Appendix D: Tables D5 and D6).

Figure 33: Bulk Density.



Structural Development.

.Humus Content.

The results, showed that Rangitikei dune had the highest humus content of 11%; No.1. (9%) and Brandon Hall (7%) had the next highest humus content; the lowest humus content was at Rangitoto (6%) (Appendix D: Table D7). No.1 dune, had high variation in sample data (Appendix D: Table D8) the significance of this is unknown. When comparing the humus content of the two structurally similar high dunes of Brandon Hall and Rangitoto, and the two structurally similar low dunes of No.1 and Rangitikei, it appears that humus declines under agroforestry. This is supported by the organic content and moisture results.

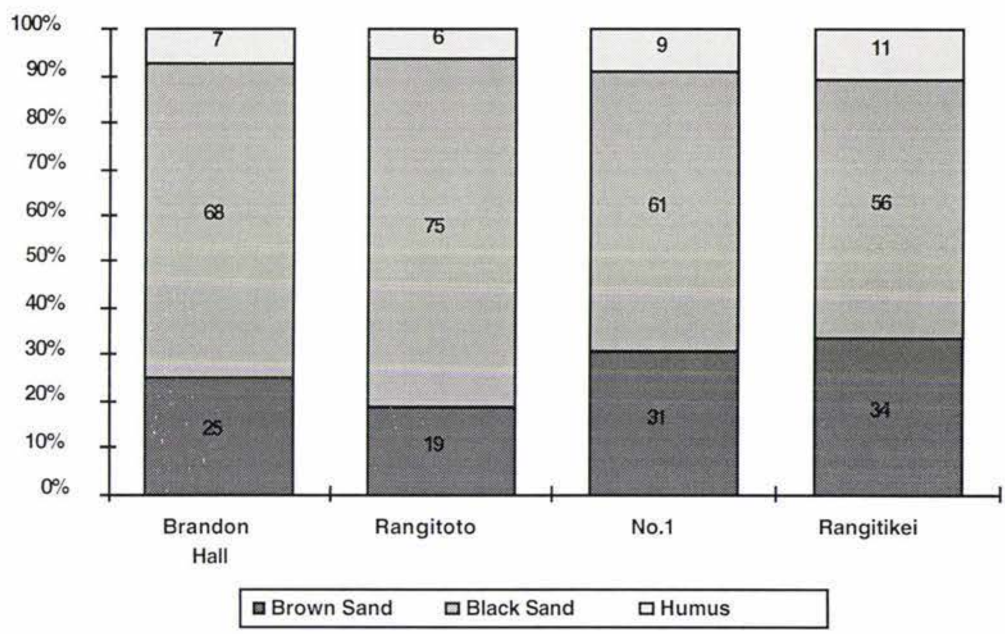
.A Horizon (Black Sand).

Investigation demonstrated that the two high dunes; Rangitoto (75%) and Brandon Hall (68%) had the highest black sand content, where the two low dunes, No.1. (61%) and Rangitikei (56%) had the lowest black sand content. Therefore it would seem that the A horizon increases under agroforestry. When comparing sample variations of Brandon Hall (6.71%) and Rangitoto (3.81%) dunes it was found that the agricultural dune had almost double the variation found on the agroforestry dune (Appendix D: Tables D9 and D10).

Discussion.

The results suggest that while humus content was lower under agroforestry (Figure 34), the increase in the A horizon and the lower sample variation on some of the dunes suggest that agroforestry soils were more stable, and structural development was more even.

Figure 34 Soil Profiles.



6.3.2.4 Chemical Analysis.

pH: There appears to be a slight decline in pH between Brandon Hall dune (6.2) and the agroforestry dunes, Rangitikei (5.9), No.1 (5.9), and Rangitoto (5.8). When historical pH (5.9) is taken into account, there appears to be little difference among the four dunes (Figure 35). (N.Z.D.S.I.R., 1958, Cowle and Hall, 1965, N.Z.D.S.I.R, 1967). However when comparing within site data, both Rangitoto and No.1 contradicted the above findings by showing a slight increase in pH over time(Appendix D: Table D11).

Ca: There appeared to be a decline in Ca between pasture and agroforestry(Brandon Hall (5.1), Rangitoto (4.3), Rangitikei (4.0), and No.1 (3.8)), but no pattern in the decline was apparent (Figure 35). This decline was also replicated within the dunes, where Rangitoto dropped from 4.8 to 4.3 over 18 months, and No.1 dropped from 4.8 to 3.8 over 54 months (Appendix D: Table 11).

P: There appeared to be an increase in P as the length of time under agroforestry increased: No.1 (13), Rangitoto (13), Rangitikei (11), and Brandon Hall (9) (Figure 35). The regular aerial topdressing at Brandon Hall, and the lack of fertilisation on the three agroforestry dunes makes the higher P values particularly significant. Contrary to the above results, P seemed to be slowly declining when comparing the within dune results; Rangitoto showed no change over 15 months, but No.1 showed a decline from 15 to 13 over 54 months. This decline could have been effected by logging just prior to the 1989 fertility test. All sites were higher in P (8.3) than historical P (N.Z.D.S.I.R., 1958, Cowle and Hall, 1965, N.Z.D.S.I.R, 1967)(Appendix D: Table 11).

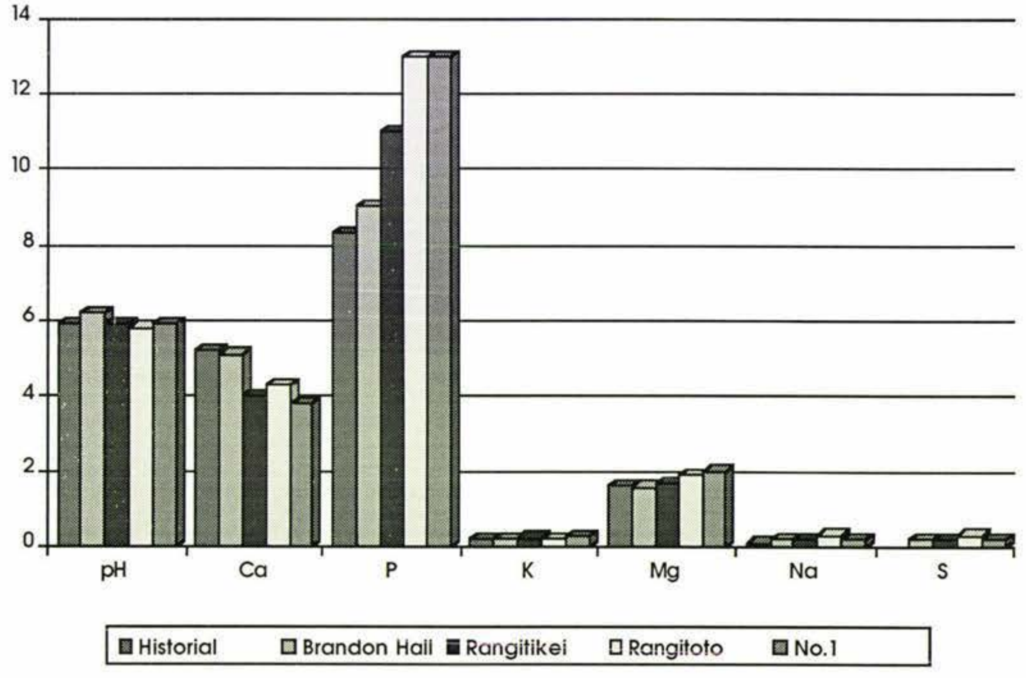
K: There was little difference between the K values from the four dunes (Figure 35). When Rangitoto (0.21), Brandon Hall (0.21), No.1 (0.25), Rangitikei (0.24), and historical K (0.2) were compared, there is less than 0.05 difference between them (N.Z.D.S.I.R., 1958, Cowle and Hall, 1965, N.Z.D.S.I.R, 1967). All four dune values were found to be higher than historical K. When comparing the within dune results a decline was found in K; Rangitoto showed decreases from 0.28 to 0.21 over 15 months and more significantly K declined from 0.49 to 0.25 at No.1 dune (Appendix D: Table 11).

Mg: There appeared to be an increase in Mg as time under agroforestry increased: No.1. (2.00), Rangitoto (1.90), Rangitikei (1.68), and Brandon Hall (1.57) (Figure 35). Contrary to the above results, Mg declined within dune, Rangitoto dropped from 2.25 to 1.90 over 15 months, and No.1 dropped from 2.16 to 2.00 over 54 months. All sites except No.1 were lower than the historical Mg (2.0) (N.Z.D.S.I.R., 1958, Cowle and Hall, 1965, N.Z.D.S.I.R, 1967). (Appendix D: Table 11).

Na: There was no change in the Na content (0.2) except at Rangitoto dune that increased to 0.3, but this was not taken to be significant, (Figure 35). All values were higher than historical Na (0.1) (N.Z.D.S.I.R., 1958, Cowle and Hall, 1965, N.Z.D.S.I.R, 1967). (Appendix D: Table 11).

S: There appeared to be an increase in S as time under agroforestry increased: Rangitikei (3.5), Rangitoto (3.0), No.1 (2.5), Brandon Hall (0.2), (Figure 35). Within dune S also increased: Rangitoto increased from 2.0 to 3.0 over 15 months, and No.1 increased from 1.0 to 2.5 over 54 months (Appendix D: Table 11).

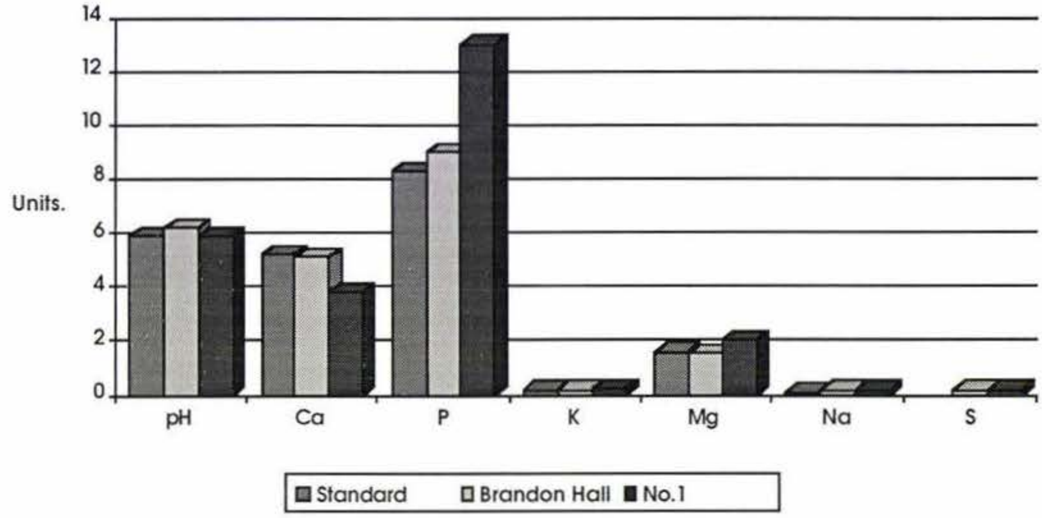
Figure 35: Soil Fertility.



Discussion.

Agroforestry increased Mg, S and P concentrations in the soil, had no apparent effect on K, or Na, and appeared to decrease the Ca content of the soil. Overall, agroforestry had limited effect on soil nutrients, albeit a slight tendency to increase some nutrients. There was also an increase in soil acidity, although this was not taken to be significant as after 104 years under *Pinus radiata*, the pH of No.1 dune was the same as that of the historical pH (Figure 36).

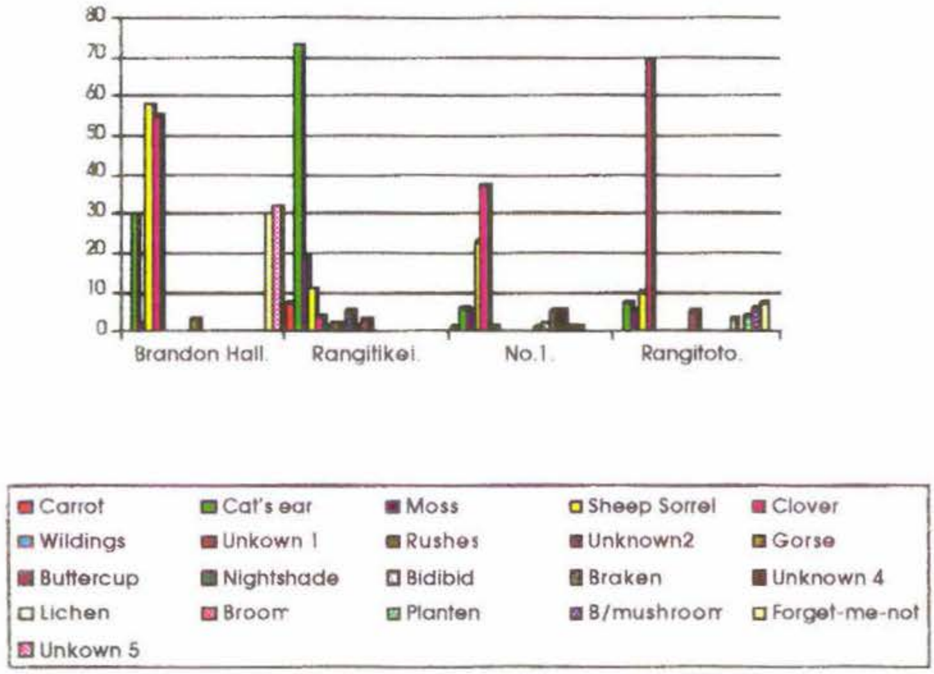
Figure 36: Comparison Of Data.



6.3.2.5 Botanical Composition.

Botanical diversity appears to increased under agroforestry (Figure 37). No.1 the oldest dune had the highest number of species (12), followed closely by that of Rangitikei (11). Rangitoto, which has the densest canopy, had the next most species (9). While Brandon Hall, the agricultural dune had the lowest number of species (7). Conversely, the weed (non-grass/needle) component of the dunes decreased with increasing agroforestry. Brandon Hall had the highest number of weeds (210), followed by Rangitikei (127) and Rangitoto (116). No.1 dune had the lowest number of weed species recorded, and this was thought to be influenced by the long ungrazed grass and the absence of tree canopy. At all dunes except Rangitikei, the predominant weed species were sheep sorrel and clover. At Rangitikei the predominant weed species was Cat's ear and Moss, with sheep sorrel ranking third and clover ranking sixth. Generally the prevalence ranking of each species changed from dune to dune (Appendix D: Table 12).

Figure: 37 Botanical Composition.



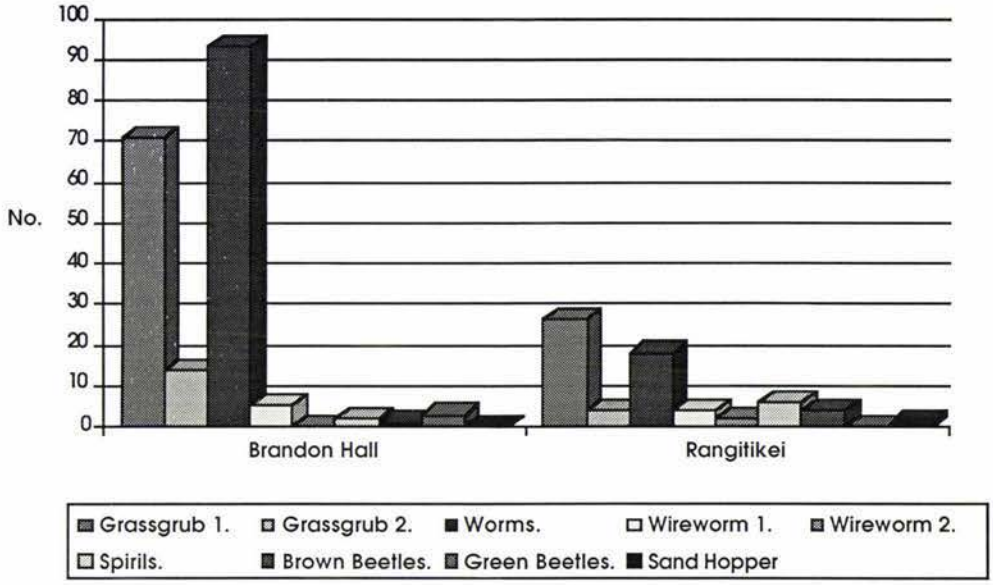
Discussion.

Agroforestry results in, greater biodiversity than agriculture, but the diversity of plants appears to play a very small role in the environment, as is indicated by the low numbers.

6.3.2.6 Soil Fauna.

Soil macrofauna biodiversity, like that of botanical composition, was marginally higher under agroforestry than under agriculture: Brandon Hall had seven species and Rangitikei had eight (Figure 38). Again the fauna component was noted to have decreased with agroforestry: at Brandon Hall 189 macrofauna were found in the samples, and at Rangitikei 65 macrofauna were found. In addition the Rangitikei dune contained macrofauna which tended to be significantly smaller than their counterpart species on Brandon Hall, especially Grassgrub 1 and 2.

Figure 38: Soil Fauna.



While the agroforestry dune had a reduced soil macrofauna component, it had a vastly increased number of fungi in comparison to Brandon Hall dune. The fungi were mostly associated with decaying wood and pine needles (Figure 39 and Figure 40). *Amanita muscaria, Armillaria spp., Lleodictyon cibarius Tul, Favolaschia calocera Heim,* unknown white *Polyporaceae, Auricularia polytricha,* and five other unidentified species, were found on the agroforestry sites, compared with only two of these species at Brandon Hall. In addition to fungi, there was far more mosses, lichens, etc associated with agroforestry than with agriculture. This was especially evident on the shady west slope of the dunes.

Figure 39: Four Different Mushroom Species At Rangitoto Dune.

Figure 40: Mosses, Lichens, etc At Rangitikei Dune.

Discussion.

Agroforestry appears to have slightly increased the biodiversity of the environment, but the role that these species play in the environment appears to be minimal, as indicted by the low numbers. However the role of soil macrofauna appears to have been partly replaced by fungi, mosses and lichens.

6.3.3 Social Sustainability.

6.3.3.1 Respect, Care And Equality Within The Community.

Sharing Of Benefits And Costs Of Agroforestry.

Benefits.

The Rangitikei District Council see agroforestry as a legitimate landuse in the District. They considered that the potential for extra jobs created by forestry, and the potential for agroforestry to help with erosion control, would be beneficial to the district (Frazer, pers com, 1994).

From the study, the biggest benefit from agroforestry was the increase in expenditure within the community.

The landowner generally sells Rangitoto Farm's wood to whoever offers the best price. In recent years the purchaser has been the local firm of Feilding Lumber, with whom the landowner has developed a good rapport. This is the landowner's preferred buyer, all things being equal. In the past the landowner has gone to Carter Holt in Bulls, Winstones in Tangimoana, and this year the landowner sold his wood to the Japanese firm Junken Nissol (Hocking, pers com, 1994).

Since the landowner acquired an additional 87 ha in 1989, he has spent considerable a part of his agroforestry income locally on pasture generation, fencing, earthworks, drainage, and roading, etc (Hocking, pers com, 1994).

From Rangitoto Farm's *"Farm Direct Cost Analysis-1st July 1992 to 30 June 1993", collated data showed that the landowner spent his money in the following way;

Bulls Township. The landowner spent $13,505.51 of $43,599.46 (31%) on farm related purchases, in his local town.

Surrounding Area. The landowner spent $27,345.47 of $43,599.46 (63%) on farm-related purchases in the immediate area surrounding Bulls (this area includes Palmerston North, Wanganui, Marton, Sanson, Levin, Feilding, and other small towns, accessible by car within a short time).

National. The landowner spent $2,748.48 of $43,599.46 (6%) on farm related purchases outside his community.

***Note:**

"The Farm Direct Cost Analysis" itemises farm expenditure only, personal food and clothing were not included. It can be assumed that in actuality, the landowner would spend more, in Bulls and the surrounding area than indicated. Expenses were allocated for each group depending on the recipients place of residence, taken from the telephone book. (Telecom, 1994a, Telecom, 1994b, Telecom, 1994c). Where the recipient is a contractor and no address was found, it was assumed the contractor lived in the surrounding area.

It should be noted that most of the national expenditure was created by the agroforestry component of the farm. The landowner however attributes this abnormally high figure to the purchase of expensive alternative species though specialist nurseries. In addition, the landowner, as a member of the executive of the Farm Forestry Association, devoted time and money to the association, which also figured predominantly in national expenses (Hocking, pers com, 1994). Both of these expenditures would be absent from most *P. radiata* agroforestry.

Last year a significant amount of money was spent on the building of a new house, using a builder from Levin. The timber came from the farm, and was milled at the Carter Holt Harvey sawmill in Bulls. Most of the other materials came from the surrounding regions (Hocking, pers com, 1994). The other remaining shareholder, his mother, did not receive a large income from the farm, and as she did not live in the district, what she did receive was not spent locally (Hocking, pers com, 1994). However the landowner believed that you could not make a clear distinction between farming and agroforestry spending patterns, because spending patterns depend entirely on the landowner as to where, and on what, money is spent (Hocking, pers com, 1994).

Cost.

The District Council recognised that agroforestry could pose a short term effect on the roading network, but they suspected there would be significant, if not a full financial contribution, from rates and road taxes in this area (Frazer, pers com, 1994). The landowner believed that in the sand country there was a good mix of forestry and dairying, thus the transport requirements of logging and dairying were compatible, the only difference being the temporal intensity of truck movement. He believed that forestry therefore occurred in the best place in the district, and would cause the least cost to the community (Hocking, pers com, 1994).

No costs were found to the district.

Equitable Distribution Of Resources.

Between Different Generations.

The landowner holds 95-98% of the shares in the Rangitoto Farm Company Limited, with his mother owning the remaining shares. The property was originally purchased in 1955, by the newly-formed family company. The shares were held by the current landowner's maternal grandparents, a maternal uncle, and his mother and father. Over time, the current landowner has acquired the shares that he now holds. The landowner is unmarried, and has no immediate heir(s), so intends that the farm be passed on to more distant relatives (Hocking, pers com, 1994).

Between Genders.

Rangitoto Farm is farmed by the sole owner, therefore only one gender is represented on this farm. The landowner has indicated however that when his parents were running the farm, his mother was involved in agroforestry right from the beginning (Hocking, pers com, 1994).

Equal Access To Participate In Agroforestry.

Agroforestry had been practised on the farm for a considerable time, so there were few barriers to the participation in agroforestry. The barrier to knowledge was overcome in the early days by using the knowledge and enthusiasm of the Forest Service Extension Officers (Hocking, pers com, 1994).

The landowner believes that the formal channels for receiving advice and training in the Bulls district are limited. The Farm Forestry Association have had "Back to Basics" field days occasionally, and provide help to members. The landowner believes that much advice can be gained from consultants, especially if the agroforester wishes to plant *Pinus radiata*; however if the potential agroforester wishes to plant alternative species, then the agroforester might find training and advice is limited as he did (Hocking, pers com, 1994, Hocking, 22.8.94).

Adequate Representation, Participation and Consultation.

Under the Rangitikei District Plan, no public consultation is required to implement agroforestry in the Bulls district. This allows the agroforester, to implement what s/he wishes within certain boundaries (Frazer, pers com, 1994, Hocking, pers com, 1994).

6.3.3.2 Quality of Life.

Income.

The landowner believes that if the property was solely under agriculture, it would be a deteriorating, subeconomic unit. He believes that the farm would not be able to generate enough income to support a normal family, plus maintain the inputs required to farm sustainably, i.e. fencing and drainage. The landowner believes that the major benefit of agroforestry is that farm income is maintained. The landowner earned a gross income of $177,872, of which $67,872 came from forestry, for the year ended June 1993 (Rangitoto Farm, Ltd, Financial Statement, 1993). The landowner has estimated that in the last five years, timber had contributed, on average, just over 30% of gross farm income, and predicts that the timber contribution would increase to around 50% in the next three to five years, if the present prices hold (Hocking, n.d.).

Work.

The landowner undertakes the majority of the agricultural and silvicultural processes by himself. The two exceptions are shearing and some pruning and thinning. For shearing he employs a shearing gang, while for pruning and thinning he used to use a part time worker, who has since left the area (Hocking, pers comm, 1994).

Health.

The landowner believes that no major health problems were created by agroforestry. He did however identify that asthmatics and people with allergies might have problems during the time of pine pollen release. The landowner personally suffered no health problems from agroforestry (Hocking, pers com, 1994).

Fulfilment.

The landowner found that agroforestry had at times caused him much frustration, but in comparison, animals had caused a lot more. For the landowner, agroforestry was not just a commercial operation, but also a means for him to follow his interests in alternative species. His base in *Pinus radiata* allowed him try something different, and his aim was to grow alternative species which would also yield a useable product. For the landowner the real rewards do not merely come from financial gain, but from the sense of achievement from growing something. The landowner believed that agroforestry was one of the few ways in which the farmer can personally change the farm's appearance and character, and this change becomes most evident when a block is logged and there is a large hole on the skyline. He believes that if a person is interested in trees, then agroforestry can provide great job satisfaction. The landowner also found that agroforesters who were not interested in trees at the beginning, often become interested later on. The final positive impact on his quality of life was that for six months of the year, the property was visited by moreporks, tuis and bellbirds (Hocking, pers com, 1994).

Superannuation.

The landowner thought that he had little use for a superannuation scheme, as he was growing his (Hocking, pers com, 1994).

Self Expression.

The landowner's entire agroforestry operation was unique to him. His mix of species, agroforestry regime, and silviculture practices were entirely of his making.

Mix Of Species.

Little will be said about this as non *Pinus radiata* species are beyond the scope of this thesis. However between 1955 and 1965 there was significant planting of mainly *Pinus radiata, Cupressus macrocarpa*, and various eucalypts, especially *Eucalyptus botryoides*, and a variety of other timber, shelter, amenity and specimen trees. From 1967-1978 there was a regular programme of *Pinus radiata* planting, and after 1979 there was further experimentation with alternative species on a variety of dunes, and this has included eucalypts, cypresses, and acacias, along with black walnuts, catalpas and chestnuts.

More recently, the landowner has switched back to planting larger areas of *P. radiata* while assessing the performance of his alternatives. The landowner has found that stringy bark eucalypts (*E. muelleriana, E. pilularis, E. globoidea and E. microcorys*) have preformed well, and intends to carry on planting these species along with cypresses and *Acacia melanoxylon* on appropriate dunes (Hocking, n.d.)(Appendix E).

Agroforestry Regime.

The landowner's agroforestry regime departs from a standard agroforestry regime. The landowner's regime produces substantial early income from production thinnings, but fewer high quality logs at time of clearfelling (Hocking, pers com, 1994). Over the years the landowner's forestry regime has changed with the prevailing technical expertise of the time, andbecasue of market forces. The landowner indicated that his production thinning regime may have to be changed in the future if the market for young, low-density timber declines. As to his alternative species, little scientific data exist, so the landowner is experimenting as he goes along.

Silvicultural Practices.

Another departure from standard agroforestry practice is the landowner's use of draughthorses to pull the production thinnings off the dunes; usually a modified agricultural tractor is used (Maclaren, 1993, Hocking, pers com, 1994).

6.3.3.3 Cultural Sustainability.

Farming Community.

In light of the fact that no submissions or objections have been received by the Rangitikei District Council regarding agroforestry, it may be concluded that agroforestry as a landuse in Rangitikei District is not a contentious issue (Frazer, 1.9.94).Of the approximately 100 farmers that the farmer knew of between the Rangitikei and Turakina Rivers, he believes that approximately 98% had planted trees, and were actively planting. The landowner believes that agroforestry in Bulls is very positively received by other members of the community. However he believes that the visual impact of agroforestry may become a problem in the future, with the rise in lifestyle blocks near Rangitoto Farm (Hocking, pers com, 1994).

Tangata Whenua.

The Maori liaison officer for the Department of Conservation, Mr Mete Kingi, could not identify anyone in Ngati Apa who had significant interest in *Pinus radiata* agroforestry. Ngati Apa's view of the prevalence and growth of *Pinus radiata* agroforestry in the district was largely a minimal one, because they did not own forests nor had money invested in forests. However he did believe agroforestry on crown lands could be an important commercial resource, should the Ngati Apa treaty claim be successful.

Mete Kingi believed that agroforestry as a joint venture opportunity had the benefit of shifting the Ngati Apa landowner from a passive owner/tenure to a more active ownership. He believed that this shift was an important step for Ngati Apa owners because it indicated a desire to be more proactive and more responsible for their land. Mete Kingi believed that the longer Maori owners remain passive about their land, the easier it is for them to lose touch with that ancestral feeling for the land, and this in turn had the effect of alienating the next generation from that bond. Taken to its reverse conclusion, once the ancestral bond is lost, then the desire to hold on to the land was also lost (Mete Kingi, pers com, 5.9.94).

Green issues.

This is not a local issue (Hocking, pers com, 1994).

6.3.4 Political Sustainability.

Central Government.

Neither the landowner, nor his father, had ever used a Forestry Encouragement Grant or Loan. The landowner believes that none of the government policies had made a major difference to what he had done (Hocking, pers com, 1994). However the landowner did admit changing his *Pinus radiata* regime in response to the political environment of the 1980s, and has maintained that regime ever since.

Local Government.

At no time had the landowner, nor his father, had problems with local government over the issue of agroforestry as a landuse (Hocking, pers com, 1994). The District Plan allowed for forestry and afforestation as a permitted use. There are no performance conditions attached which allow the landowner to plant trees at any time without applying for a resource consent. Forestry as a predominant use (permitted use) has been in the Rangitikei District Scheme since 1970 (Frazer, pers com, 1994). A resource consent was required for harvesting, but the conditions attached usually required the sand dunes to be replanted (Grant, pers com).

7. Summary and Conclusion.

7.1 Summary.

7.1.1 Economics.

Sustainable Yield Harvesting .

Logging, site preparation and heavy machinery were found to degrade the productive capacity of the agroforestry site unless good management practices were put in place. Given suitable sites and good management practices, agroforestry appeared to be able to maintain its total natural capital stock, indefinitely, and therefore sustain the material benefit and utility received from the natural resources.

Sustainable Waste Accumulation.

Sedimentation from agroforestry was found to decrease during tree establishment but had the potential to increase during harvesting. It was unknown if sedimentation would exceed the assimilative capacity. It was found that due to the low use of artificial fertilisers and the low stocking rates, agroforestry was unlikely to produce enough nutrient waste to constrict human activity. In general, stock numbers under agroforestry were lower than under pastoral farming, therefore it was assumed that the contamination from sheep dip and faecal wastes would also be considerably lower. Herbicide and fungicide use were found to be a potential source of chemical pollution if poorly disposed of. Overall, it appeared that agroforestry used fewer chemicals than pastoral farming, therefore the occurrence of chemical waste was thought to be less. Studies into slash accumulation found that slash broke down within 3-4 years and little information was found into wilding spread, thus it was assumed that agroforestry did not cause biological wastes to accumulated. Given good management practices agroforestry appears to produce less waste than can be assimilated into the environment before impacting on human activity.

Sustainable Use Of Non-Renewable Resources.

There was little information regarding the substitution and recycling of non-renewable resources in agroforestry, so tentative conclusions were drawn from this. From Rangitoto Farm it was found that very few non-renewable resources were used in agroforestry. Overall, studies found that agroforestry was a reasonably efficient landuse, especially in comparison to agriculture. Therefore it appears that agroforestry minimises the use of crucial non-renewable resources and achieves the maximum continued benefit.

Economic Return

The profitability of agroforestry was found to be affected by the following variables; development costs; harvesting and transport costs; market risks; productivity risks; management skills; the regime undertaken; and labour requirements. From the five case studies it was found that agroforestry negatively affected the farm's cashflow during time of establishment. After harvesting agroforestry was found to strongly increase the farm's cashflow above what could be expected from other farm enterprises, e.g 3-5 times that of livestock farming alone. The studies also concluded that at low discount rates the agroforestry project was significantly preferred over livestock farming. However at high discount rates, there was found to be little differences between the two, with livestock farming being marginally preferred. Therefore in a high interest rate market environment there was found to be little difference between livestock and agroforestry enterprises, but in a low interest rate market agroforestry was significantly superior. The studies found that the Internal Rate of Return between farming and agroforestry was very close for some agroforestry investments, and the external investor would find very little difference between investment options. However for other farming/ agroforestry investment options a marked difference was found and the investor/farmer would be better to leave the land in pasture. Taking into account the factors affecting the profitability, agroforestry appeared to be able to provide the farmer/ financier with a level of profit that provides a reasonable return on the capital employed.

7.1.2 Environmental.

Life Support Systems.

Energy - No information was found on studies into agroforestry energy consumption, at Rangitoto Farm, however, it was found that the use of fossil fuels was minimal. Therefore it is concluded that agroforestry appeared to have minimal reliance on external energy sources, and was a relatively stable, self sustaining landuse system.

Nutrients - Studies into the effect that agroforestry had on nutrients, found that the tree component played an important role in the maintenance of soil nutrients. Overall the studies found variation in nutrient concentration, over time, between tree densities and between sites. Stoddart (1984) concluded that there were no obvious trends in nutrient change under *Pinus radiata*. The Tikitere, and other studies, concluded that under agroforestry most elements where at an adequate to high level. At Rangitoto Farm it was concluded that agroforestry had a limited effect on soil nutrients, with a slight tendency to increase some. Agroforestry therefore appears to provide and maintain an adequate supply of nutrients within the environment.

Air - Two impacts on the medium of air were found, the first impact concerned the ability of trees to store atmospheric carbon. The importance of this was unknown, but is taken to be a positive impact. The second impact concerns the effect that trees had on windrun. Agroforestry was found to reduce the windrun, thus reducing windchill on stock and raising the soil temperature. This was thought to be beneficial for stock, in cooler climates, but its effect on the rest of the environment also was unknown. Overall agroforestry appeared not to detrimentally affect the medium of air, however the effect that agroforestry had on the medium of air was not fully understood.

Water - No studies into the effect agroforestry had on the aquatic environment were found. Anecdotal evidence suggested that agroforestry increased the quality and decreased the quantity of water in the environment. Specific studies into soil moisture, found that soil moisture both increased and decreased under trees. Therefore no conclusion was reached on the effect agroforestry had on water or it's environmental sustainability.

Soil - Studies at Rangitoto Farm found that agroforestry played an important part in reducing soil erosion. Young (1992) and Stoddart (1984) found that soil organic matter increased under agroforestry. However, Rangitoto Farm seemed to support this finding only in the long term, and not in the short term. Overall it appeared that agroforestry maintained and improved the soil physically. Agroforestry was found to increase the soil acidity, with increasing tree age and tree density. The importance of this to the environment was unknown. Maclaren (1993) believed that where soil acidification had occurred the effect was temporary and inconsequential. Overall it was found that agroforestry increased soil acidity and had the potential to degrade the soil chemically. Agroforestry was found to have three effects on soil biology, the biological composition changed, soil biota decreased, and at Rangitoto Farm the biodiversity was found to have increased. These three effects suggested that agroforestry changed the soil biology. Overall, it was concluded that agroforestry affected the soil, but whether the soil was detrimentally affected was undetermined.

Biodiversity.

The studies found that biodiversity changed under agroforestry, sometimes there was an increase sometimes a decrease. The plant biodiversity both increased and decreased, while the macrofauna was thought to have decreased in numbers but not in biodiversity. Vertebrate fauna was also found to have increased. At Rangitoto Farm the biodiversity within species was found to be low. Overall it can be concluded that agroforestry changed the biodiversity of the agroecosystem. When the increases in lichens, moss's, mushrooms and vertebrates were taken into account it appeared that agroforestry enhanced the biodiversity of the agroecosystem.

7.1.3 Social.

Respect, Care And Equality.

From the studies it was found that agroforestry could produce the following community benefits; provide rural diversification, expand productivity, provide additional employment, increase the rural economy, muffle noise, provide shelter and improve water quality. From the studies it was found that agroforestry could create the following community costs, cause a roading burden, cause a visual impact, reduce the rural economy, cause nuisances in the form of wilding eradication, noise and dust generation. It was also found that sensitive locating and good management practices could reduce most of the costs to the community, and agroforestry had the potential to improve the viability of many struggling rural areas. Agroforestry was found to have the potential to provide an equitable solution to the distribution of resources between generations and between the sexes. Agroforestry was found to potentially effect the equitable distribution of water resources. Three barriers were found to the participation in agroforestry by members of the community, these where lack of finance, distance from market, and lack of knowledge. Finally it was found that communities had strong provisions to be represented, participate, and be consulted in areas concerning resource use. However, it was found that provisions concerning social and economic issues were limited and could lead to social disharmony. Overall it appeared that agroforestry could provide respect, care and equality within the community.

Quality Of Life .

Agroforestry appeared to provide an adequate quality of life, both at time of work and into retirement. However if, the farmer had a high level of debt servicing then an undertaking in agroforestry had the potential to decreased the quality of life.

Cultural Sustainability.

There appeared to be a reluctance for New Zealand farmers to undertake agroforestry, which maybe through some cultural incompatibility. The Tangata Whenua and environmental groups appeared to have no cultural problems with agroforestry. Overall it was concluded that agroforestry was culturally sustainable.

Political.

Agroforestry appeared to be vulnerable to political change by people relying heavily on government support. If agroforestry was undertaken without governmental incentives, then agroforestry appeared to be relatively robust to political change. Overall agroforestry appeared to be relatively robust to political change.

7.2 Conclusion.

For agroforestry to be considered sustainable it must be able to maintain itself economically, environmentally and socially, at a certain rate or level over a long time. Dependant on good management practices and normal business risks, agroforestry appears to maintain the natural capital stock of the environment and remain relatively profitable. It is concluded that agroforestry is economically sustainable. In searching for measures of economic sustainability, it was found that three difficulties arose using traditional methods. Using cashflow, N.P.V. and I.R.R. as indicators it was found that those three measures made assumptions about economic return, and generally did not incorporate the three variables of cost, risks or skill very well into the calculations. In addition from some of the studies it was found that the maintenance of natural capital stock was not taken into account. It was clear that on some of the properties used that if the farming system were to continue without trees then the natural capital stock would decline through erosion, and reduce the farm's viability. Therefore the predicted returns from farming were unrealistic and farm profitability would be much less. It became clear that in measuring the economic sustainability of a system, other than non economic factors have to be taken into account. This appears to be the shortfall of existing economic evaluations. Finally these studies did not take into account the benefit of diversification on the farm. Agroforestry is thought to add stability to the farm investment and income, when rates where high then the farmer gained good returns from livestock farming, when the rates were low the farmer received better returns from agroforestry. Also when timber or livestock prices decline the other components could usually compensate for the loss. Taking all the above in to account agroforestry, is clearly a more economically sustainable landuse than most pastoral farming systems, especially on environmentally degrading lands.

Again dependant on good management practices agroforestry appears to maintain the life support systems and does not appear to adversely affect the biodiversity of the environment. It is therefore concluded that agroforestry is environmentally sustainable. Regarding the environmental sustainability of agroforestry, a number of crucial issues were raised. It was found that agroforestry changed the environment, a number of these changes were clearly identified as beneficial to the environment. However the effects of a large number of the changes were unknown, and potentially of concern. It is my belief that further research needs to be undertaken into these unknown areas, especially the effects that the biological changes have on the environment. To minimise any problems that agroforestry could create agroforestry should be matched to the environment. Agroforestry in the wrong environment, i.e. on soils that are already acidic, has the potential to adversely affect the environment. There are as many agroforestry types as there are environments; selection of sites should be a considered process.

Finally from the studies and results it was found that agroforestry could play and important role in improving the social sustainability of New Zealand rural communities. Agroforestry appeared to positively impact on rural communities, provided the necessities of life, and is relatively robust to political change, therefore it is concluded that agroforestry is socially sustainable. However, evidence suggests that farms that would most likely to benefit from agroforestry, were usually in such a marginal state that government assistance may be crucial to help these farms and become sustainable as the New Zealand government demands. Many farmers are in a no win situation, they cannot economically afford to undertake agroforestry and they cannot evironmentally and often socially afford not to undertake agroforestry.

Overall it appears the agroforestry is a profitable enterprise that improves the environment and increases viability of many rural communities. It should be considered a sustainable landuse under RMA provided certain forestry operations are carefully controlled.

Appendix A. A.E.M. Input Data.

The following data and parameters were used for the A.E.M. evaluation of the economic return of agroforestry Rangitoto Farm. These data were composed from several sources.

Table A1: Area Planted And Area Felled.

Year	Area Plntd	Year	Area Plntd	Year	Area Felld	Year	Area Felld
1994	1.0	2010	1.0	2025	1.0	2041	1.0
1995	0.5	2011	1.8	2026	0.5	2042	1.8
1996	1.0	2012	1.6	2027	1.0	2043	1.6
1997	1.25	2013	2.1	2028	1.25	2044	2.1
1998	0.2	2014	2.5	2029	0.2	2045	2.5
1999	12.0	2015	0.8	2030	12.0	2046	0.8
2000	2.7	2016	5.0	2031	2.7	2047	5.0
2001	2.0	2017	0.9	2032	2.0	2048	0.9
2002	1.1	2018	10.0	2033	1.1	2049	10
2003	0.9	2019	9.0	2034	0.9	2050	9.0
2004	0.8	2020	4.0	2035	0.8	2051	4.0
2005	1.7	2021	5.0	2036	1.7	2052	5.0
2006	1.9	2022	7.0	2037	1.9	2053	7.0
2007	1.0	2023	7.0	2038	1.0	2054	7.0
2008	0.6	2024	8.0	2039	0.6	2055	8.0
2009	1.3			2040	1.3		

(Hocking, n.d.)

The Area Planted was taken from the planting records of Rangitoto Farm (Appendix E). The data for Area Felled are the same as that for Area Planted, the rotation length was 30 years, one crop type was used, and the area was in hectares. This evaluation was restricted to one A.E.M. rotation only.

Table A2: Constants Used.

Yield Values:	
S1S2.	$115.00
S3L3.	$110.00
L1L2.	$ 90.00
Pulp.	$ 50.00

(Carter Holt Harvey, 29.3.94, Junken Nisshol, 8.4.94, Maclaren, 1993:119)

The "on truck" values were taken as composites of two quotes received in March and April, 1994, by Rangitoto Farm Ltd, for logs the landowner felled. The price for pulp was taken as an average price from Maclaren (1993: 119).

Table A3: Labour Requirements And Costs.

Labour Table Operations			
OPERATION	AGE (Yrs)	TIME (Hrs)	COST ($)
Plant	1	6.8	18
Release 1	1	4.8	18
Prune 1	5	13.8	18
Prune 2	6	11.9	18
Prune 3	8	10.0	18
Thin 1	5	5.3	18
Thin 2	8	4.0	18

(New Zealand Forest Service, 1985, Table 1, Maclaren, 1993:65,75, Roper and Aldwell, 1992:40)

The Rangitoto Farm agroforestry operation data could not be used for this economic evaluation because the regime exceeded the A.E.M. (Version 2.3) parameters, therefore a "Typical Regime" for sand country agroforestry was used instead (Table B2) (Grant, 1994). Time data were taken from Maclaren, (1993:65,73), Roper and Aldwell (1992:40), and New Zealand Forest Service (1985, Table 1). In all cases a "moderate" or "average" value was used for operation conditions. The default value of $18/hour was used for labour costs, as the landowner generally used his own labour, so no data were available.

Table A4: Spreadsheet Values.

Spreadsheet Values	
Land Value/ha	1500.00
Capital Livestock Val - sell	33.00
Capital Livestock Val - buy	33.00
Labour $/hr:	18.00
Regrassing $/ha:	0.00
Contract Supervision %:	20%
LSU /ha (before planting):	6
Materials Cost $/ha	125.00
Gross margin	51.84
Planted Area	95.65
Unplanted Pasture in agro:	151.35
Replanting Delay (Yrs)	0

Land Value/ha was assessed by several methods, Rangitoto Farm's government valuation was $455,000, which works out to be $937.50/ha. On consulting two other sources to check the validity of the valuation, it was found that land prices had increased since the government valuation. A final value of $1500/ha was taken as the "typical value" that would be paid for land, in Bulls (Plimmer, 26.8.94, Shadbolt, 1993, Hocking, pers. com.).

Regrassing cost was set at $0.00, as Rangitoto Farm usually replanted within the same year. Contract supervision of labourers was arbitrarily taken as 20%, so no data were available from Rangitoto Farm. The average livestock carrying capacity of the land, prior to planting was taken from Rangitoto Farm (Hocking, pers com). Material costs were taken from estimated costs at the Manawatu - Wanganui Regional Council (Grant, pers com).

Gross margin was calculated in Table A7 and transferred. Planted area was calculated and transferred from Table A1. The Unplanted Area was calculated from the total area of Rangitoto Farm (Table A7) minus the Area Planted (Table A1). The landowner of Rangitoto Farm replanted within the year, so correspondingly the replanting delay was set at 0 (Hocking, pers com).

Table A5: Livestock Units.

Year	LSU/Ha	Year	LSU/Ha
1	0.00	16	1.31
2	0.00	17	1.04
3	3.00	18	0.99
4	1.25	19	0.75
5	0.86	20	0.56
6	1.28	21	0.42
7	2.03	22	0.3
8	1.30	23	0.22
9	0.71	24	0.16
10	1.09	25	0.11
11	0.59	26	0.08
12	0.94	27	0.06
13	1.44	28	0.04
14	1.77	29	0.03
15	1.58	30	0.02

(Grant, 1994)

Data for this table were calculated in "Agro", a sub model of the computer model PCSTANDPAC using the parameters in Appendix B (Grant, 1994).

Table A6: Log Aggregation Table.

Age	PR (vol)	PR ($)	S1S2	S3L3	L1L2	Pulp	Logging Costs
30	192.4	$290	65.8	109.7	97.9	62.	$4.50/m3

The data for this table was calculated in "Log Grades", a sub model of PCSTANDPAC. The log aggregation table produced 12 domestic log grades, which were reclassified to form 5 log grades, the maximum allowable number in A.E.M. (Grant, 1994). Typical logging costs were taken from Maclaren (1993:120).

Table A7: Farm Accounts.

Gross Margin Calculation					
Total Farm Area(ha)	247				
Total Farm LSU	2400				
Farm Income:					
			Sales	- Purchases	Net
	Sheep		76968	8904	68064
	Wool		30000	0	30000
	Cattle		59256	32016	27240
	Other		44232	0	44232
		Total Farm Income:			169536
Farm Expenditure:					
Fixed Costs		Variable Costs			
Wages	2808		Animal Health	4248	
Electricity	1600		Feed	4488	
Weed & Pest	888		Fertiliser	5256	
Vehicles	11328		Freight	1896	
Rep. & Maint.	11808		Shearing	8016	
Admin.	13728		Seeds	1296	
Other	1176		Other	19920	
Total	43336		Total	45120	
		Total Farm Expenses:			88456
		Farm Surplus:			81080
		Farm Gross Margin/LSU			$51.84

(Hocking, n.d, Ministry of Agriculture and Fisheries, 1994:43-44, Horsfield and Co., 1994a)

Total Farm Area and Farm LSU were taken from Rangitoto Farm (Hocking, n.d., Hocking, pers com, 1994). Farm accounts for Rangitoto Farm could not be used as the accounts were significantly affected by existing agroforestry income. Therefore farm accounts for the MAF model farm - "Manawatu-Rangitikei Finishing Farm" were used (Ministry of Agriculture and Fisheries, 1994). The figures were adjusted to the slightly larger farm by multiplying the $/LSU by the number of Stock Units on Rangitoto Farm (2400 LSU). There is one exception to this adjustment: electricity was kept at a fixed value of $1600 as it appeared in the model accounts. It was assumed that a larger farm would create no more demand for electricity than the model farm. This assumption was supported by the significant lower electricity cost of Rangitoto Farm in 1993 (Horsfield and Co., 1994a).

Appendix B. PCSTANDPAC Data.

The following data and parameters were used by PCSTANDPAC for the generation of forestry data required for A.E.M. ***Stand Growth.*** Stand Treatment and Growth Simulation. Version 5.02, Forest Research Institute, New Zealand, Dec 10,1994.

Table B1: Parameters Used For *Stand Growth.*

Parameters of growth model 1.		*Parameters of growth model 2.*	
Growth Model.	23 EARLY	*Growth Model.*	15 SANDS
Basal Area fn.	Medium	*GF rating*	7
Basal Area adj.	0.0%	*Height Model*	27
Height Model	27	*Stand Volume fn.*	4
Stand Volume fn.	29	*Monthly Growth fn.*	4
Monthly Growth fn.	3	*Dune Index.*	27.0 m
Crown fn.	Beekhuis	*Start Date (of model)*	1994 Nov(0.4)
DOS adj.	0.0 cm	*Mean Top Height.*	5.0 m
Dune Index.	27.0 m		
Start Date (of model)	1994 Nov (age 4.6)		
Mean Top Height.	6.0 m		

(Grant, 1994)

Table B2: Farm Forestry Regime.

Forestry Regime.	
Initial Stocking rate.	1000 sph.
Prune 1	At 5 years, to 2.2 m height.
Thin to waste 1.	To 600 sph @ year 7.
Prune 2	At 6 years, to 4.2 m height.
Thin to waste 2.	To 300 sph @ year 8.
Clearfelling.	At year 30, mean top height 34.3, final stocking 286 stems/ha

(Grant, 1994)

Appendix C. A.E.M. Output Tables.

These data were created by A.E.M (version 2.3) and were used for evaluation of the economic return of Rangitoto Farm.

Table C1: Net Present Value Of Marginal Investment.

Disc. Rate	Own Labour	Cont Labour	Farming
3%	10583	10277	9829
4%	8007	7783	7622
5%	6338	6169	6173
6%	5206	5075	5169
7%	4406	4303	4438
8%	3819	3736	3886
9%	3373	3305	3455
10%	3024	2968	3110
11%	2743	2696	2828
12%	2513	2473	2592
13%	2320	2285	2393
14%	2156	2126	2222
15%	2014	1988	2074
16%	1891	1868	1944
17%	1782	1762	1830
18%	1685	1667	1728

This table displays the net present value of the agroforestry project for a range of discounts, using the cash flow data (excluding land, fixed costs, and capital livestock) (Knowles and Middlemiss, 1992).

Table C2: Total Farm Cashflow.

Year	Agrofy Own Labour	Agrofy Contract	Year	Agrofy Own Labour	Agrofy Contract	Farming (No Trees)
1994	80644	80393	2025	87744	81378	81080
1995	80551	80426	2026	71976	64956	81080
1996	80333	80082	2027	86946	80799	81080
1997	79900	79587	2028	94694	87769	81080
1998	80059	79596	2029	61676	57041	81080
1999	74967	71497	2030	432937	427350	81080
2000	75237	74019	2031	140198	136561	81080
2001	76528	74952	2032	117964	116388	81080
2002	75642	74812	2033	89622	88791	81080
2003	75231	69701	2034	83087	77557	81080
2004	75104	70328	2035	80024	75247	81080
2005	74967	72962	2036	108239	106233	81080
2006	74094	69021	2037	114148	109075	81080
2007	73721	72000	2038	85295	83574	81080
2008	73892	72576	2039	72224	70908	81080
2009	73075	71510	2040	93825	92260	81080
2010	72949	71205	2041	84065	82322	81080
2011	72764	71170	2042	108897	107303	81080
2012	72577	71157	2043	102351	100931	81080
2013	71905	70114	2044	117891	116099	81080
2014	70965	69290	2045	130329	128654	81080
2015	70882	69500	2046	76751	75369	81080
2016	68879	66110	2047	208788	206019	81080
2017	68841	67035	2048	79761	77955	81080
2018	65153	60532	2049	365960	361339	81080
2019	62030	58318	2050	334479	330768	81080
2020	62642	58737	2051	177184	173278	81080
2021	61292	57627	2052	208624	204958	81080
2022	58513	52160	2053	271522	265170	81080
2023	56562	47012	2054	271514	261965	81080
2024	54831	48591	2055	302969	296729	81080

This table displays the cashflow for the total farm, plus the revenue from livestock on the remaining unplanted area on the farm, less the farm fixed costs. Farm cashflow (without agroforestry) was included for comparison with agroforestry (Knowles and Middlemiss, 1992).

Table C3: Internal Rate Of Return.

IRR of Agroforestry Project	*Contract*	*Own Labour*	*Farming*
(incl. land, fixed costs, capital livestock)	8.9%	9.3%	9.9%

This table shows the internal rate of return on the agroforestry project investment. It includes the cost of land, capital livestock and fixed costs, together with the revenues and marginal costs (Knowles and Middlemiss, 1992). Knowles noted that IRR from A.E.M was often incorrect and could only be used for analysis with caution (Knowles, pers. com.).

APPENDIX D. Environmental Data.

Table D1: Organic Matter.

Sample Number	Brandon Hall.	Rangitikei.	No.1	Rangitoto.
1	4.91%	5.51%	6.24%	4.79%
2	6.62%	3.59%	5.15%	9.93%
3	4.45%	2.85%	19.94%	4.81%
4	2.88%	4.17%	5.10%	7.74%
5	3.98%	5.35%	10.59%	6.28%
6	9.19%	6.69%	5.13%	8.32%
7	9.65%	5.24%	9.52%	7.77%
8	5.12%	14.46%	5.62%	7.29%
9	7.00%	6.00%	11.26%	6.31%
10	13.55%	6.45%	7.06%	9.18%
11	8.73%	6.84%	6.14%	5.75%
12	13.62%	8.57%	11.24%	7.09%
13	8.63%	8.93%	6.75%	4.38%
14	5.67%	5.46%	6.20%	8.53%
15	6.20%	11.74%	7.45%	2.37%
16	6.63%	5.92%	7.83%	6.61%
17	5.17%	6.76%	4.89%	6.75%
18	5.90%	6.05%	7.84%	6.74%
19	3.26%	4.92%	1.16%	4.32%
20	9.46%	1.65%	2.93%	11.88%
21	3.53%	5.91%	3.20%	5.48%
22	6.75%	5.58%		
23	4.87%	8.89%		
24	8.54%	5.29%		
25		5.01%		
Average	6.85%	6.31%	7.22%	6.75%

Table D2: Statistics For Organic Matter.

	Brandon Hall	Rangitikei	No. 1	Rangitoto
Mean	0.0685	0.0631	0.0721	0.0675
Standard Deviation	0.0282	0.0261	0.0383	0.0210
Sample Variance	0.000793	0.00068	0.001465	0.000443
Count	25	26	22	21
Confidence Level (95%)	0.011041	0.010024	0.015993	0.009001

Table D3: Moisture Content.

Sample number	Brandon Hall	Rangitikei	No. 1	Rangitoto
1	11.94%	15.14%	19.59%	16.27%
2	15.72%	12.38%	17.48%	12.45%
3	6.48%	13.94%	14.93%	12.24%
4	20.91%	6.31%	24.09%	14.87%
5	15.24%	10.64%	6.24%	20.53%
6	18.92%	24.85%	26.66%	19.17%
7	18.62%	20.12%	33.97%	16.40%
8	14.82%	21.24%	16.34%	19.48%
9	23.62%	21.05%	16.50%	19.41%
10	31.60%	18.04%	34.91%	12.71%
11	22.60%	17.99%	29.40%	20.85%
12	19.75%	20.35%	33.72%	23.30%
13	26.96%	19.29%	24.66%	16.32%
14	30.13%	9.98%	21.85%	19.41%
15	25.38%	20.21%	42.89%	15.89%
16	18.02%	14.43%	26.83%	9.50%
17	18.68%	17.62%	26.88%	15.44%
18	15.82%	14.99%	47.78%	16.45%
19	19.49%	30.36%	26.06%	13.82%
20	20.41%	27.38%	20.13%	7.39%
Average	19.75%	17.82%	25.54%	16.09%

Table D4: Statistics For Moisture Content.

	Brandon Hall.	Rangitikei	No.1	Rangitoto.
Mean	0.1975	0.1782	0.2554	0.1609
Standard Deviation	0.0596	0.0588	0.0984	0.0400
Sample Variance	0.0035	0.0035	0.0097	0.0016
Count	20	20	20	20
Confidence Level (95%)	0.0261	0.0258	0.0431	0.0175

Table D5: Dry Bulk Density.

Sample Number	Brandon Hall	Rangitikei.	No. 1	Rangitoto.
1	1.25	0.81	1.16	1.03
2	1.16	0.94	1.16	0.92
3	1.20	1.09	1.00	0.54
4	1.24	0.89	1.17	0.86
5	1.26	0.95	1.19	1.09
6	1.00	0.89	1.14	0.48
7	1.01	0.69	1.34	1.15
8	1.16	1.08	1.33	0.88
9	1.17	0.90	0.88	1.11
10	0.95	0.92	1.05	0.83
11	0.79	0.95	1.21	1.20
12	0.96	0.84	1.15	0.98
13	1.08	0.74	1.02	1.16
14	1.25	1.02	1.04	1.22
15	1.12	1.06	1.02	0.92
16	1.12	0.98	1.04	1.10
17	1.07	1.00	0.90	0.99
18	1.18	1.08	1.24	1.01
19	1.26	1.06	0.81	1.06
20	0.84	1.13	1.02	1.01
21	1.20	0.92	1.09	0.96
22	1.10	1.13	1.20	0.82
23	1.14	1.07	1.06	
24	1.01	0.89		
25		0.97		
Average	1.11	0.96	1.10	0.97 T/m3

Table D6: Statistics For Bulk Density.

	Brandon Hall.	Rangitikei.	No.1	Rangitoto.
Mean	1.104	0.952	1.0931	0.9771
Standard Error	0.031	0.026	0.0314	0.0435
Standard Deviation	0.139	0.118	0.1405	0.1946
Sample Variance	0.020	0.013	0.0197	0.0378
Count	20	20	20	20
Confidence Level(95%)	0.06	0.052	0.0616	0.0852

Table D7: Humus Content.

Sample Number	Brandon Hall.	Rangitikei.	No. 1	Rangitoto.
1	0%	8%	20%	16%
2	4%	10%	4%	4%
3	4%	10%	8%	8%
4	6%	24%	36%	8%
5	6%	2%	0%	12%
6	12%	60%	12%	0%
7	8%	10%	14%	4%
8	8%	8%	18%	8%
9	4%	12%	2%	12%
10	8%	12%	0%	4%
11	8%	16%	4%	0%
12	12%	6%	16%	0%
13	4%	6%	8%	0%
14	8%	4%	12%	12%
15	8%	10%	6%	0%
16	4%	8%	6%	0%
17	4%	4%	4%	16%
18	6%	6%	6%	8%
19	4%	4%	0%	8%
20	12%	4%	4%	0%
21	8%	8%	0%	
22	12%	4%		
23		8%		
Average:	7%	11%	9%	6%

Table D8: Statistics For Humus Content.

	Brandon Hall.	Rangitikei .	No.1.	Rangitoto.
Mean	0.0681	0.06818	0.0857	0.06
Standard Error	0.0070	0.00692	0.0190	0.0125
Standard Deviation	0.0325	0.03246	0.0872	0.0558
Sample Variance	0.0011	0.00105	0.0076	0.0031
Count	22	22	21	20
Confidence Level (95%)	0.0136	0.01356	0.0373	0.0245

Table D9: Black Sand Content.

Sample Number	Brandon Hall.	Rangitikei.	No. 1	Rangitoto.
1	52%	12%	60%	64%
2	96%	34%	80%	96%
3	96%	14%	80%	88%
4	24%	24%	60%	72%
5	94%	6%	60%	88%
6	36%	20%	40%	88%
7	92%	10%	36%	80%
8	92%	88%	60%	92%
9	80%	88%	56%	36%
10	88%	8%	80%	64%
11	72%	52%	64%	55%
12	80%	74%	84%	55%
13	92%	66%	44%	100%
14	12%	68%	56%	88%
15	60%	90%	56%	64%
16	56%	48%	68%	92%
17	52%	96%	84%	84%
18	28%	58%	88%	44%
19	60%	96%	0%	52%
20	88%	96%	32%	100%
21	60%	44%	88%	
22	88%	96%		
Average:	68%	56%	61%	75%

Table D10: Statistics For Black Sand.

	Brandon Hall.	Rangitoto
Mean	0.681	0.750
Standard Error	0.055	0.044
Standard Deviation	0.258	0.196
Sample Variance	0.067	0.038
Count	22	20
Confidence Level(95%)	0.108	0.086

Table D11: Soil Fertility Results.

Test Date		Brandon Hall	Rangitikei	No.1	Rangitoto
12/8/94	pH	6.20	5.90	5.90	5.80
15/2/93		-	-	5.60	-
29/1/90		-	-	-	5.70
12/8/94	Ca	5.10	4.00	3.80	4.30
29/1/90		-	-	4.80	-
15/2/93		-	-	-	4.80
12/8/94	P	9.00	11.00	13.00	13.00
29/1/90		-	-	15.00	-
15/2/93		-	-	-	13.00
12/8/94	K	0.21	0.24	0.25	0.21
29/1/90		-	-	0.49	-
15/2/93		-	-	-	0.28
12/8/94	S	1.50	3.50	2.50	3.00
29/1/90		-	-	1.00	-
15/2/93		-	-	-	2
12/8/94	Mg	1.57	1.68	2.00	1.90
29/1/90		-	-	2.16	-
15/2/93		-	-	-	2.25
12/8/94	Na	0.20	0.20	0.20	0.30

P and SO_4 are in the units of g/g.

Exchangeable cations and CEC values are expressed as meq/100g.

Table D12: Botanical Composition.

Plant	Brandon Hall	Rangitikei	No. 1	Rangitoto
Carrot	0	7	1	0
Cat's ear	30	73	6	7
Moss	2	19	5	5
Sheep Sorrel	58	11	23	10
Clover	55	4	37	69
Wildings	0	1	1	0
Unknown 1	0	2	0	0
Rushes	0	1	0	0
Unknown	0	5	0	0
Gorse	3	1	0	0
Buttercup	0	3	0	5
Nightshade	0	0	1	0
Bidibidi	0	0	2	0
Bracken	0	0	5	0
Unknown 4	0	0	5	0
Lichen	0	0	1	3
Broom	0	0	1	0
Planten	0	0	0	4
B/mushroom	0	0	0	6
Forget-me-not	30	0	0	7
Unknown 5	32	0	0	0

Carrot - This plant was unidentified, but the foliage resembled that of May Weeds (Shell Chemical Company Ltd, n.d.).

Cat's Ear - This category comprised *Hypochaeris radicata* and other rosette plants (Shell Chemical Company, n.d., Carpenter, 1992).

Moss - This category comprised several members of the moss family.

Sheep Sorrel - This category comprised *Rumex acetosella* (Hilgendorf, 1948, Carpenter, 1992).

Clover - This category comprised *Trifolium spp.* namely *Trifolium pretense* (Red Clover), *Trifolium dubuim* (Suckling Clover) and *Trifolium repens* (White Clover) (Healy, 1982).

Wildings - This category comprised self seeded *Pinus radiata* seedlings.

Unknown1 - This category comprised an unidentified round leafed species.

Rushes - This category comprised of *Juncus spp.* (Carpenter, 1992, Healy, 1982).

Unknown 2 - This category comprised an unidentified long leafed species.

Gorse - This category comprised *Ulex europea* (Carpenter, 1992, Taylor, 1981, Hilgendorf, 1948).

Buttercup- This category comprised a species from the Runuculus family (Carpenter, 1992, Healy, 1982).

Nightshade- This category comprised *Solanum sublobatum* or Velvety Nightshade (Taylor, 1981, Healy, 1982).

Bidibidi- This category comprised *Acaena anserinifolia* (Carpenter, 1992).

Bracken- This category comprised *Pteridium esculentum* (Carpenter, 1992).

Unknown 4- This category comprised an unidentified erect long leafed species.

Lichen- This category comprised several lichens.

Broom- This category comprised *Cytisus scoparius* (Carpenter, 1992, Hilgendorf, 1948, Taylor, 1981).

Planten- This category comprised a *Plantago spp.* most likely *lanceolata* (Carpenter,. 1992, Hilgendorf, 1948).

B/mushroom-This category comprised a mid to dark brown umbonate mushroom.

Foreget-me-not- This category comprised a member of the *Myosotis spp.* (Hilgendorf, 1948).

Unknown 5- This category comprised a unknown plant with long hairy leaves.

Table D13: Soil Fauna.

Fauna	*Brandon Hall*	*Rangitikei*
Grass grub 1.	71	26
Grass grub 2.	14	4
Worms.	93	18
Wireworm 1.	5	4
Wireworm 2.	0	2
Spirals.	2	6
Brown Beetles.	1	4
Green Beetles.	3	0
Sand Hopper.	0	1

Grass grub 1 - This category consisted of the species *Costelytra zealandica* in the larval stage.

Grass grub 2 - This category consisted of a unidentified grass grub species.

Worms - This category consisted of several members of the order *oligochaeta*, i.e. earthworms.

Wireworms 1 - This category consisted of cream coloured wireworms of the family *Elateridae*.

Wireworms 2 - This category consisted of dark brown coloured wireworms of the family *Elateridae*.

Spirals - This category consisted of an unidentified species.

Brown Beetles - This category consisted of adult (dead) *Costelytra zealandica*.

Green Beetles - This category consisted of an unidentified (dead) green chafer beetle.

Sand Hopper - This category consisted of *Talorchestia sp.*

(The Entomological Society of New Zealand, 1967, Miller, 1984).

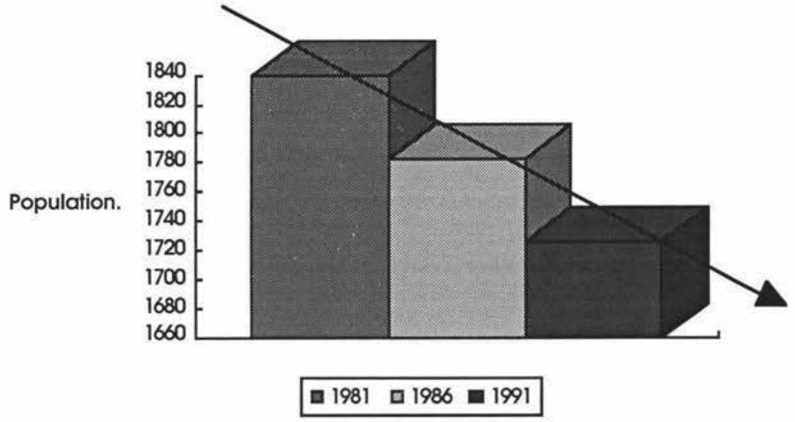
Table D14: Historical Values For Foxton Sand Soil.

Test Date.	Element	Historical Value
Approx. 1958-67	pH	5.9
Approx. 1958-67	Ca	5.2
Approx. 1958-67	P	8.3
Approx. 1958-67	K	0.2
Approx. 1958-67	Mg	2.0
Approx. 1958-67	Na	0.1

(New Zealand Department of Scientific and Industrial Research, 1958, Cowle and Hall, 1965, New Zealand Department of Scientific and Industrial Research, 1967).

Appendix E: Social Data.

Figure E1: Bulls District Population 1981-1991.



(Department of Statistics, 1982, Department of Statistics, 1987, Department of Statistics, 1992.)

Planting Programme at Rangitoto Farm.

Rangitoto Farm Ltd.

1956	1 ha:	mixture of *Pinus radiata, Cupressus macrocarpa, Eucalyptus botryoides, Eucalyptus saligna, Robinia pseudoacacia, Acacia melanoxylon.*
1958	0.5 ha:	*Pinus radiata* planted in woodlots and shelterbelts.
1963	1 ha:	*Pinus radiata* planted.
1964	1.25 ha:	*Cupressus macrocarpa* and *C. lusitanica* planted.
1965	0.2 ha:	*Pinus radiata* planted on the dunes.
1967-70	12 ha:	*Pinus radiata* planted on the dunes.
1971	2.7 ha:	*Pinus radiata* planted on the dunes and flat.
1973/4	2 ha:	Dunes and flats planted.
1975	1.1 ha:	Dunes and flats planted.
1976	0.9 ha:	Dune planted.
1977	0.8 ha:	*Pinus radiata* and Eucalypts planted.
1978	1.7 ha:	*Pinus radiata* planted on dunes and flats.
1979	1.9 ha:	*Pinus radiata* and Eucalypts planted on dunes.
1980	1 ha:	Ornamentals planted.
1981	0.6 ha:	*E. saligna*, (1981-82), planting of Black walnut, sweet chestnut, *E. botryoides, E. cladacalyx, and E. fraxinoides;* and amenity planting of *E. radiata, E. ficifola*, Acacias, Robinia, *E. leucoxylon, E. pulchell,a* and other species.
1982	1.3 ha:	Mixture of species planted on the flats and dunes. *E. saligna, E. sideroxylon, E. botryoides, E. crebra, E. microcorys, E. cladocalyx, E. globoidea,* interplanted with *P. radiata.* Also
a		woodlot/shelterbelt of *A. dealbata, E. crebra, E. saligna, E. botryoides, C. lusitanica,* and *P. radiata.*
1983	1.0 ha:	Leyland cypress interplanted with *P. radiata*, also some *C. lusitanica*, and *C. macrocarpa.* Plus 1.8 ha planted on other land(*sic*).

1984	1.6 ha:	*E. Microcorys* interplanted with *P. radiata*, *E. muelleriana* interplanted with *P. radiata*, and Leyland cypress, *E. deanei*, *E .microcorys*, *E. saligna*, *E. globoidea*, *E. cladocalyx*, black walnut, and others, planted on the dunes.
1985	2.1 ha:	of *P. radiata* planted in low density fence line plantings.
1986	2.5 & 0.8 ha:	Mostly *P. radiata* planted, the rest is a mix of *C. macrocarpa* and Leyland cypress, *E. globoidea*, *E. gomphocephala*, *E. jacksonii*, *A. melanoxylon*, *A. falciformis*, *E. saligna*, *and E. Botryoides.*
1987	5 ha:	low density planting of *P. radiata* on the dunes; 0.6 ha of mixed species also planted on dunes.
1988	0.9 ha:	*P. radiata* and cypresses planted.
1989	10 ha:	*P. radiata* planted on the dunes.
1990	9 ha:	*P. radiata* planted on the dunes and 1 ha of *C. macrocarpa* planted on the flat.
1991	4 ha:	*P. radiata* and 1.5 ha of a mixture of species planted.
1992	5 ha:	planted on the dunes and flat, 50/50 mix of *P. radiata* and other species.
1993	7 ha:	1 ha mixed, the rest are *P. radiata* planted on the dunes.
1994	7 ha:	2 ha to be a mixture of species, the remainder is *P. radiata.*
1995	8 ha:	will be planted next year, and then all of the dunes will be under trees.

(Hocking , n.d., Hocking, pers com.)

Glossary.

At mill door: A pricing system whereby the growers deduct logging, loading, and transport costs to generate a "stumpage"

Atrizine: is a germination inhibitor which kills seedlings as they germinate and usually remains active for 3-6 months.

Butt Log: The bottom log of a standing tree. The length can vary according to market specifications but is assumed to be 6m. It is the most valuable part of any tree and is often pruned.

Cartage: The trucking of logs from the forest to the mill or wharf.

CCA: Copper-chrome-arsenate wood preservative.

Clearfelling: The felling of all trees in a stand at the same time.

Clearwood: Wood free of knots, achieved through pruning.

Diameter at breast height (dbh): The trees circumference is measured and converted to give diameter.

Discount Rate: The percentage used to weight (ie discount) future values. It can represent the cost of borrowing or the opportunity cost of the money spent on the project or the clients time preference.

Farm Surplus: The difference between farm income and farm costs, excluding personal drawings, taxation, and new capital developments.

Gardoprim: A root-absorbed chemical which moves through the soil, and absorbed into the plant system via roots. This chemical remains active in the ground for up to 12 months

Gallant: A systemic or translocated chemical which is absorbed by the plant foliage.

GF rating: An index applied to radiata pine to describe the level of genetic improvement in a given seedlot.

Grazon: is a systemic or translocated chemical which is absorbed by the plant foliage.

Joint Ventures (Jvs): An agreement between a landowner and an investor under the Forestry Rights Registration Act 1983, whereby profits from tree-growing are apportioned to each according to their input. The landowner may receive cash up front, an annual rental, a share of the harvest revenue, or any combination of these.

L1, L2, L3: Unpruned sawlogs with a SED of 20 cm or more and a maximum branch diameter of greater than 6 cm but no more than 14 cm. (Carter Holt Harvey, 1994)

Log Grade: Logs are sorted into various grades, to supply differing markets. Each grade has its own specifications, such as minimisation and/or average diameter, length, branch size and straightens.

On Truck: The price received for timber after logging and loading costs have been removed

P1: Large sawlog, completely pruned, suitable for sawing with SED greater than, or equal to 40 cm (Carter Holt Harvey, 1994).

P2: Small sawlog, completely pruned logs suitable for sawing with SED of 30-39.9 cm (Carter Holt Harvey, 1994).

Paraquat: Contact chemical which is fast acting and only effective at or near the point of contact. This chemical is particularly hazardous to human health if misused.

Production Thinning: Juvenile trees are removed for posts, poles, pulpwood, or small sawlogs, as opposed to "thinning to waste" where the felled trees are left to rot.

Pruning: removing branches, including live branches, flush with the stem to promote the growth of knot-free timber.

Pulp: Or chip logs, logs with no limit on SED.

Releasing: Removing competing vegetation to allow for maximum tree growth.

Rotation: The rotation time is the period in years from planting to clearfelling.

Roundup: Systemic or translocated herbicide which is absorbed by the plant foliage.

S1: Large unpruned sawlog, with SED greater than, or equal to, 30 cm and maximum branch diameter less than, or equal to, 6 cm (Carter Holt Harvey, 1994).

S2 Small unpruned sawlog, with SED of 20-29.9 cm and which are either completely pruned, or unpruned with a maximum branch diameter less than, or equal to, 6 cm (Carter Holt Harvey, 1994).

SED: Small end diameter.

Sawlog: A log suitable in size and quality for the manufacture of sawn timber.

Silviculture: Literally, " the culture of wood", an all encompassing word. In New Zealand, the word tends to be restricted to thinning and pruning phases of a crop rotation.

Simazine: A germination inhibitor which kills seedlings as they germinate and usually remains active for 3-6 months.

Slash: Branches, bark, tree tops, unmerchantable logs, uprooted stumps, and broken trees left, behind after logging. Also used to describe branches and stemwood remaining after pruning and thinning operations.

Stems per hectare (sph): The number of live trees per hectare, commonly known as "stocking" or "tree density".

Stumpage: A pricing system whereby the price point is the standing tree. Also, the value of standing timber, when all harvesting costs have been paid.

Thinning: The removal of trees within a stand at some time before clearfelling.

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